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PHYSICAL ACTIVITY, FITNESS, NUTRITION AND OBESITY DURING GROWTH

Jana Pařízková

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PHYSICAL ACTIVITY, FITNESS, NUTRITION AND OBESITY DURING GROWTH

Secular Changes of Growth, Body Composition and Functional Capacity in Children and Adolescents in Different Environment

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FOREWORD
NUTRITION, PHYSICAL ACTIVITY AND THE RISK OF OBESITY DURING CHILDHOOD

Since several decades, childhood overweight steeply increased, but after around the year 2000, a plateau or even a decline in prevalence rates has been reported in many industrialized countries (Rokholm *et al.*, 2010). However, the problem remains important, since the prevalence of childhood obesity is still high in many countries.

While prevalence of childhood obesity was increasing, energy intake was decreasing, particularly due to decreasing fat intake (Rolland-Cachera 2002; Gibson 2010; Alexy *et al.* 2002). This paradoxical situation can be explained by decreasing physical activity and increasing sedentary lifestyle (Butte *et al.* 2007). Indeed, exercise has beneficial effects limiting the development of obesity and improving fitness in children (Kellou *et al.* 2014; Pařízková 2008).

Decreased energy intake is reported in all age groups, but the hypothesis of decreasing physical activity to account for by decreasing energy intake is less convincing in very young children. Other factors may explain the rising trend of obesity. The role of environmental factors in early life in predicting later health has generated substantial interest in recent years (Hanley *et al.* 2010).

The early adiposity rebound recorded in most obese subjects (Rolland-Cachera *et al.* 2006) suggests that factors promoting body fat development have operated in the first years of life. Particularly, early nutrition can exert long-lasting influence on health. Birth weight, growth velocity, adiposity rebound and body mass index trajectories seem to be highly sensitive to the nutritional conditions present during pregnancy and in the first years of life. Early inadequate nutrient balance in early life may account for by the paradox of increasing obesity and decreasing energy intake. The low protein-high fat diet recorded in many young children, which contrasts with the low protein-high fat composition of human milk, may favour the development of obesity (Rolland-Cachera *et al.* 2006; Michaelsen and Greer 2014; Rolland-Cachera *et al.* 2013). High protein intake can promote overweight *via* increasing Insulin like growth factors 1 and dietary fat restrictions can decrease energy density, thus programming adaptive metabolism to prevent underweight and increasing the susceptibility to develop later overweight and metabolic diseases (Rolland-Cachera *et al.* 2013). A “mismatch” between early restrictions and later positive energy balance due to increasing fat intake and low energy expenditure due to sedentary lifestyle could be particularly harmful.

In conclusion, nutrient balance of the diet varies according to the age of the child. In spite of official recommendations that dietary fat should not be restricted in young children, fat intake is often low in early life and increases with age. It should be high in early childhood and decrease with age. The high protein low fat diet recorded in early life, and low physical activity in children may have contributed to the obesity epidemic. The consequences of inadequate nutrition at different ages, and the rising sedentary lifestyle in children stress the importance of providing nutritional intakes adapted to the child's metabolic needs at the various stages of growth and of promoting physical activity which contributes to an optimal energy balance and improves health and fitness.

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PREFACE

Optimal health and a high level of fitness have been long recognized as a key to the future of any human population. Concern for the development of future generations has been a central theme in all civilizations, not only in those well developed, but also in primitive ones. However, even under positive conditions of problems can appear: provision of a favourable environment with an ample diet, adequate education and health care is no guarantee that appropriate level of physical fitness, health status and its prognosis in children and adolescents will be achieved.

The increasing level of economic conditions and the improvement of nutrition have been contributing not only to an accelerated growth and development, but also to disproportional development of body composition, which concern the whole population. This has manifested especially by an increasing ratio of adipose tissue in the organism, which has affected all age categories including the preschool one; often without more apparent changes of total body weight and body mass index - BMI ("hidden obesity"). Nutritional intake, both from the point of view of energy content as well as the composition of the diet (especially the ratio of saturated fats and simple sugars) has not corresponded to the actual needs of the organism - mainly from the point of view of reduced energy expenditure resulting from the impact of physical inactivity (WHO 2010a,b,c). This concerns already children of early age, who are characterized by highest level of spontaneous physical activity, and therefore reduced possibility to move, play and exercise is mostly unnatural at this age. This mostly continues during following years and has undesirable results.

Secular trend of increasing adiposity along with the reduction of functional capacity and motor abilities was found since youngest age, and runs parallel with increased health risks which have started to appear already during this period of growth. With regard to health problems resulting from a generally enhanced adiposity and increasing prevalence of obesity, this situation is harmful at any age including school age and adolescence, especially when considering possible delayed health effects in adult and advanced age. Introduction of an appropriate régime of not only nutrition, but also of physical activity is indispensable, starting with the very beginning of life. In this respect, an approach based on proper evaluation of the individual including genetic factors should be also implemented as all humans are special from all points of view – also as nutritional and motor individualities (Pařízková 1998, 2008, 2010, 2011).

More recently also the interrelationships between nutrition - its energy content and composition on the one hand, and energy expenditure resulting from physical activity level on the other one have been considered and analyzed in greater extent and detail. However, the effect of physical activity (PA) as a significant metabolic, nutritional, hormonal, psychological *etc* stimulus has not always been - as has been much more the effect of others like diet – more exactly defined, assessed and analyzed with regard to its character, intensity, frequency and regularity along satifactorily long periods of human growth, and also with special regard to not only genetic, but also epigenetic factors influencing the organism since early life. The last mentioned factor – the composition of early diet concerning *e.g.* proteins – was mentioned above.

This monograph is aimed, among others, to contribute to this problem and with an effort for a more complex approach. However, it has been too difficult to summarize more aspects in their mutual relationships, and also according to the present state of art, as this fragmented research is a permanently developing story. Too many new studies and reviews have been appearing during recent years until present which have not been homogenously aimed and planned, executed, elaborated and interpreted, followed up in comparable groups with regard to age span, gender, degree of sexual maturation, dietary intake, social and cultural status and many others – so consented conclusions could have been hardly achieved. But hopefully, some of the presented information could at least partly contribute to further developement of this important topic.

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CHAPTER 1

Secular Changes of Somatic Growth, Puberty and Obesity

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1. INTRODUCTION

Transformation of social-economic conditions and of the resulting way of life concerning inter alia the energy balance has been reflected also by health status of individual populations. This concerns especially children, when life conditions influence significantly growth and development of the child, and also the realization of their genetic growth potential - both at present and also as delayed consequences later on. The factors, which during certain stages of development have a positive effect, can due to their extent and importance, or in different combination and mutual interrelationships with further factors become a marked health risk. Typical example is the effect of the character of nutrition, which along with improving quality and availability of health care has become a primary manifestation of increasing social-economic level in a particular society, and therefore also result in a positive secular increase in body height in the populations.

Improving level of life conditions has been at present accompanied by the imbalance between energy intake and expenditure, due to absolutely, but often only relatively increased dietary intake, resulting from simultaneously decreased energy expenditure caused by reduction of physical activity. During recent decades an increased prevalence of overweight and obesity has been appearing

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since early childhood, accompanied by increasing health risks. Increased body weight and body mass index (BMI) has been mainly caused by excess body fat. Endocrine activity of adipocytes can influence markedly growth and developmental profile of the growing child: start of puberty, change of its course and development has as a result the limitation of applying the genetic growth potential, which can be manifested by final body height. This can be manifested by modified secular trend of body height in the given population.

CHAPTER 1a

1.1. Height, Weight, Puberty and Adiposity

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Abstract: Secular trend of body height was analyzed using the results of six National-wide Anthropological Surveys in the Czech Republic (NAS) conducted in ten-years intervals from 1951 to 2001. These data documented, similarly as in other countries a continuing increase of body height, as a result of improving socio-economic conditions. Highest increase of body height has occurred especially during puberty, due to the shift of the start and of the individual stages of puberty to an earlier age. A shift to an earlier age was revealed also in the age of adiposity rebound (AR), by more than one year earlier in both genders. Along with these changes, adiposity evaluated by skinfolds has been increasing, starting with preschool children; body mass index (BMI) during the same period fluctuated insignificantly and has not revealed clearly changes of body composition. Along with that, an alarmingly increasing prevalence of obesity in children and adolescents has appeared as a result of imbalance between energy intake (EI - nutrition) and energy expenditure (EE) due to sedentarism starting early in life.

Keywords: Acceleration, Adiposity, Adolescents, Anthropological surveys, Body height, Body mass index (BMI), Children, Environment, Genetic factors, Growth, Growth velocity, Health menarche, Mutation, Obesity, Overweight, Puberty, Secular changes, Skinfolds, Weight, Weight-to-height proporcionality.

1.1.1. INTRODUCTION

Growth is an accomplished process which reflects synthetic effect of both genetic and environmental factors. Healthy development is therefore conditioned both by genetic predispositions and environmental conditions, in which the particular subject is developing. World average of final variability of growth resulting from

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the effect of these factors achieves at present 12 % with regard to body height, and 30 % to body weight (Mascie-Taylor & Bogin, 2005).

Environmental conditions have been changing permanently in both positive and negative way, which has been in a long run finally reflected by secular changes of growth, body composition and adiposity. This combined effect is manifested as an influence of various life conditions in different social groups both at present, and also as delayed consequences. The trends of secular changes have not been, however, stable along time, but showed age and gender differences. Growth can be considered as a mirror of the whole society, reflecting very sensitively socio-economic status and health profile of a given population.

1.1.2. SECULAR CHANGES OF BODY HEIGHT IN THE CZECH POPULATION

In the Czech Republic, similarly as in other developed countries in Europe gradual changes have been occurring which concerned the level of health and social care, nutrition, education and overall improvement of life conditions of the inhabitants. This process has modified the growth and development profile of the individual, which has been manifested by the changes in body height in the individual age categories. The improvement of environmental conditions - especially of nutrition, eradication of most serious infectious diseases and improved and better accessible health care resulted in more favourable achievement of genetic component for growth (genetic growth potential), and therefore to the increase of body height in the population. Highest increase of body height has occurred especially during puberty, due to the shift of the start and of the individual stages of puberty to an earlier age.

Secular changes of average body height of Czech children and adolescents in Figs. (**1** and **2**) are given. The analysis of secular trend of body height was conducted on the basis of six National-wide Anthropological Surveys in the Czech Republic (NAS) in ten-years intervals from 1951 to 2001 (Fetter *et al.*, 1963; Prokopec *et al.*, 1973, 1986; Lhotská *et al.*, 1993; Vignerová *et al.*, 2006a). The analysis was supplemented by the comparison of research data on Czech school children followed up in 1895 (Matiegka, 1927) and by the research data of

Czech boys from Vienna Military Academy from the years 1800 – 1809. The growth data (year and sex specific height averages) were fitted by polynomial spline of 3rd order (with weighting derived from standard deviations and sample sizes; Ramsay & Silverman, 1997).

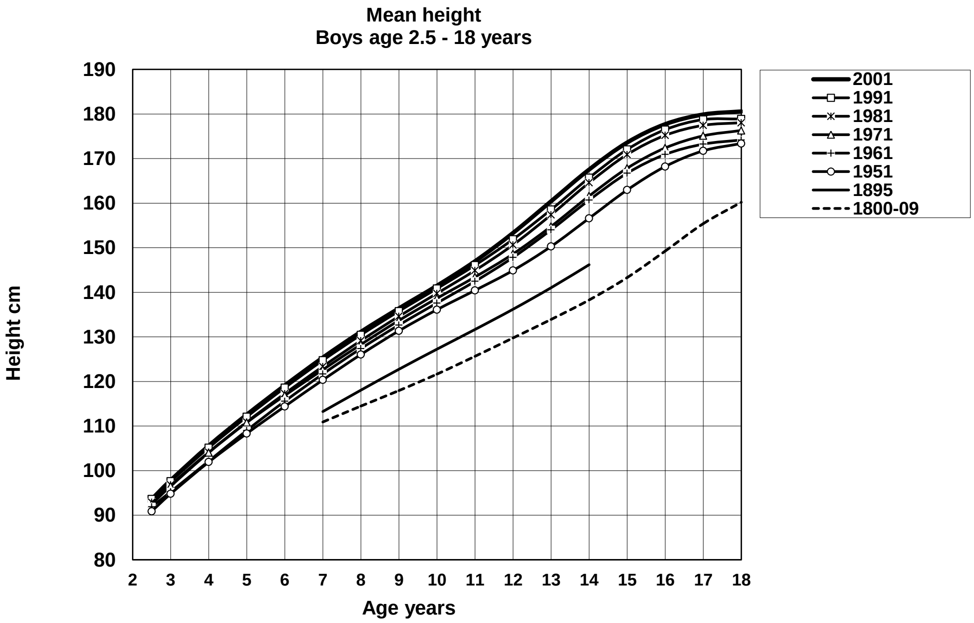

Fig. (1). Secular changes of body height – Czech boys 2.3-18 years.

Most marked differences in body height was found in the group of 15- years-old boys, in which body height increased during past 200 years by 30 cm. In the group of 12-years-old boys and girls the average body height increased from the year of 1885 by 18 cm. Present children achieve the values of the 12-15- years-old children assessed at that time at the age of 9 – 11 years already. During past hundred years pubertal growth accelerated by up to 3 years (Vignerová *et al.*, 2006a, 2006b).

The estimation of pubertal growth was conducted on the basis of first derivation of average growth curves from individual research studies (Figs. **3** and **4**). In the Year 1951 the pubertal acceleration of growth started in boys around 11 years of age, but the results of last NAS 2001 showed that pubertal acceleration started already at the age of 10.1 years (Vignerová *et al.*, 2006a). The peak of pubertal spurt shifted similarly as the age of the achievement of definite body height, *i.e.* the profile of pubertal growth spurt did not change markedly.

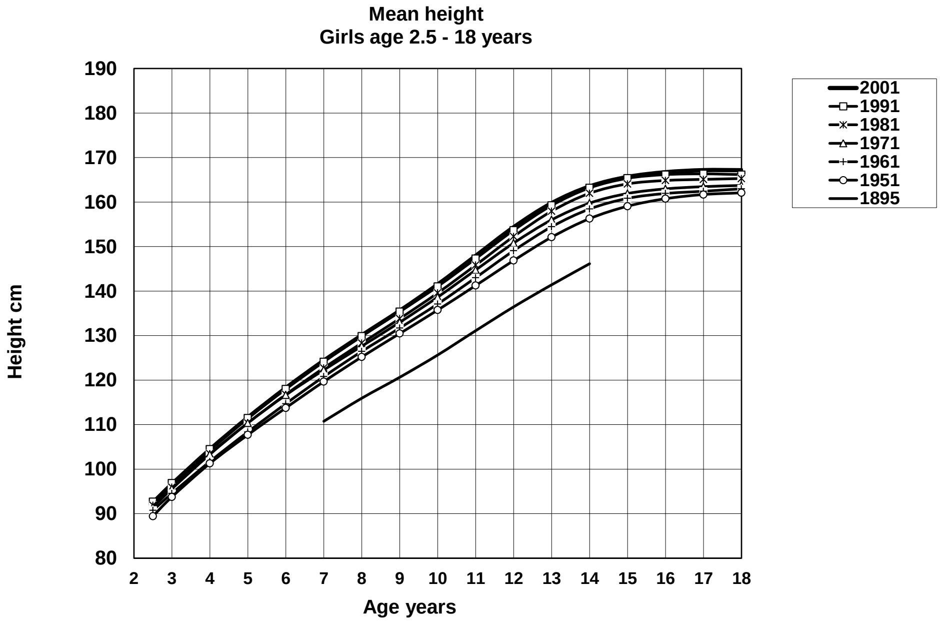

Fig. (2). Secular changes of body height – Czech girls 2.3-18 years.

This situation is similar in girls, along with approximately two years shift to a lower age during all stages of pubertal growth spurt. Also the average growth speed during the peak of pubertal growth spurt (peak height velocity) was in boys in 1951 6.5 cm per year, in 2001 7.3 cm per year, in girls 5.6 cm and 6.6 cm respectively (Vignerová *et al.*, 2006b). Secular acceleration of pubertal development in girls is demonstrated by lowering of the average age of menarche, which decreased from 15.1 year in 1895 to 13,0 years in girls followed up in NAS study conducted in 1991 and 2001 (Vignerová *et al.*, 2006a).

In last NAS studies (1999 and 2001) height increase was smaller in both sexes, and was more marked in girls as compared to boys. When comparing the differences in body height between 1991 and 2001 in boys, a difference greater than 1 cm was found only at the age higher than 12 years, with the maximal value of 1.8 cm in 13-years old boys. Greatest difference in girls was only 0.7 cm in 12-years old age category (Vignerová *et al.*, 2006a).

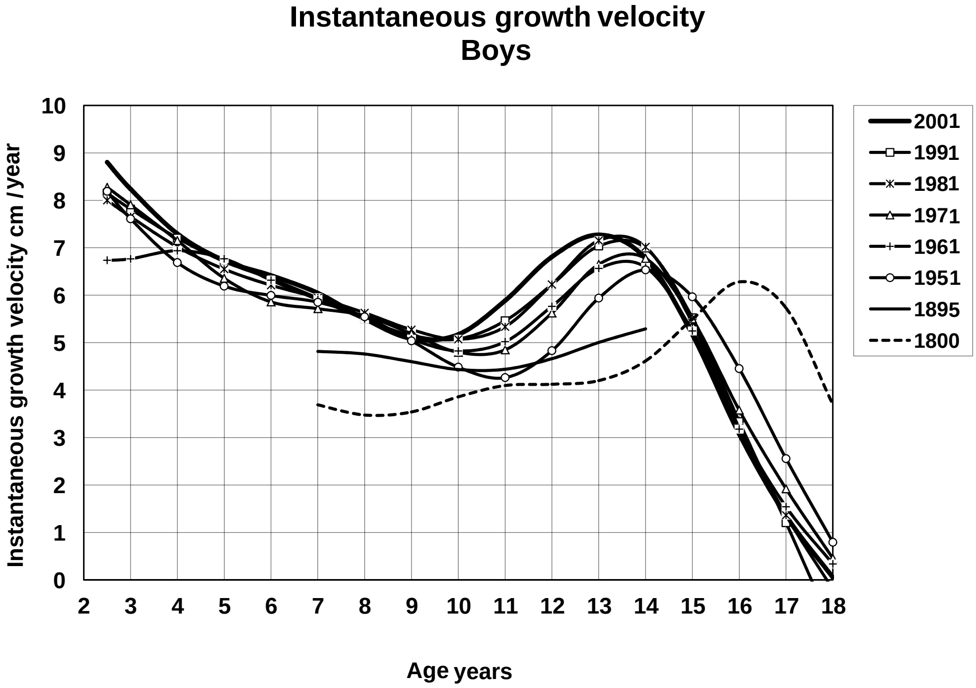

Fig. (3). Secular changes of the pubertal spurt – actual velocity of growth - Czech boys 2.5 – 18 years.

The slow-down of the trend of secular acceleration of growth in height and acceleration of sexual development in Czech girls is apparent from a long-time stagnation of the median of menarcheal age, which since 1951 has not changed and remained until 2001 on the age of 13.0 years. The age of menarche and growth profile is obviously related to socio-economic situation of a given society. In boys, however, a certain degree of acceleration of pubertal development remained stable, along with the increase of body height during puberty. As a result, the decrease of the average age of the mutation in Czech boys from 14.5 year in 1991 to 13.8 years in 2001 was revealed (Fig. **5**) (Vignerová *et al.*, 2006a, 2006b).

Hundred years ago, physical growth of boys was completed only after the age of 20 years, at present it is terminated already at the age of 18 years. In girls, the period of the end of growth is shifted by two years too. Boys at present are taller by 12 cm, and girls by 10 cm than their peers at the end of 19th century (Vignerová, 2005; Vignerová *et al.*, 2006a).

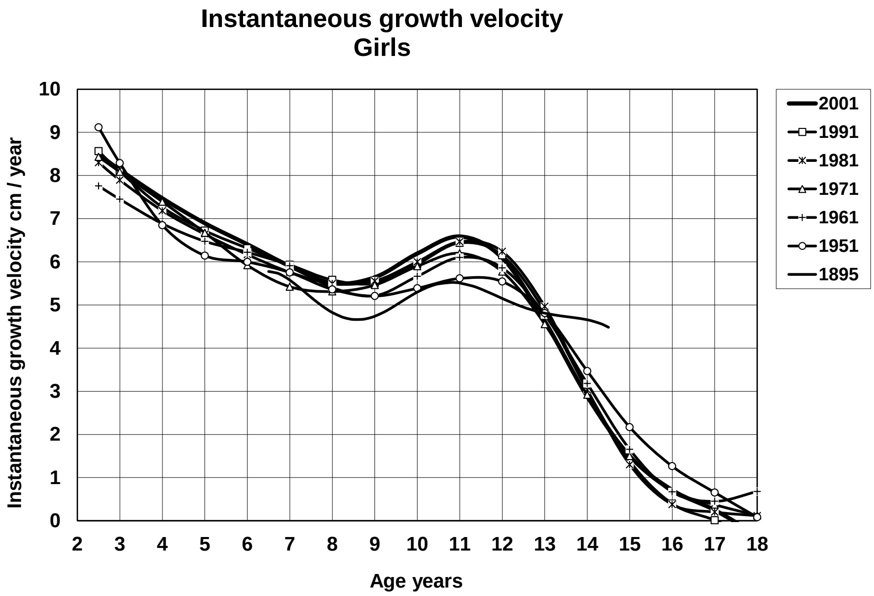

Fig. (4). Secular changes of the pubertal spurt – actual velocity of growth - Czech girls 2.5 – 18 years.

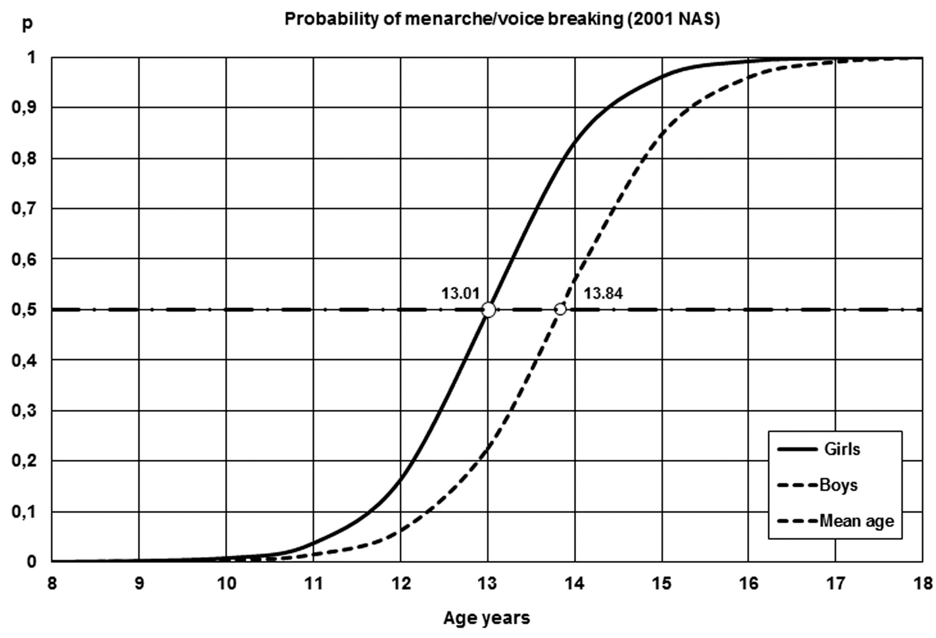

Fig. (5). The values of median of menarcheal age and age of mutation in Czech youth (results of NAS 2001).

1.1.3. SECULAR TREND IN BODY HEIGHT IN DIFFERENT WORLD POPULATIONS

Secular trend of growth in height has occurred in the majority of world populations. The development of body height in the 2nd half of the 20th century in eight European countries and in Japan is compared in a German study (Gohlke & Woelfle, 2009). Largest increase was observed in Japan and Poland, smallest one in Swedish and Norwegian populations. This witnessed greatest stability of socio-economic conditions in these countries, and also stable relationships between genetic and environmental component of growth.

Study of Komlos & Lauderdale (2007) compared the data concerning growth in the US populations with Western European trends after World War II. It is based on the data of NHES and NHANES 1959 and 2004, subjects the aged of 23 and 47 years (URL 1). This study shows the stagnation of adult height in 1930 up to 1940, *i.e.* the period of great economic crisis and World War II (Komlos & Baur, 2004). It also compares the trend of the increase of body height of the US population with the trend in sixteen European countries. The results indicate that the trend of the increase was similar, with the exception of the period of mentioned economic crisis which was in the European populations manifested much less, and only in the years of 1940 – 1945 as a reflection of the effect of World War II. Highest increase of body height was revealed in Netherlands, which is at present the tallest world population registered (URL 2). An increase of average body height was revealed also in other European studies (Papadimitriou *et al.*, 2009; Godina, 2011; Kulaga *et al.*, 2011, 2013).

Italian studies (Arcaleni, 2006, 2012) showed marked regional differences, *i.e.* largest secular increase of body height was found in Northern, and smallest in Southern Italy. Cardoso & Caninas (2010) proved the relationship between a higher increase of body height and the level of social economic status in 10 – 16 years old Portugal (Lisbon) boys. In spite that the increase in body height was comparable in both social classes, BMI increased more in boys from lower social group (see below).

Positive relationship of growth acceleration and socio-economic conditions was documented best by the research of Chinese and Indian populations. The effect of economic and resulting social transformation including the impact of western trends these changes have been apparent and dynamic. The comparison of somatic growth in 7 – 18 years old individuals from 16 Chinese cities, followed-up between the years 1950 – 2005 confirmed the acceleration of growth in both girls and boys of all age categories: an average increase of 2.5, and 2.0 cm resp. per decade was found. Total increase of average body height in Chinese population after 50 years was 6.7 cm in men, and 10.1 cm in women. Most marked increase in 13-years old boys (16.8 cm) and 11-years old girls (15.4 cm) was revealed (Ji & Chen, 2008). Corresponding trends with regard to the comparison of somatic parameters, and also of similar values of their increase were reported by another study of the same authors. The Chinese National Survey on Student´s Constitution and Health from the years 1985 – 2010 (Chen & Ji, 2013).

Similar studies were conducted in adult populations (20-49 years) from various states of India in the framework of Third National Family Health Survey (Mamidi *et al.*, 2011). Average increase of body height during ten years intervals was very small (0.5 cm in men and 0.2 cm in women), which was moreover not statistically significant. The situation in individual states of India was very different due to large differences in their socio-economic conditions and status. In some states the average values even decreased, and secular trend was negative.

The trend of the increase of body height as related to improving social economic conditions was confirmed also in Central- and South-American populations, *e.g.* Mexico (Malina *et al.*, 2008), Argentina (Orden *et al.*, 2013), Brazil (Marmo *et al.*, 2004) and Chile (Lizana *et al.*, 2011). In African populations the situation is very different, and generally more exact informations have been lacking (Henneberg & Van den Berg, 1990; Moradi & Baten, 2005; Travalgino *et al.*, 2011).

1.1.4. SECULAR CHANGES OF WEIGHT AND WEIGHT-TO-HEIGHT PROPORTIONALITY

Most urgent secular phenomenon resulting from significant social impact on growing populations has been not only the increase of the prevalence of overweight and obesity, but also the reduction of body weight during childhood. Growth and development of these children varies markedly as compared to the growth of normosthenic children. The profile of growth depends primarily on the amount and development of the adipose tissue, and clinically on the degree of obesity of a particular child. In this relationship there is apparent a negative correlation of the fat component, which is expressed also by the value of BMI and further growth parameters (*e.g.* circumferential measure *etc*.). The effect of excessive adipose tissue - without the relationship to the pathogeny of obesity - is related to the mechanical factors, which influence also the development of musculoskeletal system; however, further hormonal factors as *e.g.* the production of leptin and extra-glandular production of estrogenes by the adipose tissue can play a significant role.

With regard to somatic growth of an obese child, the overloading of the metaphyses of the growing long bones, or – on the other hand – an insufficient pressure stimulation on the epiphyseal growth cartilages due to prevalent hypokinesia is an important developmental factor. During a longer lasting period of influence a reduced realization of the inborn growth dispositions (*i.e.* of the genetic growth potential) can occur. Limiting factors of this phenomenon are both the age of the onset of obesity (the lower this age, the greater is the reflection on growth parameters of the child), and also the degree of obesity (the value of BMI or weight/height relationship).

1.1.5. ACCELERATION OF PUBERTAL DEVELOPMENT

Obesity has also a significant impact on sexual maturation and pubertal development of the child. The age of the onset of puberty is related to the prepubertal values of BMI. As reported previously, the increase by one unit of BMI ("1 BMI") from the average accelerates puberty in both sexes by 0.13 year (Karlberg, 2002). Like that also an earlier achievement of peak height velocity (PHV) appears, and in girls also to an earlier onset of menarche (Biro *et al.*, 2006; Gluckman & Hanson, 2006; Harris *et al.*, 2008; Aksglaede *et al.*, 2009). Negative impact on genetic growth disposition of the child is apparent - due to an earlier onset of puberty the prepubertal growth period is shortened, and like that also the effect of genetic growth potential is reduced In spite of the corresponding timing and also of the duration of puberty of the obese and normosthenic subjects an earlier closing of epiphyseal growth cartilages, and like that also an earlier reduction of growth potential can appear in more serious cases of obesity during childhood. The result is then a lower adult body height as compared to the prediction based on parents´ disposition.

Positive relationship beween body weight and onset of pubertal growth spurt and menarcheal age resp. was published previously by Frisch & Revelle (1969, 1970, 1971). This hypothesis was later supplemented by the relationship of the dynamics of pubertal development and threshold values of body fat of girl (Frisch *et al.*, 1973). However, studies criticising this hypothesis appeared later (Trusell, 1978; Scott & Johnston, 1982; Garn *et al.*, 1983).

At present, initial hypothesis of Frisch & Revelle (1969, 1971) is supported. Some studies confirm earlier onset of puberty in overweight girls, later onset in children with lower weight/height proportionality (Adair & Gordon-Larsen, 2001; Kaplowicz *et al.*, 2001; Davison *et al*., 2003; Aksglaede *et al.*, 2009). However, there exist views that secular acceleration of puberty in girls is not primarily conditioned by increasing prevalence of overweight and obesity in the growing population, as it appears also in normosthenic girls (Gohlke & Woelfle, 2009). In this study there was presented a trend for stagnation of the averarge age of menarche, which since the sixties of the 20th century has not changed in the majority of countries of Central Europe (Germany, Sweden, Denmark, Finland, Netherlands). However, basic marker is not body weight, or weight/height proportionality of the child, but the amount of body fat. The resulting effect of pubertal acceleration is conditioned by metabolic and hormonal activity of the adipose tissue (Fernandez-Fernandez *et al*., 2006; Navaro *et al*., 2007; Gianetti & Seminara, 2008; Aksglaede *et al*., 2009; Soliman *et al.*, 2012).

As follows, BMI is only an orientation marker – higher proportion of body fat as related to lean body mass can be found even when BMI is normal (Rosenfield *et al.*, 2009). As objective evaluation of the relationship of secular acceleration of puberty in girls and the increase of the prevalence of overweight and obesity could be only the analysis of the relationship of puberty and menarche onset to the degree of body adiposity (Buyken *et al.*, 2009; Sun *et al.*, 2012). Also a German study (Wagner *et al.*, 2012) confirms mutual positive relationship between the acceleration of sexual maturation and excessively increased body weight, namely in girls. In boys all these relationships were less close. These authors also mention the relationship of puberty onset on the distribution of body fat.

Secular trend of puberty onset and decreasing of the age of menarche - similarly as the increase of body height, correlates positively with socio-economic situation of the country in question (Veček *et al.*, 2012; Poplawska *et al.*, 2013). For example, marked economic and social changes in China were reflected in girls by the decrease of the average age of menarche from 13.2 years in 1985 to 12.6 years in 2010 (Chen & Ji, 2013).

1.1.6. SECULAR CHANGES OF BODY COMPOSITION – INCREASE OF BODY FATNESS

Increase of body fat assessed by skinfold thickness measurements was proved in school children and adolescents (Olds, 2009). This was revealed also in preschool children (Pařízková *et al.*, 2012). Further comparative analysis of BMI and of the changes of three skinfold thicknesses (triceps, subscapular and suprailiac) aimed to the evaluation of the changes of body composition - fat component resp. was conducted in 5 and 6 years old children in 1957 up to 2011 using Harpenden caliper (Pařízková, 1977; Bláha *et al.*, 1982, 1986, 1990; Sedlak, 2011). As apparent from Figs. (**6-9**), marked secular changes of skinfold values were found. Largest significant increase of skinfolds on the trunk was revealed (Table **1**).

As apparent, already at early age adiposity has increased significantly, in spite of only insignificant fluctuation of BMI. This was accompanied by worsening of the results of motor testing assessed during the same period in the same children (Pařízková *et al.*, 2012). This reveals a significant effect of increasing sedentarism which appears already at very young age. Early development of increased adiposity – especially on the trunk has been considered a marker of increased health risks (metabolic syndrome, cardiovascular problems *etc.*). Further studies in this respect conducted since the beginning of life are indispensable as a basis for preventive measures of this alarming health problem.

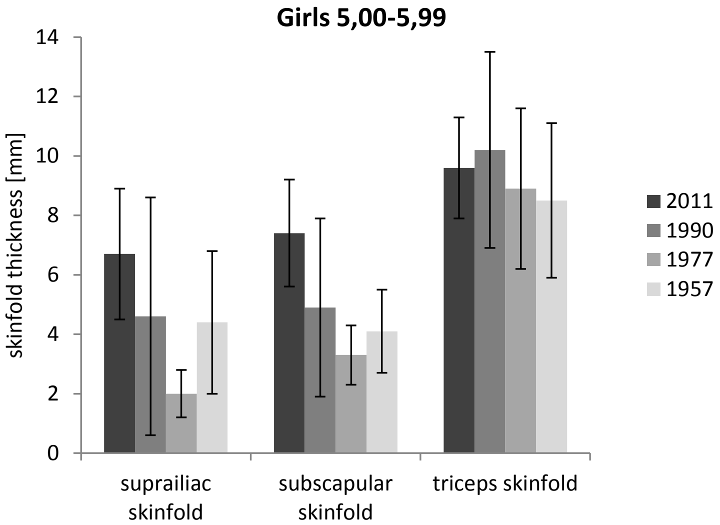

Fig. (6). Comparison of the changes of skinfold thickness (triceps, subscapular, suprailiac) in 5-years-old girls followed up in 1957 up to 2011.

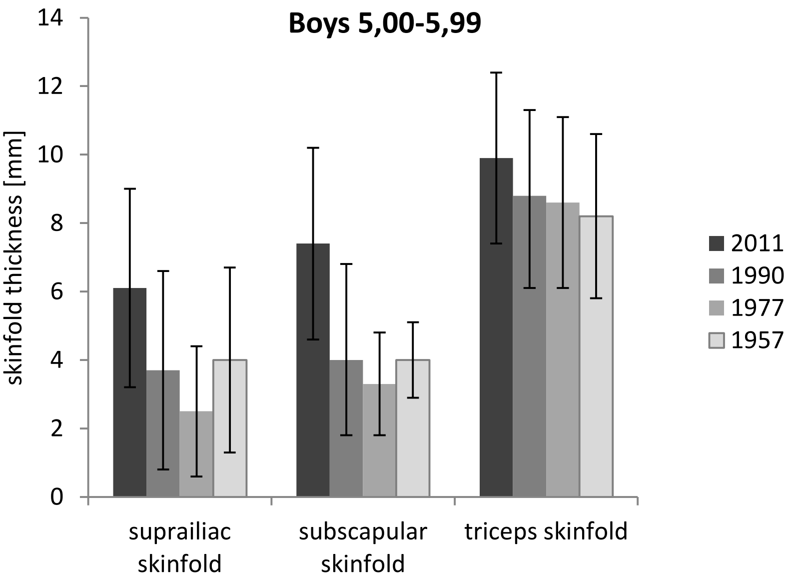

Fig. (7). Comparison of the changes of skinfold thickness (triceps, subscapular, suprailiac) in 5-years old boys followed up in 1957 up to 2011.

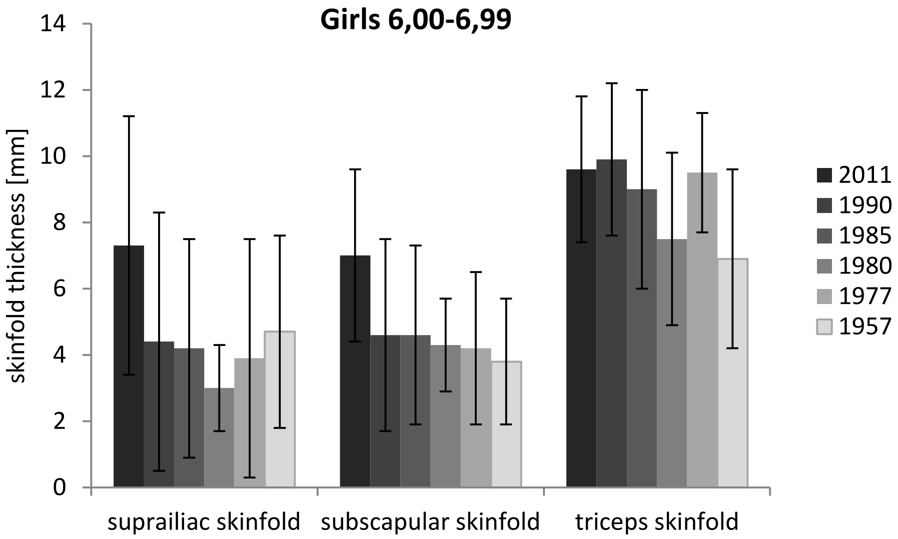

Fig. (8). Comparison of the changes of skinfold thickness (triceps, subscapular, suprailiac) in 6-years old girls followed up in 1957 up to 2011.

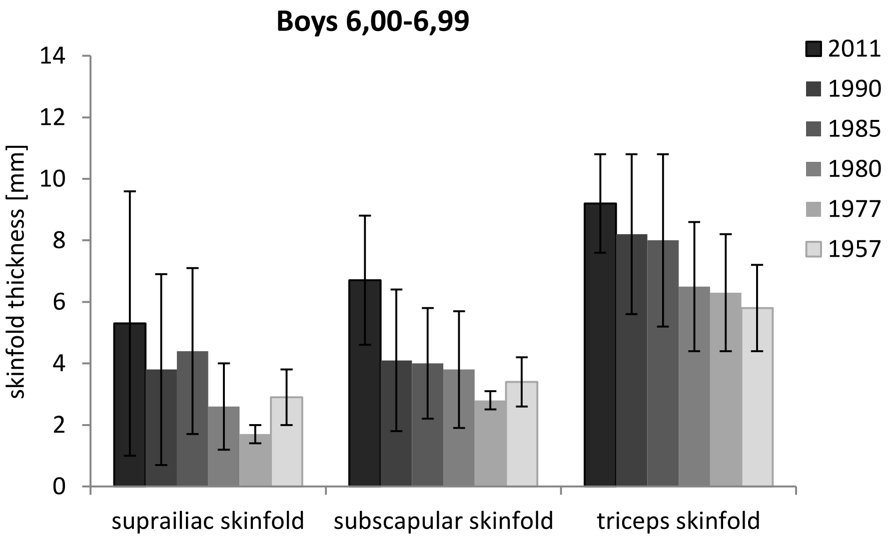

Fig. (9). Comparison of the changes of skinfold thickness (triceps, subscapular, suprailiac) in 6-years old boys followed up in 1957 up to 2011.

Table 1. Statistical significance of differences between the values of skinfold thicknesses (Kruskall-Wallis test after logarithmic transformation of data) - comparison of sample followed up in 2011 to samples followed up in 1957, 1977, 1980 and 1985.

2011 /		**1957**	**1977**	**1980**	**1985**	**1990**
Triceps						
Boys	5 years	***	*	-	-	*
	6 years	***	***	***	*	*
Girls	5 years	***	*	-	-	n.s.
	6 years	***	n.s.	***	n.s.	n.s.
Subscapular						
Boys	5 years	***	***	-	-	***
	6 years	***	***	***	***	***
Girls	5 years	***	***	-	-	***
	6 years	***	***	***	***	***
Suprailiac						
Boys	5 years	***	***	-	***	***
	6 years	***	***	***	*	***
Girls	5 years	***	***	-	-	***
	6 years	***	***	***	***	***

*P<0.05; ***P<0.001; n.s. = no significance.

1.1.7. SUMMARY STATEMENT

Environmental conditions have been changing permanently in both positive and negative way, which in a long run has been finally reflected by secular changes of growth, body composition and adiposity. During last hundred years the average body height in the adult population as well as in the individual age categories during growth continued to increase; this trend was mostly apparent during puberty. At present, the acceleration of growth is accompanied by an excess deposition of fat in the organism, and like that by the increase of obesity prevalence. Due to further shift of the onset and of frequently accelerated puberty development to younger age in the obese chidren, the validation of the genetic growth potential can be significantly reduced. At present, this phenomenon is necessary to consider as prevailingly undesirable.

NOTES

URL 1: Available at: http://www.cdc.gov/nchs/nhanes.htm Viewed 20 January, 2014.
URL 2: Available at: http://www.disabled-world.com/artman/publish/height-chart.shtml Viewed 20 January, 2014.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 1b

1.2. Body Mass Index, Weight-for-Length/Height and Obesity

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Abstract: With increasing prevalence of overweight and obesity the evaluation of the relationship of body weight to body height using body mass index (BMI) has spread universally also in children.In youngest children, maximally up to the age of 5 years only a relationship weight-for-length/height is used. In children the values of BMI are markedly dependent to the age and are specific for gender. Therefore utilization of growth reference is critical for assessment of health and nutritional status of children. In addition to the national growth references for children up to 19 years growth references WHO 2007, CDC 2000 and IOTF 2000 are mostly used. The WHO growth standards for children 0 – 5 years old were published in 2006. International comparisons of the evaluation of overweight and obesity are difficult due to the lack of consent of criteria used. In children after birth and during first year the percentile curves of BMI increase very markedly, but then they decrease. The second rise in BMI curve, *i.e.* adiposity rebound (AR), occurs between 5 and 7 years. An early AR is associated with an increasing risk of overweight. The secular trend of increased height and accelerated growth are probably responsible for shift of AR at earlier age. Until present overweight and obesity were the problem especially in high-income countries, overweight and obesity are now on the rise in low- and middle-income countries, particularly in urban settings. Selected studies from developed countries indicate, that this trend is finished.

Keywords: Acceleration, Adiposity, Body mass index, Gender, Growth, Obesity, Overweight, Prevalence, Rebound, Secular trend, Weight-for-length/height.

1.2.1. INTRODUCTION

Body mass index (BMI) is a simple index of weight-for-height that is commonly used to classify overweight and obesity in adults. Along with increasing prevalen-

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ce of over-weight and obesity concerning all age categories starting with earliest age in the eighties of the last century, the evaluation of the relationship of body weight to body height using body mass index (BMI) has spread universally also in children (Rolland-Cachera *et al.*, 1982). BMI is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2). In youngest children, maximally up to the age of 5 years only a relationship weight-fo--length/height has been further used for this classification (WHO, 2006). Weight-for-height is easier to use than BMI-for-age. However BMI-for-age and weight-for-stature will not give identical results and are not interchangeable. Differences in classification by the 2 measures varied with age and stature and were greater for shorter children. The 10th and 85th percentiles of weight-for-stature corresponded to BMI-for-age percentiles from the 3rd to the 21st percentile and from the 74th to the 92nd percentile, respectively, depending on age and stature (Flegal *et al.*, 2002).

In adults there exist clear cut-offs for low weight, normal weight, overweight and obesity, which are applied for all age categories. But in children the values of BMI are markedly dependent to the age and are specific for gender. In children after birth and during first year the percentile curves of BMI increase very markedly, but then they decrease. The second rise in BMI curve, *i.e.* adiposity rebound (AR), occurs between 5 and 7 years. An early AR is associated with an increasing risk of overweight (Rolland-Cachera *et al.,* 2006). To evaluate a child only according the values of BMI is therefore not possible. Without exact reference data it is even not possible to evaluate whether a child is under-weight, normal or overweigh and obese. Utilization of growth references (growth charts) is critical for assessment and monitoring of health and nutritional status of individual child in all countries.

Growth charts are also a very important tool for epidemiological studies, especially when evaluating the prevalence of overweight, obesity and/or underweight in a special population. For the elaboration of effective recommen-dations in this area there are indispensable also the international comparisons. Such recommendations are very difficult especially with regard of the lack of consent concerning the cut-off points used for overweight and obesity assessment. It is important to understand potential differences in interpretation of the growth assessments and possible practical consequences of such inter-pretations when different sets of available growth references are used.

1.2.2. GROWTH REFERENCES AND GROWTH STANDARDS FOR 0-5 YEARS

In the years 1998-2000 World Health Organisation (WHO) assessed in which countries growth charts have been used. From 202 countries Ministries of health 154 answered positively. Two thirds of the charts covered preschool age, all countries used charts weight-for -age, charts for the evaluation of other somatic parameters (length/height-for-age, weight-for-length/height, height circumference-for-age) were used in only some countries addressed.

The reference commonly used (68 %) was the National center for Health Statistics/World Health Organization reference 1977 (WHO/NCHS), with regional variation. Most of European countries used local standards (de Onis *et al.*, 2004a). This evaluation were the base for the decision of the WHO to construct new growth references, preferentially for children until the age of 5 years.

The 1977 WHO/NCHS reference was based on predominantly artificially, that is formula-fed child population. The evidence shows that breastfed and artificially fed infants grow differently and that the growth pattern of breastfed children most likely better reflects physiological growth. In 1994, based on the accumulated evidence, the WHO started working on new international standards which are based on a sample of healthy children breastfed exclusively or predominantly for at least 4 months (Multicenter Growth Reference study – MGRS) (de Onis *et al.,* 2004b). The new growth standards for children 0 – 5 years old were published in April 2006 (WHO, 2006). The study was based on the premise that in children growing under “ideal” conditions can be fully applied their genetic growth potential. New standards describe how children should grow, not how they grow. Growth charts and the software can be downloaded from the WHO website (URL-1).

In the Czech republic a study of Czech long breast fed infants was conducted during the years 2008-2011 (Procházka *et al.*, 2012; Vignerová *et al.*, 2012). A total of 960 infant/parent dyads in Czech Republic were recruited through paediatric practices. Anthropometric measurements were collected in infants' first 12 months of life and parent´s questionnaires were gathered during a regular preventive visit at the age of 18 months. The purpose of the study was to identify potential similarities and differences in growth patterns of breastfed infants using two sets of growth references, the WHO standards and the national growth references appropriate for the study sample. The findings of the study indicate that the breastfed Czech infants followed a different pattern of growth and development than infants from the six countries included in the WHO - MGRS (de Onis *et al.,* 2004b). Czech breastfed infants in the sample were longer with greater head circumference at all percentiles compared to WHO standards. The length and head circumference values were similar to national references. The percentile weight-for -age and weight-for-length values of infants (≤6 months) were lower, and higher (6-12 months) compared to WHO standards.

While the growth of Czech breastfed differed somewhat from the current national references (infants with all types of feeding were included in the construction of the national references) (Prokopec, 1994; Kobzová *et al.*, 2004) as well, these discrepancies were less significant than the differences in relation to the WHO standards. The study also confirms that the growth of breastfed infants is specific and different from the growth of formula fed infants. Thus, it is critical that paediatricians are aware of the relative decrease in weight gain among breastfed infants around the age of 3 months in order to avoid premature introduction of supplemental feeding at this critical time. Early introduction of supplemental feeding could be one of the factors resulting in obesity in children.

In the Czech Republic, the results of the study of breastfed children have led to a development of new growth assessment guidelines that have been already provided to paediatricians across the country in order to optimize feeding recommendations for Czech infants (Vignerová *et al.*, 2012) when using Czech growth references.

By April 2011, 125 countries had adopted the WHO 2006 standards. The main reason for their non-adoption is preference of local references. *E.g*: in the United Kingdom WHO standards were adopted for age 2 weeks up to 4 years. For other age national references are recommended (SACN/RCPCH, 2007; Wright *et al.*, 2010). A study of a large pediatric sample in Belgium and Norway found that children's growth followed the patterns in the national references more closely than the patterns outlined in the WHO growth standards (Juliusson *et al*., 2011). Thus, the national growth references have continued to be utilized in the two respective countries. In the USA the WHO standards were adopted for children 0-24 months (Grummer-Strawn *et al*., 2010).

Rolland-Cachera & Peneau (2011) emphasized that the type of growth references used by paediatricians has a major impact on the interpretation of the child's growth in paediatric practice. Thus, paediatricians need to be fully aware of differences between the available growth standards and realize the extent to which the results of routine growth assessments guide – define - their further medical and nutritional advice (Rolland-Cachera & Peneau, 2011).

1.2.3. GROWTH REFERENCES UP TO 18 YEARS

In addition to the local (national) growth references for children 5-19 years growth references WHO 2007 (URL-2) are frequently used. They are the modification of original WHO / National Centre for Health Statistics (NCHS) 1977 references. Original NCHS data set supplemented with data from the WHO child growth standards sample for under-fives were used. To develop this reference the same statistical methodology was used as in the construction of the WHO standards.

In the US they are used the 2000 CDC growth charts which represent the revised version of the 1977 NCHS growth charts. Most of the data used to construct these charts come from the National Health and Nutrition Examination Survey (NHANES), which has periodically collected height and weight and other health information on the American population since the early 1960's (CDC Growth Charts for the United States, 2000).

International Obesity Task Force (IOTF) recommends for the evaluation of overweight and obesity age specific BMI-for-age growth charts, based on 6 nationally representative samples. For each of the surveys, centile curves were drown that at age 18 years passed through the widely used cut-off point of 25 and 30 kg/m^2 for adult overweight and obesity. The resulting curves were averaged to provide age and sex specific cut-off points from 2-18 years.

These references were published in 2000 (Cole *et al.*, 2000), and updated in 2012 (Cole *et al.* 2012), but are not aimed for clinical purposes.

At present, all given reference data offer in addition to BMI growth charts also references for the evaluation of further basic somatic parameters; growth reference recommended by IOTF offer BMI growth charts only.

In the Czech republic in addition to growth references which are indispensable for obligatory preventive check-ups (*i.e.* head circumference-for-age, length/height-for-age, weight-for-age, weight-for-height and BMI-for-age) there are moreover added growth charts of five skinfold thickness (biceps-for-age, triceps-for-age, subscapular-for-age, suprailiacal-for-age, thigh-for-age), and also for some circumferential measures (upper arm-for-age, abdomen-for-age, hip-for-age, abdomen-for-height). These references are recommended for further anthropometric assessments when overweight, obesity and/or underweight are present.

1.2.4. DEFINITIONS OF OVERWEIGHT AND OBESITY

Growth reference values BMI-for-age vary according to the sample of the population in question and their construction. In some details there could be differences also according to the statistical method used, which can have an importance especially for the borderline percentiles. Growth references of WHO 2007 (URL-2), CDC 2000 (CDC, 2000) and IOTF 2000 (Cole *et al.*, 2000) which are constructed in such a way that cut-off –curves at age 18 pass through the cut-off points approximately of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity. In growth charts CDC 2000, which are constructed until the age of 20 years the cut-off values after 18 years even increase above 25 kg/m^2 and 30/m^2. Czech reference data of BMI 1991 (Vignerová *et al.*, 2006a) were assessed empirically, and then smoothed by statistical methods. Cut-off points at the age of 18 are lower than in other mentioned references.

In Tables **1** and **2** there are given either defined criteria, which are used in individual references as cut-offs for overweight and obesity, and further their concrete values in boys and girls at the age of 5, 10, 15 and 18 years.

As follows from the tables, cut-offs for obesity vary markedly with regard to their values. This is necessary to consider specially when international comparisons are conducted. Discordance in the assessment of overweight and obesity *e.g.* in children 24-60 months old when WHO 2006 and IOTF references were used is analyzed in the study of Monasta *et al.* (2010). There were compared the prevalence of overweight and obesity, as defined by the IOTF reference and by the WHO standard (2SD<), using 2001 data from the Czech Republic. The IOTF cut-off for overweight in 24–60 months old children goes from 1.7 to 1.1 z-scores on the WHO chart, and for obesity it shifts with age from 2.7 to 2.2 z-scores. As a consequence, at 5 years of age the prevalence of overweight in Czech girls is 3.4% using the WHO and 15.3% using the IOTF definition. The prevalence of obesity in boys at 5 years of age is double if we use the IOTF cut-off compared with the WHO standard at 3SD (3.1% *vs.* 1.5%, respectively).

Table 1. BMI criteria and cut-off values for selected age groups - boys.

Age years		WHO 2006 0–5 years +2SD +3SD	WHO 2007 5–19 years +1SD +2SD	IOTF BMI= 25 at age 18 BMI = 30 at age 18	CDC 85th centile 95th centile	Czech rep. 90th centile 97th centile
5 years	Overweight Obesity	18.3 20.3	16.6 18.3	17.4 19.3	16.8 17.9	17.5 18.6
10 years	Overweight Obesity	-	18.5 21.4	19.8 24.0	19.4 22.1	20.0 22.3
15 years	Overweight Obesity	-	22.7 27.0	23.3 28.3	24.0 28.1	23.5 26.0
18 years	Overweight Obesity	-	24.9 29.2	25.0 30.0	25.7 29.0	25.4 27.7

In clinical praxis BMI-for-age growth charts are an indispensable utensil, but cut-offs for overweight and obesity are only suitable for general orientation. In the case of excess weight it is always necessary to use further anthropometric measurements (arm, abdomen, hip circumferences, skinfolds), and also laboratory assessments of metabolic parameters.

Table 2. BMI criteria and cut-off values for selected age groups - girls.

Age years		**WHO 2006 0–5 years +2SD +3SD**	**WHO 2007 5–19 years +1SD +2SD**	**IOTF BMI= 25 at age 18 BMI = 30 at age 18**	**CDC 85th centile 95th centile**	**Czech rep. 90th centile 97th centile**
5 years	Overweight Obesity	18.8 21.1	16.9 18.9	17.1 19.2	16.8 18.3	17.3 18.4
10 years	Overweight Obesity	-	19.0 22.6	19.9 24.1	20.0 23.0	20.2 22.4
15 years	Overweight Obesity	-	23.5 28.2	23.9 29.1	24.0 28.1	23.6 26.0
18 years	Overweight Obesity	-	24.8 29.5	25.0 30.0	25.7 30.3	25.0 27.6

1.2.5. SHIFT OF ADIPOSITY REBOUND AND SECULAR TREND OF BMI

In children after birth and during first year of the life the BMI values increase very markedly, but then they decrease. It is cause by the growth in the size of the adipocytes which diminishes in the next year or two and then remains stable for several years while body height continues to increase. This development is reflected by aparent slimming of the child. The onset of the second period of rapid growth in body fat and second rise in BMI curve, termed adiposity rebound, occurs between 5 and 7 years. From this moment, both the size and number of adipocyte increase (Knittel *et al.*, 1979). The timing of the AR is associated with a risk of overweight, the earlier AR the higher the risk of overweight (Rolland-Cachera *et al.,* 2006). However, analysis of the Czech data suggests that the timing of AR has shifted not only among overweight and obese children, but also among low-weight children.

The assessment of the period of AR from growth curves of BMI is partly dependent on the mathematical method used, as shown by some authors (Kroke *et al.*, 2006; Rolland-Cachera *et al.*, 2006). When analyzing the shift of AR and secular trend of BMI on the basis of the results of Nationwide Anthropological Surveys in Czech Republic from the years 1951 - 2001 (1951, 1981, 1991 and

2001) was AR defined as the age position of the local minimum on the fitted smooth BMI curve. The fitting of BMI against age was carried out using the LMS method (Cole *et al.*, 1998) separately for each survey; in effect this stratifies the data on the survey year. The LMS fit is based on nonparametric smoothing of the time tracks for three parameters of the Box-Cox transformation family (median, coefficient variation, Box-Cox transformation parameter). The number of children observed in each of the four surveys was 126,082 in 1951 (62,742 boys, 63,340 girls), 87,316 in 1981 (42,832 boys, 44,484 girls), 70,299 in 1991 (34,640 boys, 35,659 girls) and 59,082 in 2001 (28,146 boys, 30,963 girls). The number of children and adolescents participating in the anthropometric surveys was highest in 1951, declining across subsequent surveys.

Compared to 1951, the time of AR has gradually shifted to earlier ages among both boys and girls at all percentiles. Among boys at the 50^{th} percentile for BMI-for-age, AR occurred at the age of 4.9 years in 2001 compared to 6.2 years in 1951. Adiposity rebound among girls at the 50^{th} percentile occurred 1.2 years earlier in 2001 as compared to 1951, Table **3**. AR at the 10^{th} and 50^{th} percentile occurred later among girls compared to boys in 1951 as well as in 2001. In contrast, girls at the 90^{th} percentile experienced AR earlier than boys at the same percentile.

The decrease of the age of AR under 5 years was referred in a number of publications in different countries, and it was always found in the relattionship to general increase of obesity prevalence in children (Rosario *et al.*, 2010; Chivers *et al.*, 2010).

When comparing percentile values of BMI used in the individual anthropological surveys of children and adolescents in the Czech Republic, we focused our attention on the comparison of research results from the years 1951 and 2001, *i.e.* on the changes which occurred during fifty years during the second half of the last century. Percentile curves which were based on surveys conducted between these years are also situated between the above mentioned curves in 1951 and 2001. In the Figs. (**1** and **2**) there are given curves of 10^{th}, 50^{th}, and 90^{th} percentiles of BMI in Czech boys and girls followed up in the year 1951 and 2001 in relation with the shift of AR to younger age.

Table 3. Age of adiposity rebound (years) in Czech children.

Centile	Boys			Girls		
	Year of the survey			Year of the survey		
	1951	2001	Difference	1951	2001	Difference
	Age	Age	Years	Age	Age	Years
10th	6.4	5.3	1.1	6.5	5.6	0.9
50th	6.2	4.9	1.3	6.4	5.2	1.2
90th	6.0	4.2	1.8	5.8	4.1	1.7

The values of 50th percentile increased between 6th and 16th year in boys, and in girls between 6th and 11th year of age. In both genders the number of subjects with overweight and obesity (cut-off 90th percentile) increased, but in girls only up to the age of 14 years. Marked reduction of all percentile values during adolescence in girls can be found when comparing these results with the year 1951. This indicates that in 1951 adolescent girls achieved, as compared to the present, much higher body weight.

The secular trend of increased height, accelerated growth, and earlier maturation are responsible for Czech children experiencing AR at earlier age in 2001 compared to the past. For boys, the onset of the pubertal growth spurt has shifted from 11 to 9.5 years of age during the past 50 years. The maximum instantaneous growth rate increased from 6.5 to 7.3 cm /year between 1951 and 2001. For girls, the period of most rapid growth occurs at 11 years of age, with a gradual shift to a younger age. The maximum instantaneous growth rate gradually increased from 5.6 to 6.6 cm/year between 1951 and 2001 (Vignerová *et al.*, 2006b).

Polish researchers who in 2010 assessed height, weight and body fat of 1,970 girls and compared the data with the results from previous surveys (1983 and 2000) achieved similar conclusions. All girls measured in 2010 have the time of AR earlier than girls measured in 1983. Authors concluded that earlier AR cannot be explained only by changes in body adiposity. It could be a marker of acceleration of development in general, and already in an early postnatal ontogenesis. The girls from the last series of measurements showed also acceleration of sexual maturation and the average menarche age was the earliest in them. Before the time of AR, girls from last series have lowest BMI and % of body fat than girls from the first series (Kowal *et al*., 2013).

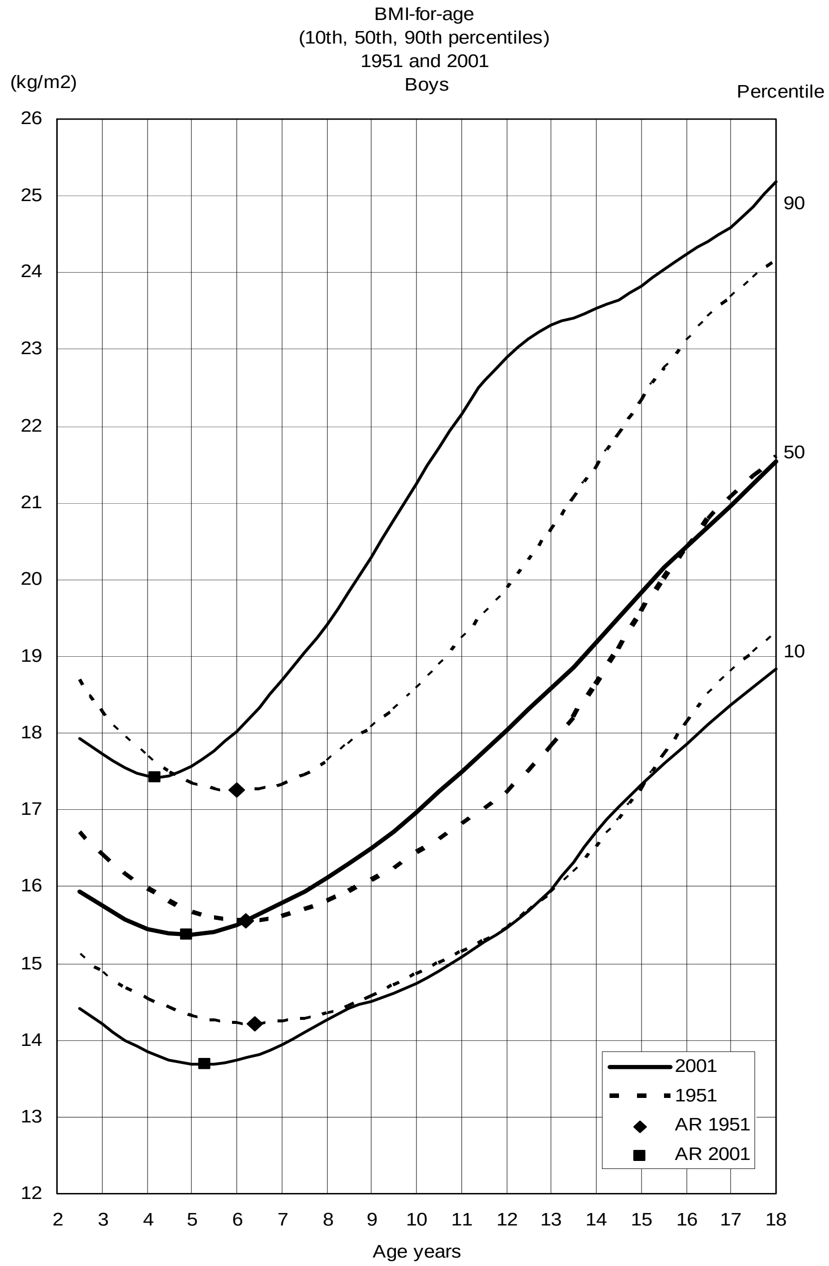

Fig. (1). BMI-for-age (10th, 50th, 90th percentiles), 1951 and 2001 – boys.

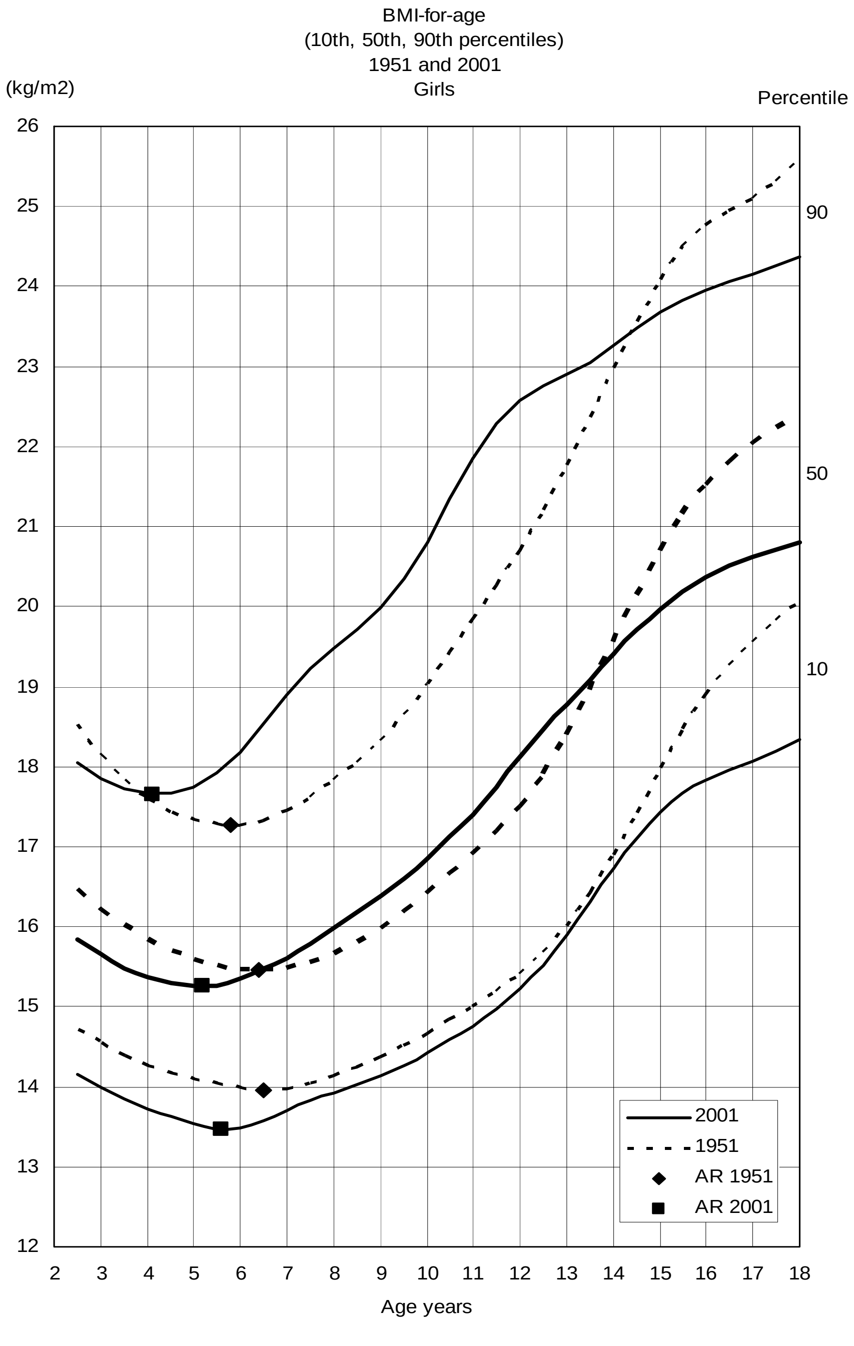

Fig. (2). BMI-for-age (10th, 50th, 90th percentiles), 1951 and 2001 – girls.

Lower values of BMI before AR in present children as compared to those before the start of obesity epidemy were indicated also by Fels Longitudinal Study (Johnson *et al.*, 2012). The sample consisted of 855 European-American participants (437 boys; 418 girls) in the Fels Longitudinal Study born between 1929 and 1999. BMI curves showed that children born in 1973–1999 had the lowest BMI values until age 5 years before the adiposity rebound but had the largest values from age 8 years onward. Similar conclusion was given also by Rolland-Cachera *et al.*, (2006). The typical pattern associated with an early AR is a low BMI followed by increased BMI level after the rebound. This pattern is recorded in children of recent generations as compared to those of previous generations. Similar trend is also apparent in Czech population, as shown in Figs. (**1** and **2**).

There follows a question resulting from the above mentioned results whether the percentile curves of BMI from previous years are comparable with the present ones. It is probable that when ontogenetic development accelerates already in early age, and especially during adolescence, percentile curves can also change their character. Therefore, as a next step a shift of percentile curves of Czech children from 1951 by 1.3 year in boys, and 1.2 in girls to an earlier age (which corresponds the shift of AR to 50th percentile during fifty years) was conducted, Figs. (**3** and **4**). As an illustration this shows a step which *e.g.* in a ten-years old child in 1951 is evaluated as a child 1.3, and 1.2 years resp. younger as compared to the figure from 2001, (*i.e.* as a child less mature compared to present children), *i.e.* at the age of 8.7 and 8.8 resp.

Using this step the borderline percentiles are spread to both sides , *i.e.* the increase of children with low body weight is comparable to the increase of children with high body weight. Values of 50th percentile are up to cca 12 years (age axes corresponds to 2001) are nearly the same in all percentiles in both genders. Higher values of BMI during adolescence in girls from 1951, when curves are shifted according to the shift of AR, in all percentiles are even more marked; in boys they are higher only in 50th percentile.

When shifting these curves according to common point of AR, Figs. (**3** and **4**), we do not find the pattern associated with an early AR, *i.e.* low BMI followed by increased BMI level after the rebound (Rolland-Cachera, 2006; Johnson *et al.*,

2012) BMI values decrease before AR and their consequences are in 1951 and 2001 similar.

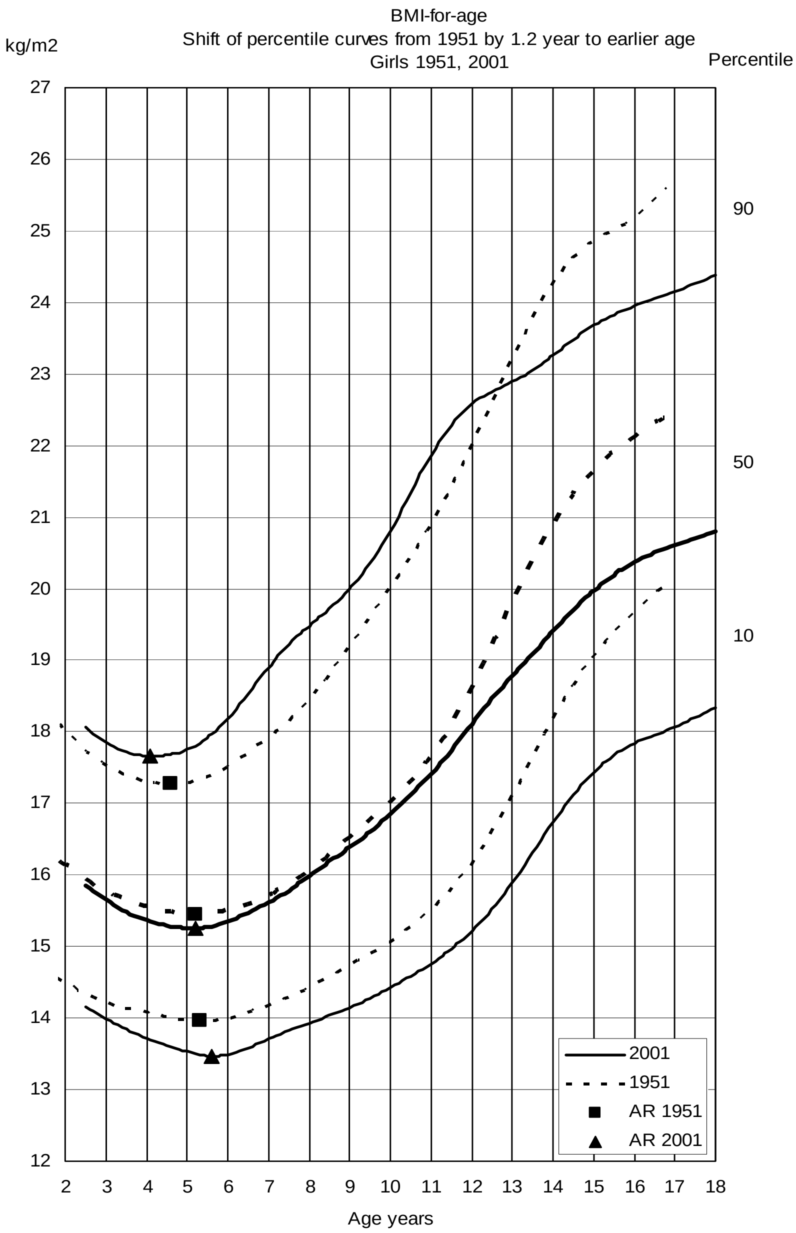

Fig. (3). BMI-for-age 1951 and 2001, shift of percentile curves from 1951 by 1.3 to an earlier age – boys.

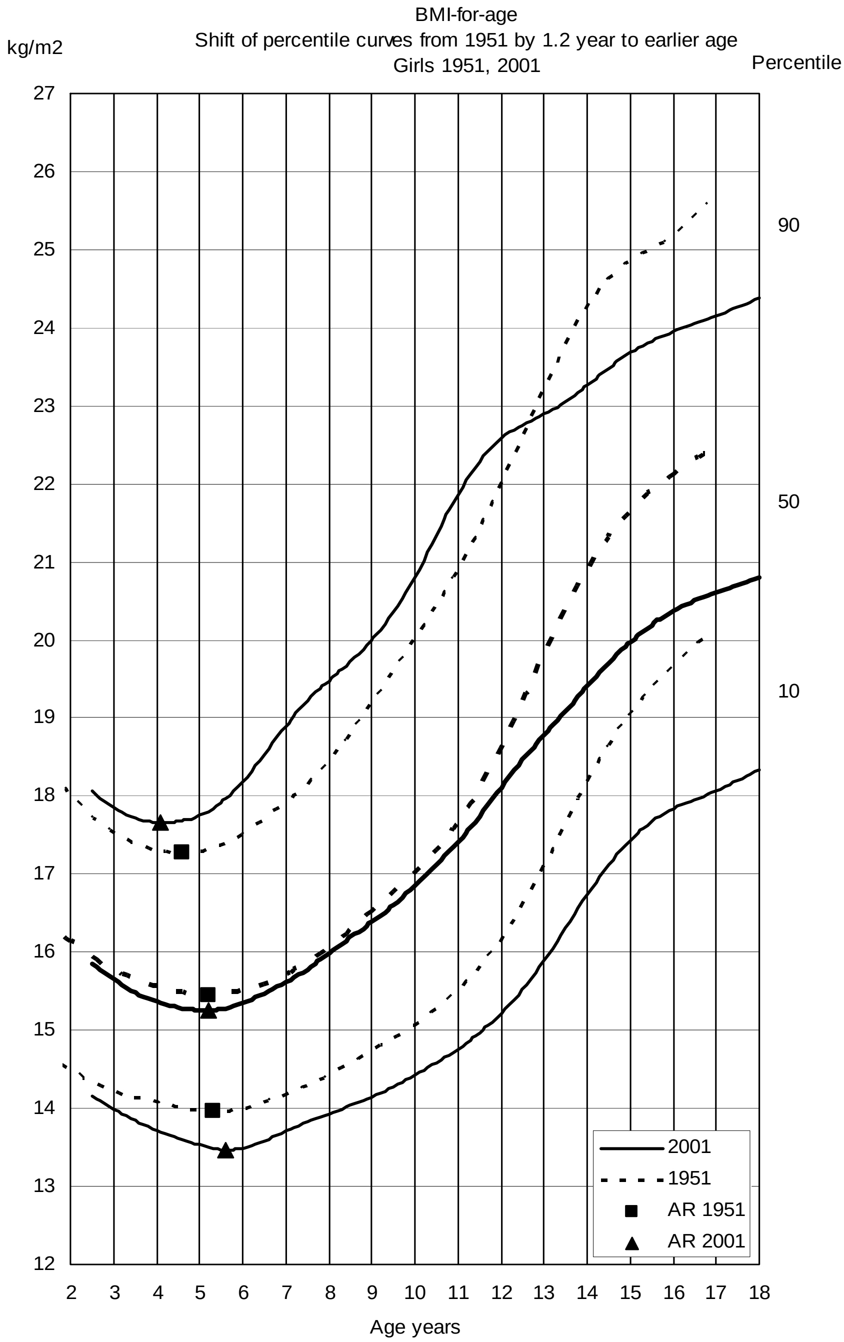

Fig. (4). BMI-for-age 1951 and 2001, shift of percentile curves from 1951 by 1.3 to an earlier age – girls.

1.2.6. PREVALENCE OF OVERWEIGHT AND OBESITY IN CHILDREN AND ADOLESCENTS IN THE WORLD

International comparisons of the evaluation of overweight and obesity are mostly very difficult due to the lack of consent of criteria used. Great problem is also the quality of data which are at the disposition. The WHO Global Database includes population-based surveys that fulfil a set of criteria. Data are checked for validity and consistency and raw data sets are analysed following a standard procedure to obtain comparable results. New surveys are included on a continuous basis and updates are published quarterly on this website (URL-3).

According to WHO Global Database in 2011, more than 40 million children under the age of five were overweight. Until present overweight and obesity were the problem especially in high-income countries, overweight and obesity are now on the rise in low- and middle-income countries, particularly in urban settings. More than 30 million overweight children are living in developing countries and 10 million in developed countries (URL-4).

In different parts of Africa the situation is very different, and the information from individual countries is very rare. Highest prevalence of obesity in North Africa was found (17%) which is driven mainly by Egypt (20.5% in 2008) and Libya (22.4% in 2007). Due to great number of population in 2010 the highest prevalence of obese children in South Central Asia (6.6 million) was found, despite low prevalence rates (Bangladesh, India, and Pakistan) (de Onis *et al.*, 2010).

In the following table (Table **4**) the prevalence of overweight and obesity (2SD < weight-for-height) in children 0 - 5 years old in different parts of the world is given.

In Japan the prevalence of overweight and obesity in children was assessed by National Nutrition Surveys, however Japan does not have its own reference values, and due to lower values of height and weight of the population the use of other references standards is questionable. When using Japanese criteria for the evaluation of overweight and obesity (Hibi's monogram) the prevalence of obese boys and girls increased from 6.1% and 7.1%, respectively, in the time-period

1976 to 1980, to 11.1% and 10.2% in 1996 to 2000. The increasing trend was most evident in 9- to 11-year-old children of both sexes living in small towns. In girls from larger cities no changes with regard to 2000 were found, on the contrary tendency toward underweight in young women was revealed (Matsushita *et al.*, 2004).

Table 4. Prevalence of overweight and obesity (2SD< weight-for-height) and 95% CI in children aged 0–5 y, in 2010, by United Nations (UN) regions.

Region	Prevalence %	95% CI
Africa	8.5	7.9 -9.5
Asia, excl. Japan	4.9	3.2 – 6.6
Latin America and Caribbean	6.9	5.9 – 8.0
Oceania, excl. Australia and New Zealand	3.5	2.4 – 4.9
Developing countries	6.1	5.0 – 7.2
Developed countries, incl. Europe, Northern America, Australia, New Zealand, Japan	11.7	8.9 – 15.3
Global	6.7	5.6 – 7.7

In China, on basis of Chinese National Surveillance on Students' Constitution and Health data sets of boys and girls at the age of 7-18 years were collected (between 1985 and 2000). BMI classification reference proposed by Working Group on Obesity in China (WGOC) was used (Ji, 2007). In 2000, the prevalence of obesity and overweight in boys aged 7-18 years decreased along with decreasing size of the city in which children lived (17.8% in Beijing, 18.1% in Shanghai, 14.4% in coastal big cities, and 7.8% in coastal medium/small-sized cities). The prevalence of obesity and overweight in girls was lower than in boys (11.9% in Beijing, 9.9% in Shanghai, 8.7% in coastal big cities, and 6.5% in coastal medium/small-sized cities, respectively). Steady increasing trend was found among both sexes and in all age groups. This trend was stronger in boys than in girls, and much stronger in children than in adolescents.

Similar trend was revealed in China also in 2010 when large cross-sectional survey was conducted in the Shandong province (Zhang & Wang, 2013). The prevalence of overweight and obesity was obtained according to the International Obesity Task Force (IOTF) cut-offs. The prevalence rates of combined overweight and obesity reached 26.86% in urban boys, 18.32% in rural boys, 14.36% in urban girls, and 11.31% in rural girls, respectively. Both mentioned studies explain the increasing prevalence of overweight and obesity by their relationship to an increasing socio-economic status.

In 2002 a comparative study of the prevalence of overweight and obesity in children 6-18 years old in Brazil, China, Russia and USA was conducted using IOTF reference standards (Wang *et al.*, 2002). This study is interesting especially due to the data from Russia which have been very rare until present. The Russian Longitudinal Monitoring Survey was the first nationally representative household survey in the Russian Federation. All members of >6400 households from all regions of Russia were surveyed 8 times in 1992–1998.

According to the results of this research in Russia overweight decreased during the study (from 15.6% to 9.0%) and underweight increased from 6.9% to 8.1%.The Brazilian data came from 2 random nationally representative samples undertaken by the Brazilian agency in charge of national statistics in 1974–1975 and 1996–1997. The prevalence of overweight increased during the study periods in Brazil (from 4.1% to 13.9%). In the United States, based on National Health and Nutrition Examination Surveys (NHANES I, 1971–1974) and NHANES III (1988–1994) the prevalence almost doubled (from 15.4% to 25.6%). In China were used data from the longitudinal China Health and Nutrition Surveys conducted in 1991 and 1997. These surveys covered 8 provinces that vary substantially in geography, economic development, and health indicators. The prevalence of overweight increased by one-fifth (from 6.4% to 7.7%).

In the USA the prevalence is regularly followed up on the basis of National Health and Nutrition Examination Surveys (NHANES), and for the evaluation from 2000 the actualized CDC growth charts. From this reason it is difficult to compare estimates in the United States with those in other countries. National estimates of overweight or obesity in children based on the NHANES data show that in 2003–2006, 31.9% of children 2–19 years old had a BMI at or above the 85^{th} percentile (risk of obesity) of the 2000 CDC BMI-for-age growth charts, and 16.3% were at or above the 95^{th} percentile of BMI (obesity) for age (Nguyen & El-Serag, 2010).

According to further studies of the prevalence of overweight and obesity in the USA childhood obesity has more than doubled in children and tripled in adolescents over the past 30 years. The percentage of children aged 6–11 years in the United States who were obese increased from 7% in 1980 to nearly 18% in 2010. Similarly, the percentage of adolescents aged 12–19 years who were obese increased from 5% to 18% over the same period. Prevalence estimates differed by age and by race/ethnic group. Trend analyses indicate no significant trend between 1999-2000 and 2007-2008 except at the highest BMI cut point (BMI for age > or = 97th percentile) among all 6- through 19-year-old boys and among non-Hispanic white boys of the same age. In 2009-2010, 21.2% of Hispanic children and adolescents and 24.3% of non-Hispanic black children and adolescents were obese compared with 14.0% of non-Hispanic white children and adolescents (Ogden *et al*., 2012).

Australian study (Olds *et al*., 2010) analyzed forty-one Australian studies of childhood weight status conducted between 1985 and 2008. The studies included data on Australians aged 2–18 years. Children were classified as overweight or obese based on BMI using the IOTF criteria. There has been a plateau, or only slight increase, in the percentage of boys and girls classified as overweight or obese, with almost no change over the last 10 years. In boys and girls, prevalence rates have settled around 21–25% for overweight and obesity together, and 5–6% for obesity alone. Most recent data were prepared by Australian Bureau of Statistics: in 2011-12, 24% of Australian boys and 27% of girls aged 5-17 years were either overweight or obese (URL-5). There was no information on reference values of BMI used in this analysis.

In spite of great effort, in Europe no consented and methodically unified study on overweight and obesity prevalence was conducted. Studies published have been mostly regional, or included only selected age categories, as *e.g*. WHO Europe Childhood Obesity Surveillance Initiative (COSI). In 2009 there was published a study comparing the prevalence of overweight and obesity in preschool children in the countries of European Union. Existing data were used including WHO database, then data from both published and unpublished documents, and finally also data gained from the contacts with their authors.

Comparisons were problematic because of different definitions and methods of data collection and analysis. Data were analysed using the IOTF cut-offs, and the WHO standards. Only data from 18 countries corresponded to necessary criteria for the analysis. Not all data included all age categories 0-59 months, and not all data could have been used for the analysis both according to IOTF cut-offs and WHO criteria (Cattaneo *et al*., 2010). The reported prevalence of overweight plus obesity at 4 years ranges from 11.8% in Romania (2004) to 32.3% in Spain (1998–2000). Countries in the Mediterranean region and the British islands report higher rates than those in middle, northern and eastern Europe. Rates are generally higher in girls than in boys.

In the Figs. (**5** and **6**) (Cattaneo *et al*., 2010) the prevalence of overweight and obesity in 2-6 years old children from 10 countries of EU, evaluated according to IOTF reference is given. The figures are modified for purposes of this book. The highest ratio of overweight and obesity in Spanish children was found (in 2006, 31.0 % in girls and 27.9 % in boys), and lowest ratio in boys from Cyprus (in 2004, 8.4 %) and in Romanian girls (in 2004, 11.7 %).

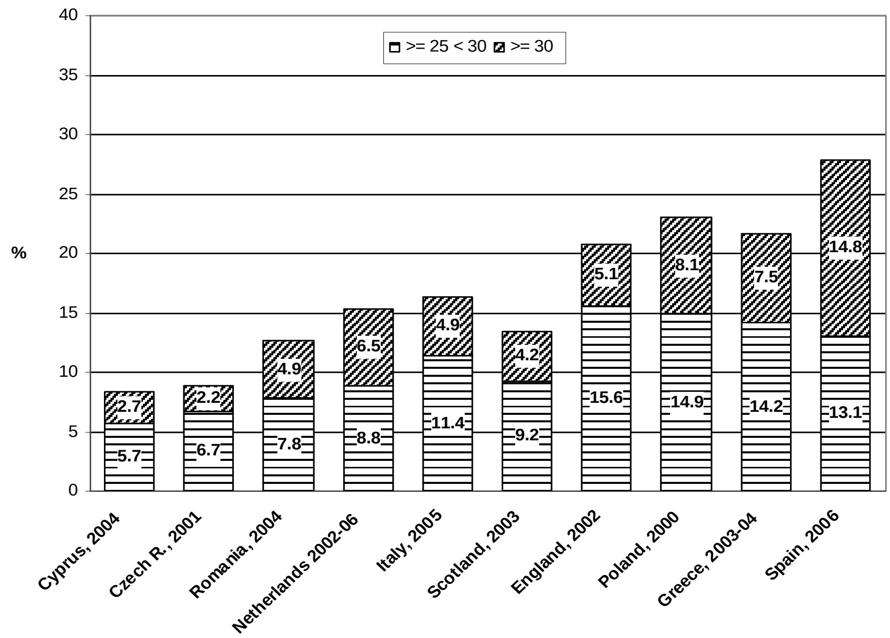

Fig. (5). Rates of overweight and obesity (the International Obesity Task Force reference and cut-offs) in children at 24–59 months of age, by country – boys.

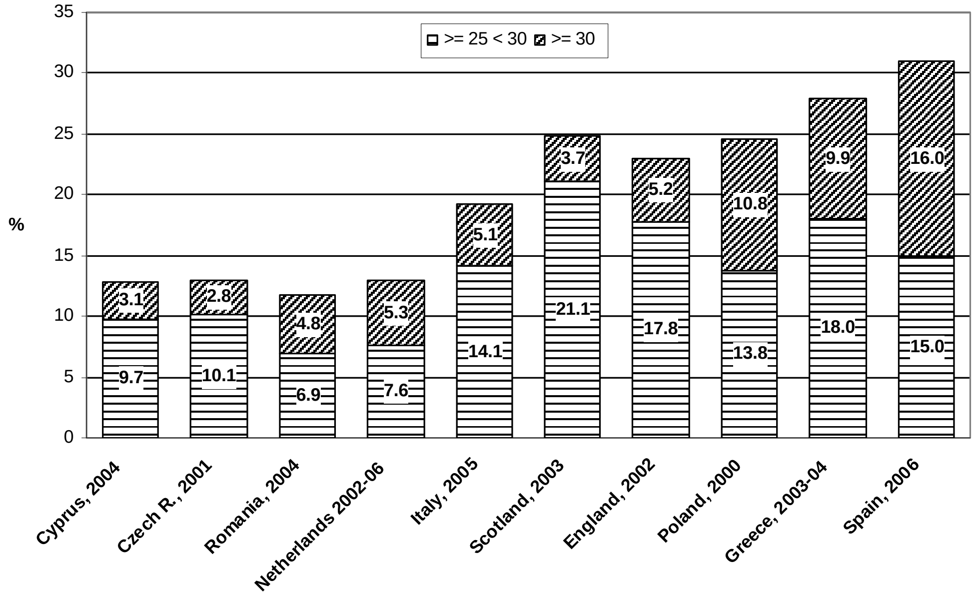

Fig. (6). Rates of overweight and obesity (the International Obesity Task Force reference and cut-offs) in children at 24–59 months of age, by country –girls.

The prevalence of overweight and obesity in children 7-17 years old in 21 countries in Europe is summarized in a publication from 2003 (Lobstein & Frelut, 2003). This study used IOTF criteria for evaluation, and the results are presented in two maps (for children 7-11 and 14-17 years). There is possible to detect two apparent trends. The first is the generally lower levels of overweight found among children in the countries of central and eastern Europe. The second trend apparent in the data is that the prevalence of overweight is higher among the southern countries of Europe, especially those outside of the former eastern bloc. The non-eastern bloc countries surrounding the Mediterranean show prevalence rates for overweight children in the range 20–40%, while those in northern areas show rates in the range 10–20%. A north–south trend has also been reported within countries (*e.g.* in Italy 23 % in the south, 13% in the central and northern areas).

In the Czech Republic the nutritional status of growing population aged 0-18 years has been regularly followed up in ten-years intervals, based on National Anthropological Surveys since 1951. Last of these studies was realized in 2001, and for further studies Ministry of health of CR no financial resources were given. Since 2001 no further information on child´s growth have been available in the Czech Republic, for the evaluation of overweight and obesity prevalence, and/or underweight. Therefore, only the situation in 2001 can be reported, and then the results of studies which are more actual, but involve only some age categories.

In Tables **5** and **6** there is given the percentage of subjects with excess weight in 2001 evaluated by Czech reference references 1991 (overweight 90^{th} > and <=97^{th} percentile, obesity 97^{th} <), and also evaluated according to IOTF criteria, in age groups of preschool children and school children 11, 15 and 18 years old. In preschool children and in boys from 15 to 18 years the percentage of children with overweight decreased (4,6 % and 5,9 % as compared to 7 % in 1991), in school children it increased (from 7 % to 8,9 % and 9,3 %). The percentage of obese boys increased in all age categories (as compared to 3 % in 1991), in the age group 15-18 years only by 0.6 % (Vignerová *et al.*, 2006a).

Table 5. Percentage of overweight and obese boys in 2001 (%).

Age (years)	N	Compared to Czech references 1991			Compared to IOTF references		
		Obesity	Overweight	Overweight and obesity	Obesity	Overweight	Overweight and obesity
3.00 – 5.99	2 100	4.6	4.6	9.2	3.4	6.0	9.4
6.00 – 10.99	5 933	6.6	8.9	15.5	3.6	13.1	16.7
11.00 – 14.99	6 341	5.6	9.3	14.9	2.4	13.9	16.3
15.00 – 17.99	5 131	3.6	5.9	9.5	1.7	9.2	10.9

Table 6. Percentage of overweight and obese girls in 2001.

Age (years)	N	Compared to Czech references 1991			Compared to IOTF references		
		Obesity	Overweight	Overweight and obesity	Obesity	Overweight	Overweight and obesity
3.00 – 5.99	2 024	5.0	6.6	11.6	3.3	9.6	12.9
6.00 – 10.99	5 936	5.6	8.5	14.1	3.2	13.4	16.6
11.00 – 14.99	6 376	4.4	7.8	12.2	1.6	10.4	12.0
15.00 – 17.99	7 896	2.5	6.0	8.5	0.8	6.9	7.7

In girls the ratio of subjects in groups with excess weight increased in all age categories, see Table **6**, with the exception of oldest age category. In this one we can observe marked decrease of overweight and obesity, but at the same time also the increase of the percentage of girls with reduced body weight.

According to IOTF criteria the ratio of subjects with excess weight is for both genders and for all age categories higher than that evaluated by Czech criteria, with the exception of oldest girls. The ratio of the obese is prevailingly lower. In girls at the age from 15 to 18 years the ratio according to the IOTF criteria includes only 0.8 % of the obese.

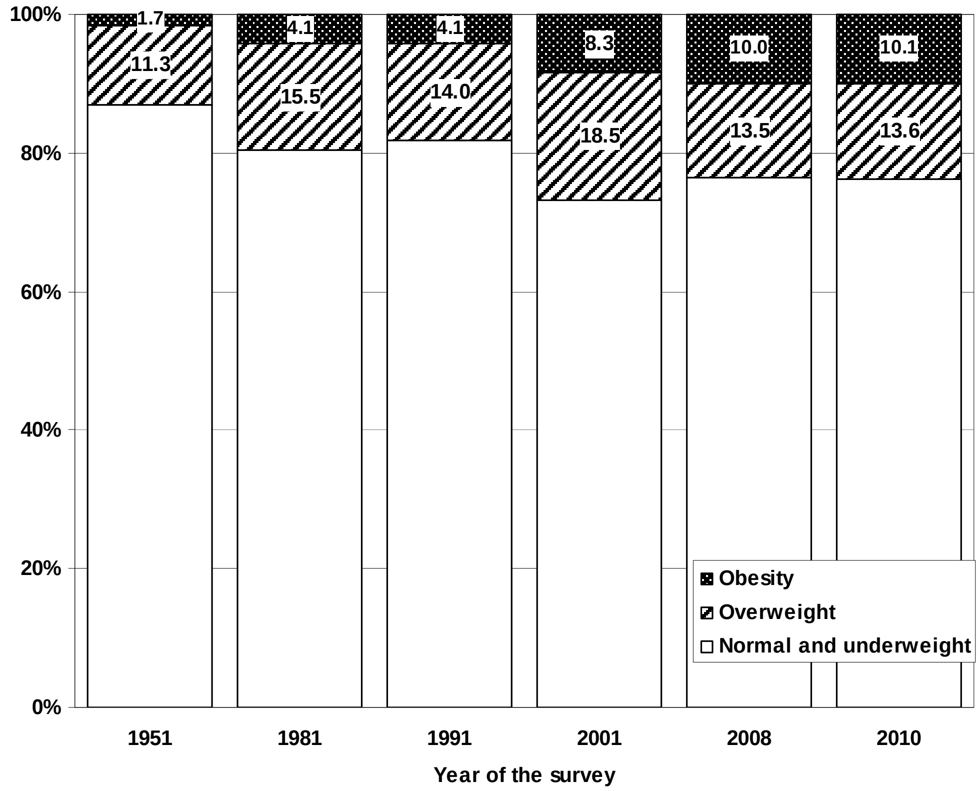

Fig. (7). Prevalence of overweight and obesity (%) in the period 1951 – 2010, 7 years old boys (WHO criteria).

In the Czech Republic (2008 and 2010) there were conducted two studies in the framework of WHO Childhood Obesity Surveillance Initiative (COSI) aimed to the evaluation of overweight and obesity in children 7 years old (Kunešová *et al.*, 2011). The authors compared data from 1951, 1981, 1991, 2001 (Nationwide Anthropological Surveys) and 2008, 2010 (COSI) using WHO cut-offs, Figs. (**7** and **8**).

The numbers of 7-years old children included in this research are from 5000 boys and girls in 1951 and 2100 in 2001. In 2008 there was examined 1531 of boys and girls, and 2594 of children in 2010. Results showed that since 1951 in boys, overweight and obesity prevalence increased from 13.0% in 1951 to 26.8% in 2001, in girls from 10.9% to 22.9%. From 2001 to 2008 obesity in boys increased; obesity in girls and overweight in both genders decreased (overweight and obesity in boys 23.5 %, in girls 19.5 %). From 2008 to 2010 in boys, the prevalence did not changes (23.7 %), in girls it increased (22.7 %).

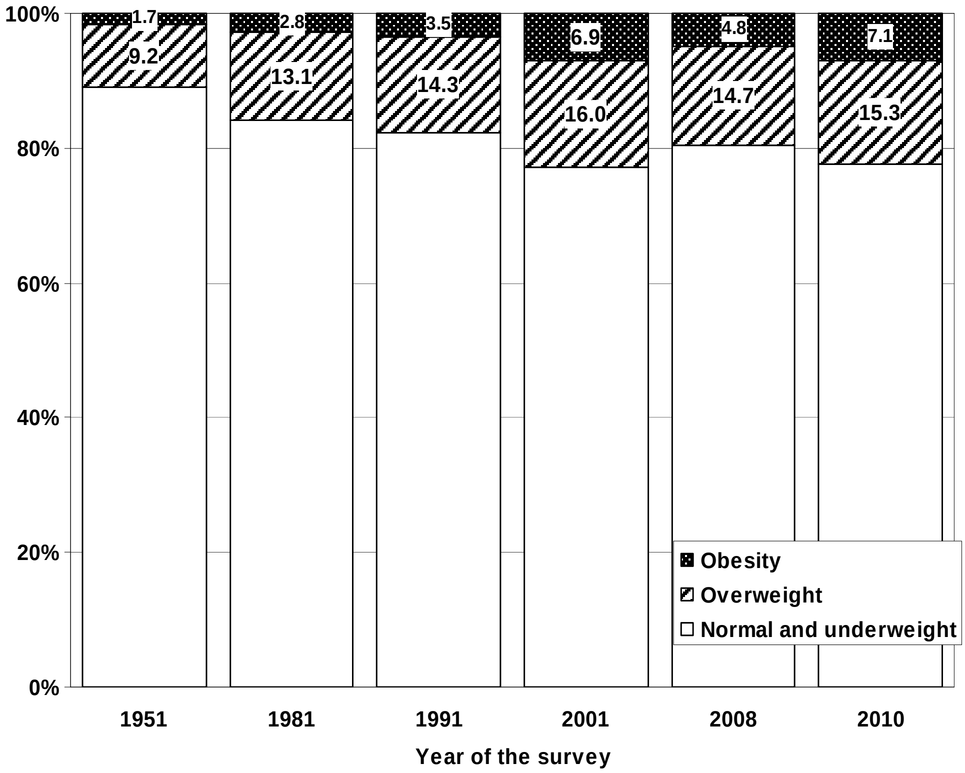

Fig. (8). Prevalence of overweight and obesity (%) in the period 1951 – 2010, 7 years old girls (WHO criteria).

A question remains whether after all past changes which resulted in an accelerated growth and development of adolescent children it is possible to compare the prevalence of overweight and obesity during such a long and varying period of time. Especially the year 1951 is, according to the nutrition situation after WW II., atypical. Also the methods for data collection in the project COSI 2008 and 2010 was different as compared of previous Nationwide Anthropological Surveys.

In 2008, the framework of the same project (COSI), 37.9 % of in 6-8-years old children (from this 15.3 % obese) was found in Portugal. This country has the highest prevalence of obese children in Europe (Rito, 2011).

In 2009 – 2010 a study Childhood Obesity Prevalence and Treatment (COPAT – supported by grant 7F08077 z MSM/7F, and through Norwegian financial mechanism (CZ 0123)), aimed to the evaluation of overweight and obesity and mode of treatment in adolescents. Prevalence of overweight and obesity at the age of 13 – 17 years was evaluated using both Czech references and WHO criteria, Table **7**. 1548 children (754 boys, 794 girls) were included in this research.

Table 7. Prevalence of overweight and obesity (%) in boys and girls 13 – 18 years old in 2009-2010 (Czech references and WHO references 2007).

	Compared to Czech references 1991		Comred to WHO references 2007	
	Boys	**Girls**	**Boys**	**Girls**
Overweight	11.7	11.7	23.3	18.3
Obesity	16.1	11.3	10.5	5.2
Overweight and obesity	27.8	23.0	33.8	23.5

The results reveal great increase of overweight and obesity as compared to the year 2001 (Vignerová *et al*., 2006a), mainly in boys. In 2001 the prevalence in 15-18 years old boys was 10.9% (using IOTF criteria) which increased to 33.8 % (WHO criteria) in 2010. In girls this increase was from 7,7 % v 2001 (IOTF criteria) to 23.5 % (WHO criteria) v 2010. In spite that the results are not fully comparable with regard to different cut-offs used, we can consider an enormous increase of overweight and obesity in adolescents. But in 7-years old children (COSI 2008, 2010) a mild decrease as compared to 2001, and following stagnation was revealed.

Above mentioned list of studies reviewing the prevalence of overweight and obesity in children is not, and cannot be complete. Nevertheless, it shows how difficult is or can be the comparison of the prevalence of overweight and obesity in the individual countries or regions, and which are the reasons for that. But generally it is possible to say that the trend of the increasing prevalence can be found in all countries with the exception of Russia in 1998). Selected studies from developed countries indicate that this trend is finished - not continuing. As was mentioned above, the comparison of absolute numbers is very problematic. Reason for that are the differences in methods for the collection of data in the individual studies, and also different criteria used for the evaluation of excess weight. Another reason could be also a different degree of development of children at the same age in the individual regions, *i.e.* different period of AR, different beginning of pubertal spurt and menarche in girls, and voice breaking in boys. Comparison of children of the same age according to historical moment and geography could be distorted.

1.2.7. SUMMARY STATEMENT

Growth references are an important tool for paediatric health monitoring. The use of the most appropriate growth references and full awareness of potential issues related to growth references is critical in order for paediatricians to make the best feeding recommendations possible, including the promotion of exclusive breast feeding through the age of 6 months. Early introduction of supplemental feeding could be one of the factors resulting in obesity in children. The systematic monitoring of the growth since the beginning of life is necessary in all age categories up to 18 years in order to detect un-desirable changes before their clinical manifestation. In youngest children, maximally up to the age of 5 years a relationship weight-for-length/height could be used. In overweight children it is recommended to use the BMI-for-age growth charts under the age of 5 to be recorded premature onset of adiposity rebound (AR). Early AR is associated with an increasing risk of overweight and obesity, which result from energy imbalance not only due to inadequate nutrition and energy imbalance at early life, but also due to reduced physical activity and suitable exercise. International comparisons of the prevalence of overweight and obesity are mostly very difficult due to the lack of consent of cut-off used.

CONCLUSIONS – SUMMARY STATEMENT

Secular changes of growth parameters of the child population reflects social and lifestyle changes along with improvements in health care. One of the main problems of the present society is inadequate energy intake along with hypo-kinesia. Increase in obesity prevalence has tackled not only technologically developed countries, but also transition and developing ones, especially in Asia. One of the most urgent problems is the global epidemy of obesity during childhood and adolescence. This applies already to preschool children, which is a serious health problem for later life, but also for overall growth profile and puberty. Hormonal action of increased number of adipocytes accelerates the clo-sing of epiphyseal plates of long bones. Increased level of estrogens in obese boys can also decrease the action of androgens during pubertal maturation, and can manifest in their feminisation (pseudomammas, gynecomastia, feminine dis-tribution of pubic hair, insufficient testicular growth, *etc*.). Another risk of excess fatness are the orthopedic and musculoskeletal problems. The deterioration of basic motor development is inadequate body posture, deterioration of the axis of lower extremities, flat feet, *etc*. Important are also algic pains appearing already in adolescent age. Follow-up of growth parameters – body height, weight, weight /height relationship, body mass index (BMI), start of puberty, the median of menarcheal age are therefore an essentials marker which gives information on the health status of the whole population.

NOTES

URL 1: Available at: http://www.who.int/childgrowth/software/en/ Viewed 15 January, 2014.

URL 2: Available at: http://www.who.int/growthref/en/ Viewed 15 January, 2014.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 2

Nutrition in Childhood Obesity Prevention and Treatment -Role of Nutrients

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Abstract: Assessment of energy intake and energy expenditure is crucial for recommendation of weight maintenance and weight loss regimen. Energy intake but also proportion and composition of individual nutrients is essential for effective weight management and diet recommendation, which should be applied during earliest periods of life. In this respect, nutritional status of the mother, factors during fetal and perinatal period play an important role from the point of view of actual, but also future consequences. Individual nutrients as well as their composition with regard to their present and delayed effect are summarized in the chapter. Diet – energy intake and nutrient composition should be considered and related to energy expenditure.

Keywords: Adolescence, Appetite, Balance, Carbohydrates, Children, Energy, Epigenetic factors, Expenditure, Equation, Food, Growth, Intake, Intervention, Lean body mass, Lipids, Management, Mother, Microbiome, Nutrition, Obesity, Weight.

2.1. INTRODUCTION

Positive energy balance caused by enhanced energy intake and/or by decrease in energy expenditure is basic cause of worldwide overweight and obesity epidemics. Factors participating in overweight and obesity development and childhood overweight and obesity prevalence are studied in pan-European, international and local projects. Young school children (6-8 years) are followed in Childhood Obesity Surveillance Initiative (COSI) which was initiated by WHO Europe in 2007. South-north gradient in obesity prevalence in Europe was confirmed in this age category (Wijnhoven *et al*. 2012). For individualized dietary and physical

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activity counselling detailed information on child´s food intake and energy expenditure is essential.

Obesity management in childhood is concentrated on introduction of lifestyle change. This change consists of change in nutrition and physical activity concurrently with change of behaviour. Pharmacotherapy is used in adolescents under defined conditions. Bariatric surgery may be used in severely obese adolescents after decision of specialised team consisting of paediatric obesitologist (endocrinologist), nutritionist, psychologist and bariatric surgeon. Change in nutrition of the child is based on adequate information about energy content of the diet, balance of energy intake and energy expenditure, proportion of macronutrients and composition of macronutrients in relation to weight change. In early infancy and in prenatal period nutrition of mother is crucial, therefore perinatal nutrition and nutrition of mother is poined out.

2.2. METHODS

Methods for evaluation of energy intake are prospective or retrospective.

2.2.1. Prospective Methods

Three or seven day dietary records: The questionnaires completed by parents or by a child who were informed how to fill it in detail (quantities, types of food, per cent of fat *etc*.) are evaluated by PC programmes. Individual PC programmes contain different databases of foodstuffs, the most valuable is a programme with database containing local foods (UK, USA, Germany, Austria and central European countries, Australia, Czech Republic *etc*). Food records are used during the long-term follow-up of the child.

2.2.2. Retrospective Methods

24 hour food recall is completed by subject with experienced dietician. It is used mostly during epidemiological studies (Hébert *et al.* 2014). When repeated in several month´s interval it may bring more valuable information.

Food frequency questionnaires (FFQ) are completed by parent or by child. Frequency of groups of food stuffs consumption in past in a defined time interval (usually a week) is recorded by patient. Number of questions is 20-200, the result can be evaluated quantitatively. In the first contact with a child the result may be less underestimated than in dietary records, for evaluation of the long-term intervention they are not used. The predictive function of energy intake assessed by FFQ was not significant, in contrast to double labelled water measurement which significantly predicted weight gain in the following 1 and 2 years (Stice & Durant 2014). The inaccuracy of FFQ is strongly influenced by nutritional status, pubertal status and gender (Beghin *et al.* 2013).

2.2.3. Questionnaires Used for Evaluation of Dietary Habits

These questionnaires are used preferably in adolescents. The most often is used Three item questionnaire (Stunkard & Messick, 1985). Score of restriction, score of disinhibition and score of hunger are evaluated. Score of restriction shows how the child limits its food intake, score of disinhibition the food intake without control, and score of hunger magnitude of hunger. In older children also hunger measurement on a line segment length 10 cm, with marks from 1-10 may be used.

Questionnaire on food preferences may help to reveal inappropriate food habits of children and in result they help to tailor the suggested change of the diet and to apply "personalized" dietary change during the consultation.

2.3. ENERGY EXPENDITURE

can be evaluated by many methods (see Chapter 3.). For rough estimation of the energy expenditure and content of the diet calculations can be used. The equations are based on body weight, or more precisely on lean body mass. Formerly, the following equations were used in children (Table **1**; FAO/WHO/UNU, 1985), which showed the lowest mean difference between predicted resting energy expenditure (REE) and REE measured by indirect calorimetry (+0.2%, p=ns), (Rodriguez *et al.* 2002, Lazzer *et al.* 2007). More exact results were obtained when, fat free mass (FFM) was assessed using DXA and used for the calculations (Schmelzle *et al.* 2004). Dual X-ray densitometry (DXA) is reference method for analysis of body composition, ie assessment of body fat mass (FM) and fat free mass (FFM). Bioelectric impedance (BIA) is less expensive but also less precise alternative for FFM estimation. US energy expenditure equations are shown in

Table **1** (according to Academy of Nutrition and Dietetics). According to the US Institute of Medicine "Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients), 2005 "total energy expenditure in overweight youth (ages 3-18) in a weight maintenance situation should be calculated, using the following equations given in Table **2**.

Table 1. Equations for resting energy expenditure (REE)[1].

Source Equation FAO/WHO/UNU, kcal/d (WHO, 1985) Boys REE = (16.6 × wt) + (77 × ht) + 572 Girls REE = (7.4 × wt) + (482 × ht) + 217
Harris-Benedict, kcal/d (1919) Boys REE = 66.437 + (13.752 × wt) + (5.003 × ht) - (6.755 × age) Girls REE = 655.096 + (9.563 × wt) + (1.85 × ht) - (4.676 × age)
Molnar, kJ/d (1995) Boys REE = (50.9 × wt) + (25.3 × ht) - (50.3 × age) + 26.9 Girls REE = (51.2 × wt) + (24.5 × ht) - (207.5 × age) + 1629.8
Schofield, MJ/24 h (1985) Boys REE = (0.082 × wt) + [0.545 × (ht/100)] + 1.736 Girls REE = (0.071 × wt) + [0.677 × (ht/100)] + 1.553
Maffeis, kJ/d (1993) Boys REE = (28.6 × wt) + (23.6 × ht) - (69.1 × age) + 1287 Girls REE = (35.8 × wt) + (15.6 × ht) - (36.3 × age) + 1552

[1]wt, weight (in kg); ht, height (in cm); FM, fat mass; FFM, fat-free mass, age (years), FM and FFM (grams).

(Adapted from Schmelzle *et al.*, Am J Clin Nutr, Aug 2004; 80(2): 365–373.).

Table 2. US energy expenditure equations.

Overweight Boys Ages 3 Through 18 Years
TEE = 114 – (50.9 × age [y]) + PA × (19.5 × weight [kg] + 1161.4 × height [m])
Where PA is the physical activity coefficient:
PA = 1.00 if PAL is estimated to be ≥ 1.0 < 1.4 (sedentary)
PA = 1.12 if PAL is estimated to be ≥ 1.4 < 1.6 (low active)
PA = 1.24 if PAL is estimated to be ≥ 1.6 < 1.9 (active)

(Table 2) contd.....

PA = 1.45 if PAL is estimated to be ≥ 1.9 < 2.5 (very active)
Overweight Girls Ages 3 Through 18 Years
TEE = 389 – (41.2 × age [y]) + PA × (15.0 × weight [kg] + 701.6 × height [m])
Where PA is the physical activity coefficient:
PA = 1.00 if PAL is estimated to be ≥ 1.0 < 1.4 (sedentary)
PA = 1.18 if PAL is estimated to be ≥ 1.4 < 1.6 (low active)
PA = 1.35 if PAL is estimated to be ≥ 1.6 < 1.9 (active)
PA = 1.60 if PAL is estimated to be ≥ 1.9 < 2.5 (very active)

(http://andevidencelibrary.com/topic.cfm?cat=3060&auth=1).

2.4. INFANT NUTRITION FOR OBESITY AND METABOLIC DISEASES PREVENTION

Exclusive or partial breastfeeding is recommended by WHO to 6 months of age. European Society of Paediatric Gastroenterology, Hepatology and Nutrition, Committee on Nutrition recommends the introduction of complementary foods at 4-6 months of age (Wu & Chen 2009). Positive influence of breastfeeding in relation to later adiposity may be mediated by bioactive components in breast milk that have long-term programmed effects on function of the child. Early exposure to leptin and adiponectin in breast milk could be involved in setting endocrine responses to feeding and appetite regulation (Savino & Liguori 2008). In preterm born infants fed by human milk lower leptin levels relative to fat mass were found in adolescence (Singhal *et al*. 2002). Breast feeding, relative to formula feeding, reduces the risk for obesity at school age by about 20% even after adjustment for biological and sociodemographic confounders. It is also associated with increased neurodevelopmental scores up to early adulthood (Agostoni *et al*. 2013). In low and middle-income populations of children and young adults, where the influences on infant feeding practice differ, beneficial effects of breastfeeding on blood pressure, BMI and risk of diabetes have not been confirmed, further studies are needed (Robinson & Fall 2012). Composition and energy content of complementary food is important. In recent review high intakes of energy and protein, particularly dairy protein at 2-12 months of age could be associated with an increase in BMI and body fatness in childhood (Pearce & Langley Evans 2013).

With the introduction of solids into the infant diet the major change is the decrease of fat intake from 50 to 30% of total energy. A protein excess, commonly found throughout all European Countries, has been associated to a higher risk of adiposity in early childhood (Koletzko *et al*. 2009). The amount of fat does not seem to be associated with later adiposity, while its quality may affect blood lipoproteins, blood pressure and also neuro-developmental performance. Early intake of dietary fibres might also have beneficial effects. Episodes of rapid growth (catch-up growth), whichever are dietary habits, are associated with later unfavourable health conditions and should be prevented (Agostoni *et al.* 2013)

2.5. ROLE OF INDIVIDUAL NUTRIENTS IN OBESITY PREVENTION AND TREATMENT

Macronutrients, proteins, lipids and carbohydrates represent sources of energy. Role of individual nutrients in obesity development and treatment is described.

2.5.1. Proteins

2.5.1.1. Role of Protein

in weight development in children is equivocal. In early childhood higher protein consumption was shown to be risk in relation to BMI and obesity. Rolland-Cachera has shown that higher protein intake at 2 years of age was associated with higher BMI and body fat content at 8 years of age (Rolland-Cachera *et al.* 1995). In early childhood higher content of protein in formulas lead to a higher weight in comparison to breast fed children (Koletzko *et al*. 2009). In children of overweight mothers low protein formula (1.65g protein/100ml) slowed weight gain in comparison with control formula (2.7g protein/100ml) between 3 and 6 months and remained lower until 2 years: it was similar to that of breastfed infants (Inostroza *et al*. 2014). Higher BMI and higher risk of obesity (RR 2.43, CI 1.12; 5.27) was found in 6 year children with higher protein compared to low protein formula used in their first year of life (Weber *et al.* 2014). Recent review concentrated on infant feeding and early nutrition confirmed the negative role of higher protein and higher energy intake during complementary feeding at age 2-12 months in relation to higher BMI at school age (Pearce & Langley Evans 2013). On the other hand, weight loss diets containing around 25-30 percent of protein were more effective in weight maintenance after weight loss in adults (Larssen *et al.* 2010) and in weight maintenance in children (Papadaki *et al.* 2010). Generally, lower content of protein in the diet is basis of protein leverage hypothesis, suggesting that small decrease in the dietary percentage of protein may have substantial effects on increase of total energy intake due to more strong regulation of protein then energy intake (Simpson & Raubenheimer 2005).

Role of milk and dairy products in relation to obesity and health risks was recently reviewed. A neutral or inverse association between consumption of milk and dairy products in children and adolescents and indicators of adiposity, incidence of dental caries, and hypertension was shown. Available data indicated that dairy products were important for linear growth and bone health during childhood (Dror & Allen, 2014). Review of articles on dairy consumption after release of Dietary Guidelines for Americans in 2010 showed that increasing dairy consumption to the recommended amount, *i.e.*, three servings daily for individuals 9 years of age or older, helped to close gaps between current nutrient intakes and re-commendations. Consuming more than three servings of dairy per day lead to better nutrient status and improved bone health and was associated with lower blood pressure, reduced risk of cardiovascular disease and type 2 diabetes (Rice *et al.* 2013). Dairy products are an important dietary source of multiple micro-nutrients, including calcium, phosphorus, magnesium, zinc, iodine, potassium, vitamin A, vitamin D, vitamin B12, and riboflavin (vitamin B2).

2.5.1.2. Perinatal and Mother´s Nutrition

In gestational phase growth of foetus is influenced by milk and milk protein intake of mother (Borazjani *et al*. 2013). Higher intake is associated with better growth of the child.

Antenatal nutrition advice can avoid prenatal and perinatal overnutrition. Maternal overnutrition and even modest increase in BMI are associated with increased risk of fetal death, stillbirth and neonatal, perinatal and infant death, for review see Aune *et al*. 2014. On the other hand, maternal undernutrition is one of the factors causing intrauterine growth retardation (IUGR) and risk of stillbirth, (Imdad *et al*. 2011).

On the other hand maternal undernutrition can stimulate hypothalamic-pituitary-adrenal (HPA) axis and increase cortisol level followed by restricted growth of foetus. Increased activity of the HPA axis may link low birth weight with raised blood pressure in adult life (Brenseke *et al*. 2013). This represents one part of Forsdahl-Barker hypothesis which shows higher prevalence of metabolic syndrome in children with low birth weight (small for gestational age, SGA), (Brenseke *et al.* 2013).

Vitamins A and E are well known antioxidants and their neonatal levels are dependent on maternal levels. Decreased levels of lipid-soluble antioxidant vitamins in preterm babies may lead to their higher susceptibility to oxidative stress. Also gestational diabetes, a common cause of macrosomia, is associated with oxidative stress which could have effects on the developing infant (Brenseke *et al*. 2013)

Individuals who had been exposed to famine during periconception had, 6 decades later, less DNA methylation of the insulin like growth factor II (IGF2) gene compared with their unexposed, same-sex siblings [81]. The Dutch famine cohort has also been used to study the transgenerational effects of famine exposure. Women exposed during fetal period to famine while in the womb, later gave birth to lower weight offspring as compared to offspring of women not exposed to famine during fetal period. This effect of in utero exposure to famine on birth weight in the subsequent generation persisted after control for potential confounding and intervening variables (Brenseke *et al.* 2013).

2.5.2. Lipids

2.5.2.1. Diet Fat

Amount of fat in the diet varies according to age of the child. In infants to 1 (2) years of age the percentage of fat should not be limited to less than 30 percent of total energy intake.

Except of the total quantity of fat, fatty acid composition of dietary fat is crucial.

In obese children (with and without non-alcoholic fatty liver disease) meal high in saturated fat induced postprandial dyslipidaemia, hyperinsulinaemia and altered lipo-protein expression in comparison with lean controls (Mager *et al.* 2013).

Mediterranean style diet is rich in polyunsaturated fatty acids but also in fiber, flavonoids and antioxidants. In obese children and adolescents using this diet, in comparison with standard diet, significant decrease not only in BMI but also in lean mass, fat mass, glucose and lipid spectrum was shown. Concurrently, an increase in n-9 monounsaturated fatty acids, vitamin E, zinc and selenium and decrease in consumption of saturated fatty acids was found. Mediterranean style diet can be recommended in weight management of obese children (Velazquez-Lopez *et al.* 2014).

In obese children a greater proportion of the low omega-3 index (sum of eico-sapentaenoic, 20:5n-3, and docosahexaenoic, 22:6n-3 acid weight%) was found in comparison with lean children. A moderate statistically significant negative correlation was found between omega-3 index and fasting insulin level and with homeostasis model assessment (HOMA) scores (Burrows *et al*. 2011). The relative intake of n-6 to n-3 PUFA in prenatal and early postnatal period has been suggested to be one factor contributing to obesity development. High intake of n-6 PUFA have proadipogenic properties mediated by ecosanoids derived from arachidonic acid (20:4n-6), (Muhlhausler & Ailhaud 2013, Ailhaud *et al.* 2008).

Predictors positively associated with obesity in group of obese Mexican children compared with normal weight children were 16:1 n-7, 20:3 n-6 and total SFA in plasma phospholipids (PL). In obese children significant differences were found also between genders (Elizondo-Montemayor *et al.* 2010). Palmitoleic acid (16:1n-7) in plasma significantly correlates with abdominal adiposity in obese children. This may support palmitoleic acid as a marker of endogenous lipogenesis (Okada *et al* 2005, Kunešová *et al*. 2002, Kunešová *et al.* 2012). StearoylCoAdesaturase (SCD1) activity (n-9 desaturase catalyze the synthesis of n-9 monounsaturated fatty acids, primarily oleoyl-CoA (18:1n-9) and palmitoyl-CoA (16:1n-7)), in relation to adipose tissue distribution seems to be altered in children with obesity (Saito *et al.* 2014). We found positive correlation of saturated fatty acids and palmitoleic acid (16:1n-7) in serum lipids with BMI and percentage of body fat in obese adolescents (Hlavaty *et al.* in press). Higher levels of n-6 PUFA were found in plasma phospholipids and sterol esters of obese children, this was more expressed in obese children with metabolic syndrome (Decsi *et al* 1996, Desci *et al.* 2000). In obese adolescents higher levels of SFA and higher n-6/n-3 in serum phospholipids were found. In obese girls lower n-3 PUFA were obtained in comparison with lean ones. n-3 PUFA positively correlated with subcutaneous fat compartments and may be protective against metabolic syndrome and low grade inflammation in obese adolescents (Karlsson *et al.* 2006, Klein Platat *et al.* 2005).

2.5.2.2. Fat Oxidation

is one of the factors influencing fat balance and subsequent fat mass accumulation. This was measured in prepubertal children after mixed meal ingestion. Only 10.8% of total fat oxidation represented exogenous fat oxidation. Exogenous fat oxidation expressed as a per cent of total fat oxidation correlated positively with total body fat mass. This may represent a protective factor against further increase of body fat mass (Maffeis *et al.* 1999).

2.5.2.3. Perinatal and Mother´s Nutrition

Dietary fatty acid intake of mother during the late pregnancy affects fatty acid composition of breast milk. Positive association between maternal intake of eicosapentaenoic (EPA) and docosahexaenoic (DHA) acid during the third trimester and n-3 /n-6 ratio during the second and third trimester and postpartum period with EPA and DHA content in breast milk was shown (Nishimura *et al.* 2014). Women who ate fish more often than once a week had lower risk of preterm birth and had neonates with higher birth weight, the association was more expressed in overweight and obese mothers (and in smokers) (Leventakou *et al.* 2014). In Copenhagen Prospective Study on Asthma in childhood the birth cohort was prospectively followed to 7 years of age of children, significant association between breast milk DHA and BMI from 2 to 7 years and fat mass was found, in girls also with adiposity rebound (Pedersen *et al.* 2012). Increase of long chain n-3 PUFA (EPA and DHA) in breast milk was induced by dietary change from 15th week of pregnancy to 4th month of lactation. Positive association of n-3 LCPUFA in early breast milk with body fat content of child measured by sum of 4 skinfolds was found in 1 year old children; arachidonic acid and n-6 LCPUFA were negatively associated with weight, BMI and lean body mass, ie overall growth to 4 month after birth (Much *et al.* 2013). Recent review evaluating effect of n-3 LCPUFA during perinatal period showed equivocal results also due to the insufficiently explained doses and sources of n-3 LCPUFA (Rodriguez *et al*. 2012).

2.5.3. Carbohydrates

2.5.3.1. Carbohydrates

represent the main source of energy intake in all age categories except for infants. Quality of carbohydrates and its effect is therefore an important issue.

The most often used indicator of quality of carbohydrates is glycaemic index (GI), calculated as the area under the glucose curve after the test food is eaten, divided by the corresponding area after the reference food multiplied by 100. The reference food is usually white bread. Glycemic load (GL) is calculated by multiplying the glycemic index by the amount of carbohydrate provided by a food (in grams).

Recent paper analyzing results of 6 studies has shown that low glycaemic index meals decreased subsequent energy intake (Rouihani *et al.* 2013a). Several cross-sectional studies were published in last years showing associations between GI and/or GL and indices of body fat content. In British children and adolescents glycaemic load was independently associated with overweight in children and with central obesity in adolescents. No association was found when body fatness measures were treated as continuous variables (Murakami *et al.* 2013). In Japanese children positive association of dietary GL with the risk of overweight in children, and in male adolescents was found, but not in female adolescents (Murakami *et al.* 2011). Children consuming more carbohydrates with low GI are more likely to meet nutrient recommendations than those consuming higher GI foods. Australian children and adolescents have a high GI dietary pattern with high-starchy food intake and low Ca intake (Louie *et al.* 2012, Louie *et al.* 2011). In Italian children GI was associated with BMI and waist z-scores, and GI was the sole nutritional factor significantly associated with waist circumference (Barba *et al.* 2012).

In this context the sugar-sweetened beverages (SSB) should be mentioned which were shown to be a significant factor contributing to the increasing prevalence of childhood overweight and obesity, for recent review and metaanalysis see (Malik *et al*. 2013). Another recent review has shown that there is insufficient evidence from randomised studies for confirmation of effect of SSB on obesity (Kaiser *et al.* 2013).

Effect of the introduction of a diet with low GL and/or low GI into weight management diets was shown in many studies with mostly positive results. In 11 years old children 6 week low GL diet positively modified body composition, decreased relative amount of body fat (%) and also waist to hip ratio (Fajcsak *et al*. 2008). 24 week intervention with reduction(elimination) of SSB induced significant BMI loss also in adolescents. Its magnitude was basal BMI dependent (Ebbeling *et al.* 2006). Higher GL during a 3 moth lifestyle and metformin intervention was associated with lower weight loss in obese insulin resistant adolescents (Joslowski *et al*. 2014). The randomized study comparing the diet according to healthy nutrition recommendation with low GI diet did not reveal any difference between the diets after 10 week intervention in adolescent girls (Rouhani *et al*. 2013b). Recent metaanalysis of the long-term effects of diet containing low GI and/or GL provided evidence for their beneficial effect with respect to insulin and pro-inflammatory markers in adults (Schwingshackl & Hoffman 2013).

2.5.3.2. Perinatal and Mother´s Nutrition

Role of glycemic index in fetoplacental growth was evaluated in works of Brand-Miller and her group. Carbohydrate food with high glycemic index in nutrition of mother may result in higher infant body fat. Nevertheless the modest change in glycemic index in pregnant women did not lead to significant difference between newborn´s birth weight or body composition. Only 1% of all variation was connected with glycemic load (Moses *et al.* 2014).

2.6. APPETITE REGULATION

Food intake is regulated by hormonal, neural, and metabolic signals. In response to these information, brain coordinates adaptive alterations of energy intake and expenditure. The food intake is modulated by changes in appetite. Appetite is regulated by central and peripheral neuropeptides. Appetite stimulating neuropeptides are neuropeptide Y (NPY), agouti-related peptide (AgRP) and melanin concentrating hormone (MCH). Appetite suppressing neuropeptides include cocaine and amphetamine-related transcript (CART), melanocyte stimulating hormone (MSH), serotonin, insulin, and leptin. Each also plays a role in the central nervous system regulation of food intake and body weight. (Brenseke *et al.* 2013).

Hypothalamic nuclei include the arcuate nucleus (ARC), paraventricular nucleus (PVN), and ventromedial nucleus (VMN) which are involved in a number overlapping biological activities.

Peripheral part of food intake regulation is provided by the gut-brain axis. Gastrointestinal peptides with anorexic effect are cholecystokinin (CCK), incretins – glucagon-like peptide 1 (GLP1) and glucose dependent inhibitory polypeptide (GIP), pancreatic polypeptide (PP), oxyntomodulin, peptid YY (PYY), enterostatin, amylin, gastric leptin, orexigenic effect has ghrelin. Most of the peptides are produced also in brain (Cummings & Overduin 2007).

2.7. ROLE OF GUT MICROBIOME IN OBESITY DEVELOPMENT

An aberrant gut microbiome is one of the newer factors found to influence obesity development. In Danish study significant changes in the gut microbiota occurred from age 9 to 18 months concurrently with cessation of breastfeeding and introduction of a complementary feeding. Microbiota characterized by lactobacilli, bifidobacteria, and Enterobacteriaceae were replaced with a microbiota dominated by Clostridium spp. and Bacteroides spp. From 9 to 18 months, a positive correlation was observed between the increase in body mass index and the increase of the short-chain-fatty-acid-producing clostridia, the Clostridum leptum group, and Eubacterium hallii. This could be one of the factors contributing to higher risk of obesity in children with early breastfeeding discontinuation. Two human enterotypes, expressed as a bimodal distribution of the Prevotella /Bacteroides ratio, start being established between 18 and 36 months of age. In this period, enterotypes are still more susceptible to shifting than in adults. Each adult individual is estimated to harbour approximately 160 different high-abundance species (Bergstrom *et al.* 2014). Feeding children by probiotic. Lactobacillus paracasei ssp. F19 in early childhood (4-13 month of age) did not influence their body composition, growth and metabolic markers at age of 8 years (KarlssonVidehult *et al*. 2014).

2.8. EPIGENETIC CHANGES

Epigenetic changes due to periconceptional parental obesity were shown expressed as altered methylation outcomes at multiple imprint regulatory regions. Significant and independent association between paternal obesity and the offsprings methylation status was found. This suggests susceptibility of developing sperm for environmental insults and also possibility that the acquired imprint instability will be carried onto the next generation (Soubry *et al.* 2013).

Maternal nutrition and environmental exposure during periconceptional period, gestation and early postnatal period influence development of the child and increase the risk of cardiovascular diseases, metabolic disorders and breast cancer (Jang & Serra 2014). This was confirmed in studies with Dutch Famine cohort. The dynamic changes of the epigenetic regulation in development, the epigenome displays labile nature, which allows it to respond and adapt to environmental stressors, including nutritional modification. For example IGF2 is a key protein in human growth and development. IGF2 gene has been shown to be characterized by a labile methylation pattern depending on the nutritional or environmental stimuli received by the growing organism during the early life. Maternal overnutrition and undernutrition also alter hypothalamic DNA methylation. These changes in DNA methylation persisted from early life to adulthood. Changes in the maternal diet or other environmental factors may induce pediatric developmental diseases and affect health also in adulthood. For review see Jang & Serra 2014.

2.9. EFFECT OF WEIGHT REDUCTION INTERVENTION IN OBESE CHILDREN

Energy content and also composition of the diet should be changed to prevent overweight development and as a part of overweight and obesity management.

Nevertheless, energy content in modestly obese children should achieve recommended daily allowances (RDA) for age and sex of the child, only in severely obese children the energy content should be reduced under RDA values. The main risks of weight reduction are shown in the Table **3**.

Table 3. The main risks of weight reduction in obese children.

Loss of lean body mass
Deceleration of growth
Food intake disorders
Hyperuricaemia
Enhanced risk of gallstone formation (cholelithiasis)

Short term weight management including moderate energy restriction, physical activity and behavioural therapy under inpatient conditions (3 weeks) lead to significant weight and fat mass loss, and decrease of leptin. Insulin, ghrelin, GH and IGF1, glucose and FFA did not change (Rigamonti *et al.* 2010). One year nutritional intervention lead to BMI z.score reduction and to decrease in HOMA index, plasma saturated FA and 20:3n-9 and increase in plasma monounsaturated FA, n-6 and n-3 PUFA (Verduci *et al.* 2011). One year lifestyle intervention lead to SDS- BMI decrease and also to significant metabolic syndrome prevalence reduction from 19 to 9%, improvement of waist circumference, blood pressure and 2h glucose values in the oGTT in contrast to children without intervention (Reinehr *et al*. 2009). Combined intervention with increased physical activity and nutritional change is the most effective (Blüher *et al*. 2014).

2.10. SUMMARY STATEMENT

In the chapter methods of assessment of energy intake and energy expenditure are described. The role of individual nutrients in relation to childhood obesity development and treatment is shown with emphasis on changing role of protein and fat proportion in the diet with age of child. Composition of individual nutrients in relation to weight change is discussed specifically role of milk and dairy products, composition of fatty acids in dietary lipids and glycaemic index of carbohydrates. Perinatal and mother´s nutrition is commented in relation to individual macronutrients.

Conclusion: Nutrition and energy balance has crucial role in childhood obesity and overweight development and management. Attenuation in the increase of overweight and obesity prevalence shown in the last years in many countries could be influenced by continuous support of rational nutrition in all age categories of children.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 3

Objective Means of Monitoring Children's Physical Activity and Health-Related Recommendations for Its Implementation

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Abstract: The objective of the chapter is to describe the basic objective means for long-term, as well as short-term field-based monitoring of physical activity in children and adolescents and to formulate education and health-related recommendations to promote an active lifestyle. The first part of the chapter introduces and describes the selected objective means for field-based monitoring of physical activity in children and youth with an emphasis on their accuracy, advantages and limitations. The introduction of different instruments together with recommendations for practical application should help the reader choose the correct instrument and use it to its full potential. The second part of the chapter presents specific suggestions and recommendations for physical activity to promote an active lifestyle based on the conclusions of foreign publications, as well as the results of the authors' own research. The proposed recommendations are of an educational and health-preventive nature. Applying these recommendations does not 'automatically' prevent 'lifestyle diseases' but substantially reduces the probability of their outbreak or worsening.

Keywords: Actigraph accelerometer, Actitrainer device, Adolescents, Energy expenditure, Environment, Heart-rate monitor, Intervention programme, Leisure time, Moderate intensity, Overweight, Obesity, Physical activity, Preschool children, Recommendation, Reliability, School, School-aged children, Steps, Validity, Yamax pedometer.

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3.1. INTRODUCTION

This chapter enriches the Ebook of a clear description of the validity, reliability and feasibility of the objective means for field-based monitoring of physical activity (PA) in children and adolescents. The exact use of objective means for field-based monitoring of PA can accurately capture the amount and level of PA, which facilitates the creation of PA intervention programs aimed at reducing overweight and obesity.

3.2. OBJECTIVE MEANS FOR FIELD-BASED MONITORING OF PHYSICAL ACTIVITY

The field-based monitoring of PA presents a sum of activities and the means required for accurate monitoring and analysis of extra-laboratory PA conducted in usual living conditions (Armstrong & Welsman 2006, Bassett 2012, Miles 2007, Pettee *et al.* 2009, Sigmund & Sigmundová 2014a, Sirard & Pate 2001, Strath *et al.* 2013, Warren *et al*. 2010). PA in usual living conditions is understood as complex, multi-dimensional behaviours that can be quantified and characterised by the following terms: frequency, intensity, type and duration (Hardman & Stensel 2003, Miles 2007, Pettee *et al.* 2009, Strath *et al.* 2013, Warren *et al.* 2010). The aim in field-based monitoring of PA by means of non-invasive instruments (accelerometers, pedometers, heart-rate monitors and multi-functional devices) and subjective methods (record sheets, diaries, logs, questionnaires and interviews) is to minimise errors and inaccuracies during monitoring and quantification. Emphasis is placed on the validity, reliability and reactivity[1] of the instruments and subjective methods, thoroughness in preparing and organising the monitoring sessions, as well as data processing and analysis. The objective of field-based monitoring of PA is to obtain the most accurate description of the level of performed PA together with related social, biological and environmental determinants, correlates and mediators to formulate education and health-based recommendations and interventions for a physically active and healthy lifestyle.

The most accurate methods of determining energy expenditure that can be used in field-based monitoring of PA are the **doubly isotope labelled water method** and **indirect calorimetry** (Montoye *et al.* 1996). Regarding the high technical, organisational and financial requirements of these methods, they are usually used only in case studies or research performed on a limited number of individuals (tens of people, maximum) (Goran 1998). However, they play a crucial role in verifying the validity and reliability of other objective and subjective measurement techniques (DeVoe & Dalleck 2001, Freedson *et al.* 1997, Jakicic *et al.* 1999, Nichols *et al*. 1999, Trost *et al*. 1998, Warren *et al.* 2010).

Indirect calorimetry measures the energy gained by food combustion that is released outside of the body through the measure of oxygen consumption (VO_2) proportionate to the amount of energy expended per unit of time, except in situations of oxygen depletion and replenishment during oxygen debt (Ganong 2005, Montoye *et al.* 1996) and excluding the anaerobic contribution. However, the amount of released energy is dependent on the type of oxidised substance and the amount of O_2 required for its 'combustion,' *i.e.*, combustion heat. 'Combustion' of 1 g of saccharides, fats and proteins releases 4.1 kcal, 9.3 kcal and 5.3 kcal of energy, respectively. An approximate measure of the type of oxidised substance is the respiratory quotient, *i.e.*, the ratio between the amount of CO_2 expended and O_2 consumed per unit of time at a stable state. The respiratory quotient is a dimensionless number, and for saccharides, fats and proteins has a value of 1, 0.7 and 0.82, respectively. Finally, energy expenditure is calculated as the product of combustion heat and the volume of consumed oxygen (Ganong 2005).

Doubly isotope labelled water (heavy water) measures energy expenditure using the difference between the received and excreted amount of hydrogen and deuterium, or $^2H_2$, and oxygen,^{18}O, isotopes per unit of time. A tested individual drinks a certain amount of water with a precise isotope content, which is then evenly distributed in the body fluids after several hours. Labelled $^2H_2$ hydrogen is gradually excreted from the organism, particularly through the urine, sweat and as '*perspiratio insensibilis*'. ^{18}O is excreted in water and also as a product of CO_2 metabolism. The difference in the elimination of these isotopes in a given period of time is used to calculate the amount of CO_2 produced. After that, using a known or estimated respiratory quotient, the approximate O_2 consumption is calculated based on the determined energy expenditure (Ganong 2005).

Regarding the validity, stability, availability and feasibility of field-based monitoring of PA, PA sensors – accelerometers (Actigraph, Caltrac, Stepwatch) and pedometers (Yamax Digiwalker, Walk4 life) – are suitable for measuring the level of PA in 2- to 18-year-old children and youth (Armstrong & Welsman 2006, Bassett 2012, Clemes & Biddle 2013, De Vries *et al.* 2009, Kohl *et al.*2000, Sirard & Pate 2001). However, the interpretation of the measured energy expenditure values must be undertaken carefully with respect to repeated over-estimation and underestimation compared with the currently applied doubly isotope labelled water method (De Vries *et al.* 2009, Leenders *et al.* 2001, 2006, Plasqui & Westerterp 2007).

For field-based monitoring of PA in children and adolescents, to obtain the most accurate description of PA in the context of social, biological and environmental determinants, correlates and mediators, a concurrent combination of objective and subjective measuring techniques is recommended:accelerometer + questionnaire; multi-functional devices; direct observation + accelerometer or pedometer; self-assessment techniques + direct observation and heart-rate sensor or accelerometer (Baranowski & de Moor 2000, Bassett 2000, 2012, Corder *et al.* 2007, Kohl *et al.* 2000, LaMonte & Ainsworth 2001, Sigmund & Sigmundová 2014a, Strath *et al.* 2013, Rowlands & Eston 2007a, Warren *et al.* 2010).

The use of accelerometers and pedometers for reliable field-based monitoring of PA in a medium-sized group of monitored individuals is particularly suitable in the case of monitoring lasting several days, a week or longer (Clemes & Biddle 2013, Freedson & Miller 2000, Janz *et al.* 1995, Sigmund & Sigmundová 2014a, Trost *et al*. 2000, Tudor-Locke *et al.* 2005, Welk *et al.* 2000, Westerterp 1999a), as well as with respect to the possible comparison of weekdays and weekend days (Sequeira *et al.* 1995, Sigmund & Sigmundová 2014a, Trost *et al*. 2000) or the different seasons (Beighle *et al*. 2008).

In selecting the objective means for field-based monitoring of PA, the following must be considered: the demands and design of the research, including but not limited to the length of monitoring, number and age of monitored individuals, amount of monitored features, validity and reliability of instruments and mea-surement methods used, natural character of the conditions and environment, as well as quantity- and quality-based aspects of the diagnostics. The following text will introduce objective means of monitoring PA of children in the field (pedometers, accelerometers, heart-rate monitors and multi-functional devices), including their advantages and limitations, our own experiences and practical recommendations.

3.2.1. Pedometers

The use of pedometers is historically the oldest and currently the most widespread method of display-device monitoring and quantification of PA (Beets *et al*. 2010, Lubans *et al.* 2009, Marshall *et al.* 2009, Montoye *et al.* 1996, Tudor-Locke *et al.* 2009a, 2009b). Pedometers are commercially available, small and lightweight electronic devices for measuring vertical oscillations. The device displays the total step count (Fig. **1**). Older types of pedometers use the principle of closing an electric circuit *via* a spring-loaded pendulum that moves vertically due to the oscillations caused by walking (Schneider *et al.* 2004). Each vertical oscillation exceeding the sensitivity threshold of the device (#0.35 g for Yamax Digiwalker pedometers) is calculated as a step (Tudor-Locke *et al*. 2002). Newer types detect movement based on the piezoelectric effect. Generally, pedometers are most accurate for determining step counts, less accurate for calculating the distance covered and least accurate for determining energy expenditure (Crouter *et al.* 2003). Therefore, the most accurate variable calculated by the pedometer – step count – is recommended for the processing and interpretation of the results of PA monitoring (Tudor-Locke *et al.* 2011).

Pedometers are acceptable in appearance and size and are user-friendly, relatively objective, non-reactive, and repeatedly applicable devices for monitoring locomotive PA in large samples of children, youth and adults (McNamara *et al.* 2010, Rowlands & Eston 2007a, Tudor-Locke *et al.* 2009b). Pedometers are capable of recording and displaying a total number of over-the-threshold vertical oscillations, *i.e.*, steps per monitored time. Pedometers provide a reasonable assessment of a child's daylong PA (McNamara *et al.* 2010) and PA during a certain segment of the school day (Brusseau *et al.* 2011, Tudor-Locke *et al*. 2006). However, pedometers are only used when the total amount of PA is of interest (Rowlands & Eston 2007a). They cannot identify the type and intensity of PA, sense oscillations during cycling, skating or skiing or sense increased energy expenditure in the case of uphill walking or carrying objects (Armstrong & Welsman 2006, Rowlands & Eston 2007a, Sirard & Pate 2001). Placing the pedometer on the ankle allows for some detection of movement oscillations during cycling and skating, but this type of PA monitoring is generally less reliable than using the pedometer attached to the side at the waist (Armstrong & Welsman 2006). Therefore, in significant behavioural projects and studies, the pedometer is located **on the side of the waist of monitored individuals** (Chan *et al.* 2004, Roemmich *et al.* 2004, Tudor-Locke *et al.* 2009b; Tudor-Locke *et al.* 2004a). Pedometers used in field-based monitoring are **most accurate in monitoring normal walking** (Bassett *et al.* 1996) and total daily PA (McNamara *et al.* 2010, Sequeira *et al.* 1995, Tudor-Locke *et al.* 2009b).

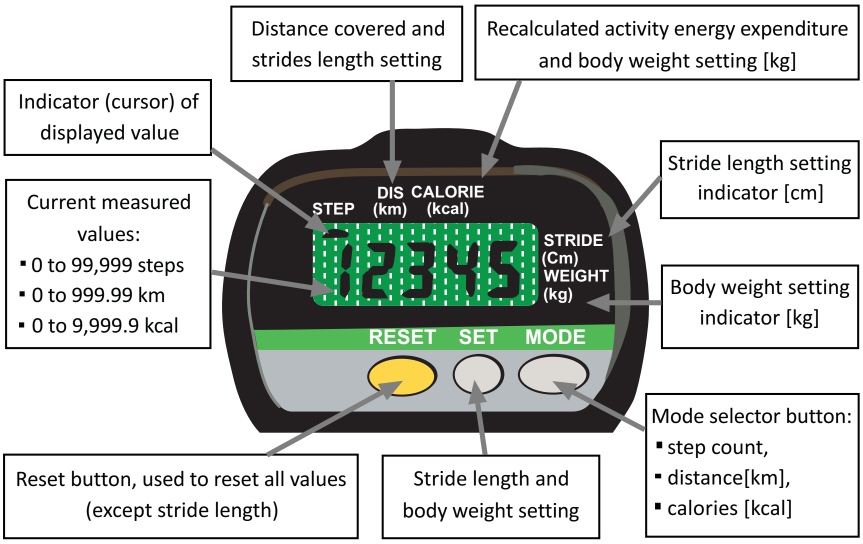

Fig. (1). Yamax Digiwalker SW-700 pedometer display with descriptions.

Walking, running and other types of spontaneous PA in children are accompanied by a large number of redundant movements, hops and excessive gestures that can also occur during usual communication, *i.e.*, 'PA luxury'. To prevent the undesired recording of excessive steps, newer types of pedometers (*e.g.*, Silva) are equipped with a filter that allows walking or running movement to be registered only after six consecutive 'steps'. In spite of this and other methodical difficulties, pedometers remain suitable quantifiers, especially of all-day PA and are recommended for children from four years of age (McNamara *et al.* 2010).

Although pedometers are of simple design and have many limitations in monitoring PA, their advantage is that they show the recorded PA values on the display (Fig. **1**). Immediate and clear feedback in the form of step count shown on the instrument display appears to be a promising motivation factor leading to increased PA in children and adults (Chan *et al.* 2004, Kang *et al.* 2009). Watching TV, videos or playing computer games as a reward for reaching a certain number of steps during PA motivated 8- to 12-year-old children to be 24% more physically active compared with children without feedback from the pedometer display (Roemmich *et al.* 2004).

The period required for reliable field-based monitoring of PA in children using pedometers should be **six days or more**, ideally **including both weekend days** (Rowe *et al.* 2004). A satisfactory degree of validity in field-based monitoring of PA in children and youth using pedometers attached to the side at the waist has supported the worldwide use of this method (Table **1**).

Table 1. The validity of determining PA using pedometers in selected studies of children and youth – ordered according to accuracy of criterion measurement.

Pedometer	Variable	Participants	Period	Criterion	Validity	Study
Yamax Digiwalker DW-200	average number of oscillations (steps/min)	10 childrenaged 10.1±1.7 years	2 units: - free PA lesson	Direct observation Tritrac-R3D	$r_{S\,PA}$=0,97** $r_{S\,sitting}$=0.80**	Kilanowski *et al.* (1999)
		15 ♀, 15 ♂ aged 9.3±0.8 years	- sitting in the classroom		$r_{S\,PA}$=0,98** $r_{S\,sitting}$=0.50*	

(Table 1) contd.....

Pedometer	Variable	Participants	Period	Criterion	Validity	Study
Yamax Digiwalker DW-200	number of oscillations - side of waist - ankle - wrist	15 ♀, 15 ♂ aged 9.3±0.8 years	8-minute walk at 4 and 6 km/h, 8-minute run at 8 and 10 km/h and 14 minutes of ball throwing, playing and drawing	Oxygen consumption (VO_2)	$r_{S\,waist}$=0.81** $r_{S\,ancle}$=0.79** $r_{S\,wrist}$=0.67**	Eston *et al.* (1998)
	number of oscillations - side of waist - ankle - wrist	21 ♂ aged 9.6±0.5 years			$r_{S\,waist}$=0.86** $r_{S\,ancle}$=0.83** $r_{S\,wrist}$=0.29*	Louie *et al.* (1999)
–	step count	11 children aged 4-6 years	1 day	Direct observation	r_S=0.93**	Saris & Binkhorst (1977)

Table Footnotes: ♀ – girls; ♂ – boys; PA – physical activity; r_S – Spearman's correlation coefficient; Tritrac-R3D – three-dimensional accelerometer;Statistical significance is expressed as *p<0.01 and **p<0.001.

The comparison by Kilanowski *et al.* (1999) of three short-term monitoring techniques of the PA of 7- to 12-year-old children sitting in a classroom (r_S=0.50–0.80 $p<0.01$) and at break time (r_S=0.97–0.98 $p<0.001$) revealed close correlations in the step count recorded by the Yamax SW-200 pedometer, data from the triaxial Tritrac-R3D accelerometer, and direct observation using CARS, the PA classification scale (Puhl *et al.* 1990).

Out of a number of available and tested pedometers designed to measure walking and for the field-based monitoring of PA (AccusplitAllinace 1510, Accusplit Fitness Walker, Eddie Bauer Compustep II, Freestyle Pacer, Colorado on the Move, KenzLifecorder, L.L. Bean Pedometer, New-Lifestyles NL-2000, Omron HJ-105, Oregon Scientific PE316CA, Sportline 330 and 345, Walk4Life LS 2525, Yamax Skeletone EM-180, Yamax Digiwalker SW-200, SW-500, SW-700 and SW-701), the Yamax Digiwalker pedometers appeared to be the most valid and reliable (Bassett *et al.* 1996, Crouter *et al.* 2003, Le Masurier *et al.* 2004, Schneider *et al.* 2004). Compared with other pedometers, the Yamax Digiwalker repeatedly showed the closest correlations and the lowest differences with respect to criterion measurement – indirect calorimetry and direct observation (Crouter *et al.* 2003), data from the Actigraph accelerometer (Le Masurier *et al.* 2004) or calibrated distance meter (Rolatape) (Bassett *et al.* 1996). Very close correlations, r=0.98 (Crouter *et al.* 2003), and minimal differences, 0.1% (Bassett *et al.* 1996), were also observed in the comparison of walking step counts measured by the Yamax Digiwalker pedometers attached to the right and left sides of the waist.

3.2.2. Accelerometers

Accelerometers (Fig. **2**) are portable sensors designed to detect changes in movement speed by means of an internal piezoelectric crystal. The crystal is capable, through its own mechanical deformation, of converting kinetic acceleration to changes in electric impulses that, using individual somatic characteristics, can be recalculated to units of energy expenditure (De Vries *et al.* 2009, Montoye 1996, Westerterp 1999b). From a user's point of view, the wide range of available accelerometers can be divided according to:

a) Dimension of movement detection ⇨ (linear × plane × spatial),

b) Range of results ⇨ (only final × final and interim),

c) Operation and settings ⇨ (manual × PC),

d) Display of results ⇨ (immediate × recalled).

Ad a) Spatial movement detection (Actical, Actigraph GT3X, Mini-Motio--logger, RT3, Tritrac-R3D), unlike single-dimension accelerometers (Actigraph GT1M, Caltrac), does not require precise positioning of the device on the body of the monitored individual.

Ad b) The recording and display not only of final monitoring results (Biotrainer, Caltrac) but alsoof interim results at any point (Actical, Actigraph, Activtracer, Actiwatch, Biotrainer, Stepwatch activity monitor, Mini-Motionlogger, RT3, Tritrac-R3D), allows for a detailed PA analysis and comparison of individual monitored phases (school or training units × breaks periods, school time × out-of-school time).

Ad c–d) Some devices (Actiwatch, Biotrainer, Caltrac) are provided with a display, which increases the size of the instrument but provides immediate feedback on the results and usually allows for immediate modification to the input variables and selection of the displayed output variables.

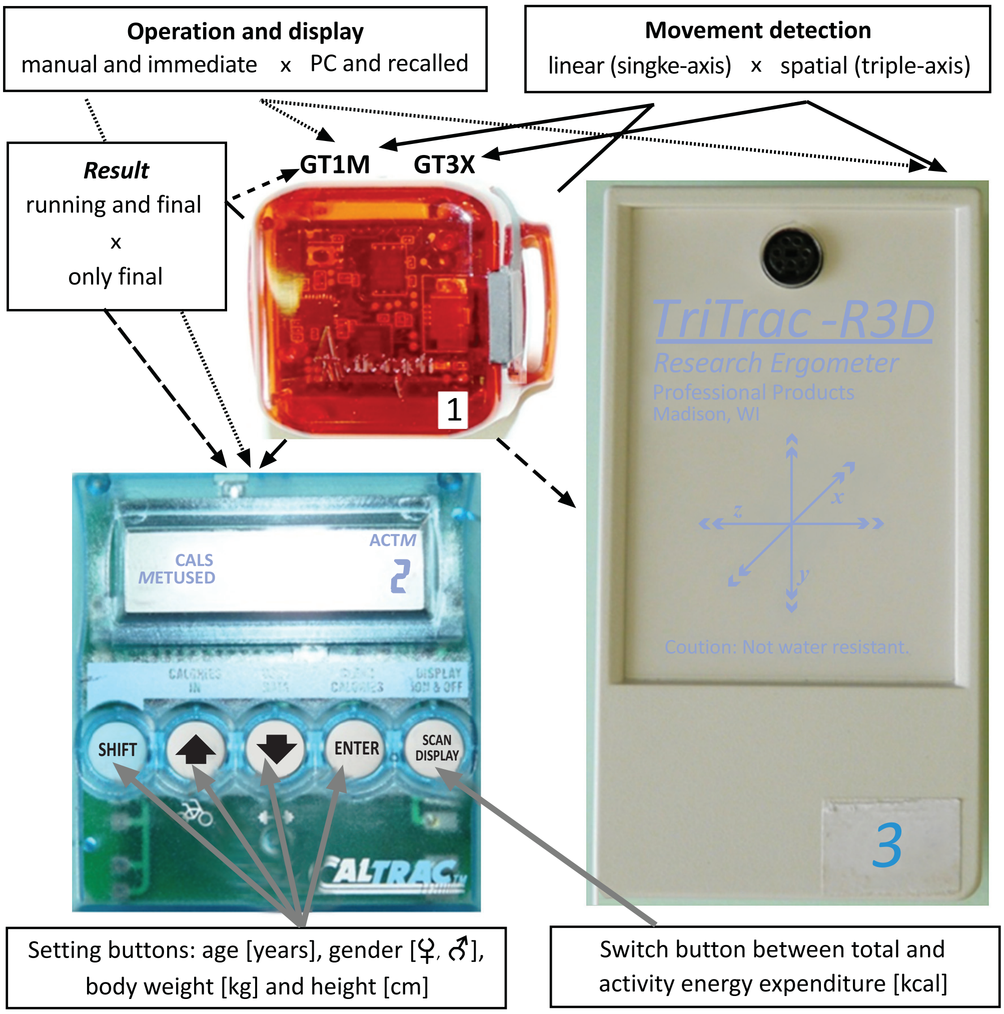

Fig. (2). Examples of the Actigraph GT1M, GT3X (1), Caltrac (2) and Tritrac-R3D (3) accelerometers with the identification of basic design features and functions.

Accelerometers enable a higher precision and accuracy than pedometers (Adamo *et al.* 2009, Bassett 2012, Rowlands & Eston 2007a) and allow for an objective analysis of the frequency, intensity, and duration of PA during various segments of the day with minimal interference into daily life (Rowlands 2007b).

The most suitable position of the accelerometer for field-based PA monitoring appears to be **at the waist**, on either the right or left side (De Vries *et al.* 2009, Nilsson*et al*. 2002, Pambianco *et al.* 1990, Trost *et al.* 2005).

For valid and reliable monitoring of habitual PA in children and youth using accelerometers, a minimum of four days of monitoring is required (Corder *et al*. 2008, Fairclough *et al*. 2007, Janz *et al.*1995, Trost *et al.* 2005). **Seven days** is considered the optimum time period (Janz *et al.*1995, Trost *et al*. 2005, Trost *et al.* 2000), **including both weekend days** (Rowlands 2007b, Trost *et al.* 2000).

Table 2. The validity of determining PA using the Actigraph accelerometer in selected studies of children and youth – ordered according to accuracy of criterion measurement.

Variable	Period	Participants	Reliability	Criterion	Validity	Study
PA duration	$5\times^{30\ min}$ free play	23 children 5-6 years old	–	Direct observation	r_P=0.77*	Hands & Larkin (2006)
	$39\text{-}45^{min}$ of organised PA	48 ♀, 30 ♂ 3-4 years old	–		r_S=0.72†	Kelly *et al.* (2004)
Total number of 'activity count'	$10\times^{60\ min}$ PA of various intensity	144 ♀, 125 ♂ aged 3-5 years	Left-right side comparisonr_P=0.84 (15^{min} PA, 16 children)		Intensity $r_{P\ low}$=0.59† $r_{P\ moderate}$=0.50† $r_{P\ high}$=0.61† $r_{P\ total\ PA}$=0.58*	Sirard *et al.* (2005)
TEE [mJ/day]	3^{day} PA of pre-schoolers	52 ♀, 52 ♂ aged 2-7 years	–	Double isotope labelled water	$r_{P\ all\text{-}day\ PA}$=0.33*	Montgome-ry (2004)
	$7\text{-}10^{day}$ PA of pre-schoolers	34 ♀, 51 ♂ aged 3-6 years	–		small difference in TEE(0.3 MJ/day)	Reilly *et al.* (2006)

(Table 2) contd.....

Variable	Period	Participants	Reliability	Criterion	Validity	Study
AEE [kJ/min]	5×$^{4\ min}$ PA: sweeping cycling running throwing aerobics	74 ♀ aged 14.2±0.3 years	–	Oxygen consumption (VO_2)	$r_{P\ sweeping}$=0.31 $r_{P\ cycling}$=0.40† $r_{P\ running}$=0.45† $r_{P\ throwing}$=0.49† $r_{P\ aerobics}$=0.42†	Schmitz *et al.* (2005)
Total number of 'activity count'	3×$^{2\ min}$ PA: walking, running	16 ♀, 13 ♂ aged 3-6	–	Oxygen consumption (VO_2)	'counts' × $VO_{2[mL/kg·min]}$ $r_{P\ walking\ and\ running}$=0.82†	Pate *et al.* (2006)
	3×$^{3\ min}$ PA: walking, running	8 ♀, 8 ♂ aged 6-9	Left-right side comparisonr_P =0.84-0.92		$r_{P\ walking\ and\ running}$=0.83*	Garcia *et al.* (2004)
	10×$^{4\ min}$: walking, running, cycling, aerobics, TV a PC sitting	74 ♀ aged 14.1±0.3 years	Left-right side comparison 94% inter-instrumental agreement		'counts' × $VO_{2[MET]}$ $r_{P\ total}$=0.84†	Treuth *et al.* (2004)

Table Footnotes: ♀ – girls; ♂ – boys; PE – physical education; PA – physical activity; TEE – total energy expenditure; AEE – activity energy expenditure; MET – PA intensity quantifier; r_P (r_S) – Pearson's (Spearman's) correlation coefficient; Statistical significance is expressed as *p<0.01 and †p<0.001.

The output units most often assessed to characterise the level of monitored PA are 'activity counts' [number/min] and the duration of moderate to vigorous physical activity [min] (De Vries *et al.* 2009, Trost *et al.* 2005). These are consistent, absolute units that need not necessarily respect individual particularities, especially in an ontogenetically dynamic group of children and youth. The relative output unit of PA characteristics from the accelerometer is the total or activity energy expenditure related to a unit of body weight and monitoring period [kcal/kg·day^{-1}; kcal/kg·min^{-1}], which at least partially accounts for individual somatic differences (Harrell *et al.* 2005, Mudd *et al.* 2008, Puyau *et al.* 2004, Sallis *et al.* 1990). Alternatively, the level of PA can be assessed according to the proportion of activity and total energy expenditure [%] or the multiple of the proportion of total energy expenditure and basal energy expenditure that refer to individual PA quality (Haskell 2009, Saris *et al.* 2003).

Currently, the most commonly used type of accelerometer for monitoring field-based PA is the Actigraph accelerometer. Owing to very favourable findings on its validity in measuring field-based PA in children and youth (Table **2**), the world of PA monitoring today is dominated by the three-dimensional Actigraph GT3X accelerometer (3.8×3.7×1.8 cm; 27 grams), which provides data on the total as well as the current energy expenditure (Cardon *et al.* 2007, De Vries *et al.* 2009). Wearing the Actigraph on the side of the waist for PA monitoring is as easy and non-limiting as wearing a pedometer (Fig. **3**).

Fig. (3). Pocket for the Actigraph accelerometer and location on the body for PA monitoring.

3.2.3. Heart-Rate Monitors

Heart rate is one of the fundamental physiological parameters closely related to the intensity of PA and the energy expenditure during PA (Bassett 2000, Pettee *et al*. 2009). Energy expenditure is determined from a linear dependence between heart rate and oxygen consumption (SF–VO_2) over a wide range of PA intensities (Bassett 2000, 2012, Pettee *et al*. 2009, Wilmore & Haskell 1971). During recent decades, heart-rate monitoring has undergone rapid technological development

(Pettee *et al*. 2009). Presently, these devices are stylishly designed and have comfortable sensors that do not prevent free movement or disturb habitual PA (Armstrong & Welsman 2006).

Contemporary technology allows heart-rate data detected *via* a chest sensor to be sent to a wristwatch-style receiver and stored for several days (Armstrong & Welsman 2006, Bassett *et al*. 2000, 2009, 2012). Through a wireless connection, the stored data in the heart-rate monitor can be quickly transferred to special software programmes providing a wide range of interactive visualisation and analytical tools. Using these programmes, heart-rate monitors can be individually set and calibrated according to basic somatic and physiological characteristics (age, body weight, gender, VO_{2max}, resting heart rate and its variability, *etc*.).

Table 3. The validity of determining energy expenditure using heart-rate monitors in selected studies of children and youth – ordered according to accuracy of criterion measurement.

Variable	Period	Participants	Criterion	Validity	Study
TEE [mJ/day] [kcal/kg·min] [kJ/min]	1^{day} PA	10 ♀, 9 ♂ average age 8.7 years	Double isotope labelled water (DLW – mJ/day) Oxygen consumption (VO_2 – mJ/day)	TEE_{HR} 12.3% > $TEE_{DLW}$$TEE_{HR}$ 10.4% > TEE_{VO2}	Emons *et al*. (1992)
	2-3^{day} PA	17 ♀, 19 ♂ aged2-16 years		Non-significant difference in TEE:TEE_{DWL} 3.2% > TEE_{HR}	Livingstone *et al*. (1992)
		4 ♀, 5 ♂ with celebral palsy aged 10.7±1.6 years		Non-significant difference in TEE:TEE_{DWL} 0.9% > TEE_{HR} $r_{S\ TEE\ DWL \times HR}$=0.88**	Van den Berg-Emons *et al*. (1996)
	1^{day} PA	9 ♀, 10 ♂aged 10.5 years	Oxygen consumption (VO_2 – kcal/kg·min)	Non-significant difference in TEE: TEE_{HR} 7.6% > TEE_{DLW}	Bitar *et al*. (1996)
	2^{hour} sleep	4 ♀, 12 ♂aged 8.7±2.7 years		Non-significant difference in TEE:TEE_{VO2} 0.8% > TEE_{HR} $r_{S\ TEE\ vo2 \times HR}$=0.63*	Beghin *et al*. (2002)

(Table 3) contd.....

Variable	Period	Participants	Criterion	Validity	Study
TEE a AEE [kJ/min]	1^{day} PA	7 ♀, 13 ♂ aged 11.1±3.8 years	Tritrac-R3D accelerometer	Non-significant difference in TEE: $TEE_{Tritrac}$ 1.2% > $TEE_{HR}AEE_{Tritrac}$ 8.2% < $AEE_{HR}r_{S}$ $_{TEETritrac×HR}$=0.96** $r_{S\ AEE\ Tritrac×HR}$=0.84**	Rodriguez *et al.* (2002)

Table Footnotes: ♀ – girls; ♂ – boys; PA – physical activity; TEE – total energy expenditure; AEE – activity energy expenditure; HR – heart rate; DLW – doubly isotope labelled water; Tritrac-R3D – three-dimensional accelerometer; r_S – Spearman's correlation coefficient; Statistical significance is expressed as *p<0.01 and **p<0.001.

Comparison of the heart-rate records using doubly isotope labelled water, oxygen consumption or the Tritrac-R3D accelerometer suggests that this value can be used for determining all-day energy expenditure in children (Table **3**). However, this procedure is associated with a number of technical and organisational difficulties; therefore, it is not usually used for weekly or longer-term field-based monitoring of PA in large samples of children or youth (Armstrong & Welsman 2006). A limitation of the extensive use of heart-rate monitors for the precise determination of energy expenditure is a high degree of individual biological variability among somatically similar individuals of the same age and gender.

Precise determination of energy expenditure during PA requires individual analysis and calibration of the heart-rate monitor (Haskell *et al.* 1993) because the linear SF–VO_2 dependence tends to be disturbed in the case of very low or very high values of PA intensity (Acheson *et al.* 1980, Armstrong 1998, Fudge *et al.* 2007), as well as because of the high inter-individual and intra-individual SF–VO_2 variability during activities of identical intensity (Li *et al.* 1993, McCroy *et al.* 1997). Moreover, aspects such as body temperature, amount of active muscle mass, current level of fitness, type of physical exercise (static × dynamic), hydration status, stress, use of medication, and ambient temperature and humidity have an effect on heart rate (Armstrong 1998, Bassett & Fitzhugh 2009) without a significant influence on oxygen consumption (Acheson *et al.* 1980, Montoye *et al.* 1996).

During field-based PA monitoring, technical and organisational aspects often present limitations in determining energy expenditure based on heart-rate monitors, which is subject to individual knowledge of VO_{2max}. Therefore, heart-rate recording is more often used for determining and examining the level of fitness (Pettee *et al*. 2009), determining the intensity of current PA and controlling training processes. The use of heart-rate monitors alone for long-term field-based monitoring of PA in a large sample of participants is rather ponderous. A suitable way of overcoming these difficulties appears to be combining the use of a heart-rate monitor and a movement sensor (accelerometer or pedometer), or using multi-functional monitoring devices (Andre & Wolf 2007, Baranowski & de Moor 2000, Bassett *et al*. 2000, 2009, 2012, Brage *et al*. 2005, Corder *et al.* 2007, 2008, Kohl *et al.* 2000, LaMonte & Ainsworth 2001).

Heart-rate monitoring is considered a valid and reliable method for assessing PA over extended time periods (Armstrong & Welsman 2006), but is an indirect measure that indicates the relative stress placed upon the pulmonary system by PA (Armstrong 1998). The limitations associated with heart-rate monitoring are primarily caused by biological variance, while the limitations associated with accelerometers are predominantly biomechanical (Brage *et al*. 2004). Considering the fact that the errors related to heart-rate and accelerometer PA monitoring are independent, combining the two techniques may provide a more accurate assessment of PA than either technique alone (Bassett 2012, Rowlands & Eston 2007a).

3.2.4. Multi-Functional Devices

Multi-functional devices for field-based monitoring of PA are equipped with a combination of various active sensors, allowing for more comprehensive and accurate PA recording compared with the exclusive use of a single-function device (Brage *et al.* 2005, Corder *et al.* 2007, Haskell *et al.* 1993). The multi-functional devices currently in use are based on a heart-rate monitor and a movement sensor (accelerometer, pedometer or revolution counter), as this combination increases the accuracy of determining energy expenditure compared with an independent heart-rate monitor or movement sensor (Brage *et al.* 2005, Corder *et al.* 2007, Haskell *et al.* 1993).

Originally, movement sensors were designed to monitor simple locomotion – walking. At present, they are used to monitor all-day PA, including sport and sedentary activities. Therefore, determining all-day energy expenditure using a single-movement sensor is more difficult compared with walking. Inaccuracies in determining energy expenditure using a single sensor are associated with the position on the body. In most cases, the sensor is located on the side of the waist, which is relatively comfortable and non-limiting; overall energy expenditure is calculated more precisely using transformation equations that take limb activity into account (Ainsworth *et al.* 2000, Bray *et al.* 1992, Freedson *et al*. 1998, Hendelman *et al.* 2000, Puyau *et al.* 2004, Trost *et al*. 1998, 2000). The Dynaport multi-functional devices (McRoberts, BV, The Hague, The Netherlands) and IDEEA monitor (MiniSun, Fresno, CA), with five concurrent accelerometric sensors on various parts of the body, give more precise figures of current and total energy expenditure during regular PA, as well as during specified types of PA (Zhang *et al.* 2004). Both the Dyport and IDEEA are costly and difficult in terms of technical and organisational preparation of long-term field-based monitoring of PA in larger samples.

A relatively accurate multi-functional device for determining energy expenditure during walking, running and other field-based types of PA (5% error rate) is the Actiheart (Mini-mitter, Sun River, OR, http://www.camntech.com/cnt_actiheart.htm) (Brage *et al*. 2004, 2005). The Actiheart consists of a combination of a heart-rate sensor and accelerometer (Fig. **4**), and uses their individual advantages.

The Actiheart is a lightweight (12 g), waterproof device that is attached to the chest using adhesive electrodes during PA monitoring. In the case of the shortest 15-second interval of recording heart rate and energy expenditure, the Actiheart is capable of detecting and storing data for a period of 10 days. The advantage of this device is its accuracy and simplicity of use. Some of the disadvantages include the use of adhesive electrodes, the ‘wired’ connection of the heart-rate sensor and accelerometer, and the price of the device and required software. Moreover, precise determination of energy expenditure is subject to individual calibration, as group calibration considerably decreases the accuracy of energy expenditure figures (Fudge *et al.* 2007).

Fig. (4). The Actiheart multi-functional device (heart-rate sensor + accelerometer).

The Sensewear device (BodyMedia Inc., Pittsburgh, PA, http://www.bodymedia.com/) is a light, wireless and comfortable multi-functional monitor for measuring energy expenditure during PA in usual living conditions. During measurement, the transmitter (Fig. **5**) is attached to the triceps of the right arm, between the olecranon and acromion, directly on the skin. The receiver displays energy expenditure, step count and duration of medium to high intensity PA and can be worn as a wristwatch or attached to the clothing (Fig. **5**). The Sensewear multi-functional device measures movement by a two-dimensional accelerometer, heat flow by an internal heat sensor, and skin temperature and amount of evaporated sweat during PA by a thermal sensor and hypoallergenic electrodes (Jakicic *et al.* 2004). For determining energy expenditure in children, youth and both healthy and sick adults, the Sensewear was validated for energy expenditure determined by measuring VO_2 oxygen consumption (Andreacci *et al.* 2007, Dwyer *et al.* 2009, Hill *et al.* 2010, Jakicic *et al.* 2004) and doubly isotope labelled water (St-Onge *et al.* 2007) during short-term PA (Andreacci *et al.* 2007, Dwyer *et al.* 2009, Hill *et al.* 2010, Jakicic *et al.* 2004) as well as several-day PA (St-Onge *et al.* 2007).

Fig. (5). Wireless transmitter and receiver of the Sensewear multi-functional device.

The Actitrainer is a promising multi-functional device for field-based monitoring of PA (Groffik *et al.* 2012, Neuls 2008, Sigmund *et al.* 2014b, 2014c) with few references in the literature (Fig. **6**).

The Actitrainer (ActiTrainer™, Florida, USA, http://www.actigraphcorp.com /support/devices/actitrainer/) is a small (8.6×3.3×1.5 cm), lightweight (53 g) multi-functional device, consisting of a heart-rate monitor, tri-axis solid-state accelerometer, electronic pedometer, inclinometer, and ambient light sensor. Data recording can be viewed on a built-in display.

When turned on, the Actitrainer can monitor and continually store recorded data over a period of seven days. When the display is off, a 14-day continuous PA record can be obtained. Advantages of the Actitrainerinclude rapid data transfer from the device to computer software, simple setting of individual characteristics of the monitored individual and quick charging with a USB connector (Fig. **6**).

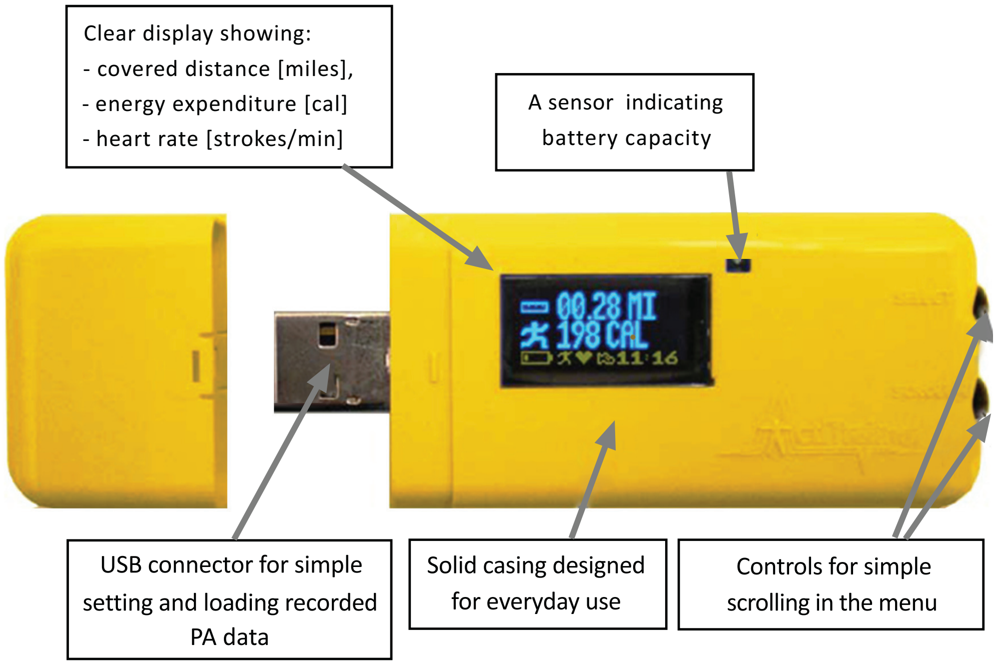

Fig. (6). The Actitrainer multi-functional monitoring device (accelerometer + pedometer + inclinometer + heart-rate sensor) with description of controls.

Wider use of the Actitrainer for field-based monitoring of PA in larger groups is currently prevented by the high price of the device. The validity and reliability of step counting using the ActiTrainer in non-laboratory conditions has been verified in a study with 20 non-obese university students (Neuls 2008), and the feasibility of assessing PA patterns in normal weight and overweight/obese children has been verified in a study with two-day monitoring of Polish (Groffik *et al.* 2012) and Czech (Sigmund 2014b) preadolescent girls and boys. Based on a two-day monitoring of PA in 338 Czech school children aged 9-11-yearsusing the ActiTrainer, participation in a physical education lesson was found to lead to a significantly higher overall daily moderate-to-vigorous PA duration compared with that during the day without the physical education lessonfor overweight /obese girls ($p< 0.05$), normal-weight girls ($p< 0.05$) and boys ($p< 0.005$). Participation in the physical education lesson contributed not only to significantly higher light PA in the normal-weight girls and boys ($p< 0.01$) during the school day but also reduced school-time sedentary time in the overweight/obese children

($p < 0.01$) and normal-weight girls ($p < 0.005$) (Sigmund *et al.* 2014c). Moreover, participation in the physical education lesson significantly reduced the overall daily sedentary time in the normal-weight children and overweight/obese boys ($p < 0.05$).

The Actitrainer accelerometer was positioned around the waist above the right knee and continuously measured PA in the children at 15-second intervals for the entire time of being worn on the body. When monitoring PA, the Actitrainer was secured at the waist using a neoprene pouch and an elastic belt. When collecting heart-rate data, a Polar chest strap, the Wearlink T31 (Polar Electro Inc., New York, USA), was worn across the sternum.

3.3. RECOMMENDATIONS FOR FIELD-BASED HEALTH-ENHANCING PHYSICAL ACTIVITY AND EXAMPLE OF INTERVENTION PROGRAMME

3.3.1. Recommendations for Field-Based Health-Enhancing Physical Activity

PA improves fitness, decreases body weight, extends active longevity and promotes health (Haskell *et al.* 2007, Jakicic *et al.* 2009, LaMonte & Blair 2009). Performing PA is influenced and limited by the specific characteristics of individuals, *e.g.*, age, gender, current health condition, socioeconomic status or type of employment (Sallis & Owen 1999), as well as by other variables, *e.g.*, the surrounding environment, time of year and weather (Tucker 2007), yet there are verified general recommendations for PA to promote health (Cavill *et al.* 2001, 2006, DHSSPS 2011, Hardman & Stensel 2009, Haskell *et al.*2007, 2009, Janssen & LeBlanc 2010, Oja *et al*. 2010, Pangrazi 2000, Pate *et al*. 2006, PCPFS 2001, Saris *et al.* 2003, Strong *et al.* 2005, Timmons *et al.* 2007, Tremblay *et al.* 2011; Tudor-Locke *et al.* 2011, USDHHS 2000, 2005, 2010, WHO 2010).

In the monitoring and recording of field-based (non-laboratory) PA performed by the general population of children; research is limited by the monitoring methods applied. The level of PA can be determined with minimum technical requirements according to the FITT characteristics – frequency, intensity, type and time of PA (Sharkey 1997). Alongside the FITT characteristics, the level of PA can be observed and analysed using the data from simple objective monitoring devices;

pedometers (step count), accelerometers (energy expenditure or duration of PA of a certain intensity) and heart-rate monitors (heart rate and its variability or duration of PA of a certain intensity) (Bassett 2000, Freedson & Miller 2000, Pettee *et al*. 2009, Rowland 2007, Rowlands & Eston 2007a, Trost 2001, Tudor-Locke *et al.* 2001, 2002).

Recommendations for field-based health enhancing PA have, during recent decades, undergone dynamic development reflecting significant the technological advancement of monitoring devices (Freedson & Mileer 2000, Haskell 2009, Tremblay *et al.* 2011) and a worldwide effort to address the undesirable decrease in PA in the general population and the related increase in diseases related to a consumerist lifestyle (Branca *et al.* 2007, LaMonte & Blair 2009). Extensive epidemiological studies have verified and particularised the proposed re-commendations based on the FITT characteristics of PA, step count or energy expenditure during PA, with respect to various age categories of girls and boys (Cavill *et al.* 2001, DHSSPS 2011, Hardman & Stensel 2009, Pangrazi 2000, Pate *et al.* 2006, PCPFS 2001, Timmons *et al.* 2007, Tremblay *et al.* 2011; Tudor-Locke & Bassett 2004b, Tudor-Locke *et al.* 2009b, USDHHS 2010, Vincent *et al.* 2003).

The recommendations for field-based health enhancing PA are based on four elementary principles (Oja *et al.* 2010):

- Performing any PA is more beneficial than not performing any PA.
- The health benefits of PA considerably prevail over the associated health risks.
- Most health benefits of PA increase with higher intensity, increased frequency or longer duration.
- Health benefits of PA are, to a considerable extent, dependent on age, gender, race and nationality.

The recommendations with the least number of references in literature apply to field-based PA to enhance the health of preschool children (DHSSPS 2011, NASPE 2009, Timmons *et al.* 2007). With respect to age-based ontogenetic and psychosocial differences it is not appropriate to formulate recommendations for field-based PA in 3- to 18-year-old girls and boys all at once for the whole age spectrum.

One of the key determinants in human ontogenetic development is the onset and course of puberty; therefore, general recommendations for field-based PA will be presented separately for the age groups of 3- to 6-year-old preschool children (Table **4**), 6- to 11-year-old children (Table **5**) and 11- to 15-year-old adolescents (Table **6**). Health-related recommendations for field-based PA are derived from moderate to vigorous-intensity PA. Vigorous-intensity PA is typically accompanied by faster breathing, sweating and a considerable increase in heart rate. This physically demanding PA increases energy expenditure by at least six times above resting metabolism (6 METs). Examples include running, aerobics or fast cycling. Moderate-intensity PA is characterised by medium effort (3–6 METs), faster breathing than at rest, a noticeable increase in heart rate and subjective feelings of warming of the organism. General examples include jogging, working in the garden or brisk walking (Cavill *et al.* 2006, Craig *et al.* 2003, Haskell *et al.* 2007).

Table 4. Recommendations for physical activity in preschool children aged 3 to 6 years.

<table>
<tr><th>FITT characteristics</th><th>Daily number of steps</th></tr>
<tr><td>➢ Pre-schoolers should accumulate at least 60 minutes of organised physical activity each day.</td><td rowspan="2">➢ Pre-schoolers should perform 13 000 steps on most days of a week</td></tr>
<tr><td>➢ Pre-schoolers should accumulate at least 60 minutes of non-organised physical activity each day.</td></tr>
<tr><th colspan="2">Other recommendations</th></tr>
<tr><td colspan="2">➢ General physical skills (running, throwing, kicking, taking-off, jumping, etc.) should be developed in pre-schoolers as a basis for more complex physical tasks.</td></tr>
<tr><td colspan="2">➢ Pre-schoolers should be provided with safe indoor and outdoor environment and aids for performing various types of physical activity.</td></tr>
<tr><td colspan="2">➢ Parents, teachers and others responsible for the education of pre-schoolers should understand the significance of physical activity and facilitate the development of general physical skills.</td></tr>
<tr><td colspan="2">➢ Pre-schoolers should not be sedentary for more than 60 minutes at a time (except when sleeping).</td></tr>
</table>

To promote health in school-aged children, a minimum of 60 minutes of moderate to vigorous PA per day is recommended (Beighle & Pangrazi 2006, Corbin *et al.* 1994, Jago *et al.* 2006, Pate *et al.* 2006, Rowlands *et al.* 2005a, Strong *et al.* 2005). This amount of PA recalculated to a relative value of activity energy expenditure represents at least 6-8 $kcal/kg \cdot day^{-1}$ (Pangrazi 2000). Separate activity energy expenditure values are rarely used to formulate general health-oriented recommendations for field-based PA. These values are more frequently associated with FITT characteristics of PA or daily number of steps. However, they are most frequently used together with energy intake values to formulate recommendations for the reduction or prevention of excessive body weight (Donnelly *et al.* 2009, Jakicic *et al.*2009, Jebb 2002, Saris *et al.* 2003).

Table 5. Recommendations for physical activity in school-aged children aged 6 to 11 years.

FITT characteristics	Daily number of steps
➢ Physical activity of at least moderate intensity for 90 minutes a day.	➢ On most days of a week should equal 12 000 steps in girls 14 000 steps in boys
➢ Distribution of PA into shorter sessions of at least 10-minute duration to perform a total of 90 minutes a day.	
Other recommendations	
➢ Promotion of physically active transport (walking and cycling) of children to and from school, after-school clubs, and other leisure-time activities.	
➢ Promotion of general motoric development as opposed to narrow focus on sports.	
➢ Promotion of speed and skill oriented physical activities as opposed to strength-focused activities.	
➢ Increase the number of children who participate in organised physical activity (including Physical Education lessons) 3–4 times a week.	
➢ Children should learn the basics of various types of physical activity (skating, cycling, skiing, swimming, climbing, *etc*.) and basic gymnastic movements before the onset of puberty.	
➢ Continuous screen time should not exceed 90 minutes a day.	

Due to the dramatic worldwide increase in the incidence of overweight and obesity in children (Branca *et al.* 2007, Dvořáková *et al.* 2010, Hedley *et al.* 2004, Ogden *et al*. 2012, Olds *et al.* 2011, Janssen *et al.* 2005, Kunešová *et al.* 2011, Lissau *et al.* 2004, Pařízková & Lisá 2007, 2010, Strauss & Pollack 2001, Vignerová *et al.* 2006, 2007, Wijnhoven *et al.* 2013), numerous recommendations and PA intervention programmes focus on reducing excessive body weight and maintaining optimum weight (Donnelly *et al.* 2009).

The threshold of the daily number of steps that is very likely to prevent obesity is 12,000 in 6- to 12-year-old girls and 15,000 in boys (Tudor-Locke *et al.* 2004a). This number of steps roughly corresponds to 120 minutes of moderate to vigorous PA daily in girls and 150 minutes in boys (Bassett *et al*. 1996, Welk *et al.* 2000). However, Colley *et al.* (2012) proposed that 12,000 steps per day should be used as a target to determine whether children and youth aged 6–19 years are meeting the current PA guideline of 60 minutes of daily moderate to vigorous PA. However, regular and long-term and implementations of PA lower than the above-mentioned daily steps threshold of 12,000 steps for girls and 15,000 steps for boys can lead to a significant reduction of obesity in children (Sigmund *et al.* 2012, 2013).

Table 6. Recommendations for physical activity in adolescents aged 11 to 15 years.

<table>
<tr><th>FITT characteristics</th><th>Daily number of steps</th></tr>
<tr><td>➢ Physical activity of at least moderate intensity for 60 minutes a day.</td><td rowspan="4">➢ On most days of a week should equal
11 000 steps in girls
13 000 steps in boys</td></tr>
<tr><td>➢ Physical activity of moderate intensity or walkingfor at least 30 minutes 5 times a week.</td></tr>
<tr><td>➢ Physical activity of vigorous intensity, enhancingand maintaining cardio-respiratory fitnessfor at least 20 minutes 3 times a week.</td></tr>
<tr><td>➢ Combination of the previous recommendations for vigorous and moderate physical activity split into10-minute or longer sessions within a day.</td></tr>
<tr><th colspan="2">Other recommendations</th></tr>
<tr><td colspan="2">➢ Promotion of physically active transport (walking and cycling) of adolescents to and from school, after-school clubs, and other leisure-time activities.</td></tr>
<tr><td colspan="2">➢ Specialised sports training in adolescents should respect their general physical development.</td></tr>
<tr><td colspan="2">➢ Promotion of speed and skill oriented physical activities as opposed to strength-focused activities.</td></tr>
<tr><td colspan="2">➢ Increase the number of adolescents who participate in organised physical activity (including PE lessons) 3 times a week.</td></tr>
<tr><td colspan="2">➢ Increase the number of adolescents who spend at least 50% of Physical Education lessons in moderate to vigorous physical activity.</td></tr>
<tr><td colspan="2">➢ Continuous screen time should not exceed 2 hours a day.</td></tr>
</table>

3.3.2. The Example of School-Based Physical Activity Intervention Programme

A four-year implementation of the daily school-based PA intervention programme (Table **7**) led to increased daily PA and had a favourable effect on the lower prevalence of overweight/obesity of young school-aged children (Table **8**, Figs. **7** and **8**).

Table 7. PA environment and school-day PA content of intervention and control schools between 2006 and 2010.

Description and Examples			
Intervention Schools			**Control Schools**
PA Environment			
Involved			**Not Involved**
Environment/ Equipment	PA-friendliness	Environment/equipment more PA-friendly compared with control schools	Environment/equipment less PA-friendly compared with intervention schools
	Pitch	Larger pitch with artificial turf	Smaller concrete pitch
	Playground	Playground with safe climbing frames, swings and a sandpit	Small playground without age adapted equipment
	Grassy area	Grassy area and school yard separated from public areas	No grassy areas
	Gymnasium	Larger gymnasium with various PA aids and equipment	Smaller gymnasium without age adapted aids and equipment
	PA corners	PA corners in corridors and classrooms or rooms designed for board and table games	Standard corridors without PA corners or classrooms designed for games
Type (duration)	**Frequency**	**PA Content**	
PE lessons (45 minutes)	2 per week	Overall development of children's motor activity and fitness though movement games, simplified sports games, gymnastic and athletic exercises, and constitutional in co-educational teaching	
Short breaks (3–5 minutes)	2–3 per day	Breathing and stretching exercises in classroom	Painting, drawing, writing in classroom
Long break (20 minutes)	3–4 per week	Movement playing in corridors/room for table and board games	Painting, drawing, writing in classroom
After-school care (40–90 minutes)	each day	Movement and sports games, exercises with PA aids and equipment in playground/gym	Painting, drawing, singing, doing homework, reading, playing board games in classroom

Table Footnotes: PA – physical activity; PE – physical education.

A school intervention PA programme was conducted in two intervention schools in the Czech Republic between 2006 and 2010. PA was monitored using a Yamax Digiwalker SW-200 pedometer (Yamax Corporation, Tokyo, Japan), the Caltrac accelerometer (Muscle Dynamics Fitness Network, Torrance, CA, USA) and an individual PA log-book for at least twelve continuous hours a day during seven consecutive days. School-based PA (PE lessons, PA during short breaks and longer breaks and PA at after-school care) in environments compatible with PA (child-friendly gyms and school playgrounds, corridors with movement and playing around corners and for games) (Table **7**) plays a vital role in the reduction of overweight and obesity levels among younger pupils.

Table 8. Impact of participation in physical activity intervention programme on the odds of child obesity/overweight during 2006–2010.

Baseline				**Controlled PA intervention**				**Follow-up**	
Grade of primary school (calendar year)									
1st (2006)				**2nd (2007)**		**3rd (2008)**		**5th (2010)**	
	n	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Group									
Control	88	Ref.		Ref.		Ref.		Ref.	
Intervention	88	1.17	0.57-2.40	0.34*	0.16-0.72	0.09†	0.04-0.27	0.25†	0.12-0.53
Gender									
Girls	88	Ref.		Ref.		Ref.		Ref.	
Boys	88	2.64*	1.24-5.62	1.99	0.94-4.20	1.85	0.83-4.12	1.85	0.90-3.80
R^2		0.06		0.10		0.25		0.14	

Table Footnotes: N – number; OR – odds ratio; CI – confidence interval; Ref. – reference group; statistical significance *$p<0.005$, ‡$p<0.001$; R^2–Nagelkerke coefficient of determination, logistic regression model, Enter method.

In the intervention schools, with the exception of two mandatory 45-minute PE lessons, the core PA within the school PA intervention programme was particularly during the school breaks and during the after-school care that immediately followed the end of a free lunch hour. In both intervention schools, during both the longer school breaks (20 min, 4–5 per week) and the after-school care (40–90 min daily), both individually and in small groups, children were offered various PA aids and equipment (skipping ropes, hoops, foam balls, soft balls, volleyballs, soft tennis and badminton rackets, age-adapted baseball bats and balls, hopscotch, ropes, frisbees, kick scooters) to be used in a gym or in the larger pitch or playground (Sigmund *et al.* 2012). During the after-school care, playing with PA aids and equipment was enriched with physical games (*e.g.*, tag, PA rhymes, hide-and-seek, and dodge ball) and age-adapted sports games (throw ball, football and floor ball played on a smaller pitch with smaller goals). During these games, children were allowed to choose freely not only the content but also the intensity of the selected PA according to their preferences, fitness, agreement with teammates and current weather conditions or available sports aids and equipment. In both intervention schools, the school PA programme was implemented in a friendly and creative atmosphere between the school management members, teachers and the researchers and research assistants (students on teaching practice). At the end of the two-year intervention, both intervention schools accepted, adapted and embedded the design of the PA intervention programme within their regular daily curriculum.

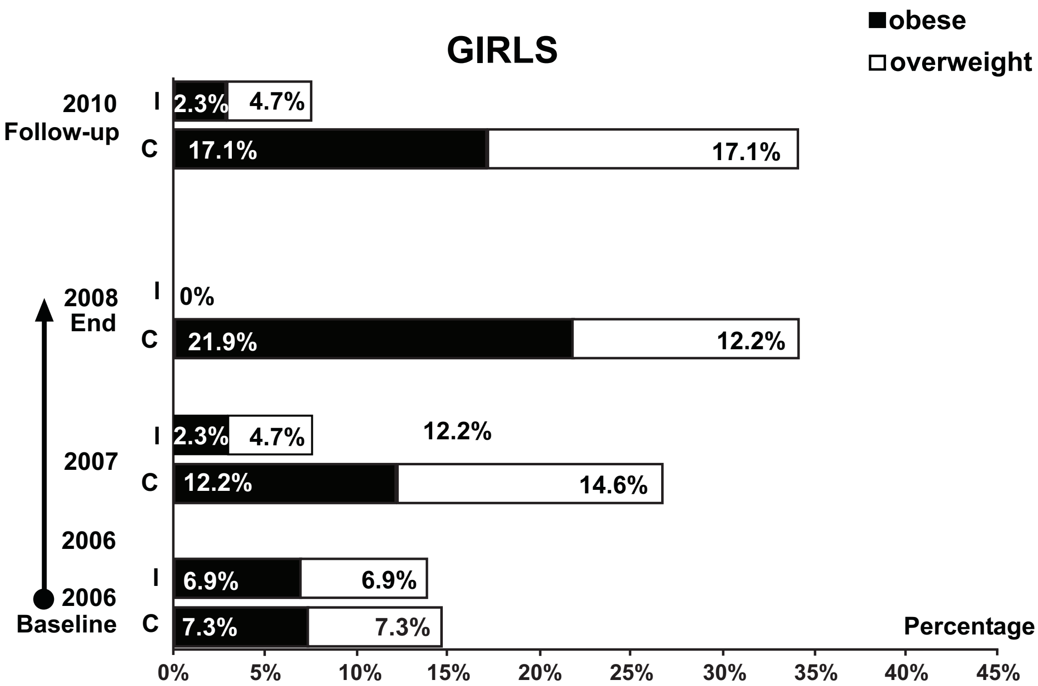

Fig. (7). Mean percentages of obese and overweight intervention (I) and control (C) girls throughout the intervention and follow-up.

However, reductions in overweight and obesity levels were observed starting about a year after the PA intervention commenced (Table **8**, Figs. **7** and **8**). Increased school-based PA also had a positive impact on leisure time PA during schooldays and on PA over the weekends of intervention children.

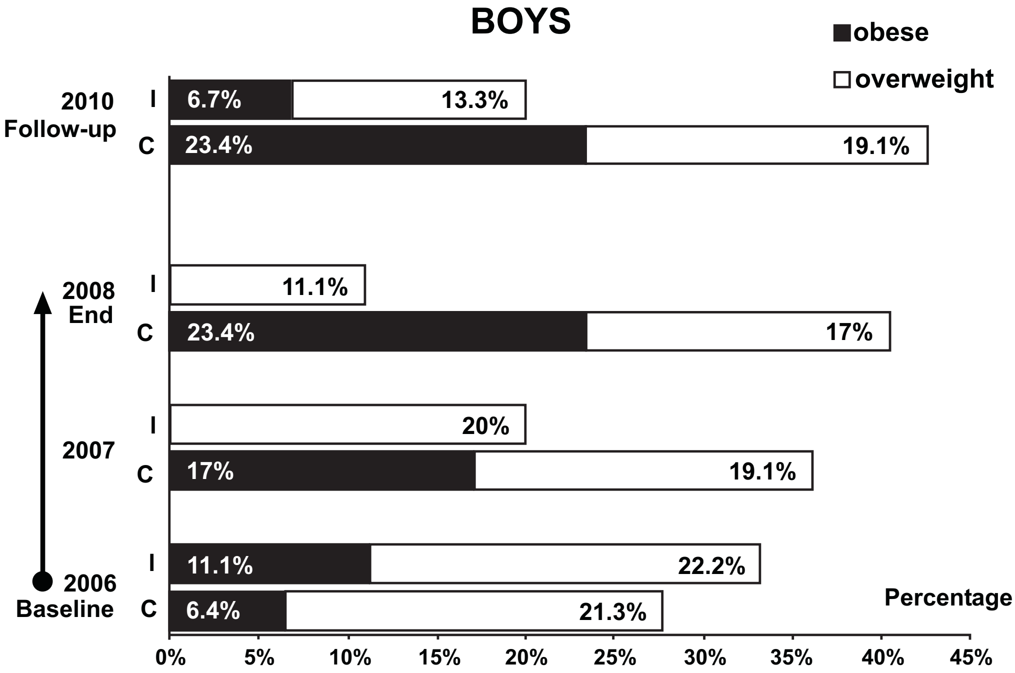

Fig. (8). Mean percentages of obese and overweight intervention (I) and control (C) boys throughout the intervention and follow-up.

3.4. CONCLUSION - SUMMARY STATEMENT

The chapter describes non-invasive means to monitor field-based physical activity and provides answers to questions concerning appropriate configuration of these means in order to carry out inter- and intra-group comparisons. The description of the non-invasive means with an emphasis on the validity and reliability during short-term and long-term field-based monitoring of physical activity results in the formulation of recommendations in the area of education and health to maintain a physically active lifestyle.

The verified and regularly applied methods of field-based monitoring of physical activity developed by the Institute of Active Lifestyle, Faculty of Physical Culture, Palacký University, use accelerometers, pedometers, record sheets, and questionnaires, and allows a sufficiently precise description of physical activity on the basis of which health and education recommendations and physical activity intervention programmes can be developed.

School-based physical activity (physical education lessons, physical activity during short breaks and longer breaks, and physical activity at after-school care) in environments compatible with physical activity (child-friendly gym and school playground, corridors with movement and playing around corners and for games) plays a vital role in overweight and obesity reduction among younger pupils. However, reductions of overweight and obesity levels were observed starting about a year after the physical activity intervention commenced.

The results of four years of monitoring of physical activity indicates favourable effects of the daily school-based physical activity intervention programme on prevalence of overweight/obesity, which was maintained two years after the end of direct involvement of the researchers.

Two years of direct involvement of the researchers in the school-based PA intervention programme seems to be sufficient time for the intervention schools' staff members to adopt the design and content of the intervention programme.

NOTES

[1] Reactivity can be defined as a change in the normal behaviour of participants caused by their awareness of being monitored (Welk *et al.* 2000). PA monitored by pedometers can be higher as a result of the participants' awareness of the number of steps and the act of entering data into record sheets (Clemes *et al.* 2008). However, monitoring over a period that exceeds four days is considered sufficient for the reliable recording of habitual PA (Foley *et al.* 2011, Rowe 2004, Sigmundová 2013, Tudor-Locke 2005, Tudor-Locke 2009a, Vincent 2002).

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 4

Metabolic and Hormonal Characteristics Related to Energy Balance and Adiposity During Growth

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Abstract: The function of adipose tissue is influenced by many factors as hormones, cytokines, but adipose tissue is active also as an endocrine organ. The amount of adipose tissue and its function is also influenced by external factors as nutrition and physical activity. The age and the stage of sexual development has to be taken into account too, and the differences between children in prepubertal, pubertal age and in adults in adipose tissue metabolism can be therefore found. The factors which influence adipose tissue's metabolism and the factors produced by adipocytes will be also presented. All mentioned factors are influenced by external factors, specially by exercise. Acceptable work load and exercise and the adaptation to it has to be considered and applied in children as compared to the adults. Hormonal and cytokines regulation of adipose tissue can be also changed by exercise in obese subjects.

Keywords: Adipose tissue, Age, Cytokines, Exercise, Hormones, Physical activity, Sex maturation.

4. ADIPOSE TISSUE AS AN ENDOCRINE ORGAN

4.1. Introduction

The structure of adipose tissue (AT) changes during the development of the human subjects and is influenced by hormones and cytokines already in intrauterine life. The Basic cells of the adipose tissue - adipocytes - begin to differentiate during the fetal life about the 14^{th} gestational week. This differentiation is influenced by many transcriptional factors - cytokines, and by nutrition and hormones from placenta. More considerable development of adipose

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tissue (namely brown adipose tissue BAT) can be found around the 25th gestational week. BAT has very important function for the keeping of the body temperature after the delivery. The activity of BAT is checked by hypothalamus which stimulates sympathetic nervous system and the secretion of norepinephrine through the activity of the receptors beta-3 norepinephrine. BAT has by the way the stimulating effect on UCP (the uncoupling proteins). UCP (namely UCP-1 - thermogenin) located on the inner side of mitochondrial membrane play the important role in thermogenesis. The function of BAT is also regulated by triiodthyronin T3. Some authors demonstrated BAT also in the healthy adult humans (Cypess *et al*., 2009, Virtanen *et al*., 2009).

The differentiation of the multipotentional cells in white adipose tissue (WAT) continues during further life. Adipose cells are able to increase their volume or their number during the whole life of the human subjects. The development of adipose tissue and its metabolism is influenced by many factors - hormones and cytokines. On the other side, white adipose tissue (WAT) shows also as functioning endocrine organ. All the hormones which are secreted in AT or which influence AT metabolism are associated with each other. Their level can be influenced by many other factors *e.g.* by exercise, which results in the increase of the hormonal sensitivity.

In the first part of this chapter there will reviewed hormonal factors which are involved in the activity and regulation of adipose tissue. Second part is devoted to the changes of the adipose tissue and its reaction to hormones under condition of various physical activity and exercise, with special attention to the period of growth.

4.2. Factors Which Influence Adipose Tissue

4.2.1. Hormones Linked to Adipose Tissue´s Metabolism

Thyroid hormones, cortisol, sex hormones (androgens, estrogens), factors reelased from CNS, catecholamines, growth factors as growth hormone, and IGF-1 insulin, glucagon and others influence the activity of AT.

Thyroid Hormones (TH) and Thyreotrophin Stimulating Hormone (TSH)

take part in the regulation of general metabolism and the tissue differentiation. Their level in the blood during the compensated energy balance is normal. Some authors present in the case of increasing energy expenditure (EE) and balance moderately increased level of TSH, especially in unadapted subjects (subclinic hypothyroidism).

Thyroid hormones have a very important role - in the regulation of heat production. T3 facilitates the effect of norepinephrine and stimulates the expression of beta - adrenergic receptors. On the other hand, norepinephrine stimulates enzyme thyroxin - 5´deiodinase type II activity. The synergism of T3 and norepinephrine leads to the stimulation of UCP (Silvestri E. *et al.*, 2005). The decreased level of triiodthyronin (T3) and thyroxin (T4) was found after nutrition deprivation in laboratory animals (rats) and in the human subjects too. This can be explained by decreasing regulation of gene 5´-deiodinase expression in the liver and thyroid gland (TG). TSH increases lipolysis by the activation of hormone-sensitive lipase.

Adipose tissue also regulates the secretion of thyroid releasing hormone (TRH) in hypothalamus by the effect of the low level of leptin, because the paraventricular neurons TRH contain leptin receptors. TRH (thyroid-releasing hormone) is produced in hypothalamus in the response to stimuli as body temperature, dietary intake, stress and some hormones (*e.g*. catecholamines). The hypothalamic-pituitary-thyroid axis is very important regulating complex.

Thyroid hormone level is connected with insulin receptors number in adipocytes. Their number is increased in the case of hyperfunction of thyroid gland (TG) and decreased in the case of its hypofunction. T3 and T4 regulates lipogenesis and lipolysis, fatty acid oxidation and the effect of insulin (MacMurray & Hackney, 2005). A higher level of triacylglycerol and sometimes higher level of total cholesterol in blood was found in hypofunction of TG (Amin. *et al.,* 2011).

Cortisol

The level of cortisol-binding protein (CBP) can be decreased in obese patiens and by this way the increase of the level of free cortisol in the blood and then its higher excretion in urine can be found. Jessop D.S. *et al.* (2011) assumes decreasing of the answer of HPA (hypothalamus - pituitary -adrenal axis). The frequency of ACTH (adrenocortocotrophine hormone) pulses is increased and their amplitude is decreased (particullary in the morning). The daily rhythm of cortisol secretion is disrupted. The level of cortisol can be in adipose tissue higher in view of the presence of enzyme 11- beta-hydroxysteroid - dehydrogenase-1 (11HSD-1) in obese patients. This enzyme transforms inactive cortisone in active cortisol, inactive 11-dehydrocortisone in active 11-dehydrocortisol, inactive 11-keto-forms in active 11-hydroforms. Higher level of 11- HSD-1 in AT, especially in the visceral adipose tissue, is probably caused by the effect of cytokines, sexual hormones, growth hormone, thyroid hormones, insulin-like growth factor–1 (IGF-1), insulin and the others factors. Cortisol stimulates apetite *via* interactive complex between hypothalamus and adrenal gland and *via* their effect on neurotransmitters –neuropeptid Y (NPY), leptin and gastrointestinal hormones.

Cortisol assignes lipolytic effect and the inhibition of hormone-sensitive lipase (HSL) activity, the stimulation of gluconeogenesis in the liver and the inhibition of the glycogen-synthase activity.

Sexual Hormones

A low level of **sex-hormone-binding globulin (SHBG**) was found in obese men Due to that the level of free t**estosterone** in the blood is normal, but the level of total testosterone can be slightly lower. On the other hand, the **estrogen** level would be higher. This can be explained by the activity of enzyme aromatase which changes in AT androgens to estrogens.

Estrogens are very long known as a regulator of adipose tissue. They inhibit lipolysis *via* decreasing of lipoprotein lipase activity. Estrogens influence the proliferation of preadipocytes and their differentiation. Growth factors, insulin and glucocorticoids assigne also similar effect.

With regard to the binding capacity of sexual hormones in both genders, women have the same binding capacity for estrogens in visceral and subcutaneous adipose tissue, but in men the binding capacity in the subcutaneous AT is higher. In men enzyme aromatase plays the important role in amount of estrogens in AT. There are other enzymes in AT too - 5-17-beta- hydroxysteroid- dehydrogenase (beta HSD5, AKR1C3), and 3-3-alfa-hydroxysteroid-dehydrogenase (3-alfaHSD3, AKR1C2) (Dufort *et al.*, 2001).

4.2.2. Central Nervous System

Metabolism of AT is also regulated by the factors released from CNS, which influence the nutrition take and EE. These factors maintain the energy balance in equilibrium. This concerns also **melanocortin** (MC), derived from propio-melanocortin (POMC), its receptors (MCR-4, MCR-5) and their antagonists - agouti and agouti -related protein (AgRP).

The next factor - **leptin** has the influence on the production of melanostimulating hormone (alpha- MSH) synthetized especially in nucleus arcuatus. Alpha-MSH is an agonist for the MC4 receptor, leptin inhibits AgRP (an antagonist of MC4 receptor). Leptin also influences the production of insulin, ghrelin, peptid YY (PYY), glucagon-like-peptid (GLP-1), cholecystokinin (CKCK), HP axis and thyroid hormones.

Other neuropeptides as metakefalin, alfa-melanin concentrating hormone (MCH), galaknin (secreted in paraventricular nucleus and lateral part of hypothalamus), dopamin and gama-aminobutyric acid (secreted in dorsomedial parts of hypothalamus and in nucleus arcuatus) can take part too in the activity of AT.

Orexigenic peptid NPY synthetized in *n. arcuatus* is also regulated by leptin. NPY increases dietary intake, decreases EE, stimulates insulin secretion and inhibits HP axis (Morton & Schwarz 2001, Amin *et al*. 2011). So called orexogenic neuropeptides (NPY, MCH, orexins A and B, opioids, ACRP) increase nutrition take, insulin level in the blood, also the tonus of para-sympathetic nervous system, and decrease the tonus of sympathetic nervous system. Anorexigenic neuropeptides. cocain and amphetamine - regulate transcript (CART), corticotrophin-releasing hormone (CRH), melanocortinsystem (POMC, MSH and MC4R). On the other hand, they inhibit nutrition take, blood level of insulin, also the tonus of parasympathetic nervous system, and increase tonus of sympathetic nervous system.

4.2.3. Further Hormlnes Participating in Lipid Metabolism

Catecholamines

belong to the most powerful regulators of lipid metabolism. Subcutaneous adipose tissue contains above all alpha-2 receptors, whereas visceral adipose tissue contains more beta-receptors. Therefore the lipolytic effect is enhanced more in visceral AT than in subcutaneous AT. Catecholamines also regulate the production of leptin, interleukin - 6 (IL-6) and tumor-necrosis factor (TNF-1). Catecholamines receptors beta (1.,2.,3 and probably 4) stimulate lipolysis and induce thermogenesis. Catecholamines receptors - alfa inhibit lipolysis and regulate the differentiation of preadipocytes.

Sympathetic nervous system increases catabolic effect (lipolysis) and activate hormone-sensitive lipase. This concerns also the effect of physical activity (PA) and exercise. Parasympathetic nervous system has anabolic effect by increasing of the production of insulin and by increasing of the capture of fat acids and glucose.

Growth Hormone (GH)

The level of GH in the blood is slightly lower in obese adults. Some authors describe the ability of pituitary gland to increase GH secretion due to some stimulation such as physical activity (PA) in young obese and non-obese men, and in non-obese women (Kanaley *et al.*, 2001). GH stimulates the release of insulin-like growth factors (IGFs), increases gluconeogenesis in the liver and the mobilization of fatty acids from adipose tissue, influences the activity of lipoprotein- lipase and hormon-sensitive lipase (LHP) – also during PA, and releases insulin from the cells to the blood circulation. GH stimulates also glycogen synthesis and lipolysis. GH also blocks glucose entry to adipose cell.

Insulin-Like Factor -1 (IGF-1)

The level of total IGF-1 is slightly lower in obese adults, but the free form of IGF-l is higher due to the low level of its binding protein IGFBP-1, and the binding protein-3 (IGFBP-3). IGF-1 in the cooperation with cortisol, insulin, T3 and GH has the high influence on the differentiation of preadipocytes into mature adipocytes.

Insulin

secreted by pancreas, influences the metabolism of glucose by the stimulation of glycolysis and by the incorporation of glucose into triacylgycerides. Insulin increases lipoprotein-lipase activity and reduces lipolysis by the inhibition of hormone-sensitive lipase. Insulin stimulates also leptin expression.

Glucagon

secreted by pancreas, promotes the mobilization of fatty acids and glucose, stimulates glycogenolysis and gluconeogenesis.

4.2.4. Factors Secreted in Adipocytes

Adipose tissue secretes many **(adipo)cytokines**, *e.g*. leptin, adiponectin, several interleukins (IL-1beta, IL-6), tumour necrosis factor-alpha, resistin. On the other hand these cytokines appear to be important regulators of adipose tissue metabolism.

Leptin

is a cytokine which regulates nutrition intake and EE. Leptin is connected with the activity of several other hormones. Leptin is produced mainly by adipose tissue and so its level is higher in the obese. Leptin acts through the leptin receptor (LEPR or ObR) highly expressed in CNS, especially in hypothalamus and also in gonads and adipose tissue. Obesity is connected with the decrease of leptin receptor and by this way the leptin resistance is developed. The effect of leptin is much larger: it controls the function of ovaria, the proliferation and apoptosis of cells.

Leptin also stimulates hematopoesis and angiogenesis, myelinization of nervous system, immunity response, blood pressure and the development of osseous tissue. Leptin regulates also HPA axis, the secretion of GH and gonadotrophins (GT), especially luteizing hormone (LH). Leptin influences apetite *via* its inhibitory effect on hypothalamic neuropeptide-Y (NPY). Leptin is produced in many other organs, in placenta, muscles, adipocytes and many others.

Higher amount of leptin is produced in the subcutaneous than in visceral AT. In women the quantity of leptin is three times higher than in men. Roemmich *et al*. (1998) has also noted the gender differentiation in leptin concentration in children. This differentiation is caused by the different amount of subcutaneous fat in boys as compared to girls due to the greater androgen concentration in boys. The production of leptin is influenced by insulin, glycaemia, TNF-1, Il-6. Leptin stimulates the expression of anorexigenous peptides as PMOC, cocain- and amphetamin-related transcript factors in *n. arcuatus*. On the other hand, leptin inhibits the expression of orexigenic peptides such as NPY and agouti-related protein. Leptin also regulates lipid synthesis in the liver. Leptin activity is related to catecholamines, cortisol, insulin, growth hormone, thyroid hormones and sex hormones (Lechan & Fekete 2006). Leptin stimulates lipid oxidation.

Adiponectin

is also known as adipocyte-complement-related protein (ACRP). Its level is in the obese lower. Adiponectin acts through two receptors, influences lipid metabolism and has an antiatherogenic character. It is present in the white adipose tissue, more in the subcutaneous than in visceral AT.

Adiponectin is secreted in pulses by adipocytes and its expression and secretion from adipocytes are reduced by TNF-alpha. The increase of insulin sensitivity and decreased adiponectin in children of 5- and 8-years old was found (Murphy *et al.* 2008). Sexual differentiation of adiponectin can be proved during puberty, and the lower level is found in boys. Adiponectin leads to the stimulation of fatty acids in the liver and the muscles, and slows down gluconeogenesis in the liver.

TNF-1 (Tumor Necrosis Factor-1)

is also secreted by adipocytes in WAT, more in subcutaneous AT. Obese individuals have higher level of TNF-1. It is asssumed that TNF-1 stimulates hormone-sensitive lipase, and lipolysis and glycolysis. It regulates also leptin secretion, inhibits the differentiation of adipocytes and CCAAT/EBO-alf-

-enhancer-binding protein, PPAR gama-2 (per-oxisme proliferator activated receptor gama- 2) and lipogenesis.

IL-6 (Interleukin-6)

is secreted by many cells, in AT by adipocytes, and 2-3 times more in visceral AT. It is connected with thromboembolism. Il-6 inhibits the secretion of adiponectin and the activity of lipoprotein lipase, and in this way it induces lipolysis. Its expression is stimulated by catecholamines, insulin and glucocorticoides.

Resistin

is secreted by adipocytes, its function is hitherto unclear. Its higher level is known in obese murines. The secretion of resistin is stimulated by insulin and glucocorticoides, and inhibited by beta-adrenergic receptors.

Visfatin

was found in adipocytes; it binds to the insulin receptors and has hypoglycemic effect. Its role in human subjekt has been made clear.

Adipsin (ASP- Acylation –Stimulating Protein/Adipocyte Trypsin)

is secreted by adipocytes. It regulates the storage of the fat in AT *via* the stimulation of glucose transport, it enhances the activity of lipoprotein-lipase, promotes the triglyceride synthesis, decreases lipolysis and the release of NEFAs from adipocytes (Kershaw & Flier 2004).

PAI-1 (Plasminogen Activator Inhibitor-1)

is secreted in adipose tissue and in the liver. It is increased in the human subjects with visceral obesity, and is decreased during exercise and nutrition restriction. Its increased level leads to the decrease of fibrinolysis and to the rise of creating thrombus.

Renin –Angiotensin

complex and its components (renin, angiotensinogen, angiotensin I, angiotensin

II, angiotensin receptors type I and II and angiotensin-converting enzyme, and other proteases) are also present in AT, mainly in visceral AT. This complex has the function in the differentiation of adipocytes (Kershaw & Flier 2004) and the regulation og blood pressure.

4.2.5. Gastrointestinal Hormones

Ghrelin

is produced in the stomach, in smaller amount in placenta, kidneys, adrenal cortex, pituitary gland and hypothalamus, in large amount in obese subjects. The receptor for ghrelin is growth hormone secretory receptor type 1a (GHS-RHIa) expressed in hypothalamus. Ghrelin increases gastric motility, gastric and pancreatic secretion, influences lipid and glucose metabolism, inhibits lypolysis and stimulates lipogenesis.

Obestatin

is peptide derived from ghrelin precursor. Its level is lower in obese subjects.

4.2.6. Enzymes in Adipose Tissue

Adipose tissue expresses many enzymes which influence sexual hormones activity.

Aromatase-CYP19(Estrogen Synthase)

changes androgens on estrogens, androstendione on estrone and testosterone on estradiol in WAT, its level in obese is higher and can lead to pseudogynecomastia in men.

17-beta-Hydroxysteroid- Dehydrogenase

(17-beta HSD) causes the conversion of weak androgens or estrogens - andro-stendione to testosterone and estrone to estradiol.

11-beta- hydroxysteroid dehydrogenase I (11-beta HSD-1) mediates the conversion of inactive cortisone to cortisol. 11-beta-HSD-1 is expressed particularly in visceral AT (Stuining & Waldhaus 2004).

4.2.7. Summary Statement

The survey of the main hormonal and cytokine factors and their influence on AT is presented in this section. But AT is also the source of many hormones and cytokines. The secretion of these factors is increased in obese subject.

4.3. Intervention and Prevention of Obesity by Exercise

4.3.1. Introduction

It is well known that the prevalence of overweight and obesity is increased not only in the adults, but also in growing individuals, especially during puberty. At this age many changes are obvious in body composition due to sexual maturation. The increasing production of gonadal steroid hormones (testosterone in boys and estradiol in girls) begins 1 or 2 years before apparent physical changes of the child´s body (in adrenarche). The onset of prepubertal and pubertal hormonal changes is influenced in girls by the increase of amplitude of luteizing hormone and follicle-stimulating hormone in pituitary gland and gonadotrophin-releasing hormone in hypothalamus. These physiological hormonal changes can cause the higher prevalence of obesity in puberal age.

Energy expenditure consists of three compounds - basal metabolism, adaptive thermogenesis and energy necessary for physical activity. Total daily energy expenditure (EE) increases considerably due to physical activity (PA, by more than 50% of basal metabolic rate – BMR) during extremely high physical load. The question is whether the increasing physical activity and the increasing production of heat leads to some changes of hormonal production. The energy intake and output are linked to the effects of many hormones and cytokines as catecholamines, cortisol, insulin, growth hormone and insulin like - growth factor, thyroid hormones, gonadotrophines and sex hormones and also leptin, adiponectin and others.

Previously, regulatory changes were considered, and now we take into account the influence of physical activity on some hormonal changes. How high can be the intensity of the exercise, how long its duration for these hormonal changes, especially in the childhood. Can a child or adolescent undergoes the same load of physical activity?

Exercise has high effect on the function of endocrine glands, and on many regulatory systems. Low or moderate intensity of exercise facilitates lipolysis and is useful for the prevention and the treatment of overweight. Adaptation to training and exercise reduces that lipolytic activity, but the sensitivity to regulating hormones is increased and so lipolysis is unchanged.

4.3.2. Hormonal and Cytokines Changes During Exercise

Thyroid Hormones

have the important function in thermogenesis. Thyroid hormones influence neurons in paraventricular nucleus and have also effect on dietary intake and physical activity (Lechan and Fekete, 2006). T3 influences the function of epinephrine and by this way the mobilization of free fatty acids from adipose tissue as a source of necessary energy source during exercise. The level of T3 and T4 in the blood during exercise is not changed. But some studies showed the reduction of cortisol and rT3 (reversed T3) in the untrained subject. Another author showed an increase of T3 after exercise, an increase of cortisol and rT3, and an decrease in T3 during the exercise in other subjects (Ciloglu F. *et al.*, 2005). The blood level of T4 is unchanged. Different results were provided in the other studies (Kanake-Gantenbein, 2005).

Calorigenic effect of thyroid hormones is bound to mitochondria. T3 increases their number and also their activity in many tissues as the skeletal muscles, the heart and the others (Goglia, 2005). T3 influences in this way the metabolism of carbohydrates, lipids and proteins.

UCP (Uncoupling Proteins),

located in the inner mitochondrial membrane, play an important role in this proces. UCP2 mRNA is present especially in WAT, spleen and pancreatic beta cells, UCP3 mRNA is expressed mainly in the skeletal muscles, and in smaller amount in WAT, BAT and heart (Pecqueur *et al.*, 2001). T3 induces the expression of UCP2 and UCP3. UCP levels are increased in many situations as the high energy expenditure, cold, but also at the occasion of high level of leptin or thyroid hormones (Hackney A.C. *et al.*, 2003, Silvestr E. *et al.*, 2005, Loucks A.B., Heath E.M., 1994).

Cortisol

plays the role in gluconeogenesis in the liver and in the decrease of glucose utilization by the cells. Cortisol also stimulates the mobilization of fatty acids from adipose tissue, also at the occasion of increased physical activity. Its level in the blood is stimulated during exercise and the highest production of cortisol by adrenal cortex can be found during the high exercise intensity; in contrast , low intensity of physical activity diminishes cortisol level. The increase of cortisol secretion is caused by ACTH and CRH (corticotrophin releasing hormon) stimulation, and by higher level of interleukin-6. It has also to be taken into account the duration of exercise. Cortisol response to morning exercise is significantly higher than in the afternoon. That is caused by diurnal rhytm of HP axis activity and by diurnal rhytm of cortisol secretion (Kanaley. *et al.*, 2001). The increase of cortisol during exercise is also observed in children (Corral *et al.*, 1998, Hill *et al.*, 2008). This increase also takes part of the body's adaptation to this extreme situation (Hackney A.C. *et al.*, 2003).

Testosterone

is raised at the beginning of exercise, and after 45 – 60 minutes of the exercise begins to decrease. High intensity or the long duration of training caused the reduction of testosterone blood level too (Liu Te Chi *et al.*, 2009). Brownlee *et al.* (2005) showed the influence of cortisol on the testosterone level. The level of cortisol during exercise is increased, and that increase can have negative effect on blood testosterone. Some authors (Urhausen and Kindermann, 2002) showed that the ratio of testosterone to cortisol can be used as a marker of anabolic or catabolic state of training. The diminished ratio T/C can be a marker of overtraining or fatigue. Testosterone has anabolic effect in the muscles and stimulates protein synthesis in childhood, – especially in prepubertal boys

(Vingren *et al.*, 2010). The effect of exercise on the level of sexual hormonesis is not dependent on the secretion of both GT (gonadotrophines) - FSH and LH. The correlation between the testosterone secretion and the development of insulin resistance was confirmed. Exercise can also improve insulin sensitivity.

LH

in women during exercise is increased in follicular phase and decreased in luteal phase with new increasing in the end of this phase. The level of **FSH** is increased during follicular and luteal phase too, but the increase in the luteal phase of menstrual cycle is lower. Blood level of estrogens during exercies is increased in follicular and decreased in the end of luteal phase of the menstrual cycle. Adaptation to long term exercise (intense training) can lead to the decrease of estrogen level (Day D.S. *et al.*, 2005). In chilhood the level of both sexual hormones depends on sexual maturity in both genders.

Adrenalin

plays significant role in the utilization of glycogen as the additional source of energy. The level of adrenalin is increased on the onset of exercise and the increase depends on the intensity and the duration of exercise. Adrenalin enhances the heart rate.

Epinephrine and Norepinephrine

known as catecholamines have the fast influence on the metabolism of glucose and free fatty acids. Their effect takes part in the mobilization of glycogen from the muscles and the liver, in the mobilization of freee fatty acids and in the increase of the energy output. The level of epinephrine and norepinephrine in the blood is enhanced during exercise, more in the high intensity (in anaerobic exercise), but is decreased in the prolonged aerobic exercise, or after the adaptation – training, both in the adults and in children (Pullinen *et al.*, 1998).

The important effect of catecholamines is to increase cardiac output and the supply of oxygen to the muscles. Catecholamines and the sympathetic nervous system play the key role in lipolysis during the exercise by increased responsiveness of adipose tissue to beta-adrenergic stimulation. Catecholamines increase the activity of hormone-sensitive lipase. Their effect is facilitated by human growth hormone during the moderate intensity of exercise (MacMurray and Hackney, 2005).

GH and IGF-1

are increased during exercise. The level of increasing depends on the exercise duration and on the age of the subject (Bouix. *et al.*, 1994, Nemet and Eliakim, 2012). GH takes part in the mobilization of freee fatty acids and in the keeping of glucose equilibrium. GH increases also gluconeogenesis in the liver. Some studies revealed that the GH response during exercise depends on degree of the child maturity (Bouix. *et al.*, 1994). GH level is higher in postpubertal than in prepubertal age. Children have relatively higher oxidative metabolic activity during the exercise than adults, which is important for their growth and maturation.

ADH

increases during exercise to maintain plasma volume because the loss of water is undesirable. The plasma volume is also influenced by the secretion of **aldo-sterone** in adrenal cortex and by renin-angiotensin.

Hormones which are in the connection with the regulation of the blood pressure are also increasing according the physical load.

Prolactin

also shows the increasing level during exercise, higher in the cold environment.

Parathormone (PTH)

is raised only during high intensity and long duration of exercise. Bouassida and others (2006) suggest PTH increased level in serum after the exercise.

Physical activity, especially excessive leads to **stress**. It is known that cortisol and catecholamines are antistress hormones. But the regulation of HP axis in obese subjects is changed, pulses of ACTH have the higher frequency and the lower amplitude, particullary in the morning. The level of total cortisol is decreased, but free cortisol is increased due to the low level of cortisol-binding protein (CBP), locally in the AT. The other situation is caused by the activity of 11- HSD which converts inactive cortison to active cortisol. The activity of this enzyme 11-HSD in the obese subjects is higher.

Gonadotrophines Secretion (GT)

higher secretion of luteinizing hormone (LH) and slower secretion of follicle-stimulating hormone (FSH) in follicular phase of the menstrual cycle during exercise are found. These changes are smaller in luteal phase. The secretion of estradiol and progesterone is simultaneously increased more in follicular phase. The level of the increase of these hormones is dependent on the exercise load. The long duration of exercise (training) can decrease estrogen in female and testosterone in males.

4.3.3. Metabolic Changes as Related to Hormonal Activities During Exercise

High intensity of the exercise can result in higher metabolism of glycogen to glucose caused by the increased level of epinephrine *via* beta-adrenergic receptors and Ca++-calmodulin from sarcoplasmatic reticulum. The increase of glycogen breakdown can lead to its depletion in the liver according the duration and the intensity of the physical activity. Glycogen serves as a storage of energy for the maintenance of glucose homeostasis. (Eriksson J.A. *et al.* 1989) provided that the breakdown of glycogen may be lower in children.

Glycaemia

is maintained in the blood during the exercise by the balance of muscle glucose uptake and hepatic glucose production, by glycogenolysis and gluconeogenesis and by metabolism of free fatty acids from adipose tissue. Lipolysis and the oxidation of free fatty acids can be increased during the exercise, especially in the prepubertal age, that is caused with growth hormon secretion. Some data indicate that the children well regulate glycaemia during the prolonged exercise of the moderate intensity.

Insulin

blood level is increased on the onset of the exercise in the prepubertal chlidren. In this prepubertal age the sensitivity to insulin is decreased. But later, in the postpubertal age or in the adults, the insulin blood level decreases during exercise as the economic regulatory mechanism. The decrease is higher in the untrained adult subjects. On the other hand, **glucagon** level increases more in the untrained persons. The secretion of insulin and glucagon is influenced by catecholamines. Insulin inhibits lipolysis, stimulates lipoprotein-lipase activity especially in subcutaneous adipose tissue and inhibits hormone-sensitive lipase (MacMurray and Hackney, 2005). Delamarche. *et al.* (1994) found a significant decrease of glycaemia on the onset of the short exercise in children. Later the correlation of this decrease reaches the preexercise values in boys, but the correlation is lower in girls. The same gender difference is found in the secretion of catecholamines. It is explained by the earlier onset of the pubertal maturity in girls (Hagobian T.A. *et al.*, 2008, 2009).

The level of some regulatory hormones depends on the intensity or on the duration of the exercise. Epinephrine, norepinephrine, growth hormone, cortisol and glucagon are increasing during the higher intensity or the longer duration of the exercise, on the other hand insulin decreases. The effect of adaptation - training is very important factor for the regulatory hormonal system. Therefore, training leads to lower response to norepinephrine, epinephine, glucagon and insulin during exercise.

Exercise influences the energy balance and **apetite** (Hagobian 2008, 2009) has provided the results of acetylated ghrelin in women and men during exercise. In this study, women responded to the onset of the exercise with higher level of acetylated ghrelin, and lower level of insulin, as compared to men. **Ghrelin** plays the role in the regulation of the energy balance, influences lipid and glucose metabolism by stimulation of lipogenesis and by the inhibition of lipolysis. Ghrelin also influences the differentiation of adipocytes, it also stimulates the motility of gastrointestinal tract. Future research is needed for understanding the function of this - sometimes termed as hunger hormone (King J.A. *et al.*, 2013).

Leptin

responds to exercise later, its level is decreased during exercise of the long duration (some hours) (Hickney M.S. *et al.*, 1997, Hackney A.C. *et al.*, 2003).

Regulatory effect of many hormones and cytokines is linked to the intensity and the duration of exercise and to the training. Training seems to reduce the hormonal effect, but increases hormonal sensitivity. (Nemet. *et al.* 2002, Nemet. *et al.* 2010) showed that training at the beginning leeds to the catabolic state GH-IGF-1 axis. This author hypothesizes also the possibility of the stimulation of cytokines as interleukin-6, inter-leukin-1beta and tumor-necrosis factor-alfa.

Releasing Hormones from Hypothalamus

begin to increase their secretion in the start of the exercise. The secretion of growth hormone and TSH in the anterior part and ADH (antidiuretic hormone) in posterior part of pituitary gland depends on the exercise intensity. Hormone secretion in adrenal cortex (cortisol, aldosterone) increases, pancreatic secretion of insulin decreases and glucagon increases due to exercise.

ADH (antidiuretic hormone) level is also increased due to the loss of water during the exercise. The increase of the other regulating system of plasma volume (renin-angiotensin- aldosteron system) can be also found.

4.3.4. Hormonal and Metabolic Changes due to Exercise During Various Periods of Growth

Childhood and especially pubertal age is very sensitive periods of development due to numerous hormonal changes. Prepubertal age - adrenarche is characterized by the onset of the secretion of androgens in the adrenal cortex. The pubertal age 2-3years later (after adrenarche) is characterized by the development of sexual signs and by **growth spurt**. This growth spurt is influenced by the release of growth hormone and IGF-l and by the increase of the secretion of sex steroid hormones. The secretion of sex hormones is controlled by CNS, mainly by LH and FSH secretion influenced by GRH (gonadotrophin-reelasing hormone) from hypothalamus.

The cause of the onset of puberty is not well known. Many different results have been mentioned (*e.g*. Charilaus and Gregory, 2007). (Matzoros *et al.* 1997) suggests the role of leptin as a regulator of fat mass and as the regulator of the onset of puberty. It is known that the level of testosterone in boys can increase or decrease during exercise according to its intensity, but SHBG declines during the pubertal phase in boys and by this way the level of free testosterone shows the minimal changes.

Regulating hormonal effects are mentioned differently in many studies. Ethic and methodological factors limit the possibility to follow hormonal changes during exercise in children. During childhood it has to be taken into account the level of sexual maturation, the intensity and duration of exercise, and the same applies to puberty. Some studies suggest that the training load leads initially to an increase in pro-inflammatory cytokines and to decrease of IGF-1 level. After the adaptation to the training the level of pro-inflammatory cytokines fall and the level of IGF-l achieves the primary level (Jurimae J. *et al.*, 2010).

Exercise has very useful effect on the **body composition** of adults, but more useful effect has on the developing body of the children, on their growth and their maturation. The optimal programme of the training intensity and its duration especially in the childhood and the puberty have to be determined.

4.3.5. Summary statement

Various changes in the level and activity of hormones and cytokines during exercise were shown. The results of individual studies concerning these individual factors are specific: the intensity and the duration of exercise must be taken into account. This concerns especally the critical periods of growth and development, *e.g*. pubertal age. Therefore, exercise is very important factor for the intervention and the treatment of obesity mainly during childhood and adolescence.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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ABBREVATIONS

ACRT	=	adipocyte-complement-related protein
ACTH	=	adrenocorticotrophin hormone
ADH	=	antidiuretic hormone
AgRp	=	agouti-related protein¨
ASP	=	acylation-stimulating protein
AT	=	adipose tissue
BAT	=	brown adipose tissue
C	=	cortisol
CART	=	cocain-amphetamin-regulate transcript
CBP	=	cortisol-binding protein
CNS	=	centzral nervous system
CHCK	=	cholecystokinin
CRH	=	corticotrophin-releasing hormone
GH	=	growth hormone
GHS-RHIa	=	growth hormone secretory receptor type Ia
FSH	=	follicle-stimulating hormone
GLP-1	=	glukagon-like peptid
GT	=	gonadotrophins
GRH	=	gonadotrophin-releasing hormone
HSL	=	hormone-sensitive-lipase
11-HSD	=	11-hydroxysteroid-dehydrogenase
HPA	=	hypothalamus-pituitary-adrenal
IGF-l	=	insulin-like factor-1
IGFBP	=	insulin-like factor-binding protein
IL-3	=	interleukin-6
LEPR	=	leptin receptor
LH	=	luteizing hormone
MC	=	melanocortin
MCR-4,MCR-5	=	melanocortin receptor 4 or 5
MCH	=	melanin concentrating hormone

MSH	=	melanostimulating hormone
NEFA	=	nonessential fatty acids
NPY	=	neuropeptid Y
PAI-l	=	plasminogen-activator-inhibitor-I
PPAR gama-2	=	peroxisme-proliferator-activated receptor
POMC	=	propiomelanocortin
PTH	=	parathyroid hormone
SREBP	=	steroid- regulatory- element binding protein
T	=	testosterone
T3	=	triiodthyronin
rT3	=	reversed triiodthyronin
T4	=	tetraiodthyronin
TNF-1	=	tumor-necrosis factor-l
TRH	=	thyreotrophin.reelasing hormone
TSH	=	thyreotrophin-stimulating hormone
UCP	=	uncoupling proteins
WAT	=	white adipose tissue

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CHAPTER 5

Physical Activity, Fitness and Adiposity During Growth and their Secular Changes in Different Environment

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Abstract: Physical fitness (PF) in children and adolescents has been declining during last decades along with physical activity (PA) level. As shown by numerous studies, the beginning, rate and rapidity of these changes has been different in various parts of the world as related to local environmental, social, economic, cultural, climatic, and other life conditions. Significant relationship of these changes to health status and prognosis was also revealed. The seriousness of this problem has been emphasized especially that it started to appear already at very early periods of life. Studies of children revealed increasing adiposity along with deteriorating motor abilities already in preschool age, when the level of PA is spontaneously highest. This goes along with earlier adiposity rebound (AR), increasing adiposity and decreasing PA level. Preschool period is defined as one of the critical stages of development, when reduction of natural activity can have more serious consequences than later on. In schoolchildren and adolescents adiposity has been also increasing, and functional capacity along with motor abilities decreasing in many coutries; positive consequences of increased PA régimes have been greater due to the possibility for more intense exercise and sport activities. Increased effort for intervention – which should be based on individual somatic and functional evaluation – should start as early as possible.

Keywords: Adiposity, Adolescents, Aerobic power, Body composition (BC), Energy expenditure (EE), Energy intake (EI), Fat-free mass (FFM), Functional capacity, Lean body mass (LBM), Motor abilities, Physical activity (PA), Physical fitness (PF), Preschool children, School children, Secular trends.

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5.1. INTRODUCTION

5.1.1. The Role of Physical Activity (PA) and Physical Fitness (PF) During Growth and Develoment

The effect of both nutrition and physical activity (PA) - as main items of energy intake (EI) and energy expenditure (EE) along with their mutual relationships, balance and turnover cannot have apparently an identical impact during the whole life, especially during different periods of growth and development. Various factors can modify this effect; during last time especially studies of the effect of genetic factors and their role concerning also nutritional and motor behaviour have been conducted.

Genetic factors influence markedly also PA level: it was shown that *e.g.* monozygotic twins resemble more significantly with regard to total amount of PA during certain time unit most, as compared to dizygotic twins, or normal siblings (Ledovskaya *et al.* 1972). The same applies to motor stereotypes and style when performing certain athletic tasks (Sklad 1972). Offspring in active families also resemble often to their parents with respect to their own PA. The same applies also to body composition (BC), adiposity and functional capacity.

The origin and development of different body composition (BC) and adiposity can be influenced significantly by ***epigenetic factors*** since the very beginning of life. Factors which influence an individual during fetal period have a significant impact - especially nutrition. The way that a fetus obtains and allocates nutritional resources has profound delayed consequences for its life-long health due to the different programming ("Barkerś theory" : Barker 2004, 2007, 2012). Intrauterine programming can apply therefore also to later obesity. Physical activity (PA) and physical fitness (PF) has been also considered. However, Helsinki Birth Cohort Study did not prove any significant association between body size at birth and cardiorespiratory fitness later in life. But early growth between 2 and 7 years was associated with cardiorespiratory fitness (CRF) in adulthood (Salonen *et al.* 2011). For a desirable development an adequate nutrition and energy balance is indispensable since the very beginning of life, including the nutritional status of the mother. When epigenetic factors coexist with genetic predispositions, their effect can be even more pronounced.

So called "***critical periods***" (*e.g.* early fetal, perinatal, and/or prepubertal and pubertal one, *etc*.) are the stages of development when the same or comparable factor can stimulate positively (but also negatively), and influence the organism from various points of view quite differently than during others, mostly later periods of life. The effect of the abovementioned epigenetic stimuli can manifest at present - during first months and years of life, but in addition may have delayed consequences during adult and advanced age ; this was mostly possible to study with the help of experiments using laboratory animals (see Chapter 6.). In physiological context, especially *reduction of PA in early childhood* – when it is *spontaneously on its highest level* – can have *negative present and delayed effects* on the organism, the character of which is related also to genetic predispositions.

World Health Organization (WHO) updated and summarized key facts concerning PA, which is considered an essential risk factor for non-communicable diseases such as cardiovascular diseases, cancer and diabetes, related to overweight and obesity. *Physical inactivity is the fourth risk factor for death worldwide*, and approximately 3.2 million people die each year due to physical inactivity. Globally, one in three people is not active enough, which concerns considerably children and adolescents. Physical activity has significant health benefits and contributes to prevent non-communicable diseases which are the greatest health problem resulting also in marked economic consequences. Policies addressing physical inactivity are operational in 56 % of WHO member states which agreed to reduce physical inactivity by 10 % by 2025. As follows from many clinical, epidemiological *etc*. studies, the prevailing majority of overweight and simple obesity have been caused at present by mutually unadjusted EI and EE, their positive imbalance and inadequate turnover.

The best way to prevent mentioned health problems is to start with efficient interventions as early as possible in life, and pay the main attention to children and adolescents. This concerns especially overweight and obesity which has been spreading all around the world (WHO 2010a.b.c., Lobstein and Frelut 2003, Berghöfer *et al.* 2007, and others). Participation in optimally arranged and guided exercise is also an essential part of childrens' *education* - which has traditionally had positive results from early historical periods. This applies as well up to the present when great attention to physical education and sports occurs in the best schools, and especially those who are privileged to attend.

Early adaptation of the child to optimally increased physical activity and exercise has always prevented excessive adiposity, contributed to the optimal development of vital organs (the heart, lungs, *etc*.), bones, joints, skeletal muscles *etc*. (Pařízková 1963, 1977, 1989, 1991, 1995, 1998, 2008 *etc*.). In addition, when experienced in an optimal way, it supports a desirable body posture which has prevented orthopedic problems, and also positively influenced psychological dispositions, *etc*. Individuals adapted to higher PA during growth could also adhere to it more frequently also during later life.

5.1.2. Conclusions

This Chapter 2. will focus on the effect of PA during different periods of growth and development, especially those defined as critical ones when due to possible varying sensibility of the organism PA can have different, mainly more pronounced influence. This concerns both present and also delayed effects during later periods of life. Therefore, the results of available studies on the influence of PA during epigenetic periods, then during preschool, school and adolescent age, as well as on its consequences will be reviewed. The results of longitudinal studies of the same individuals lasting more years will be emphasized, and also studies on secular changes of PA, physical fitness (PF), body composition (BC) – especially adiposity, and nutrition, and their relationship to health in different countries will be presented. Lifestyle modifications focused on physical activity regimes have been therefore considered and suggested, especially with regard to obesity intervention and prevention.

5.2. PHYSICAL ACTIVITY AND CRITICAL PERIODS

5.2.1. Spontaneous Physical Actvity in Early Life

The level of spontaneous physical actvity is changing during the whole life (see Chapter 3.), and the possibility for its practice is specially important in critical periods of life like preschool age, pre-adolescence and adolescence. The same applies, however, also during adulthood and advanced age (Pařízková 1977, Pařízková and Eiselt 1968) , but one of the the key roles in the formation of the organism from morphological and functional point of view includes especially critical periods during growth. At present, the most important problem is that environmental conditions do not satisfactorily enable and favorize the application of both spontaneous and organized physical activity which characterize this early period of life (Pařízková and Hainer 1995, Pařízková 2010).

5.2.2. Inactivity in Early Age

Negative impact of inactivity is especially marked during the early period of growth when the need and the level of spontaneous physical activity is highest (Pařízková and Hainer 1990, Sigmund *et al.*, 2009), as compared with following growth periods and adulthood. Increasing reduction of PA concerns not only the industrially developed countries (Ianotti and Wang 2013a, b), but also countries under transition (*e.g.* Kenya; Onyvera *et al.* 2012). This is manifested by the changes of body mass index (BMI) during the period of so called ***"adiposity rebound" (AR)*** when also body fat (evaluated from skinfolds; Pařízková 1977, 2008, 2014) is simultaneously increasing. In addition, during the same time of AR the level of spontaneous PA starts to decrease simultaneously, after its previously higher level (Pařízková 2011, 2014). Especially this "critical period" is essential and important from the point of view of the impact on energy balance – both nutrition and activity : earlier start of AR may predispose for easier development of obesity (Rolland-Cachera 2011, Rolland-Cachera *et al.* 1984, 2006). Due to the changes of lifestyle, percentiles of BMI shifted from the fifties of the last century to the beginning of this millenium to higher positions in growth grids (see Chapter 1., Vignerová *et al.* 2007), changing therefore the criteria for overweight and obesity. At the same time, adiposity increased and motor abilities deteriorated already in preschool age (Pařízková *et al.* 2012, Sedlak *et al.* 2015).

5.2.3. Body Mass Index (BMI)

The assessment of BMI and definition of its percentiles for a particular child (see Chap.1) has been consented for the evaluation of the level of somatic growth; however, it does not always reflect the changes of PF and adiposity. In China, BMI growth curves for subjects 0-18 years were also introduced for monitoring growth and discovering overweight and obesity (Li *et al.* 2009a,b, 2012, 2013). *Healthy BMI norms* for children and adolescents were introduced in addition, based on results from selected subgroups that have *higher level of PF* (Chen *et al.* 2002). Association between BMI and PF index were not linear (Mak *et al.* 2010), but parabolic-curvilinear among subjects aged 7 to 18 years (Zhao *et al.* 2012). Therefore, this approach can be considered as more suitable of definition of optimal BMI percentiles (Chen and Chang 2010), especially during critial periods of growth.

This effect of PA applies not only with regard to the present developmental status and critical periods of the growing organism, but can have also significant delayed consequences in later life, as can only be indicated *e.g.* by the results of experimental models using laboratory animals. Significant delayed positive consequences of an adequately increased physical activity - daily moderate exercise of the pregnant rat mothers during the whole pregnancy – manifested significantly in their adult offspring (microstructure of the heart, lipid metabolism; Pařízková 1975, 1978, 1979a,b, 1980, 1982, 2010; Pařízková and Petrásek 1978, 1979a,b; Pařízková and Rolland-Cachera 1997; see Chapter 6.). Newborns of mothers continuing to exercise during pregnancy had slightly lower birth weight, decreased adiposity, along with same length (Clapp and Capekess 1990) demonstrating the effect of PA during fetal period. Delayed effects of an adequate motor stimulation and education in early life may concern also other characteristics during later life.

5.2.4. Conclusions

The effect various levels of PA can be revealed in all periods of life, starting with the earliest ones. This concerns also the fetal period – *i.e.* the PA régime of pregnant mother. This applies similarly during this period of development as the effect of nutrition. Therefore, régimes of suitable PA should be introduced as soon as possible including the PA regime during pregnancy.

5.3. HISTORY OF THE STUDIES OF HUMAN GROWTH

5.3.1. Growth and Development Studies

With regard to history, studies of human growth have an old tradition. The word "anthropology" with respect to growth appeared already in the 17^{th} century, and "auxology" in the 19^{th} century. Since the 18^{th} century scientists focused attention on human growth in greater detail until present time. As defined by Tanner (1962), "growth of children is the mirror of the society".

Reviews of the results of growth and development studies were presented in Conferences of International Association for Human Auxology (*e.g*. Johnston *et al.* 1999). Research of somatic growth was initiated and developed by Tanner (1962) which was mostly focused on morphological changes (height, weight, circumferential measures, skinfolds, level of bone and sexual development), not on total body composition (from the point of view of absolute and relative amounts of lean, fat-free body mass and adipose tissue), or on functional parameters (cardiorespiratory efficiency, motor development, *etc*.).

First systematic measurements of school children in the Czech countries were conducted at the end of the 19 century (1895; Matiegka 1927). Up to hundred thousands of school children were measured. Research included also functinal parameters (vital capacity, results of motor tests *etc*.). This also enabled, inter alia, the comparison of the secular trend of growth of children in Czech countries during previous decades starting with the end of nineteenth century up to the present time (see Chapter 1).

However, up to now there has *not been any information whether increased body size and BMI run paralel with correspondingly increased size and improved development and function of vital organs* – especially the heart and lungs, skeletal and muscular mass *etc*. in normal, healthy children. This has a special relationship to PF, and should be followed up and analyzed in future studies when adequate methods for the evaluation of the size and their eventual secular changes concerning vital organs in healthy growing subjects will be available. The context of growth and development related to energy intake and expenditure – nutrition (dietary intake) and physical activity régimes (PA) were also not included and evaluated in greater detail up to the preszent.

5.3.2. Conclusions

Many other studies of growth have been then conducted in different parts of the world, at the beginning mainly in the industrially developed countries; more recently such studies were conducted also in many other countries including the transition and developing ones (see following subchapters). Up to the present main attention has been focused on morphological parameters.

5.4. BODY COMPOSITION DURING GROWTH

5.4.1. Changes of Body Composition (BC) in Children and Adolescents

Since the fifties of the last century up to hundred thousends of Czech children were measured regularly in ten-year intervals until the beginning of this millenium (Bláha and Vignerová 2004). At the same time, studies of growth and development were supplemented by the evaluation of body composition – the absolute and relative amounts of lean, fat-free body mass and total body fat using hydrodensitomentry (underwated weighing with simultaneous measurements of the air in the lungs and respiratory passages, and skinfold thickness measurements; Pařízková 1961a, b, 1963, 1977, 1989, 1995), along with functional and biochemical parameters characterizing PF and nutrition in normal and obese children (Pařízková 1995, Pařízková and Hills 2005).

More recently, bioimpedance analysis (BIA) and dual energy X-ray absorbtiometry (DEXA) have been used for this sort of research in children and adolescents in many countriss. However , up to the present the reliability of BIA measurements in children of earlier age , has not been considered exact enough and reliable due to the changing composition of different tissues during early, preschool growth (Bláha & Vignerová 2004). DEXA measurement could have a negative impact on growing organism, so more technical development of this method has been required so as to eliminace possible health risks.

5.4.2. The Effect of Various PA During Growth

Adaptation changes to various physical activity (PA) concerning BC and PF with regard to the effect of exercise along with nutrition during various periods of growth were also followed up both in humans and/or experimental model using laboratory animals (Pařízková 1966, 1977,1982, 1991 *etc*.). Less informations has been available with regard to more detailed and exact assessments of physical activity levels, functional capacity and physical fitness.

5.4.3. Conclusions

Body copmposition has been shown as an essentials characteiistic of human growth which varied in both genders according to age, nutrition, PA and PF. Absolute and relative amounts of lean, fat-free body mass and adipose tissue have been therefore included in many studies of growing children and adolescents

5.5. PHYSICAL ACTIVITY AND FITNESS IN EARLY LIFE

5.5.1. "Motor Individuality"

"Motor individuality" similarly as "nutritional individuality" (Widdowson 1962, 1983) develops since early life (Pařízková 2012, Hnatiuk *et al.* 2012): *e.g.* the difference between the age when individual children start to raise their head, creep, sit and walk independenty can be quite marked. Individuality appears also with regard to nutrition and develops since early life: intake of food, and preference or aversion of individual food items, their absorption, metabolization and utilization were also found, since early growth periods, individually quite different (Widdowson 1962, 1983), and with various consequences concerning weight increments, body composition changes and others.

5.5.2. The Impact of PA

The impact of PA can be revealed very early in life, starting with pregnancy : as mentioned above, it was found that exercising pregnant mothers gave birth to newborns who had the same length, slightly lower weight and smaller skinfolds than newborns of control mothers (Clapp and Capeless 1990). Infants stimulated from the motor point of view by their parents or other caretakers were characterized by an accelerated overall development during first months of life (Koch 1978). - The importance of PA for adquate development has been appreciated and recommended for infants, toddlers, and preschoolers (Gunner *et al.* 2005).

A *longitudinal study* of a group of Czech children revealed an increased number of steps/day during last year in a kindergarten, and a significant reduction during the first class of primary school (Pařízková and Hainer 1990). The reduction of spontaneous PA, when comparing preschool and school age was confirmed also by other methods (see Chapter 3; Sigmund *et al.* 2007, 2009). Around the period of entering primary school, adiposity rebound (AR; Rolland-Cachera 2011, Rolland-Cachera *et al.* 1984, 2006) also appears along with the increase of adiposity (assessed by skinfold thickness measurements; Pařízková 1977). These studies showed an enhanced level of spontaneous PA during preschool age, which increased also EE and reduced adiposity. This period is defined also as "golden age of motor development". PA and EE were found to be significantly highest during preschool age as compared to school years, adolescence and young adult age (Sigmund *et al.*, 2009; see Chapter 3.). The increase of PA level and activity energy expenditure (AEE; using doubly labelled water) along with increasing age (from 3 up to 16 years) was revealed, which can be contributed to increasing weight because there was no relation between AEE/kg weight and age (Hoos *et al.* 2003).

Cross-sectional measurements of various morphological and functional parameters in children from 3-4 to 6-7 years revealed not only increasing body size, but also changes in adiposity. This was characterized by the sum of ten skinfolds which slightly decreased in boys, and remained approximately the same in girls. Along with that, the performance in a modified step test, characterizing the cardiorespiratory fitness, and motor performance (20 m run, broad jump and ball throw) improved significantly. Mentioned motor tests have been until present used for the evaluation of motor development as they are natural for this age. Some of these functional characteristic were used, along with the measurements of height and weight, also by Matiegka (1927) around the end of nineteenth and beginníng of the 20th century. Broad jump characterizes coordination and strength of lower extremities, and ball throwing characterizes the same in upper extremities; both are better developed in active, and more skillful children. This is, among others, also due to the increasing level of spontaneous PA along with increasing age until the beginning of entering of primary school. The level of performance was found, compared to girls, to be always higher in boys, along with lower adiposity. The suitability and usefulness of mentioned motor tests which were always a part of children´s games in kindergartens or under home conditions were validated repeatedly in the evaluation of PF of many thousands of Czech preschool children (Pařízková 1977, 1996b,c, 2010; Pařízková *et al.* 1977, Pařízková and Adamec 1980).

5.5.3. The Impact of Spontaneous PA

The impact of spontaneous PA level was significant already in preschool age : a study in a kindergarten during the whole year PA was evaluated with the assistance of teachers, using special methodical approach and evaluation (Pařízková *et al.* 1979b, 1986a,b, 1996b). Most active children tended to have lower values of body mass index (BMI) and of the percentage of body fat along with higher energy intake, and higher value of index characterizing the cardiorespiratory efficiency during step test modified for preschoolers. The serum level of HDL was significantly higher in most active children (Pařízková *et al.* 1986a,b, 2010), which is a favourable marker of cardiovascular health. Significant correlation between the percentage of body fat on the one hand, and total cholesterol (TCh) and triglycerides (TG) level on the other hand was found, indicating a significant role of PA on adiposity and serum lipid level already in early age (Table. **1**). This effect may be a predisposition for more reduced adiposity and metabolic development in later life (Pařízková 1979b).

Table 1. Correlation between the percentage of body fat and serum lipid level in preschool children (4.7- years-old, Pařízková *et al.* 1986b. Pařízková 2010).

	r	p<
Total cholesterol TC	0.448	0.01
Triglycerides TG	0.494	0.01

5.5.4. The Impact of Organized Exercise

Not only spontaneous, but especially organized PA and exercise influnce pre-school children significantly. In the Czech republic special physical education classes for preschool children together with one parent, or any other caretaker were organized since the sixties of the last century. Children who participated for the longest time were characterized by higher level of performance in mentioned motor tests, especially broad jump and ball throw (Pařízková 2010).

5.5.5. Dietary Intake

Dietary intake was also evaluated : the intake of energy, protein, fat and carbohydrates was in Czech preschool children higher than the recommended dietary allowances (RDA). This was found in both cross-sectional and longitudinal studies of Czech preschool population (Pařízková 2010, Pařízková and Rolland-Cachera 1997), and was considered also for school years. Greatest difference from RDAs was found with regard to fats. Environmental conditions had also marked effect on diet – the intake of all items of food intake was highest in the capital of Prague as compared to smallest communities. This was accompanied by lower level of physical performance as demonstrated by worse results in motor tests (broad jump, ball throw; Pařízková 2010).

5.5.6. Conclusions

As apparent, special individual character of morphological development and motor abilities can appear since early childhood; the effect of both spontaneous and adequately organized PA and exercise is manifested positively since earliest life. The results of an adequate PA appear mostly positive, so intervention in desirable PA régime at this age are justified.

5.6. PHYSICAL ACTIVITY, FITNESS AND ADIPOSITY IN SCHOOL AGE AND IN ADOLESCENCE

5.6.1. Reaction to the Transition from the Rest to the Work Load

The transition from resting conditions to a work load is easier during growth due to a relatively smaller percentual increase of the values of basal metabolic rate (BMR; METs). The increase *e.g.* at the age of 12 years during a the same work load (2 W/ Kg body weight) on a bicycle ergometer in boys is cca 600 % of BMR, and at the age of 30 y it is cca 850 % BMR (Pařízková 1982). At a higher age, EE for the same work load and PA, expressed in the values of BMR, and accompanying functional and metabolic changes are relatively much larger than before puberty. From this follows that *for a growing child transition from rest conditions to exercise is relatively easier*, and therefore undergoes it much more wilingly than an older subject.

5.6.2. Effect of Family on PA

With regard the factors influencing significantly PA is the effect of family – especially mothers´ and their education level was revealed: *e.g.* girls with University education mother were more likely to participate in vigorous PA at the weekends, and moderate-to-vigorous PA during the morning commute to school (Sherar *et al.* 2009). A review on the relationship of family environmental correlates of PA in youth showed that the variables of the home and school environment - father´s PA, time spent outdoors, school-related PA, and support of other significant factors: mother´s education level, family income, non-vocational school attendance had an important role (Ferreira *et al.* 2007).

5.6.3. The Effect of Sexual Maturation on PA, PF and BC

Level of PA decreases during sexual maturation which can be a confounding factor (Cummings *et al.* 2011; Sigmund *et al.* 2009). Evaluation of PA has been difficult without more exact methods – mostly self-reported informations were available (Loustalot *et al.* 2009). More exact approaches were needed and introduced (see Chapter 3.; Sigmund *et al.* 2009). Along with that, BC measurements revealed that during school age and adolescence also the adiposity of the organism was increasing – in boys less along with higher PF. Relatively greatest gender difference of BC and adiposity during prepuberty and puberty were found, which were diminishing gradually during later life (Pařízková 1977, 1982) along with generally increasing body fatness. Physical performance was always higher in boys, but results in skill and sensomotor tests were better in girls starting with preschool age (Pařizková 2010, Pařizková *et al.* 1986a).

Modifiable factors like increasing access to equipment at home and school, and improving neighborhood aesthetics may impact youth PA (Millstein *et al.* 2011); neighborhood walkability environment correlated with youth PA (Rosenberg *et al.*

2009). The extent to which children and youth are physically active is influenced by a number of complex interrelated factors which vary due to the environment (Pradinuk *et al.* 2011).

5.6.4. Internatinal Biological Programme (IBP)

Cross-sectional studies in the framework of the Internatinal Biological Programme (IBP) in the Czech republic were conducted mostly in the sixties of the last century ; an essential part of this laboratory research were also the assessments of adiposity, aerobic power and motor development based on previous fitness studies. The measurements included subjects of both genders in age categories 12,15,16, 25,35,45 and 55 years from different parts of the Czech republic. (n = 2346, Seliger 1977, Seliger *et al.* 1978, Pařízková 1982, and others). Only normal subjects without any health problems were included in this study. More than 70 somatic, body composition, cardiorespiratory efficiency and motor parameters were assessed in all subjects. This study enabled to demonstrate age changes during growth and adulthood, gender differences, and also the impact of the adaptation to regular exercise and sport. Table **2** shows selected results of the comparison ot body composition and aerobic power (extrapolated from the measurements of oxygen consumption during standard work load on a bicycle ergometer; Seliger 1977) in control and regularly exercised boys 12, 15 and 18 years old. Developmental changes and the impact of adequate exercise were apparent in all age groups, and were relatively greater in older subjects with longer duration of exercise and sport (Pařízková 1982). Dietary intake in these groups was normal or in some cases increased compared to RDAs. These measurements enabled, inter alia, also the evaluation of secular changes of BC and PF over decades up to the present.

5.6.5. Longitudinal Observations of PA, PF and BC

Most apparently and convincingly the impact of PA and exercise was proved by longitudinal observations of PA, PF and BC in the groups of the same individuals. Longitudinal study lasting 8- to 14-years of the groups of the same Czech adolescent boys participating in training of different sort revealed significant relationships between BC, performance and intensity of training. Subgroups of

10.8 – 17.8 years old boys – one exercising regularly (under pedagogic guidance and survey, more than 8 hours per week during the whole 8 yearsˇs period of observation – training in light athletic, basketball *etc*.; Sport Schools attached to the Research Institute for Physical Education - VÚT), as compared to a control, relatively inactive boys of the same age showed significantly lower development of body fat and enhanced development of lean, fat-free body mass in the exercised group. Both subgroups had the same physical education at school (two 45-mins classes per week). Absolute amount of fat after 8 years remained the same in exercising boys, and increased in control boys (Pařízková 1968, 1976, 1977), and *vice versa* for LBM (FFM). Along with that aerobic power (VO_2 assessed during maximal work load on a treadmill, in absolute and relative values – per kg of total, and lean body weight) was significantly highest in exercising boys (Šprynarová *et al.* 1987). Boys adapted to exercise were significantly more ectomorhic (Pařízková and Carter 1976). Only a reduced number of boys (n=16) could be followed longer since the beginning of this study (*i.e.* for 14 years), but without apossibility to differentiate their PA regime. Further age changes, *i.e.* increase of adiposity in young adulthood were observed at the age of 23.7 years (Pařízková 1977).

Table 2. Comparison of body composition and aerobic power in control, inactive and exercised boys (International Biological Programme IBP, n = 1860).

Age		Control Inactive			Exercised		
		X	SD	CV	X	SD	CV
12 years	Fat %	18.5	5.1	27.5	14.9	3.8	25.5
	VO_2 max ml/kg/min	44.5	7.8	17.6	45.5	7.6	16.7
15 years	Fat %	13.3	4.2	31.5	12.1	3.6	29.7
	VO_2 max ml/kg/min	43.2	7.7	17.8	53.0	5.5	10.3
18 years	Fat %	12.9	4.4	34.1	9.9	2.7	27.2
	VO_2 max ml/kg/min	45.3	9.5	20.9	55.4	4.6	8.3

Another five-years longitudinal study concerned girl gymnasts from Sport School (attached also to VÚT) followed up from 11 up to 15 years of age. The effect of the intensity of training, resp. of its interruption was evaluated after shorter intervals during individual years of this study. Height, weight, BMI increased regularly, but the sum of ten skinfolds fluctuated several times during each individual year due to the changes of the intensity of training (regular training during the school year, more intensive training during summer training camp, its interruption during the rest of each summer, return to regular training during the school year and so forth). No similar changes were observed in normal control girls (Pařízková 1977). Changes of skinfold thicknesses reflected markedly and significantly the intensity of PA and special training in gymnastics. (Skinfold measurement enables, inter alia, to evaluate how inensively an athlete participates in training, because changes of weight and BMI do not refect it reliably; Pařízková 1989). In both mentioned longitudinal studies PA was directly controlled by participating pedagogues regularly involved in these studies, which could give most reliable information on PA level during the whole period of observation.

5.6.6. Relationships Among PA and PF

Cross-sectional studies of the relationships among PA and PF were conducted in various countries (Mamabolo *et al.* 2007). Recommended levels of PA were therefore suggested to avoid excess deposition of body fat (Martinez-Gomez *et al.* 2010a,b). As the tracking was only moderate, an intervention increasing PA could emphasize the tracking. Gender differences seem to appear not homogeneously in all populations, *e.g.* in the studies of Flemish youth (Lefevre *et al.* 1998) height and weight differed only starting with 10 years, but girls were always fatter. Starting with preadolescent growth spurt, boys improved their fitness level, in contrast with girls who did not. Boys were better in static strength, explosive strength and running speed at all ages.

The appraisal of PF was found to be closely related to the level of PA and training (Berkey *et al.* 2000). Pediatric review on PA assessment tool, for the evaluation of its effect on adiposity has recommended more recently acceleromenters, as this information combined with doubly labelled water technique may provide the most comprehensive information (Ellery *et al.* 2014). Activity monitors, which seem to be a useful measure of total PA can predict the total EE as their results correlate with doubly labelled water measurements of EE. This was shown in *e.g.* children monitored during 14 days (Ekelund *et al.* 2001; see Chap 3.). Further wearable monitors of PA as pedometers, heart rate monitors, multiple sensor systems, or global positioning system have been implemented. This approach improved signficantly the evaluation of PA which in the majority of previous studies have been assessed by self-reporting questionnaires, not guided and checked to be exact enough.

As mentioned above, most reliable are the results of longitudinal studies where PA régime and training is directly controlled by qualified pedagogues. This was already proved *e.g*. by Mayer (1968, 1974) : results on PA reported by questionnaires of obese and normal weight boys were the same, in spite that the results of secret filming showed marked differences in PA level and character which was significantly lower in the obese.

PF studies in the USA started at the end of the sixties of the last century when a youth fitness battery was developed, which differentiated between performance-realated and health-related fitness testing. Various tests were unified, computerization of the results and norm-referenced and criterion-referenced evaluation were made possible. This all enabled the comparisons according to age, gender, environment, SES, secular changes and other aspects, which contributed to the concern of youth fitness and health considerations and recommendations (Morrow *et al.* 2008).

5.6.7. The Effect of Various Environment

The effect of the environment was also revealed : children in *rural and urban* environment differed significantly in aerobic fitness, as shown in ten- and eleven-year old children in the **USA** and **Russia**. Russian students achieved higher score for 15 m Progressive Aerobic Cardiovascular Endurance Run (PACER) than American ones, and in both countries females had worse results. Russian students walk to and from the school; the students of both nationalities who achieve a superior fitness level participate in after-school activities; but school activities in the USA appear to be more recreationally oriented than in Russia, where students participate in structured training in sport clubs (Hastle *et al.* 2010).

Further studies of physiological parameters during rest and exercise were conducted in **Chinese** children and youth, *e.g*. the relationships between heart rate reserve and oxygen uptake reserve were evaluated (Hui and Chan 2006). Peak oxygen uptake in 12-18 years old boys in Hong Kong living in a densely populated area was very similar to those observed in boys from most other population groups (Barnett *et al.* 1995). However, cardiopulmonary endurance in school teenagers of both genders at different ages in mainland Chinese cities was better than that in Hong Kong. Muscular strength and endurance of sport performance except for standing broad jump were weaker in Hong Kong than in inland cities (Hong *et al.* 1997). Increasing obesity prevalence in Hong Kong was revealed associated with physical inactivity and inappropriate food behavior (Fu and Hao 2002).

A longitudinal study over 7 years (8-16 years) in boys and girls when at least three times aerobic power (VO2max predicted from bicycle ergometer test) and PA levels (from a survey) revealed significant correlations. In spite of simultaneous decline of these parameters in both **Caucasian and Afro-American** subjects, aerobic power tracked better than PA levels (McMurray *et al.* 2013).

Results in step test in large sample surveillance in 15 **Chinese** provinces (12,14 and 17 years old) revealed better results in rural groups having the lowest socioeconomic status, compared to urban, metropolis ones, with highest socioeconomic status. Results were also higher in southern than in northern groups. Differences in lifestyle, absence of exercise, higher body weight in urban and/or northern areas can elucidate this gap in performance (Ji *et al.* 2007). Among influencing factors on physical endurance of Chinese primary and middle school students aged 10 to 17 years were urban and rural residence, BMI, having breakfast, consumption of milk, physical education classes, time and willingness for participating in exercise (Li *et al.* 2013). In girls, higher speed fitness, leg power and muscle power and lower physical stamina (as evaluated from the resuls of 50 m running, standing broad jump and sit-ups , 50m x 8 shuttle running tests) may be associated with early menarche (Fu *et al.* 2013).

5.6.8. Changes of Dietary Intake

As shown in previous studies , dietary intake has been proved in some studies to decrease, as compared to previous time (Durnin *et al.* 1974) in spite of increasing adiposity and obesity prevalence , obviously due to decreasing EE resulting from reduced PA. An adequate and desirable balance between EI and EE is more easily preserved when both are on a higher level (Pařízková and Heller 1991), and therefore be more easily and exactly corresponding. In such a case it is not necessary to have for the prevention of enhanced adiposity a strictly adjusted diet with reduced EI. This specially unsuitable for growing subjects because of the possibility of the deficiencies concerning some essential dietary components. – With regard to diet, its inadequate composition (high saturated fat and simple sugars – also in beverages, reduced vegetable and fruit), is mostly considered as a negative factor of increasing adipozity of the growing population. This aplies especially to hypokinetic individuals with reduced PA and EE.

During growth and development it is very difficult to define such a diet of reduced energy content, and simultaneously achieve all RDAs for all indispensable items, especially vitamins and minerals. Dietary intake *e.g.* in a group of adolescent hockeyists (Table **3**) with demanding sport training was considerably higher than RDAs for this age group, but BC was more favourable along with higher PF than in a group of peers with usual, relatively inactive lifestyle and lower food intake (*e.g.* 13.8 +/- 1.7 % body fat ; Pařízková 1977, 1994, 1998).

Table 3. Body mass index, body composition and food intake (directly controlled during one week) in adolescent hockeyists.

	X	SD	CV
Age	15.4	O.5	32
Height cm	170.3	8.5	4.9
Weight kg	53.9	8.4	15.6
BMI	20.2	1.3	6.4
Fat %	8.8	3.6	40.9
Intake – Energy Mj	16.6	3	1876
Protein g/day	166	3	18.6
Fat “	163	40	24.9
Carbohydrates “	511	103	20

Dietary intake which does not correspond to EE during adolescence, resulting from reduced PA has been considered as one of the main causes of excessive deposition of fat. Two other studies in adolescents (the European Youth Heart Study – EYHS , and Healthy Lifestyle in Europe by Nutrition in Adolescents – Helena study) also showed that more physically active and leaner adolescents had higher EI than less active adolescents with larger adiposity (Cuenca-Garcia *et al.* 2014). Total truncal and abdominal adiposity was associated with higher fat intake regardless of PA (HELENA Study; Labayen *et al.* 2013).

5.6.9. Conclusions

Apparently, energy balance during growth is best assured in a more optimal way when both EI and EE are on a high level, enabling an increase of PF along with the reduction of adiposity. Such an approach reduces the risk of eventual deficiencies of essentials dietary components which could result from strictly monitored diet.

5.7. SECULAR CHANGES IN PHYSICAL ACTIVITY (PA) AND PHYSICAL FITNESS (PF) IN DIFFERENT ENVIRONMENT

5.7.1. The Relationships Between PA, PF and Overall Functional Capacity

The relationships between PA, PF and overall functional capacity have a special character in various individual countries, due to their history, social and economic situation, food intake and many others; all that has undergone also marked changes along time. Secular changes of PA level have been therefore followed especially in the industrially developed countries in which the prevalence of non-communicable diseases has been on the highest level, and mostly it has been still increasing. More recently, similar studies have been conducted in transition and developing countries as well. However, it has been still difficult to compare the individual results due to the lack of an homogenous approach, *i.e.* comparing groups with identical age range, gender, level of sexual and skeletal development, nutrition and dietary intake, then using also the same metodology and criteria, at least comparable morphological and functional parameters, period of measurements, *etc*. Many studies have been partly similar and overlapping, but not identical and of the same character.

Secular changes also depend on the period and intervals between individual observations. When comparing shorter, more recent periods an increase was found *e.g.* in **Spanish** children *e.g.* with regard to speed-agility and cardiorespiratory fitness, which were higher in 2006-7 as compared 2001-2 measurements. On the other hand, muscular strength components were lower in 2006-7 (Helena study; Molinar-Urdiales *et al.* 2010). When comparing data after more decades, the results are mostly more different. For that reason, results of individual studies are given in greater detail, and only some general conclusions could be possible.

5.7.2. Secular Changes of PA and PF

Secular changes of PA and PF are mostly closely interrelated, have been often folloved up simultaneously, and are related in many countries to the developement of obesity prevalence ; this concerns also preschool children (Freedman *et al.* 1997, Pařízková and Hills 2005, Katzmarzyk *et al.* 2012, Ross *et al.* 2009, Lioret *et al.* 2009, Kwon *et al.* 2010, He *et al.* 2011, Thomas *et al.* 2011, Puder *et al.* 2011, Pařízková 2011, Ogden *et al.* 2012, Frizzel *et al.* 2013, Pařízková *et al.* 2013, Wethington *et al.* 2013; see Chap. 6). Early development of obesity is a predisposition for many additional heath problems – metabolic syndrome *etc*. (Guinhouya *et al.* 2011, dos Santos *et al.* 2013, and others).

As mentiond before, secular changes of PA as related to adiposity and motor abilities were revealed already in **preschool** age – when comparing the results of studies starting with the fifties of the last century up to the beginning of this millenium skinfold thickness (especially on the trunk) increased significantly, along with significant decrease of motor abilities (performance in broad jump and ball throw; Pařízková 2012, Pařízková *et al.* 2012; see Chapter 1). Early beginning of increased body fat, especially during the period of adiposity rebound (AR) is considered as a predisposition for an easier development of obesity later in life (Rolland-Cachera *et al.* 2006).

5.7.3. Secular Changes in Different Countries

In the **USA** the character of problems – PA régime, health status, and their relationship to nutrition and dietary intake varies significantly with regard to health-related fitness including BMI. However, information has not been recently complete and representative. Local ethnic differences have not been considered in greater detail. The majority of Americans meet or exceed criterion – reference standards ; gender differences are not consistent. Poor morhological fitness - overweight and obesity has been increasing since the early 1980s. However, secular data for specific fitness are less extensive. Selected regression analyses suggest a recent decline in maximal oxygen power in girls, but fairly stable values in boys during the period from 1930s and today. The peak of aerobic power in boys was revealed in the 1960s and 1980s, and present values are somewhat lower than before. This general trend may be consistent with the decline since the 1980s in aerobic performance assessed with the 20 m shuttle run. More exact data on fitness are therefore indispensable also in the USA (Malina 2007).

PA levels and changes in self-reported PA over a 7-year period (1985-6 and 1992-3) were examined in a sample of 5115 subjects from communities in the **USA** - Minnesota and California. The total cohort decrease in mean PA was approximately 30 % in each group. In young adults the reduction of physical activity was considerable when comparing it with previous periods; it is therefore possible to speculate that this decrease can result from previous PA régimes. Similar conclusions were drawn also from many other studies of schoolchildren, adolescents and university students (Helena study – Ruiz *et al.* 2011, Sigmund *et al.* 2009, Sigmundová *et al.* 2011; see Chap. 3.), which concerned also the transition countries with considerably changed environmental conditions

The Bogalusa Heart Study (Freedman *et al.* 1997) showed in **US school children and post-high-school subjects** (5-24-years old) that relative weight and adiposity increased from 1972-4 approximately twofold up to 1994, which was more marked since 1983 – 1994, and started in early life. Largest increase was seen among 19 – to 24-years olds. Later, this increase has resulted also in an increased prevalence of metabolic syndrome during childhood and adolescence (Li *et al.* 2012) witnessing negative impact of changing lifestyle concerning mainly diet and PA level (Eisenmann 2003). Tracking of PA and adiposity from childhood to adulthood (Herman *et al.* 2009) in a longitudinal study revealed that BMI, but not PA tracked well over 22 years ; the majority of overweight youth remained overweight as adults, however, the majority of overweight adults were not overweight youth. Numerous factors interfere with the variability of PA during growth and development, and the same applies to the development of body fat which is mostly not possible directly to follow.

Regressive analyses suggest a recent decline in maximal aerobic power in **US girls**, but fairly stable levels between the 1930s and today in boys. However, the highest values for boys occurred in the 1960s and 1970s, and more recent values are somewhat lower. The general trend since the 1980s may be consistent with the decline in aerobic performance assessed with the 20m shuttle run (Malina 2007). Low PA along with inadequate diet (sweets, chips, fries *etc*.) were revealed as most risky obesogenic factors in **US adolescents** (Ianotti and Wang 2013). Systematic review of the studies on PA during school recess revealed that, among forty-four variables, those providing access to school facilities, providing unfixed equipment, and identifying ways to promote encouragement for PA have the potential to inform on strategies for increasing PA during recess (Ridgers *et al.* 2012). 60 min/day of aerobic and muscle strengthening PA was recommended, but the number of children meeting this demand is not exactly known, and a decline in the **USA** is considered. Therefore, National Health and Nutrition Examination Survey (NHANES, USA) concerning youth fitness (NNYFS), consisting of household interview, PA and PF examination in a mobile examination center was conducted (Borrud *et al.* 2014). Even when step counts/day vary with aerobic fitness level, the fittest middle school students achieved their highest values (Le Masurier and Corbin 2006). On the other hand, sedentary time and vigorous PA are independently associated with cardio-respiratory fitness in middle school students (Moore *et al.* 2013).

There has been little research on **longitudinal patterns of temporal changes of PA and sedentary behavior** especially in the ethnically diverse teens as they transition to adulthood. In a National Longitudinal Study of Adolescent Health (n = 1300; Gordon-Larsen *et al.* 2004) PA and sedentary behavior trends were followed up by longitudinal questionnaires during the period 1994-5 - 2001. Incidence, reversal and maintenance of achieving five or more weekly bouts of moderate to vigorous physical activity, 14 hours or more of weekly TV and video viewing, computer /video game screen use were all assessed. The vast majority of adolescents did not achieve five or more of moderate activity per week, and continue to fail to achieve this amount of activity until adulthood.

As related to fitness, hand grip strength was compared in **US and Canadian** children and adolescents. As strength is significantly related to body weight which has increased during last four or five decades, its increase has been expected. On the basis of 18 studies in boys and 17 in girls from 1966 in subjects 6 – 19 years, it was shown that male grip strength decreased significantly over mentioned period, but the change was small. The cause of this failed prediction has been discussed (Silverman 2011), considering lack of exercise.

Level of PA among children and adolescents *e.g*. in **Europe** was analyzed on the basis of systematic electronic search of studies using assessments through accelerometers and published up to March 2012. Within 131 European studies only 35 clearly reported the proportion of youth meeting PA recommendations (Guinhouya *et al.* 2011). Another review summarized available data on direct representations of physical activity in a range of contexts together with indirect measures as fitness, sedentariness and attitudes. The conclusions drawn were that PA in clearly defined contexts such as active transport, school physical education and organized sports, has been declining in many countries (Dollman *et al.* 2005). This was considered previously *e.g*. in the framework of European Youth Heart Study (Anderson *et al.* 1996, 2008).

In **Estonian and Lithuanian** children (n = 12 226) the secular changes of Eurofit test performance ranged over 10-year period (1992-2002) on average from -0.98 to +0.49 % p.a. , with performance less variable for Estonian children than for Lithuanian children. Secular changes were clearly consistent across age and gender groups; however, secular changes varied among individual tests and were not always in line with European and global changes (Jürimae *et al.* 2007a,b,c, 2009). Also muscular fitness in 13-16 years old Finnish adolescents slightly improved over the period 1976 (n=643 boys, 331 girls) and 2001 (n=579 boys, 271 girls). Study in Estonian 6-years old children included the assessments of BMI, 8 skinfolds, 10 circumferential and 2 breadth easurements. Physical activity was evaluated with the help of questionnaire. Girls were fatter than boys; results of some Eurofit test battery - handgrip strength of dominant hand, sit and reach, standing broad jump, 3 min endurance 10 x 5 m shuttle run were better in boys. Flamingo balance was better in girls. sit-ups, bent arm hang and sit-ups did not vary. PA did not influence the results of motor tests at this age (Oja and Jűrimae

1990), when obviously its range could not vary much yet.

Secular changes of the results of Eurofit testing performance over 10-years period (1992-2002) in **Estonia and Lithuania** varied among tests and were not always in line with other European and global changes (Jürimae *et al.* 2007).

A large proportion of **Danish** children and adolescents has not complied with the national recommendations for children to be at least 60 mins/day physically active; from 1988 to 2002 PA level decreased (Holstein *et al.* 2007). Longitudinal and secular trends in PA and sedentary behavior during adolescence indicated substantial changes along time, *i.e.* negative shift in activity patterns (reduction of moderate to vigorous physical activity, particularly among girls). On the other hand, increases in leisure-time computer use was revealed (Nelson *et al.* 2006).

With regard to secular changes of aerobic fitness characterized by the results of long-distance running during the period 1964-2009, in the framework of the comparisons among Asian children from **China and Republic of Korea** have large declines in this performance. Reduction of it was smaller *e.g.* in **Japan or Singapore** (Tomkinson *et al.* 2007a, b). A network of social, behavioral, physical, physiological and psychosocial factors which influenced mentioned populations may be responsible for these changes and their range; also their rate and length of period in which these factors influenced mentioned populations have surely played a decisive role.

Secular changes were especially apparent in the countries where socioeconomic conditions have developed fast and more markedly, *e.g.* in **China**, which experienced an overall and positive secular trend reflected by an accelerated physical growth, advanced puberty, steady increments of adult height and changes of body shape. However, these changes are also a risk for health problems as elsewhere (Ma *et al.* 2009, 2012 *etc*.). Secular changes concerned PA level, and the prevalence of having been active for a total of 60 mins per day in Chinese students is still low. The heavy homework burden and long homework time were reversely related to PA (Zhang *et al.* 2012). This concerned not only urban child populations (Ji *et al.* 2007), also many minorities in this country (Ma *et al.* 2009, Song *et al.* 2012, Hui *et al.* 2006). Association between PA, BMI, PF, motor performance and environment were assessed in other groups of Chinese population (Zhao *et al.* 2005, 2012, and others).

Along with decreasing PA, a secular decrease of the level of aerobic fitness and physical performance also in **Australasian, Asian and New Zealand children and adolescents** was observed (Tomkinson and Olds 2007, MacFarlane and Tomkinson 2007, Albon *et al.* 2010, Tomkinson *et al.* 2007a,b, 2012 and others). Secular changes of aerobic fitness test performance in **Australasian children** and adolescents were evaluated using five different maximal field-running tests during the period 1961 and 2002. Overall, the aerobic performance declined at an average rate of -0.24% per year. Early in the 1960s, changes in performance shifted from improvements to declines, with the rate of decline accelerating until about 1990, and slowing thereafter. Secular changes did not differ according to gender, but were markedly different for children and adolescents (Tomkinson *et al.* 2007; Tomkinson and Olds 2007a,b).

Forty-six studies reporting on the aerobic fitness in Australasian and New Zealand children and adolescents (n = 161 419, 6-17 years old) revealed that there has been also a marked decline during recent decades, *i.e.* from 1961 to 2002. This decline was cca by -0.24 % per annum; early in 1960s, changes in performance shifted from improvements to declines, with the rate accelerating until about 1990, and slowing thereafter. The changes were comparable in both genders, but different in children and adolescents. – Similar changes were apparent also in Czech preschool children which concerned both adiposity (skinfolds) and motor development (broad jump from the spot, ball throw) when the increase in adiposity and decline of the results in jumping and throwing tests (see Chap. 1; Pařízková *et al.* 2011,2012) accentuated especially after 1990.

Systematic review analyzed temporal changes and correlates of PF as related to PA level and sedentarism among **school children in Sub-Saharan Africa**. Transition of PA and PF shifted from traditional lifestyles to those usual in the industrially developed countries. More research data have been available for children from higher social economic strata (SES) which show a particular threat to these welfare children by accelerating the onset of chronic diseases starting with obesity. Vast heterogeneity of methodology complicated the evaluation of fitness; temporal changes were not found (Mathuri *et al.* 2014).

In **Algeria** secular changes have been observed with regard to height and weight, and also weight to height ratio, and also height for age. Cases of malnutrition have become rarer. Social-economic improvements reduced malnutrition, but body height remained still lower than *e.g.* in the USA. A study of Dekkar (1991) showed that from 10 to 19 years the explosive strength of lower limbs has increased, but the speed of movements did not change, and the endurance of the trunk flexor muscles has apparently decreased. Urban and rural children did not differ significantly, with the exception of hand grip strength. Physical working capacity (PWC) was greater in prepubertal Algerian boys, but after puberty the overseas values of PWC were larger. Also girls had better results until puberty as compared to Romanian, Canadian and Belgium peers. Czech students achieved always better results. More abundant nutrition and reduced PA resulting in greater burden of body fat is considered as a cause, and therefore recomending more intense physical education.

5.7.4. Secular Changes in Highly Developed Areas and those under Natural Conditions

Special effect of secular environmental changes was revealed by comparing populations living in cities and those under more remote natural conditions. Aerobic power – maximal oxygen consumption in absolute and relative values (ml/kg/min) was higher in 1970-1 in the **Inuits** as compared to the national **Canadian** sample, but by 1980/1981 much of this advantage disappeared, particularly in girls and older boys (Shephard 1991a,b,c, Shephard *et al.* 1991a,b,c); physical performance test scores have fallen short of potential. In the 1970s, urban Canadian subjects were substanstially inferior to that of Inuit students, living in the high arctic and practising a traditional, physically active lifestyle. These differences have diminished until 1990s when Inuits apoproached their lifestyle to the usual Western one, *i.e.* reduced their PA (Shephard 2007). The decrease of PF of Canadian children and youth was further confirmed with regard to the 2007 – 2009 Canadian Health Measures Survey (Tremblay *et al.* 2010).

Large amount of motor performance data in Canada revealed that **urban children** apparently showed a small increase of physical performance from the mid-1960s to about 1980, partly due to intensive governement promotion. Health related tests however revealed small but progressive deterioration of health-related fitness along with the increase of adiposity (BMI, skinfold thickness). In 1980, the fitness levels of urban children were markedly inferior to that of Inuit students living in the high arctic and practising a traditionally active lifestyle. However, by 1990, the Inuit had adapted many of the sedentary habits of Canadian city dwellers who lost much of their previous advantages. and were not reaching their fitness potential. At present, Canadian students seem to be somewhat more fit than those in the USA, but less fit than their peers in some of the European countries (Shephard 1991a,b, 2007).

Traditional Inuit life, decades ago and recently revealed a marked differences between Canadian and Inuit subjects. Differences in growth and development among the indigenous and founding people have been attributed to genetic factors. More recent evidence points to a substantial and probably overriding influence of socioecoomic factors including dietary practices. When economic conditions improved for Inuits, the disparities within Canada have disappeared. Canadian growing population including Inuit children has grown both larger and more uniform size from one ethnic group to another. Skinfold thickness has increased in growing national Canadian as well as Inuit subjects (1954 up to 1981). Physical working capacity at the heart rate 170 beats/min. (W, W/kg; PWC_{179}) increased in National sample slightly during the same period, similarly as strength measurements. - In Canadian Cree children increasing central adiposity was revealed along wth the changes of lifestyle; waist circumference correlated negatively with pedometer step counts, shuttle run time, and positively with sweetened beverage intake (Downs *et al.* 2008).

The analysis of 32 studies from **different continents** concerning the validity of field-based tests in youth provided evidence-based proposal for most reliable field-based fitness tests for use with children and adolescents: 20-m shuttle run test for cardiorespiratory fitness, hand-grip strength and standing broad jump test to measure musculo-skeletal fitness, 4 x 10 m shuttle run for motor fitness, and then height, weight, BMI, skinfolds, circumferences and percentage of body fat estimated from skinfold measurements to assess BC (Artero *et al.* 2011a,b, Ruiz *et al.* 2011). Imbalance between EI and EE resulted in some countries in secular increase of BMI, adiposity, obviously also in reduced development of muscular tissue and decreased PF level which was reported in numerous studies.

Meta-analysis comparing **PF data from 55 reports** on the performance of children and adolescents aged 6-19 years in various countries, using the 20 m shuttle run test (20mSRT) during the period 1981-2000 was conducted. Following corrections for methodological differences, the evaluation of the comparisons over mentioned period was possible in 11 countries; rapid decline of 0,43 % of mean values per year was found. Most marked decline was observed in older age groups which was similar in both genders. The rate of this decline was not related to relative wealth of the country quantified by per capita gross domestic product (GDP; Tomkinson *et al.* 2003, 2007a,b, Tomkinson and Olds 2007a,b). Decrease of PA along with increasing age was observed in urban Korean and Chinese children, which indicates that present lifestyle may have greater impact in 13-14 years than 10-11 years old subjects (Yamauchi *et al.* 2007).

5.7.5. Conclusions

Mentioned tests have been used in many of studies of youth fitness in various countries where the life conditions are markedly diversified. The conclusions of individual studies and the evaluations of their variability are mostly hampered by differences in measurement techniques, and the size, age range, level of sexual development and bone age, nutrition of samples measured, differing number of subjects (mainly failure of representative ones), *etc*. The same applies to the results of meta analyses. Further studies evaluating secular changes of PA and PF in different countries, which could enable better analysis of factors resulting in negative consequences will be indispensable.

5.8. PHYSICAL ACTIVITY AND FITNESS, MOTOR DEVELOPMENT AND HEALTH IN DIFFERENT ENVIRONMENT

5.8.1. The Effect of Various Life Style under Different Environment

The effect of PA and consequences of different adaptation to exercise on health development during growth was in a focus of attention more or less recently in many countries. Some of them reveal both generally comparable, but again contrasting results. In addition, individual studies combine varying choice and selection of individual morphological, functional, health *etc*. parameters with regard to **various lifestyle, environment, social economic status (SES), dietary** intake *etc*., and conclusions drawn from such observations have not been always homogenous and corresponding. However, even when sampling (size, mode and criteria of their selection, health status *etc*.) methods, timing *etc*. in different environment have not been identical, some interesting conclusions could be drawn.

With regard to the effect, the **character of PA and exercise is essential as well as their intensity, duration and frequency;** this is not always exactly examined, and often the results of questinnaires only which were not controlled have been mostly used for PA evaluation. Adaptation to exercise and development of fitness early in life has been considered as one of the predispositions for active lifestyle later in life; however, many possible following factors later in life may interfere, or not made these predispositions realizable, or made them imposssible at all.

Considering the delayed effects of early adaptation to increased PA and exercise, a 20-years **longitudinal study** of Dutch 400 boys and girls indicated that that fitness in adolescence is only weakly related to adult PA, and that the longitudinal relationships between PF and PA are only meaningful with maximal aerobic power (Kemper 2001, Kemper *et al.* 2001). Adult activity levels and associated health outcomes are only modestly correlated with activity and fitness measures from childhood to adolescence. However, it appears that methodological limitations in measuring PA levels exactly and permanently may result in an underestimation of the importance of the influence of PA on health (Leonard 2001). As mentioned above, observations in humans are interfered by too many additional factors including nutrition, profesional activity, education, health status, cultural involvements, marital status *etc*. during following later life.

5.8.2. The Impact of Different Character of Exercise

Dynamic, aerobic exercise has been mostly recommended as mostly effective from the point of view of development of health oriented PF and desirable health prognosis generally (Boddy *et al.* 2014). Especially **cardiovascular fitness** is important for healthy metabolic traits; this was shown in 524 Spanish adolescents 15.3+/- 1.4 years old by the Cross-sectional multicentric AVENA Study (Mesa *et al.* 2006) as a marker and predictor of health outcomes. Cardiorespiratory fitness was found in children and adolescents to be independently and negatively related to increased body fat with normal body weight and BMI (Marquez-Vidal *et al.* 2010). The European Youth Heart Study revealed that cardiovascular fitness is inversely associated with abdominal adiposity, and seems to modify the association between PA and abdominal adiposity, which is considered a significant marker of cardiovascular health risks. In low-fit children and adolescents, time spent in vigorous PA seems to be the key component also linked with abdominal adiposity (Ortega *et al.* 2010). Reduction of PA and PF is related not only to total but also abdominal fat, which was proved to be a much more serious health risk (Ortega *et al.* 2008, Espana-Romero *et al.* 2010)

Endurance exercise training results in profound adaptations of the cardiorespiratory and neuromuscular fitness that enhance the delivery of oxygen from the atmosphere to the mitochondria and enable a tighter regulation of muscle metabolism and utilization of lipids, which reduce their deposition in the organism. Use of endurance training is limited during growth, and intermittent exercise (games, selected sports) in children and youth has been preferred. Aerobic power has been assessed from the maximal oxygen uptake (in absolute and relative values – ml/min/ kg body weight, and / or lean, fat-free body mass; VO_2). Peak values despite the absence of a VO_2 max plateau in young children is recommended as an index of aerobic power in youth (Armstrong *et al.* 1996). In addition to aerobic training (swimming, bicycling *etc.*), research has increasingly indicated that resistance training incompassing a broader range of training modalities can also offer unique benefits in children (Faigenbaum *et al.* 2009).

The importance of fitness measurements (PF) as a marker of health (Ortega *et al.* 2008) is related to the possibilities of the evaluation of health prognosis, as indicated in many studies (*e.g.* the Healthy Growth in Cariri Study; Da Silva *et al.* 2013). Mentioned secular changes have been considered especially from the point of view of health – both present and future : PA and fitess and its relationships to cardiovascular disease risk factors have been analyzed and considered (Froberg and Andersen 2005, Kriemler *et al.* 2008). In general, it appears that both PA and cardiovascular fitness are separately and independently asscociated with metabolic syndrome in youth, possibly through different causal pathways (Steele *et al.* 2008). Cardiorespiratory fitness and adiposity are related not only to possible further development of obesity (Livingston 2000, Davison *et al.* 2010), but also to insuline resistance during adolescence (Cummings *et al.* 2010), cardiovascular risk (Day *et al.* 2009), blood pressure (De Moraes *et al.* 2013) and other health problems. Socio-economic and behavioral factors play an important role in this respect as shown *e.g.* in Brazilian children (Guedes *et al.* 2012).

PA, fitness, skinfold and waist circumference were all independently associated with **clustered cardiovascular risk** as revealed in children from Denmark, Estonia, and Portugal (the European Youth Heart Study ; Andersen *et al.* 2008). For that reason – inter alia – more attention is focused on studies of physical fitness level of youth in numerous countries (eg USA, Cooper 2005a,b), Peru (Bustamante *et al.* 2012), Hong Kong (Mak *et al.* 2010), Egypt (Elnashar and Mayhew 1984, El Ansari *et al.*, 2010), and others.

5.8.3. The Role of Social , Environmental and PA Conditions

Environment, secular changes, season, social economic conditions, body composition, energy intake *etc.* on PA are considered in the evaluations of health (Fulton *et al.* 2009, Rich *et al.* 2012, Gracia-Marco *et al.* 2013, Jimenéz-Pavón *et al.* 2013, 2014a,b and others). Socio-ecological correlates were found for excessive TV viewing (Mota *et al.*, 2010) - as a marker of sedentarism - in US children (non-Hispanic whites, non-Hispanic black, Hispanic and others, 6 to 18 years old) , with regard to race and sex. High poverty level and and having TV in bedroom were associated with excessive TV viewing in all race and ethnicity groups. Age, gender, PA, adequate sleep, family structure and other factors were further causes of excessive TV viewing (Sisson *et al.*, 2012 a,b, 2014, Sisson and Broyles 2012). Regular exercise – physical education lessons (Fulton *et al.* 2009a,b) can reduce cardiovascular risk in children (Kwon *et al.* 2010). PA, cardiovascular fitness and body fat were associated with low-grade inflammation in adolescents (Martinez-Gomez *et al.*, 2010a,b). Increased PA and PF were also associated with improvements in metabolic risks (Simmons *et al.*, 2008).

Rural children had higher rates of obesity compared to national average in the USA along with poorer fitness (FITNESSGRAM battery tests) and 30 % failed to meet the minimum PA recommendations. 43% of all children in Oklahoma, USA failed to meet the fitness standard for muscular strength and 36% failed to meet it for flexibility (Shriver *et al.* 2011). On the other hand, a study in Greek children showed that only three of more than hundred possible fitness parameters were significantly different betwen urban and rural children, and these differences were not uniformly distributed under these environmental conditions. It was concluded that the place of residence has no clear impact on PF in this particular growing population (Tsimeas *et al.* 2005). Additional factors obviously influenced the character of these diferences.

5.8.4. PF and Health Parameters

Review of **42 cross-sectional and longitudinal studies** revealed in groups of 5-19 years aged subjects a signifcant relationship of insulin sensitivity and PA (in 78 %), or cardiorespiratory fitness (in 69%), and/or strength (in 66%) In studies which examined both PA and cardiorespiratory fitness concurrently, evidence suggested that they were both correlated with insulin sensitivity independently of adiposity, and especially when PA was more intensive and vigorous (Berman *et al.* 2012). Adolescents with type 2 diabetes were characterized by lower PA level and tended to spend more time being sedentary than similarly aged healthy youth (Nelson *et al.* 2006). Degree of insulin resistance can be predicted from daily PA (Richardson *et al.* 2013). The evaluation of negative changes of PA level along with an adequate diet are related to the markers of insulin resistance (Helena study; Jimenéz-Pavon *et al.* 2013, 2014).

Worldwide variation in the performance of children and adolescents was analyzed in **109 studies of the 20-m shuttle run in 37 countries** : global variability was wide and significant. According to these comparisons, best performing were children from Northern Europe - Estonia, Iceland, Lithuania, Finland, and worst performing were children from Singapure, Brazil, USA, Portugal and Greece. Being overweight was the main cause of worse results (Olds 2007, 2008, 2009, Olds *et al.* 2003, 2006, 2007, 2010). Reduction of PA was thus related both to low level of PF as well as to an increased adiposity. PA in the USA youth decreases with age, and is also always lower in girls and obese subjects. There was a significant three-way age - BMI -race/ethnicity interaction for mean minutes per day moderate to vigorous PA (Belcher *et al.* 2010).

5.8.5. Conclusions

General evidence for secular trends in children´s PA level and PF demonstrated their decline; however, the results have not been still conclusive satisfactorily due to limited research data which were conducted under different conditions. Most frequent health problem overweight and obesity resulting from reduced PA and PF has been revealed, as a predisposition for numerous following development of metabolic and cardiovascular disorders (see Chap. 6.). It has been always conluded that PA during growth and development period has not been satisfactory, and has not corresponded to natural trends during this period of life. Standartization of methods is also urgently required. Apparently, more coordination and cooperation would be necessary to get more consistent results.

5.9. PHYSICAL ACTIVITY AND PHYSICAL FITNESS AS RELATED TO NUTRITION AND ADIPOSITY IN DIFFERENT ENVIRONMENT AND SOCIAL ECONOMIC STRATA

5.9.1. The Relationship of PA and PF to Nutrition

Attention was also focused on physical fitness of youth as related to **various social economic status (SES/)** and therefore to the **effect and relationship to nutrition** (Béghuin *et al.* 2014). In this respect it has been always indispensable to consider again the degree, range and character of these factors, mainly the dietary intake, which was mostly not exactly followed up and evaluated according to recommended dietary allowances; body weight as related to height and BMI were mostly used as criteria. Morover, the effect of genetic predispositions and epigenetic factors could result in different sensitivity of the growing organism to various PA, EE and EI, especially when considering delayed consequences. Studies concerning this problem have had again quite a different design for getting meaningful general conclusions; however, results of some of them are mostly reported here for information in greater detail.

Poor nutritional status resulting in *muscle wasting* had negative effect on performances which require a high energy flux over a various periods of time. Studies in seriously malnourished children and youth in differing environments - geographical, climatic *etc*. and including various social economic status (SES) gave similar results on the deterioration of somatic, functional, fitness and nutritional development. PF can be influenced differently when malnutrition results not only in muscle wasting, but also stunting – reduced growth in height (Pařízková 1987, Malina *et al.* 1991). The results vary according to the characteristic of PF. Static performance and muscle strength, especially that related to body weight might not be influenced. Studies concerning this topic have been still limited.

Functional consequences of **chronic, long- term malnutrition** are an important issue in **rural Africa**, but also in some **Asian countries** where subsistance depends on physical work and capacity. Interventions for their improvement, first of all social and economic ones which improve nutrition are an essential task. Not only body size, but mainly functional status and working capacity have to be increased. Recent but also presently assessed status is not acceptable. In Senegalese children 5-13 years of age height, weight, skinfolds, motor performance (dash, standing broad jump, ball throw, hand grip strength) and results of submaximal step test were assessed. Children were delayed in growth as compared with WHO / INHS reference data, and could be considered as mild-to moderately undernourished. Variance in motor performance can be, under speciál local conditions, partly explained by bodily dimensions (Benefice 1998, Benefice and Malina 1996, Benefice *et al.* 1999, 2001a,b, 2011,2012 Benefice and Ndiaye 2006). In children older than 7 years , those with higher BMI performed better than in all tasks than those with lower BMI.

A study of Brazilian 8-years old children of low social economic status (SES) revealed not only inferior growth but also worse motor performance as compared to children of high SES, with the exception of the endurance run. Studies in Indian children 10-16 years of age revealed lower values of somatic parameters and reduced development of cardiorespiratory efficiency (aerobic fitness - test on veloergometer), as compared to Hungarian, Dutch, Chinese, Polish, Tibetan, Japan, German, Nykyuga children, and also to another groups of untrained or trained Indian peers (Khanna *et al.* 1998). The impact of low SES concerns *e.g.* unfavorized and favorized Indian castes; children and youth of parents from low castes have reduced growth and body size, and functional development which has undesirable consequences until adult age with regard to future working capacity and productivity (Satyanarayana *et al.* 1986, 1989, 1991). The seriousness of the consequences of resulting malnutrition depends on its degree, duration and timing during growth.

5.9.2. The Effect of Different Degree and Character of Nutrition

The impact of **mild- to moderate malnutrition** was followed up in 9,5 – 14.5 years old Mexican (Zapotec) and Mexican American boys. Along with lower height, weight, fat-free mas (FFM) and adiposity (skinfolds) hand grip strength was also reduced in Zapotec as compared with Mexican American boys. Both Mexican groups had height and weight below WHO standards (Malina *et al.*, 2011). Size, muscularity and strength differed significantly among overweight, obese, normal and stunted Mexican children in Oaxaca; but stunted and normal children ran greater distance than overweigth and obese children. Normal, stunted and overweight and obese children did not differ consistently in other fitness items and indicators of activity and inactivity. Overweight and obese children had less strength per unit of body mass and poorer endurance. Normal and stunted children did not differ consistently in fitness (Malina *et al.*, 1995, 1998, 2011, 13a,b).

Relationship between the body mass index (BMI) and strength and motor fitness were later compared in white and black American children 6-13 years of age with a history of good nutrition, and in rural Mexican children 6-14 years of age with a history of mild - to moderae undernutrition (Malina *et al.* 1998). Grip strenght was positively correlated with BMI, but results suggested that a larger BMI tended to have negative influence on the performance of tasks requiring the projection of the body (jump, dash). A threshold level of BMI in this relationship could be suggested for these motor tasks, as in mild-to-moderately under-nourished children the correlation was not found. Excess fatness along with high

BMI had negative impact on motor development especially in overweight subjects.

Comparison of 7-14 years old Mexican (Merida) and Polish (Londz) children showed higher weight in Polish children, due to better nutrition. Grip strength, shuttle run and vertical jump showed greater dependence on body build (Siniarska *et al.* 1998). For grip strength and vertical jump, Mexican children achieved better results in the earlier years (up to 9 years of age), after which Polish boys displayed greater strength, and both genders performed better in vertical jump. Results for shuttle run, reaction time and spine flexibility were generally better for Polish children. Lodz children showed 1 year delay in biological age as compared with Merida children ; a correction for this augmented the observed differences in body build and physical fitness variables. Genetic factors were considered especially for grip strength and shuttle run, however effects of environment, previous adaptation for special tasks could be also hypothetized.

5.9.3. Body Composition, BMI, PF and Motor Develoment

Relationship between body composition, level of motor develoment and physical fitness are mostly signficant as shown *e.g.* in Grade 1 learners in South Africa, but also in other populations (Kemp 2013). The effect of dietary intake and nutritional status is most closely significant – more severe malnutrition and resulting wasting has negative or even detrimental influence on the level of PA and PF (Bénéfice *et al.* 1996,1998, 1999, Kimhi 2003, Monyeki *et al.* 2005, 2007). However, *mild undernutrition might not have only negative effect, and especially the performance in dynamic, weight bearing activities may be facilitated due to lower body weight, BMI_and body fat*; the reverse was true for overweight and obese subjects. This effect depends especially on the degree of under nutrition – only slightly reduced dietary intake within certain range may not have always detrimental effect of dynamic performance (Monyeki *et al.* 2005, 2007). In addition, also additional factors like the degree of adaptation to PA level and exercise have obviously an influence. *E.g.* in Mozambique school-age children and adolescents, the undernourished groups performed significantly worse in absolute strength tasks, better in endurance tasks, and equally in flexibility and agility compared to with groups with normal weight peers (Prista *et al.* 1998, 2003).

The impact of previous environmental conditions on South African primary school children (6-13 years) was apparent - white children had higher scores (height, weight, BMI, standing broad jump, shuttle run, sit-and-reach, sit-up – Eurofit testing battery) and crickett ball throw than children living in separated communities due to apartheid laws. In the majority of cases, the children of mixed ancestral origin had scores that ranged between the other two ethnic groups (Armstrong *et al.* 2011). The technique of such measurements of fitness were found to have an essential role: Tanzanian and Norwegian children attained similar relative value of VO max_2 in the bicycle ergometer test, however the comparison was hampered by differences in altitude, and the lack of experience with bicycle skills in Tanzanian children. This very probably underestimated the aerobic power in Tanzanian children, which reached significantly higher estimated VO max_2 in the shuttle run compared to the bicycle test (Aandstad *et al.* 2006).

Moderate undernutrition influenced morphological and motor characteristics, and also the results of psychological tests (Rocha-Fereira *et al.* 1991, 1998). Another study in Brazilian preschool children confirmed previously found gender differences in body height, weight, circumferential, breadth measures and motor development (broad jump, 20 m dash, shuttle run; higher in boys), adiposity (skinfolds; greater in girls). The comparison of Brazilian (Saõ José dos Campos) and Czech children (Prague) showed that in general, Prague children had better performance than Brazilian ones, with the exception of broad jump. Analysis of food intake showed that Brazilian children varied considerably in the estimated energy and protein intake at home. which was bellow the RDAs (Rocha-Ferreira and Rocha, 1998); this did not apply to samples from Prague where the food itake was generally higher than RDAs (Pařízková and Adamec, 1980, Pařízková *et al.* 1977, Pařízková 2010). The effect of geographical and especially social conditions influenced children markedly early in life.

As followed also from some previously mentioned observations, the **effect of nutrition** (but mostly not assessed simultaneously by exact measurements) resulting in different body size obviously **varies due to the character of performance**. Weight-bearing activities, *i.e.* transferring one own´s body weight along a distance is significantly interfered by increased relative weight, BMI and fatness. In these conditions, the performance in *e.g.* 2400 m run could be better in smaller, undernourished growing subjects as shown *e.g.* in Maputo (Mosambique) children. Muscle strength, which is more dependent on total and especially muscle mass is smaller in such subjects, and is therefore best in normal subjects in which also the results of sit-and-reach and in the 10 x 5 –meter run in boys and sit-ups in girls is on a higher level, due to the effect of lifestyle and adaptation to PA of children with better social and nutrition status. The results in sit-and-reach test and 1 600 m run did not vary between normal, wasted, stunted and wasted-stunted subjects (Prista 1998). These results are in agreement with other studies which showed that body size is not always determinant of physical fitness and health - *Mosambique children performed in some aspects better than their peers from some developed countries*. The use of body size as a decisive indicator of nutritional status and positive health may be contraversial, especially when using international reference values for children of different ethnic, social, economic and cultural backgrounds in different parts of the world.

Similar conclusions were drawn from a study of other preadolescent populations. The effect of marginal malnutrition as related to RDAs can vary due to the character of performance – a dynamic one is influenced in a different way compared to *e.g.* strength one which is dependent on body weight and especially LBM – FFM, and thus muscle development. The results of step test were better in children with marginal malnutrition and lower weight and fatness in South of Italy as compared to children from richer families in Northen Italy who had higher body weight due to more abundant nutrition (Ferro-luzzi 1977,1979).

Special lifestyle including an increased PA influenced also other growing populations *e.g.* in Tunisia. Two subgroups of 11- and 12-years old boys, either from higher, well-off, and/or from lower social economic strata (SES, with more modest, but sufficient nutrition), and with greater PA revealed some differences in body height, weight and BMI, but not significantly in body composition. These parameters were lower in absolute (not relative) values only as compared to Czech boys. Tunisian children from high SES were intermediate, and in step test were worse than their peers from poorer familes. However, there were differences in muscle strength, especially as related to total and/or lean body mass, and also in motor performance (50 m dash, 300 m run, broad jump), vital capacity and step test characterizing cardiorespiratory efficiency (Table **4**). Physical performance was better in boys from lower SES in spite of slightly lower body height and weight, and similar body composition. More modest diet was assumed, but the main difference was more intense PA régime. (Table **4**, Pařízková and Merhautová 1970, Pařízková 1977). Greatest differences in body size as compared to Czech children were found.

Table 4. Anthropometric and functional characteristics of 11-years-old Tunisian boys of different SES (T 1 = lower level, T 2 ´high level).

	T1		T2	
	X	SD	X	SD
Height cm	137.0	8.0	140.5	6.5
Weight kg	31.5	4.9	36.5	7.4
BMI	16.8		18.5	
Muscle strength Extensors of the trunk kp	61.4	11.3	58.1	9.8
Flexors of the elbow “	20.1	4.4	18.4	3.6
Extensors “ “ “ “	14.1	2.2	12.8	2.2
Flexors of the knee kp	15.8	3.9	15.8	2.2
Extensors “ “ “ “	29.2	3.9	28.2	4.4
Step test index	118.9	13.4	111.9	15.8
Vital capacity ml	1953	284	2054	341
“ ml/kg/weight	62		55	
Performance 20 m dash s	9.4	0.6	9.5	0.7
300 m run s	67.5	6.1	69.4	6.4
Broad jump cm	255	29	226	41

The effects of **altitude and malnutrition** was followed up Bolivian boys and girls 7-15 years old living in La Paz at the altitude of 3600 m, and in children from Clermond-Ferrand in France. In Bolivian children a reduced aerobic power (measured and evaluated directly by VO_2 max, and field test 20 m shuttle run) was found irrespective of their socioeconomic and nutritional status. In contrast, at both altitudes marginal malnutrition did not alter VO_2 max when adjusted to body dimensions. The altitude of 3 600 m does not modify anaerobic performances involving mainly alactic metabolism.When the performance is longer than few seconds, anaerobic performance is reduced by chronic hypoxia. which applies at any nutritional and socioeconomic situation. In contrast with aerobic performance, a marginal malnutrition reduced anaerobic performance at high as well as low altitudes. both in absolute or relative values (adjusted to body dimensions), obviously due to an impaired muscle function resulting from malnutriton. When children are well fed, the increase in aerobic power during growth is the same (Fellmann *et al.* 1998).

The comparison of normal and marginally malnourished school children in Colombia showed the depression of the development of arobic power associated with with nutritional deprivation, reduced growth and body size which occurs as a consequence of chronic dietary energy deficiency (Spurr *et al.* 1991).

5.9.4. The Effect of SES, Nutrition and Environment on PF

Children of higher SES and urban living were found to engage in lower PA, higher sedentarial behavior and reduced aerobic fitness than children of lower SES, and rural living females (Muthuri *et al.* 2014). **Greek** children from rural areas were heavier but fitter compared to children living in urban areas (Tombalis *et al.* 2011). The effect of SES as a confounding factor has been revealed especially for **US** junior high school females; the explanation for this is that boys are more likely to engage in vigorous exercise regardless of SES (Bohr *et al.* 2013). In South African children the effect of SES was apparent – low activity and TV watching was more frequent in low SES children (McVeigh *et al.*, 2004).

Argentinian population was located, as compared to the **USA**, at the 10^{th} percentile in the shuttle run, at 55^{th} percentile for pull-ups at the age of 13 years, and percentiles progressively decreased with age, to reach 30^{th} percentile at the age of 17 years. The 12-min run moved from 5^{th} percentile up to $85\text{-}90^{th}$ percentile at the age of 17 in boys; girls achieved only 10^{th}-15^{th} percentile at 13, and remained on 20^{th} percentile at 17 years of age. Sumilar trend had the development of abdominal muscle power, Argentinian population remained at $30\text{-}35^{th}$ percentile. Marked differences in performance were observed in groups with different exercise and sport participation (Narvaez-Pérez *et al.* 1991).

The effect of **organized exercise and sport** in special Sport school in **Cuba** revealed positive results of the adaptation to regular regime of training (track-and-field, basketball, baseball and boxing , age 12-13 years). Improved results of aerobic power - maximal oxygen uptake, maximal oxygen debt and anaerobic threshold were observed (Arbesú 1991). Differences due to various food intake were revealed also with regard to strength and motor fitness.

Growth, exercise and nutrition during growth in **China** was followed up (Ji-di Chen 1991). Increasing height and weight during decades was observed similarly as in other countries. Positive impact of the adaptation to special exercise along with adequate nutrition was observed ; increased energy output due to exercise prevented again greater deposition of fat in spite of higher food intake in many young athletes. Body weight status and and PF were associated also in Chinese children (Shang *et al.* 2010).

Rural Kenyan children had lower BMI, waist circumference, and triceps skinfold, and also lower prevalence of overweight and obesity along with better results in 20m shuttle run test than **urban Kenyan and Canadian** children of the same age. Both groups of Kenyan children and urban Canadian children did not differ in isometric strength. These results indicate signs of nutrition and PA transition in urban Kenyan children (Adamo *et al.* 2011). The effect of urbanization was apparent – rural Kenyan children were shown to be more physically active and had lower indices of adiposity (Ojiambo *et al.* 2012). Another study in **Greek** children showed that obesity rates are higher in rural compared with urban areas, despite an apparent higher level of physical fitness of children living in rural areas (Tambalis *et al.* 2011).

Also in another population in **Abkhasia** where in a small community in the Caucasian mountains with **increased longevity** (high prevalence of subjects more than 90 years old) slower growth of height and weight, and reduced adiposity (lower values of BMI and skinfolds) characterized children and adolescents. PA was on a high level since early up to the advanced age. Children had an adequate, but not abundant food intake (Kozlov 1987); overeating in this population was unacceptable for all age categories. Metabolic and health parameters were on a more favourable level - all that differentiated this long-living population from ethnically comparable population in the capital of Tbilisi, in whom faster growth, greater food intake and adiposity did not run parallel with longevity; posibility for the comparison of such situations could be hardly found any more. It can be concluded that faster growth – increased values of height, weight and BMI including greater adiposity during particular critical periods of growth was not accompanied in mentioned populations by correspondingly improved functional development, cardio-respiratory fitness level and life expectancy - also due to reduced stimulation by PA. Even when other factors – genetic, geographic, climatic *etc*. have to be considered, these observations surely emphasize positive role of more modest, but adequate diet and increased PA during lifetime starting with early childhood.

5.9.5. The Effect of Radiation on PF

As a special exemple of an environmental situation on PF , the **effect of small doses of radiation** after the accident in 1985 in the Chernobyl area (Ukraine) was revealed. In 1990, the evaluation of somatic development, results of spirometry and PWC_{170} and testing of motor development were conducted. PWC_{170} was lower than expected, and increased vegetative lability, general weakness, drowsiness and apathy were shown. Achievements in 20-m run, throwing a ball, and weighted ball and 6-min run were also conducted. Children living in clean areas had better results than children in zones with increased radiation. (Kozlova 1998).

5.9.6. Conclusions

The effect of nutrition related further also to SES and environment applies differently according to its character – severe or mildly reduced, normal, or abundant and excesive. This effect applies also differently with regard to various aspects of PF - *e.g*. dynamic, aerobic performance and/or static one. Muscle strength which depends on total, and especially lean body weight is more closely related to nutrition and SES; higher adiposity usually does not influence strangth negatively. Endurance, aerobic performance or skill can be even better in the individuals of smaller body size, BMI and especially lower adiposity. Environment – urban and rural conditions, climate, above sea level furthr modifies the effect of exercise and/or inactivity, with regard to age and gender.

5.10. RELATIONSHIP OF PHYSICAL ACTIVITY, FITNESS AND COGNITIVE OUTCOMES

5.10.1. Cognitive Outcomes of PA Régimes and Exercise

PF has the relationship also to other characteristics of the growing organism : meta-analysis of the results on the effects of PA and PF revealed a signfican and positive effect on children´s achievement and cognitive outcomes, especially in the case of higher aerobic exercise (Fedewa and Ahn 2011). It was also shown that the effect of PA resulting in *higher physical and aerobic fitness and muscular performance can have a beneficial relationship to* **learning and memory,** academic achievement and performance, improve cognitive flexibility and cognitive performance in special tasks, learning memory, *etc*. (Kemper 2001, Raine *et al.* 2013, Ardoy *et al.* 2014, London and Castrechini 2011, Themanson *et al.* 2008, Wittberg *et al.* 2012, Bass *et al.* 2013, Eveland-Sayers *et al.* 2009, Wu *et al.* 2011, Pontifex *et al.* 2011, Hillman *et al.* 2009a,b, Moore *et al.* 2013, Raine *et al.* 2013, and others).

A review of studies on PA, nutrition, and obesity to **cognition** and **scholastic performance** across human lifespan considered their mutual relationships, and the preliminary data showed that increased PA suggests increased cognitive health and function. In spite of the lack of exact research information, the preliminary data are promising and matched with the declining physical health of industrialized countries (Burkhalter and Hillman 2011b). Further studies confirmed significant association of PF and academic performance among schoolchildren (Van Dusen *et al.* 2011)

It was found also in old age that not only PF indexed by cardiovascular fitness and muscular strength , but also motor fitness including motor speed, balance, motor coordination and flexibility showed a strong association with cognitive functioning in the old age (Voelcker-Rehage *et al.* 2010). Additionally, functional brain imaging data revealed that physical and motor fitness were differentially related to cognitive processes.

5.10.2. Conclusions

As revelaed by numerous studies, cognitive outcome and flexibility, learning and memory, academic achievement and performance have also an important relationship to PA and PF. Increased level of PA and PF as a part of life style can improve also congnitive outcome of regularly exercising individuals in various age periods including the growing ones.

5.11. SUMMARY STATEMENT

As shown by the majority of studies in different countries and continents, the level of PA and PF during last decades has been decreasing, manifesting the changes of the way of life including also dietary intake as related to energy expenditure. The reduction of PA and PF level have shown some differences related to the geographical, economic, social, cultural and further conditions. Largest changes were relatively more apparent in the industrially developed countries, but more recently concerned also selected transition and developing ones. The effect of increased level of physical activity régimes and of org-anized exercise has been shown always significant and differentiated due to their character, intensity, frequency and duration ; this was manifested best by longitudinal studies of the growing individuals. Body composition – the relative and absolute amounts of body fat and lean, active body mass (LBM) have been influenced according to these characteristics of PA and exercise, and the same applied to various markers of PF – cardiorespiratory efficiency and endurance, muscle strength, skill, sensomotor development *etc*. In spite of geographical differences, mentioned studies showed also increasing health risks due to reduced PA. Negative changes of PA and PF were associated especially with an increasing prevalence of overweight and obesity and accompanying comorbidities - especially the metabolic syndrome and cardiovascular, metabolic, orthopaedic and psycho-logical problems.

With regard to nutrition, both extremes – malnutrition , especially chronic one and/or overnutrition resulting in overweight and obesity have significantly negative effect on PA, and both reduce PF. level. Results of inadequate nutrition is differentiated according to the character of physical performance. Danymic, aerobic performace is on a higher level in growing individuals with adequate, but often even slightly lower values of BMI, but adequate BC. On the other hand, muscle strength can be higher in those with higher BMI and higher adiposity.

However, only general conclusions can be made as the individual studies vary significantly with regard to methods, criteria, selection of subjects, age range, gender, level of sexual development, bone age, nutrition *etc*. Meta-analyses have mostly varied in the selection of the individual nations, population groups, continents and further above mentioned characterstics.

It can be recommended that following international and national studies should have coordinated aims, methodological approaches, comparable criteria and sampling, number of subjects (best representative samples), statistical elaboration *etc*. for a more exact analysis of the conditions and causes of reduced PA, PF, increasing obesity and further deterioration of health status. Such an approach can also better define the means for the improvement and prevention of this un-satisfactory situation.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 6

Obesity, Physical Activity and Fitness During Growth

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Abstract: Due to health risks resulting from obesity and reduced metabolic and cardiorespiratory fitness, an increasing attention has been focusing on physical activity (PA). Its reduction - sedentarism has been considered as one of the most important causes of overweight and obesity, especially when it appears early in life. - Obesity during growth is characterized by temporarily accelerated growth in height, increased amount and changed distribution of adipose tissue (mainly on the trunk), reduced physical fitness (PF; especially aerobic, cardiorespiratory one), skill, endurance and motor development. This situation decreases even more PA, resulting in further increasing adiposity and obesity prevalence. Present or later development of metabolic syndrom, cardiovascular diseases, orthopedic and psychological problems can accompany early start of increased adiposity. Various approaches starting with a monitored diet have been suggested and elaborated for intervention, obesity treatment and prevention, with the emphasis on régimes with increased PA and special exercise. Best results with regard to BMI and fat reduction along with increased PF and reduction of metabolic disorders in specialized pediatric centers and summer camps with adequate control and guiding by physical education pedagogues and nutrition specialists have been achieved; however, positive results of these interventions have been mostly only temporary. Therefore, it is necessary to adhere to a permanent régime of both increased PA and monitored diet without interruption, which always increases adiposity and reduces PF. In such a case it is recommendable to repeat interventions more times. However, as best management of obesity during growth, an early intervention and prevention using natural factors as an optimal PA régime along with monitored adequate diet are suggested and elaborated.

Keywords: Adiposity, Adolescents, Aerobic power, Body composition, Children, Diet, Exercise, Fat distribution, Functional capacity, Motor abilities, Muscle strength, Musculoskeletal problems, Nutrition, Overweight, Obesity, Physical

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activity (PA), Physical fitness (PF), Prevention, Treatment.

6.1. INTRODUCTION

Global epidemy of obesity concerns all age categories including children and adolescents. Childhood obesity prevalence has increased in all continents (see Chapter 1). Along with technological advancement, undesirable way of life including hypokinesia and seden-tarism has spread nearly in all concerned countries During more recent years overweight and obesity prevalence has been increasing in many countries also in very young individuals including preschool children as given in numerous documents and projects of World Health organization (WHO 2004, 2010, 2013 *etc.*) and also analyzed by many further studies (Lobstein and Frelut 2003, Bac *et al.* 2012, Wijnhoven *et al.* 2013, Greier *et al.* 2014, and others).

In addition to significant role of genetic and epigenetic factors which condition both nutritional and motor individuality and their rection to environment, the way of life including both inadequate nutrition - as related to reduced energy expenditure (EE) due to reduced physical activity (PA) - have been generally considered to belong to most important causes of obesity during growth (*e.g.* Goran *et al.* 1995, 1998a, 1999, Pařízková 1966, 2008, 2011, 2013, Pařízková and Hills 2005, and others).

Selected previous studies revealed (*e.g.* Durnin 1984) that during the second half of the last century the energy intake (EI) in growing subjects did not, as compared to previous periods, increase significantly or not at all; however, as related to energy expenditure (EE) it has not been corresponding and adequate. Moreover, dietary intake changed mainly its character – increased saturated fats, simple sugars (WHO 2010a, 2013) and protein intake – especially in early life - have had marked complex influence in growing populations (Rolland-Cachera 1995) with inadequately reduced PA, not corresponding to its naturally increased trend at this age.

In spite of plateauing of overweight and obesity prevalence in some - especially developed countries (Salanave *et al.* 2009, Wabitsch *et al.* 2014, Kunešová *et al.* 2011, and others) – the number and percentage of the obese are still undesirably high, especially from the point of view of facilitated development of continuing excess fatness along with comorbidities during folowing life (WHO 2010C, 2011, 2013).

6.2. CONCLUSIONS

Similarly as in previous chapters, referred studies in this one vary significantly with regard to the choice and combination of individual parameters, age range, level of sexual development and bone age, hereditary background, epigenetic influences, ethnicity, methods, number and selection of individuals in followed-up groups, age of the onset of overweight and obesity, its duration and degree, and many other aspects. The comparison of the results of various studies and their presentation is therefore difficult, and only some general conclusions can be mentioned.

As indicated by the above mentioned epidemiological and clinical studies, global epidemy of overweight and obesity concern more and more often also growing individuals starting with early age. As an essential cause the imbalance between energy intake (inadequat amount and composition of the diet) and energy expenditure (reduction of PA, work load and exercise) can be considered.

6.3. SECULAR CHANGES OF PHYSICAL ACTIVITY AND PHYSICAL FITNESS IN OBESE CHILDREN

6.3.1. Secular Changes in the Prevalence of Overweight and Obesity

Prevalence of obesity has undergone a special development along last decades which varies in different countries. When comparing results of overweight and obesity of children from the fifties of the last century and most recent ones, an increasing secular trend for both was found; only during the last decade some stagnation – levelling of the prevalence was found (WHO 2010a,b,c, 2011). In France or Japan, Greece, Australia and some others the increase in overweight and obesity prevalence seems to be finished too (Salanave *et al.* 2009, Wabitsch *et al.* 2014, and others). In the USA, California they have been shown to be decreasing and/or stabilizing along with some improvement of PF (Aryana and Baranowski 2012). The same was observed in 7-years-old girls in the Czech republic

(Kunešová *et al.* 2011, Sigmundová *et al.* 2011; see Chapter 1,2). But in other countries obesity is still on an undesirable level. Individual studies give often contradicting and different results, also due to various criteria for childhood obesity; however, the risk for obesity is still persistent, and moreover has been started in signficantly earlier age.

6.3.2. The Role of Energy Imbalance in Various Parts of the World

Imbalance between EI and EE resulted in most countries in secular changes: increase of BMI, adiposity, and obviously also in reduced development of muscular tissue (see Chap. 1, 5.), and decreased PF level was reported. National representative data from the 1981 **Canada** fitness Survey showed that during the period from 1981 to 1996 BMI, as an indirect marker of adiposity increased at the rate of nearly O.1 kg/m^2 per year for both genders, indicating clear secular trand towards an increase of BMI. The prevalence or overweight among boys increased from 15 % in 1981 to 28.8 % in 1996 and among girls from 15 % to 23.6 %. The prevalence of obesity more than doubled over that period, from 5 % to 13.5 % in boys, and 11 % in girls (Tremblay and Willms 2001). All these changes were considered as a result of sedentarism.

General increase of directly assessed adiposity in children and adolescents since the sixties of the last century up to the beginning of this millenium was proved also directly by the comparison of more than one million of triceps skinfolds measurements of children and youth in 27 countries (Olds *et al*. 2009). Calculated percentage of total body fat also increased during this period indicating the world trend for this undesirable health problem caused by inadequate diet and physical inactivity.

Highest prevalence of obesity in the countries with highest economical and industrial development has been still apparent from numerous studies, where it also started to appear earlier than in other parts of the world. However, present status reveals that the situation is nearing among different areas including the countries under transition. Mostly increasing trend for overweight and obesity was previously found in the **USA, UK, Canada** *etc*., and lowest until not long ago in **China**: however, this has changed too, and childhood obesity has been increasing also in this mostly populated country. In the last two decades (1985-2005), obesity in primary and secondary students in Beijing has changed its characteristics from sporadic to epidemic, with features of both developed and developing countries (Li *et al.* 2008). The trend for the increase was similar in all compared countries. The situation has been further changing up to the present, and increasing seriousness of this problem as a health risk was mostly revealed. Associarion with the changing way of life – especially nutrition , PA level and PF development have been mostly shown.

6.3.3. The Role of Epigenetic Factors

The origin and development of various adiposity can be influenced since the very beginning of life. In addition to genetic factors, also epigenetic factors which influence an individual during fetal period have a significant impact - especially **nutrition**. It was shown that *e.g.* children of mothers malnourished during pregnancy gave birth to smaller newborns, and the weight of placenta was also changed (Barker 1994); however, in adult age the development of a group of chronic diseases – *e.g.* type 2 diabetes, coronary heart disease, hypertension *etc.* is more frequent in early malnourished individuals than in those with normal intrauterine growth. and fetoplacental development. The way that a fetus obtains and allocates nutritional resources has profound delayed consequences for its life-long health. due to the different **programming** ("Barkerś theory" : Barker *et al.* 1998a,b, 2004, 2007, 2012). This was manifested *e.g.* by the consequences of World II famine in The Netherlands concerning also increased predisposition for obesity (Roseboom *et al.* 2006), or in India with regard to total and central adiposity, and hyperinsulinemia (Yajnik 2004, Yajnik *et al.* 2002). Intrauterine programming can apply therefore also to later obesity (Barker 1998a,b). Physical fitness (PF) has ben also considered in this respect. Helsinki Birth Cohort Study did not prove any significant association between body size at birth and cardiorespiratory fitness later in life, but growth between 2nd and 7th years was associated with CRF in adulthood (Salonen *et al.* 2011). For a desirable development an adequate nutrition and energy balance is indispensable since the very beginning of life, including the nutritional status of the mother. Epigenetic factors have therefore an essential role; when moreover also genetic pre-dispositions exist, the influence of early factors can be even more pronounced.

6.3.4. Secular Differences in Obesity Prevalence in Different Countries

National differences in obesity prevalence have been partly due to local social and economic situation (see Chapter 1), which also appeared when comparing children from different **social strata (SES)** in the same country – *e.g*. USA, China, Brasil (Lobstein and Frelut 2003). The National Health and Nutrition Examination Surveys showed that overweight and obesity prevalence increased since 1963 up to 1991 in all age groups (6-17 years); the greatest increase occurred since 1976 to 1980, which was similar to the increase in US adults (Troiano *et al.* 1995). Also in other countries the increase in childhood obesity was revealed, and especially in the countries with lower level of industrial development and SES this increase was observed later than in the USA. As mentioned above, global prevalence and increasing trends of overweight and obesity has appeared more recently also in early, preschool age.

This concerned also **African** countries; in **Asia** the prevalence and expected trends have been lower, however due to the size of population the number of tackled children the absolute numbers are highest (de Onis *et al.* 2010). In a rural African community few children had above normal values of BMI; however, in the 3- and 4-year-old group more subjects were found to have excess fat (triceps and subscapular skinfolds ; Monyeki *et al.* 1999) (see Chapt.1).

Systematic review on obese children and adolescents in **Latin America** revealed too that overweight children were found already in preschool age, and this has been increasing up to 12-19 years (16.6 – 35.8 %). Overall, between 42.5 and 51.8 million children aged 0-19 years in the region were affected (Rivera *et al.* 2014). Increase of childhood obesity prevalence included also children in **Asian and Pacific Islands** which varies widely among ethnic subgroups, and indicated the need for disaggregating these results and also the intervention strategies according to that (Shabbir *et al.* 2010).

6.3.5. Differences in Obesity Criteria (BMI)

Percentiles of BMI, and developmental BMI grids were locally elaborated and introduced in many countries (see Chap.1.) and have been mostly serving for the diagnosis of obesity. As mentioned above, the percentiles which characterize overweight and obesity as introduced by different organizations like WHO and IOTF (International Obesity Task Force by WHO) are not identical. Moreover, it is ***recommended to use local criteria for BMI***, which can vary in ethnically different populations. When groups of Czech children were characterized as overweight and obese using the above mentioned criteria, different prevalence of overweight and obese children resulted (see Chapter 2, Kunešová *et al.* 2011). Overweight and obesity prevalence was highest when using WHO criteria, then IOTF ones ; local criteria which is possible to consider as most reliable, gave also different results. Therefore, when comparing the prevalence of overweight and obesity *e.g.* in different countries, it is necessary to consider which criteria or percentiles of BMI were used for the evaluation (Rolland-Cachera 2011).

From the point of view of optimal BMI criteria for adequate evaluation of overweight and obesity, a special approach was suggested, *i.e.* to *define percentile norms on the basis of* ***BMI assessed in the categories of growing individuals who had the optimal level of PF*** (Chen *et al.* 2002). Body composition (BC) and adiposity should also to be taken in account. This could contribute to more exact definition of a desirable, optimal BMI of a growing child.

6.3.6. Conclusions

With regard to an adequate definition and diagnosis of overweight and obesity during various stages of growth, BMI percentiles, preferably based on the evaluations of both WHO and national growing population, were consented to be generally used. However, other aspects such as body composition (BC) or functional characteristeics should be also taken in acccount for evaluation.

6.4. MORPHOLOGICAL CHARACTERISTICS OF GROWING OBESE

6.4.1. The Role of the Age of Adiposity Rebound

Lower age of adiposity rebound (AR) along with simultaneously reduced PA (see Chapter 1a, b.) was revealed as a predisposition for the development of obesity sooner or later. Since the middle of the last century until the beginning of this millenium the age for AR decreased in Czech boys from 6.2 to 4.9 years, and in girls from 6.4 to 5.2 years (see Chapter 1.; Vignerová *et al.* 2007). During this period of decreasing age of AR, overweight and obesity in the Czech and also other populations increased, indicating earlier start of AR as a marker and predisposition for an enhanced obesity development.

6.4.2. Morphological Characteristics and BC of Growing Obese

As shown in the studies of Czech obese children, especially those with an early start and longer duration of it, not only increased body weight, BMI and fat ratio, temporarily faster growth in body height, but also increased lean, fat-free body mass, heart volume and some skeletal measures were found (Pařízková 1977, 2011). Relative and absolute amounts of total body fat were increased (Pařízková 1961a,b, 1963), and also different distribution of subcutaneous fat in the obese was revealed. In normal-weight children gender differences in skinfold thicknesses, especially larger deposition of fat on the trunk – abdomen and hips was found in girls. In obese subjects of both genders skinfold thicknesses were increased in the same way, and gender difference were not apparent: fat distribution resembled to that found usually in postmenopausal overweight women. Along with that, circumferential measures were greater – especially of waist , which increased also the index waist/height (Table **6.1**).

When obesity has lasted during a longer time and since earlier age, lean, fat-free body mass was also greater. Skeletal mass is also often greater as characterized *e.g.* by an increased breadth of humeral and femoral comdyles; in obese boys also, as compared to normal weight individuals, an increased biiliocristal diameter was found, witnessing along with the distribution of subcutaneous fat certain degree of feminization in this respect (Pařízková 1977, 2011, 2012, Pařízková and Hills 2005).

Morbid obesity has appeared in greater number of growing subjects, characterized by BMI far above highest percentiles. Fat distribution (Goran *et al.* 1995, Pařízková 1977, Pařízková *et al.* 2012 and others) has been followed up also more recently, especially due to its relationship to metabolic syndrom, When children from 6 to 16 years were measured *e.g.* during a rehabilitation stay in the Convalescent house (especially for children with obesity), up to 10th percentile BMI values were not included altogether officially in Czech or any other growth grids for BMI percentiles 10th percentile up to BMI values not included at all in the official present Czech or any other growth grids for BMI percentiles (Blaha and Vignerová 2004).

When various indices of fat distribution (waist /height ratio, subscapular / triceps skinfold ratio, 5 trunk / 5 extremities skinfold ratio) were compared, in children with highest fat percentage and highest BMI the accumulation of fat on the trunk as related to fat on the extremities was always highest, and *vice versa* for subjects with lowest BMI and fat percentage (Table **6.1**; Pařízková *et al.* 2012). Presented follow-up reveals that this risk starts to appear already during earlier periods of growth, especially when adiposity is excessive. – Also a 20-year analysis of school-age children revealed an increase of adiposity and variations in proportion and distribution of subcutaneous fat; this change was greater in the overweight group, mainly in central skinfolds (Ferrari *et al.* 2012). Similarly as the percentage and distribution of fat, PF of obese school children *e.g.* in Thailand was worse than in normal weight children, and did also not show any gender differences (Pongprapai *et al.* 1994), similarly as found previously in Czech obese children (Pařízková 1977).

Table 6.1. Fat distribution in groups of girls (a) and boys (b) with different BMI and body composition (percentage of body fat).

Girls	Fat %	Index	Index
		Waist /Height x 100	Subscapular/Triceps
X	17.7	39.2	0.78
SD	2.0	2.2	0.16
X	24.3	41.2	0.74
SD	3.7	2.4	0.15
X	30.5	47.0	1.03
SD	1.7	3.7	0.29
X	33.2	53.0	1.1
SD	1.9	6.3	0.21

Boys	Fat %	Index 1	Index 2
		Waist /Height x 100	Subscapular/Triceps
X	17.6	40.2	0.76

(Table 6.1) contd.....

Boys	Fat %	Index 1	Index 2
		Waist /Height x 100	Subscapular/Triceps
SD	2.6	2.4	0.14
X	22.1	45.1	0.72
SD	3.8	3.3	0.20
X	28.2	48.8	0.65
SD	3.9	4.2	0.18
X	34.4	59.0	1.10
SD	2.4	7.0	0.25

Indices characterizing the distribution of fat :

Index 1 = Circumference of waist cm / Height cm x 100

Index 2 = Subscapular skinfold mm / triceps skinfold mm

Growth in height is temporarily accelerated in obese children and AR apears at earlier age. Excess fat deposition - especially on certain sites of the body which interferes with movement, and is also overloading the growing body. Increasing strain results in further reduction of PA and decreases the level of PF. Developing *circulus vitiosus* worsens even more the functional and health status as well as its prognosis, and increases metabolic and other health risks.

6.4.3. Conclusions

Morphological characteristics of growing obese include not only increased body mass, BMI and fat amount, but also other deviations as compared to normal weight subjects of the same age. Increased lean body mass, heart size, bone robusticity, circumferemtial measures, and different distribution of fat were revealed. Some of the differences are temporary as accelerated growth in height, or earlier adiposity rebound which indicates the importance of the effect of factors influencing the develpment of the child in early age - especially inadequate nutrition and reduced EE due to sedentarism.

6.5. FUNCTIONAL CHARACTERISTICS OF GROWING OBESE

6.5.1. Changes of Functional Capacity and Aerobic Power

The level of PA, PF and adiposity are closely interrelated and play mutually an essential role, both as causes and consequences of obesity. The effect of the overloading the growing organism with excess fat is mostly apparent during weight-bearing, dynamic activities. Aerobic power characterized by maximal oxygen uptake (VO_2 max) during running and cycling shows the differences between obese and normal weight children . The absolute oxygen uptake during maximal treadmill testing can be the same in the obese and normal weight adolescents (Pařízková 1977, Maffeis *et al.* 1994, Goran *et al.* 1998a, b, 1999), however this absolute value of VO_2 max was always achieved after shorter running at a lower speed, *i.e.* during shorter and smaller work performance (Šprynarová and Pařízková 1965). Relative values were found decreased in the obese (VO_2 max/min / kg body weight and/or lean, fat-free body mass; Pařízková 1977, Pařízková *et al.* 2003), indicating reduced aerobic power in the overweight and obese growing subjects during this particular work performance (Treuth *et al.* 1998).

Growing obese individuals have often difficulties with both treadmill and bicycle ergometer testing due to their weight, and especially lack of experince with both of them. Cardiorespiratory fitness can be more easily evaluated when using walk/run test (12 min) which is associated significantly with the results of bicycle ergometer test, during which peak oxygen uptake (VO_2 max) , anaerobic thresholds (AT) and other parameters are measured. The effect of excess fatness is best documented by increased aerobic power found after weight reduction treatment by diet and exercise in longitudinal studies (Table **6.2.**, Pařízková 1977, Pařízková *et al.* 2003, 2013).

The role of increased cardiorespiratory fitness was in further studies documented by the decrease of central and total adiposity in overweight and obese children with high cardiorespiratory fitness (Nassis *et al.* 2005). As indicated above, performance levels and decline in aerobic fitness in the growing population persisted even when was matched for fatness, *i.e.* increasing fatness was not the only cause of performance deterioration (Olds *et al.* 2007). but obviously aggravated it.

BMI and weight gain in Chinese children showed strong negative association between cardiorespiratory fitness levels (20-m multistage fitness test; He *et al.* 2011). For *screening obesity* in China it was recommended to take for more meaningful evaluation *high-level growth and fitness population as reference,* to adapt secular gowth changes of Chinese youth (Ji and Sun 2004). However, the differences between urban-rural, north south, developed-developing areas had to be taken into account in this huge country. - Static lifestyle along with inadequate dietary behavior were most frequent reasons of overweight and obesity in Chinese primary and middle-school students (Song *et al.* 2012). Prevalence of obesity which has been previously lower among minority students in China has been increasing also, demanding early prevention (Li *et al.* 2009).

Table 6.2. Changes of morphological and functional chanacteristics after intervention and reduction therapy by monitored diet, organized exercise and PA régime and psychological intervention of obese preadolescent children in a summer camp (7 weeks) (Pařízková 1977, 2008).

	Boys				Girls			
Reduction	Before		After		Before		After	
	X	SE	X	SE	X	SE	X	SE
Weight kg	65.7	3.2	58.6	2.8	70.3	2.8	63.1	2.3
Lean body mass %	68.6	0.9	74.8	1.1	68.1	0.9	72.9	1.0
Consumption O_2 ml/min	770	30	570	30	730	50	620	80
O_2 ml/min								
" /kg weight	11.6	0.2	9.7	0.4	10.2	2.0	9.7	2.0
Vital capacity ml	2942	105	3073	115	2640	124	2838	133

6.5.2. Changes of Motor Abilities and Muscle Strength

Along with deteriorated aerobic fitness, motor abilities are partly reduced in growing obese, depending on their character : muscle strength measurements showed the same and even higher values in the obese, obviously due to greater lean body mass in those who were overweight or obese during longer periods of growth (Pařízková 1977). The medicine ball throw was above of the reference group of children (Korstein-Reck *et al.* 2007). Another study showed that the development of the level of gross motor coordination over time was strongly related to weight status - overweight children demonstrated poorer performance. After two years in those with increasing BMI (negative factor) the performance was poorer, but in participants in organized sport clubs (positive factor) was better (D´Hondt *et al.* 2013).

Another aspect of obesity problem is that it has been also appearing at younger age : *gross* motor coordination (characterized by KTK – Körperkoordinationstest für Kinder) in relation to weight status showed worse results in different age groups of the obese. This situation, when comparing 5-7, 8-9,10-12 years old groups, deteriorated further with increasing age and duration of obesity. This was mostly apparent in test items requiring physical properties next to dynamic body coordination (D´Hoondt *et al.* 2011). Fundamental motor skills (special test including walking, running, jumping, hopping, skipping, stair climbing and ladder climbing) were on a lower level in obese children as early as at 4-6 years of age (Vameghi *et al.* 2013).

Unhealthy PF levels acompanied by increased body fat and abdominal adiposity (abdominal circumference, skinfolds) was shown in Brazilian elementary school students. In girls body fatness and abdominal adiposity were more pronounced. The results of fitness tests (flexibility, sit-and-reach test, abdominal strength /stamina, 1- minute abdominal tests; and aerobic stamina: 9 minute running / walking test) were worse in females and were related to excessive abdominal adiposity (Andreas *et al.* 2010).

Urban and rural environment may have an important role for PA and PF as related to BC : another study showed that none of the rural Kenyan children was over-weight or obese, and were more fit as compared to urban Kenyan children, who were leaner than Canadian children (Adamo *et al.* 2011). Transition process under urban life conditions resulted in changes of BC and PF level of growing individuals. Fitness (20-m shuttle run) and PA levels were negatively correlated to obesity characteristics in Mexican children ; PF was a stronger correlate and better predictor of obesity than PA in this group (Galaviz *et al.* 2012).

6.5.3. Conclusions

Obesity during growth significantly reduces PF - especially the aerobic, dynamic one requiring the transfer of one own´s body weight over some distance. Muscle force due to frequently increased lean, fat-free body mass (LBM , FFM) is mostly not tackled , and can be even greater. Also the ability of small muscle groups can be normal.

6.6. FACTORS CHANGING PHYSICAL ACTIVITY IN THE OBESE

6.6.1. The Effect of Environmental Conditions

A special problem concerning what turns obese youth from physical activity was considered on the basis of studies published in 1950-2009, in an effort to define and understand the barriers to PA in adolescents. For example, different ethnicity, socioeconomic status (SES) and many others were analyzed. Thirty five barriers, 13 of which occurred in PA situation in the school setting, 18 were not linked to specific setting, and the remainder were identified as common across both contexts. The fact that these barriers emerged from studies which focused on topics such as victimization and mental health is particularly poignant and reflects potentionally pervasive influence of adolescent ´s excessive weight not only in relation to PA situations, but also to other aspects of their lives (Stankov *et al.* 2012). In children, sociocultural determinants influence markedly PA depending also on their own perception (Lindquist 1999, Economos *et al.* 2014, Dollman *et al.* 2009).

A systematic review of studies published in or after 2000 showed that the relationship between PA, PF and overweight in *e.g.* adolescents showed that obesity and overweight were inversely related to PA; however, it was summarized that a distinction of excessive body weight as cause or effect of low levels of PA and PF is lacking (Rauner *et al.* 2013). However, despite lack of definitive evidence to prove a causal relationship, there has been considered with enough certainty that low levels of PA and PF are linked to increased adiposity in obese children and adolescents. This was revealed also *e.g.* in the tropics (Lau *et al.* 2013).

It was also analyzed that mentioned lack of evidence has been due to the uncertainty of the assessments of PA (*e.g.* often only by questionnaires) and of its character, or varying tests for PF evaluation. With regard to the causes of obesity, various further reasons can play a role – ethnicity, gender, body composition which can influence *e.g.* resting energy expenditure (REE), and therefore also their multiples (METS) characterizing total EE. When it is adjusted for trunk lean tissue mass, lower REE was found in the obese African American children and adolescents. These factors may contribute to the difficulty in weight management (Tershakovec *et al.* 2002).

6.6.2. Conclusions

As follows from selected available studies of the development of childhood obesity, there is a need for a complex long term evaluation of additional simultaneously interfering effect of essential factors which increase and/or decrease PA and PF (Venditti *et al.* 2014). Not only genetic, epigenetic and nutritional factors as causes of obesity (which were followed most often up to the present), but especially more exact evaluation of PA concerning its character, intensity, frequence and duration should be conducted starting with the early periods of life.

Obesity seems to be – *inter alia* - both caused, and also resulting in reduced PA. Lack of oportunity for desirable PA and exercise - *e.g.* in large urban agglomerations - were also considered as one of the main causes of excessively increased adiposity.

6.7. PHYSICAL ACTIVITY, FITNESS, CARDIOVASCULAR AND METABOLIC RISKS IN THE OBESE

6.7.1. PA, PF and Cardiovascular Risks in Growing Obese

Increased interest in childhood obesity and reduced PF has been due to the accompanying health risks and **deterioration of health** status **both presently and also as delayed consequences.** Systematic review and meta-analysis concerning **cardiovascular disease risks** in children and its association with BMI were therefore conducted (63 studies of 49 220 children). It was shown that BMI outside the normal range significantly worsens risk parameters for cardiovascular disease, and that especially in obese children the *risk could be greater than previously thought* (Friedemann *et al.* 2012).

Body fat and cardiorespiratory fitness were related to cardiovascular risk as found also in Chinese children (Wang *et al.* 2011). This was also indicated by further study revealing in young children the relationship between PA and clustered cardiovascular diseases factors including increased blood pressure (Jimenéz-Pavón *et al.* 2013, Monyeki 2008).

Especially children with larger waist girth are more likely to have multiple risk factors than children with smaller waist girth (Monyeki *et al.*1999, 2006, 2008a,b). Health problems appeared even in normal weight children, but in those with abdominal adiposity higher blood pressure was found (Zhang *et al.* 2013). Obesity (BMI), abdominal adiposity (waist circumference, waist to hip ratio), triceps skinfold, fasting blood glucose, serum triglycerides have increased, and high density cholesterol (HDL-c) decreased from 2003 to 2008 also in Indian adolescents (Singhal *et al.* 2010) which indicates increasing health risk also in this population.

Even when not always significant associations beteen PA and CVD risk (characterized *e.g.* by carotid intima media thickness and stiffness) were proved, high volume of vigorous PA accross childhood were independently associated with lower metabolic and CVD risk in adolescence (Ried-Larsen *et al.* 2013).

Excess weight may lead to the development of left ventricular mass beyond that expected from normal growth. Increased mass may also precede the development of increased blood pressure (Urbina 1995). PA score and physical working capacity (PWC_{170}) were found to be a significant predictor of cardiovascular fitness in high adiposity children (Taylor and Baranowski 1991). Especially increased abdominal adiposity characterized by increased waist circumference (see bellow) was associated with high blood pressure in Mexical children aged 8 to 10 years (Colin-Ramirez *et al.* 2009).

Musculoskeletal fitness and fatness are moreover related to inflammatory biomarkers, and muscular and cardiorespiratory fitness level are independently associated with metabolic risks in adolescents (Artero *et al.* 2011, 2012, 2013).

6.7.2. Metabolic Risks in Growing Obese

The effect of the combination of muscular and cardiorespiratory fitness (CRF) should be increased so as to reduce metabolic risk in youth (Artero *et al.* 2011). Higher levels of muscular fitness have been inversely associated with insulin resistance, clustered cardiometabolic risk, and inflammatory proteins. Generally, the influence of muscular fitness was weakened, but remained protective after considering cardiovascular fitness (CVF). Also higher level of this fitness seems to some extent counteract the adverse cardiovascular (CV) profile of overweight and obese individuals (Artero *et al.* 2012, 2013). Children with high BMI and low level of PF had the most adverse metabolic syndrome score in youth of both genders (The Aerobics Center Longitudinal Study – Eisenmann *et al.* 2007). In a study (Andersen *et al.* 2011a, b) clustering of CVD risk factors developed between the age of six and nine years; at nine years of age clustered risk was highly associated with low PF level. CVD risk was shown to be strongly associated with low cardiorespiratory fitness (CRF; Andersen *et al.* 2011a,b,c). High systolic blood pressure was significantly associated with high BMI , but children with low BMI were less likely to be hypertensive (the Ellisras Longitudinal Growth and Health Study; Monyeki *et al.* 2006, 2008a,b).

6.7.3. Inflammatory Condition and Insulin Resistance

It can be considered that obesity corresponds to a subclinical inflammatory condition that promotes the production of pro-inflammatory factors involved in the pathogenesis of insulin resistance (Bastard *et al.* 2006, Rubin and Hackney 2010). Unfavourable level of PF and adiposity (percent body fat, visceral adiposity) were associated with higher levels of hemostatic markers (fibrinogen, plasminogen, activator-inhibitor-1, D-dimer, C-reactive protein) putting individuals with these characteristics at greater risk for future cardiovascular disease (Barbeau *et al.* 2002).

Inflammatory along with anthropometric factors also increased **visfatin** levels in obese children in China (Li *et al.* 2013) where metabolic syndrome has an epidemic status among obese school children in Beijing (Wan *et al.* 2007). In this country where rapid changes in lifestyle have recently occurred the relationship between serum high-sensitivity **C-reactive protein** (**CRP**) and obesity, and impaired glucose metabolism in children and adolescents was found (Yang *et al.* 2006). Also in Taiwan plasma high sensitivity, C-reactive protein levels and insulin resistance status among school children was revealed (Wu *et al.* 2006). Adiposity was related to CRP concentration in further study of school children, but not to PA, aerobic fitness and diet (Thomas *et al.* 2008).

The effect of the combination of muscular and cardiorespiratory fitness (CRF) should be increased to reduce metabolic risk in youth (Artero *et al.* 2011). Higher levels of muscular fitness have been inversely associated with **insulin resistance**, **clustered cardiometabolic risk, and inflammatory** proteins. Generally, the influence of muscular fitness was weakened, but remained protective after considering cardiovascular fitness (CVF). Also higher level of this fitness seems to some extent counteract the adverse cardiovascular (CV) profile of overweight and obese individuals (Artero *et al.* 2012, 2013). In a study of Andersen *et al.* (2011) clustering of CVD risk factors developed between the age of six and nine years; at nine years of age clustered risk was highly associated with low PF level. CVD risk was shown to be strongly associated with low CRF (Andersen *et al.* 2011a,b,c). High systolic blood pressure was significantly associated with high BMI , but children with low BMI were less likely to be hypertensive (the Ellisras Longitudinal Growth and Health Study; Monyeki *et al.* 2006, 2008a,b).

In general, it appears that both PA and cardiorespiratory fitness (CRF) are separately and independently associated with metabolic risk factors in youth, possibly through different pathways (Steele *et al.* 2008). PA is important to protect against clustering of cardiovascular diseases (CVD) risk factors already in young children, being more consistent in those older than 6 years (IDEFICS Study – Jimenéz-Pavón *et al.* 2013, Artero *et al.* 2013). The quantification of how much and what kind of PA is necessary has to be defined with the help of further research.

But it is always necessary to consider mutual relationships and dependance - primarily healthier and fitter children - may be genetically predisposed - could more often prefer to participate in exercise than those who are in this respect not so well off; however, increased PA and CRF are in any case more closely associated with better health status and prognosis. Even when not always significant associations beteen PA and CVD risk (characterized *e.g.* by carotid intima media thickness and stiffness) were proved, high volume of vigorous PA accross childhood were independently associated with lower metabolic and CVD risk in adolescence (Ried-Larsen *et al.* 2013).

A special symposium on correlates and clinical consequences of fat stored in specific body depots was devoted, aimed to the overview of approaches, and to aid in the early identification of children and adolescents who are at increased health risk because of obesity and obesity-related conditions (Katzmarczyk *et al.* 2012).

6.7.4. Obesity and Psychological Complications

Among obese adolescents, *e.g.* an elevated depressive syndrome was associated with lower level of cardiorespiratory fitness; there is a question whether cardiorespiratory fitness acts as a mediator of this syndrom´s effect on obesity, or obesity-related health on the comorbidities (Shomaker *et al.* 2012; see Chap.7.). Obesity proved to have adverse effects on both motor performance but also on physical self-perception as found in middle age students compared to normal weight ones (body dissatisfaction ; Morano *et al.* 2011).

6.7.5. Conclusions

As apparent from the abovementioned studies, obesity has been demonstrated – along with morphological and functional deviations – as a serious health risk for more body systems, especially the cardiovascular system. Health risks concern also metabolic conditions, inflammatory markers, insulin resistence resulting in metabolic syndrom which has been appearing also in younger obese subjects. Increased PA and CRF are in any case more closely associated with better health status and its prognosis.

6.8. MUSCULOSKELETAL PROBLEMS IN GROWING OBESE

6.8.1. Impact of Excess Fat on Musculoskeletal System During Growth

Reduced PA and resulting decreased level of PF in the obese may be a cause of further health problems (Shultz *et al.* 2009). A key but a potentionally modifiable risk factor of obesity that has started to appear is the beginning and development of musculoskeletal problems due to the *inadequate loading of the areas of growth activities of the epiphyses* by excess body fat content. Until recently, attention was focused mainly on skeletal and joint problems, such as the risk of fractures and osteoarthritis. Moreover, obesity has a negative effect on soft tissues - *e.g.* tendons, fascias, cartilages, *etc*. (Widhalm *et al.* 2012). Functional and structural limitations resulting from the additional load on the locomotor system by excess fat, results in *aberrant mechanics of movements* due to low adaptation to an increased PA and reduced PF. Increased stress on connective tissues can therefore cause musculoskeletal accidents (Wearing *et al.* 2006, Stovitz *et al.* 2008, Mauch *et al.* 2008, Chen *et al.* 2013, Matusik *et al.* 2012, Chang 2013. Increased joint pain and discomfort is commonly reported in obese children with decreases of PA.

Obese children typically display a *slower, more tentative walking pattern with increased forces to the hip, knee and ankle* during "normal" gait. This is related to a higher prevalence of muscular malalignement in overweight children, suggesting that such individuals are poorly equipped to undertake certain form of PA (Schultz *et al.* 2009). This situation further reduces the level of PA and worsen the overall status of the obese.

6.8.2. The Most Frequent Problems of the Obese

Flat feet; scolioses; pains of the back, shoulder, hip and knee joints; tibia vara and valga; deteriorated body posture and muscle flabbiness, and some others can appear in the obese most frequently already during childhood and adolescence (Wearing *et al.* 2006a.b, Stovitz *et al.* 2008, Chang *et al.* 2013, Chen *et al.* 2013, Mauch *et al.* 2008, Widhalm *et al.* 2012). The beginning of such problems is due to the early reduction of PA and increased adiposity starting with preschool age. However, cross-sectional and longitudinal evaluations showed the deterioration of body posture also in normal-weight preschool children (Pařízková 1979a, 1998, 2008, 2010), which was confirmed by following observations along with increasing adiposity at the beginning of this millenium. These observations indicate the seriousness of musculoskeletal problems due to their early beginnings, which aggravates this situation with regard to following development. This is closely related also to PA – *e.g.* in Chinese adolescents bone mass was positively influenced by certain measures of PF and muscular strength, as well as by age, weight and pubertal stage. PF was a significant positive predictor of bone mineral density of the L2 to L4 vertebrae in this population group (Cheng *et al.* 1998).

6.8.3. Flat Foot Syndrome

A study of in 7-12-years old obese children showed a prevalence of 59% flat foot syndrome, which was higher in boys (67%) than in girls (49%; Chang *et al.* 2010). The structure of the foot was impaired in obese children - *e.g.* the longitudinal medial arch (MLA) and the angle of foot (FA) was decreased , and the Chippaux – Smirak index was increased. A significant correlation of z-score for BMI and MLA was revealed, and this relationship is increasing with age and increasing obesity (Villaroya *et al.* 2009). Fat deposition has been complicating the evaluation of flatfootedness, but it was shown that in the obese, adipose deposition also was increased, along with simultaneously decreased MLA (Riddiford-Harldand *et al.* 2011a,b-). A longitudinal study of the development of flat feet in preschool age, during later years showed a greater prevalence in younger, obese boys who were also characterized by greater laxity of joints (Chen *et al.* 2013).

6.8.4. Additional Musculoskeletal Problems of Growing Obese

The nutritional status characterized by z-score of BMI correlated significantly with the seriousness of *scoliosis* in 13.37 year old subjects (Matusik *et al.* 2012). **Pains of the lower part of the back** were found in 10-18 years old subjects caused mainly by the characteristics of PA and BMI (Akdag *et al.* 2011). Pains of other joints, especially the hip joint, were revealed in another follow-up of obese children (Stovitz *et al.* 2008, Akdag *et al.* 2011). **Silent slipped capital femoral**

epiphysis and a high prevalence of **tilt deformities** were also revealed in obese children and adolescents which might predispose later for hip osteoarthrosis in obese adults (Wabitsch *et al.* 2004). Similarly as flat feet, this symptom interferes with normal PA; musculoskeletal problems resulting from inadequate motor stimulation are also the cause of an inappropriate development of the skeleton, joints and other related tissues. Underdeveloped functional and cardiorespiratory development further contribute to reduced PA, increase of deterioration of skill and endurance, and continue enhancing adiposity.

Increased prevalence of the **accidents of musculoskeletal** system – *e.g.* **fractures** of mostly lower extremities (ankle, knee, foot, leg), but also others have been found to be more frequent in obese children and adolescents (Valerio *et al.* 2012, Kessler *et al.* 2013, Paulis *et al.* 2014 and others). This goes along with reduced PF and skill, impaired balance and coordination.

6.8.5. Impact of PA on Musculoskeletal Problems During Growth

Undesirable impact of obesity on musculoskeletal system can be positively influenced by increased PA and suitable exercise. which contribute not only to the reduction of fat and increase of lean (LBM), fat-free body mass, but also to the development of bone mass. Daily PA during adolescence and early young adult age was significantly related to bone mineral density at the lumbar spine and femoral neck (Kemper *et al.* 2000). Significant relationship between the development of LBM, bone and aerobic fitness was found in Brazilian children (Fonseca *et al.* 2008). Bone mineral density was found to be related to leptin and insulin concentrations in children (do Prado *et al.* 2007). PA and achieved higher level of PF during the most active period of maturity, with respect to longitudinal growth plays a vital role in optimising peak bone mass; these benefits may extend to adulthood (Khan *et al.* 2011). However, another study showed that increased PA during adolescence did not result in any positive differences, and an earlier start of an enhanced PA, *i.e.* before puberty was recomended for the achievement of the improved bone development (Cheng *et al.* 1999). These findings indicate that musculoskeletal problems can be prevented by an increased PA and exercise, but provided they are suitable and intense enough to achieve a favourable muscle development, and started at earlier age - best before more marked obesity develops.

6.8.6. Conclusions

Along with metabolic and cardiovascular risks, musculoskeletal and orthopedic problems complicate functional capacity and health during growth , and with increasing duration decrease further PA and PF, contributing to *circulus vitiosus, i.e.* deteriorating further both present and later status of children and adolescents. Intervention using increased PA and suitable exercises can reduce also these risks and and improve along with functional capacity also musculoskeletal development.

6.9. INTERVENTION STUDIES OF CHILDHOOD OBESITY USING EXERCISE

6.9.1. Special Character of Intervention for Reduction of Weight During Growth

As compared to adult age, it is quite a demanding task to reduce weight and BMI of an obese child, who has to grow up, and develop further all body components except fat. Necessary and best solution is to **change body composition, reducing fat and simultanously increase lean, fat-free body mass** along with developing vital organs and increase in height. Such a result is more easily to be achieved when along with monitored diet (but not reduced markedly) and increased EE due to regular exercise of a desirable character and intensity are implemented. As shown before (Chap. 5.) in regularly exercising adolescents, best balance between EE and EI was achieved when both were on a higher level. However, *best management of excess fatness during growth is, anyway****, not to let overweight and obesity to develop at all,*** *by introducing proper life style early in life by prevention.*

As mentioned before, obesity during growth is not always due to overeating, but mainly to inadequate composition of diet (increased intake of saturated fats, simple sugars, reduced fibre – fruit and vegetables, *etc.*) unadjusted to reduced EE due to hypokinesia. Therefore, proper exercise and PA régimes have been used to improve the status of obese subjects, and guarantee harmonious develepment.

When using too much reduced food intake, slow-down of growth in height was observed (Pařízková 1977).

6.9.2. Chacteristics of Suitable Exercise Intervention for Growing Obese

Such an exercise has to be prevailingly of dynamic, *aerobic* character with proper intensity, duration and frequency, and be also regular and individually tailored. Aerobic exercise enables best the utilization of lipids and reduction of the adipose tissue in the organism. However, this is often not possible for excessively obese children and adolescents when they start their therapy, due to reduced PF.

At the beginning of such an treatment treatment the *exercises under water* in a swiming pool, excluding the effect of one own´s body weight, and later in *lying, sitting, kneeling positions* - before some weight is lost are recommended. Usual dynamic exercise is most often not possible or too difficult to be introduced, especially in advanced obesity.

Overlooking and guiding of an indispensable régime of monitored diet, exercise and behavioral, psychological intervention is most optimally realizable either in a special clinical centre, or summer camp, in a spa and the like, where treatment can be overlooked and guided permanently during necessary period of time. Very good experiences were gained during children´s vacation in specially organized summer camps (Pařízková *et al.* 1971, 1982, 1993, 2002, 2013, 2014). There it was always optimally assured to maintain an optimally monitored diet, and adequate exercise of all suitable character (sport games, some light athletic disciplines, trekking, dancing *etc*.). PA régime should have been always attractive and individually tailored, also due to psycho-behavioral intervention as a part of therapy.

6.9.3. Results of the Interventions for Reduction of Weight by Exercise

After seven weeks of reduction treatment in a summer camp obese subjects decreased body weight, BMI and fat amount (both in percentage and absolute values), and improved significantly their functional characteristics - *e.g.* aerobic power, vital capacity and motor performance. Reaction concerning pulse rate and oxygen uptake during the same standard work load on a bicycle ergometer indicated in repeated longitudinal studies the improvement of functional status, *i.e.* EE during the same work load was lower, *i.e.* more economical and more acceptable (Pařízková 1977, 2011, 1982, Pařízková *et al.* 1971, 2002, 2011, 2013).

When evaluating the results of fat reduction the reaction to maximal work load on a tread-mill, oxygen uptake - especially when related to total and/or lean body mass - increased, indicating higher level of aerobic power and functional capacity. Such an improved performance was moreover achieved after a larger work load on a tread-mill and after longer running time, indicating after the reduction treatment and loss of excess fat a higher level of higher performance and PF (Šprynarová and Pařízková 1965). Both systolic and diastolic blood pressure decreased similarly along with total cholesterol level (Pařízková 1977, 1993, 2013, Pařízková and Hills 2005).

Positive results were found after *intervention and reduction* treatement including also *exercise in the* spa. Along with reduced BMI and body fat, also blood pressure, serum lipids level and leptin which correlates with body fat decreased significantly (Lisková *et al.* 1998, Bláha and Vignerová 2004, *etc*.). In another similar study insulin, leptin, insulin-like growth factor (IGF1), growth hormone binding protein (GHBP) decreased, and insulin sensitivity increased (Kratzsch *et al.* 1997) indicating the improvements concerning metabolic disturbances in obese children after treatment by exercise and diet.

Further studies on the effect of adequate reduction using diet and exercise were conducted in other groups of growing obese subjects in different institutions like Pediatric Clinics specialized for reduction treatment of obese children and youth, both in- and outpatient ones. Mentioned complex treatment had always positive results concerning morphological, functional, hormonal, biochemical, psychological, othopedic and other parameters (Pařízková 1977, 1982, Pařízková and Hills 2005, Kratzsch *et al.* 1997, Lísková *et al.* 1998 and others). Especially adequate exercise which was supervised had a significant positive effect not only on body fat and PF level, but also on metabolic risks factors as found also *e.g.* in Chinese obese children in early puberty (Chang *et al.* 2008, Wang *et al.* 2011).

A **multidisciplinary inpatient program** with moderate (1200-1600 kcal/day balanced nutrition regimen), daily PA and behavior modification induced major weight loss, decrease of body fat and an increase of aerobic fitness as well as of the quality of life of severely obese children and adolescents (Knöpfli *et al.* 2008). Similar results were obtained using comparable multidisciplinary inpatient treatment in other groups of severely obese growing subjects (Prado *et al.* 2009). – Most of these programs included both inpatient or summer camp treatment with outpatient and medical check-ups during school year, which controlled and guaranteed better their results.

6.9.4. Conclusions

As proved by numerous studies, along with monitored diet a suitable individually tailored PA régime and exercise have been proved as efficient means for intervention, treatment and prevention of obesity during childhood and adolescence. Best results were always gained in special centres – summer camps, inpatient and outpatient departments of pediatric clinics specialized for reduction interventions, especially when used in a long term, without interruption, and/or repeatedly. This approach guaranteed efficient control and overlooking of exercise therapy. Not only BMI and BC, but also PF level improved significantly which predisposed also for greater involvement in active way of life later on.

6.10. REACTION TO THE INTERRUPTION OF INTERVENTION AND REDUCTION TREATMENT

6.10.1. Consequences of the Interruption of Reduction Intervention

However, when treatment was interrupted after returning home from special centres, summer camps or spas to usual lifestyle during school year, the worsening of the situation was observed as the conditions of treatment could not be adhered to adequately. Yo-Yo effect - significant fluctuation of BMI and adiposity were found *e.g.* in a four-year longitudinal study of the groups of the same obese boys followed up from 11 to 14 years, when these subjects were treated using the above mentioned kind of reduction treatment repeatedly during following four years in summer camps (Pařízková 1977, 2008). Significant decrease of BMI and body fat was always found after each year summer camp (lasting seven weeks, organized nad overlooked by Pediatric cliníc, with the cooperation of physical education pedagogues), and significant increase of BMI and fat after following school year (yo-yo-effect). After four years, the resulting value of BMI was significantly lowest as compared to the initial value, and much closer to the fiftieth percentile of local standards of BMI.

The same appeared in fat percentage which had corresponding character, and after four years of longitudinal follow-up the average fat percentage was also more similar to average normal values for boys of the same age. Lean, fat free body mass (kg, assessed by hydrodensitometry with the measurements of the volume of the air in respiratory passages) which was greater than in normal boys generally increased, and remained the same after summer reduction treatment during prepubertal years. Later on, lean body mass (kg) slightly decreased after summer reduction treatment, which was found also at following occasions.

Corresponding fluctuation in functional capacity was also observed, but was finally increased after four years of repeated reduction of fat. This result indicates that the intervention and adequate treatment have to be started as early as possible; even when lean body mass is greater in obese subjects, it is preferable not to reduce it along with adipose tissue. In seriously obese children, for the achievement of best possible and long lastig results it is recommendable to use such a treatment repeatedly, several times when necessary, and at earliest stages of overweight and obesity development (Pařízková 1977, 1982, 2008, Pařízková *et al.* 2002, Pařízková and Hills 2010).

Negative effect of the interruption of obesity treatment was shown also in other growing populations. Intervention in Chinese obese children in early puberty included exercise supervised by professional sports teachers for 9 of the 12 months, and health education implemented all 3 months. Anthropometric parameters, serum lipids, glucose, insulin and homeostatic model assessment for insulin resistance (HOMA-IR) were measured at months 0, 3, 9, 12 of the intervention. PF (upper- and lower limb strength, flexibility and endurance) were assessed before and after intervention. All parameters improved in the intervened group, but in the control group - obese without intervention followed up simultaneously *e.g*. cholesterol and other mentioned metabolic risk factors increased.

However, 3 months after terminating the exercise treatment serum triglycerides, glucose, insulin and HOMA-IR level in the intervened group returned to the pre-intervention level. Supervised exercise treatment can effectively slow the progress of obesity, improve insulin sensitivity and metabolic risk factors, but once the supervised exercise is finished, health benefits weaken or disappear (Chang *et al.* 2008).

35-weeks of extra-curricular, mainly aerobic dynamic PA (swimming and water games, folk dance, and soccer) improved physical performance (30 m dash, 400 m run, standing long jump, and fist ball throw) in obese 7-years old Hungarian boys. Adiposity (five skinfolds) decreased significantly; however, after 4 months interruption of this program skinfolds increased significantly along with the deterioration of PF (Ildikó *et al.* 2007). Interuption of intervention (life-style focused, fitness-oriented gym classes compared to standard ones in control group) had always deteriorating effects; on the other hand, school-based fitness benefits during school years in middle-school children (BMI above 95th percentile for age) were lost during summer vacation without intervention (*i.e.* increase of body fat, decrease of cardiovascular fitness characterized by the measurement of max O_2, increase of fasting insulin levels; Carrel *et al.* 2005,2007).

Positive effect of organized PA during academic year with regard to body fat a PF was also deteriorated by summer vacation break, resulting in decreased PF level in Greek school children who reduced their PA (Christodoulos *et al.* 2006a,b, 2012). Similar results were achieved in overweight and obese children 6-10 years old in Belgium using comparable approach of therapy (D´Hondt *et al.* 2011). Ongoing, controlled intervention of PA and diet is necessary for sustainable positive changes of body composition and PF, as shown also in a study of elementary school children in the USA (Yin *et al.* 2012, Pienaar *et al.* 2013).

6.10.2. Conclusions

As apparent, interventions and treatment in childhood obesity using exercise should be sustained for a period long enough and without interruption, and repeated if necessary. Achieved improvement after intervention concerning BC, PF and reduction of health risks are mostly lost or significantly decreased. As a part of treatment should be the support of a permanent interest and will in an adequate PA régime which should be cultivated throughout their lives.

6.11. OTHER APPROACHES USING PHYSICAL ACTIVITY INTERVENTION OF CHILDHOOD OBESITY

6.11.1. Approaches for Obesity Intervention

With regard to the seriousness of the problems of overweight and obesity during growth and development, a number of interventions of various character concerning most important factors – especially EI and EE - were considered and applied. Recommendations of dietary intake have been mostly used, however marked reduction of EI has not been preferred in growing obese as its reduction was found to reduce also growth in heigth, or lean body mass (LBM). As an aim increasing moderate to vigorous PA régimes outside of schools were also emphasized and recommended (Stone *et al.* 1998). These interventions included mostly different approaches due to various situations, under various conditions for interventions, and also did not use always comparable criteria with regard to the achievement of desirable results.

Some selected examples are given ; in addition, reviews and synthesis on PA intervention in youth concluded also that school and community studies have been limited for several age groups only, with none bellow third grade, and only few at college age. The conclusions and recommmendations are not always cor-responding and homogenous. Many approaches have been used previously in childhood obesity including pharmacological or bariatric treatment which are surely not, except in the case of most serious accompanying comorbidities, suitable and physiological for growth period – but seemingly only as a last possibility for effective intervention.

An increased PA and increasing PF have been emphasized as a critical intervention in the framework of various approaches in obesity prevention and treatment more recently (Flynn *et al.* 2006, Whitlock *et al.* 2005, 2008, 2010, Waters *et al.* 2011, Haynos & 0'Dobahue 2012), which should start as early as possible – in preschool age (Pařízková 2008, 2011, Lanigan *et al.* 2010). The importance of PA in the prevention and treatment of childhood obesity was reviewed previously (Steinbeck 2001); even when the studies did not always check real PA using only questionnaires and not more exact methods, and did not use BC evaluations (at least sknfolds) but only BMI , they recommend to include an increased PA régime in obesity tretament and prevention. - Due to vast spread of childhood obesity also *e.g.* in Latin America, PA interventions including exercise were conducted, as follows from a systematic review of Hoehner *et al.* (2008). Evidence with "best practice" recommendations for reducing obesity summarized a review of nearly one thousand of reports, but no single programme was found up to the present to be a model of best practice; however, using PA and exercise has ben always confrmed.

6.11.2. The Role of Family

As the interventions should start very early in life, the role of family is essential. Parent´s perception of their children´s health, weight, eating behavior and PA at home and schools plays an important role; a study of *e.g.* Jaballas *et al.* (2011) showed that most parents demonstrated concern regarding these factors. Support for parental perception using education and help are essential determinants for improving the conditions for reducing overweigth and obesity of their children (Zhao *et al.* 2013, Sung-Chan *et al.* 2013).

6.11.3. Leading Role of Schools

Schools should promote PA in the framework of their programs, as recommended by most important US institutions involved in cardiovasclar health, PA, PF and nutrition (Pate 2013). As prevention should be in the first place, school initiative should be developed and supported, along with community efforts where health professionals play a key role emphasizing the importance of PA including also family-based activities (Naylor and McKay 2009). Well organized school-based PA was shown to decrease overweight and obesity in children aged 6 to 9 years. PA in physical education lessons, PA during short brakes and longer recesses, PA after-school nursery in compatible environments (child-friendly gym and school playground, corridors with movement and playing around corners and for games) contributed children to achieving >10 500 steps and > 10.5 Kcal/kg per school day across the 2 years of the follow-up (see Chap.3). This régime resulted in a stop of the usual decline of PA due to age. Leisure time included more PA during schooldays and weekends. After 1 year the odds of being overweight or obese was almost three times lower in intervened children compared to control ones (Sigmund *et al.* 2012, Sigmundová *et al.* 2011).

Higher **school-day PA** was found to be associated with higher moderate-to-vigorous PA among the US youth (Long *et al.* 2013). Futher systematic review summarized the evidence on the effectiveness of school-based interventions in promoting PA (increase of moderate-to vigorous PA), PF (VO_2 max; also blood cholesterol *etc.*), and reduction of time spent watching TV (Dobbins *et al.* 2013). PA intervention derived from self-efficacy and social cognitive theory administered by pre-school teachers in the USA (Start for Life) increased moderate-to-vigorous and vigorous PA of intervened children compared to those with typical care (Annesi *et al.* 2013). Environmental intervention based in schools and lasting 6 months improved students' PA and PF in public schools in Mexico City (Aburto *et al.* 2011, Jago *et al.* 2011).

A 4-year cluster randomized controlled childhood obesity prevention study showed that a school-based intervention can reduce the prevalence of overweight and obesity in 6- to 10 years old children affecting eating habits at home and at school, which were considered as decisive for these changes rather than an increased level of PA (Marcus *et al.* 2009). Body composition and PF changed favourably along with improvement of insulin sensitivity in overweight children due to school-based exercise program (Carrel *et al.* 2005). Intensive school-based nutrition education and lifestyle interventions can have a significant impact on insulin resistance, subclinical inflammation, diabets and other health risks in adolescents (Singhal 2010a,b, Singhal and Misra 2010, Singhal *et al.* 2010, 2011).

Some studies showed that **school-based PA intervention** has in participating children no effect on BMI (Ralston *et al.* 2014, Venditti *et al.* 2014) ; however, when PA is not controlled and well defined with regard to significantly changed character, intensity, frequence and duration, and also not individually tailored, this effect may not be apparent. Moreover, adiposity can change - increase or decrease - even without significant changes of BMI which does not directly measure adiposity. *E.g.* secular changes of adiposity in preschool children from the fifties of the last century up to the present were apparent without changes of BMI (Pařízková *et al.* 2012, Sedlak *et al.* 2015), and the same sometimes in obese adolescents treated for obesity by exercise (Pařízková 1977, 2008), in whom mostly body composition and PF changed significantly.

Meta-analysis of the results concerning changes of aerobic fitness in obese children intervened by aerobic exercise revealed moderate positive effect on aerobic fitness, and **programs based on aerobic exercise** lasting more than 12 weeks (3000 minutes total exercise time in three sessions per week, with more than 60 minutes per session) obtained better results. Combined programs failed in this case to improve aerobic fitness (Saavedra *et al.* 2011). Interventions in children screened for overweight seem to be in primary care limited, and seem to have only a short- to medium-term modest improvement (approximately 10-20 % decrease in percent overweight or a few units´change in BMI). However, there was suggested that overweight improvements can be possible (Whitlock *et al.* 2005).

Longer intervention recommending the improvement of the quality of PE classes, allowing more time to train teachers and for individual counselling was implied in Santiago Chile (Kain *et al.* 2009). This program resulted in reduction of obesity and improvement of PF level. - At least one hour of moderate PA/day along with healthy diet was recommended by Health Council of the Netherlands (Kemper *et al.* 2004). Another weight management program recommends 45 minutes of PA of moderate intensity, performed 3 to 5 times per week, also for obese children (Poirier and Desprès 2001).

Biggest multi-centred random controlled **school-based clinical intervention** for obese children (aged 7-13 years) will be conducted in Beijing, Shandong, Chongquing, and Shandong, Heilongjiang and Guangdong provinces. Nutrition education (special developed carton style nutrition education handbook) and PA intervention will be implemented in all intervention schools of 5 cities except the capital. In Beijing, nutrition intervention will be applied in 3 schools and PA intervention among another 3 schools. Height, weight, waist circumference, body composition (assessed by BIA), PF, 3 days dietary record, PA questioonaire, blood pressure, plasma glucose and lipid profiles will be followed (Li *et al.* 2010).

6.11.4. Afterschool Programs

In highest-risk children participation should be also increased during the time after school. Limited evidence still suggests that such programs can improve PA levels, but some studies showed that after-school programs can improve PA. The effect of fitness-focused afterschool program was associated with 14.7 % increase in the probability of being physically fit after 2 years (London and Gurantz 2013). Moving-after-school program in US, Colorado increased PA which included disadvantaged children (ethnic-diverse and low SES). This concerned also obese children who accumulated more light PA after intervention (Schuna *et al.* 2013). The quality, attractiveness and availability of these programs play obviously a decisive role. Another after-school program was effective in reducing the percent of body fat along with improvement of cardiorespiratory fitness; this concerned elementary school children who attended the sessions (80 mins of age-adequate moderate-to-vigorous PA) at least three times a week. No changes were revealed in blood pressure and HDL-C serum levels. After interuption during summer these postive results disappeared (Yin *et al.* 2012).

6.11.5. Residential Treatment Programme

Moderate dietary restriction, PA program and and psychological support was effective in decreasing body fat, improving maximal and submaximal performance and aerobic fitness in the Medical Pediatric Centre Zeepreventorium (Deforche *et al.* 2003).

Ambulatory outpatient treatment using multidisciplinary approach can also have a significant positive effect – reduction of weight, BMI, total cholesterol (TC), and an increase in aerobic power (Korsten-Reck *et al.* 1990). However, a diet which was used (1200 kcal) decreased only weight, and could - when continuing - also decrease the growth in height as shown previously (Pařízková 1977, Pařízková and Hills 2005).

6.11.6. The Impact of Video Programs

Some ntervention studies indicate that another approach as *e.g.* **active video-games** may have potential to increase PA and improve body composition in children; however, this should be verified by future research (Foley and Madison 2010). **Interactive video game cycling** can have also a significant effect on overweight and obesity in children : cycling to music was just as effective as stationary cycling while playing video games at improving PF, BC and TC profiles in overweight and obese teens, and resulting in increased attendance, vigorous intensity of PA and distance pedalled (Adamo *et al.* 2010). – Structured aerobic exercise program reduced, along with improvement of PF anger expression and reduction of aggressive behavior among healthy overweight children (Tkacz *et al.* 2008).

Evaluation of a **web-based program** promoting PA and healthy eating in adolescents revealed also an improvement of PA, reduction of sedentary behavior and an increase of vegetable eating (Cullen *et al.* 2013). The results of an internet short-message service-based intervention for promoting PA in Hong Kong children was evaluated as a possible mean for preventing obesity in children (Lau *et al.* 2012).

Exergames – active video games stimulate light-to-moderate PA and EE due to WII Fit activities (Graves *et al.* 2010). A campaign – VERB for encouraging PA in cbildren positively influenced PA which persisted up to adolescence (Huhman *et al.* 2010). In Singapore - PRIDE for PLAY program emphasized **personal responsibility** in daily effort for Lifelong Activity for Youth (Chia 2007) was implemented.

6.11.7. Conclusions

Due to the seriousness of the problem of childhood obesity, a number of approaches for intervention have been elaborated and introduced. The role of family is essential, and most often **school and after-school peograms** have been used, prevailingly with desirable results. As follows from mentioned programs of PA interventions, to be effective they should be intense enough and be designed to meet multiple objectives – not only improve BMI, BC and optimize PF, promote health-related behavior, but also to facilitate mental development. Video programs can be also helpful in this respect. Experiences based on mentioned obesity intervention studies result also in recommendations for more robust policy, funding programs and financial support at both federal and state levels which have to be implied to the education sector regarding PA (Siedentop 2009).

6.12. EXERCISE AS A PREVENTION OF HEALTH RISKS ACCOMPANYING OBESITY

6.12.1. Impact of PA on BC and Cardiovascular Risk

There has been an accumulating evidence that PA can have a beneficial effect on the risks for cardiovascular diseases (CVD) in children (Andersen *et al.* 2011) which is considered a potential for primary prevention of CVD risk in European children (Froberg *et al.* 2005, Hansen *et al.* 2005). Again, it is necessary to emphasize that **only certain character, intensity, frequency and duration of PA, especially more vigorous one can have significant positive effect** on health.

Data from 2008 Healthy Hearts Prospective Cohort Study of Physical activity and Cardiometabolic Health in Youth showed that only vigorous PA was consistently associated with lower levels of waist circumference, BMI index score, systolic blood pressure, and increased cardiorespiratory fitness in youth (Hay *et al.* 2012). The PLAY study showed lower serum CRP levels in groups with higher PA (Harmse and Kruger 2010), The particular character of PA is obviously necessary to have in this respect a significant impact. However, reducing adiposity by available factors was considered for improvement of health situation.

Desirable effect of PA was confirmed also in a longitudinal study - time spent in vigorous-intensity PA was associated with several positive health outcomes in 9-14-years old US (Luisiana) school children as found 2 years later on (Carson *et al.* 2014). Clustered CVD risk was found in US adolescents 10-20-years old with lowest level of cardiorespiratory fitness (Lobelo *et al.* 2010). Comparison of results of two studies – in Europe (HELENA Study) and Brasil (BRACAH Study) showed that performing the recommended amount of PA (≤60 min/day) attenuated the effect of sedentary behaviour on diastolic blood pressure in 6-1--years old Brasilian girls (BRACAH Study); in boys of the same age in both studies PA did not attenuate the effects of sedentary behavior on systolic blood pressure as in girls in HELENA Study.

Less than recommnded PA in combination with 2-4 h of sedentary behavior increased systolic blood pressure in boys from both studies (de Moraes *et al.* 2013). Unfavourable levels of PF and percent body fat and visceral adiposity were associated in obese US teenagers with high levels of hemostatic markers - fibrinogen, plasminogen activator inhibitor-1 (PAI-1), D-dimer, C reactive protein (CRP), putting individuals with this profile at greater risk for future CVD (Barbeau *et al.* 2002).

6.12.2. Impact of PA on Further Heath Risks

Last but not least, emotional suffering, stigmatization, mental health disorders, poorer psychological functioning, social performance and health-related quality of life were also analyzed in obese subjects during growth (Warschburger 2005; see also Chap.7.). Social-emotional well-being in addition to ther lifestyle routines is essential for the prevention and intervention of obesity during the transition to adolescence (Chang and Gable 2013). – Further, on the basis of epidemiological studies, the relationships between energy intake and balance, PA, obesity and cancer are also hypothetized as modifiable life style factors (Pan and DesMeules 2009).

6.12.3. Conclusions

Obesity interventions using PA resulting in the reduction of BMI and body fat reduced and limited also health risks concerning more bodily systems – provided that PA has been intense enough, of necessary character and duration. Especially of cardiovascular diseases which are closely related to increased adiposity can be reduced due to the introduction of a desirable PA regime.

6.13. EXPERIMENTAL ELUCIDATION OF SELECTED MECHANISMS OF FAT REDUCTION BY INCREASED PHYSICAL ACTIVITY

6.13.1. Reasons for Using Experimental Model

The effect of PA during longer life span including the developmental period can be hardly followed up in the individual body tissues of living humans. There exist studies in normal healthy adult subjects where blood sampling or tissue biopsies are acceptable (Pařízková *et al.* 1984, Melichna *et al.* 1994), which concerned especially young athletes. In children and adolescents this would be hardly possible due to ethical reasons, when such procedures are not the part of any clinical treatment. Such an approach have been possible mainly in children treated for special diseases, but mostly not in children treated only for simple obesity.

6.13.2. Hormonal Changes of Adaptation to Increased Exercise

Therefore, some problems were analyzed using experimental model using laboratory animals (Rattus rattus). Work load and activity is a stress, so the evaluation of the activity of catecholamine synthetizing enzymes in the adrenals of rats adapted to a different level of exercise showed significant differences. In the animals adapted to exercise (daily running on a tread-mill during 1-3 h / day) significantly higher activity of tyrosin-hydroxylase, dopamin-β-hydroxylase and phenylethanolamine-N-methyl-transferase in the adrenals was found as compared to control, and even more as compared to hypokinetic animals living in small spaces with reduced activity since weaning. Plasma corticosteron levels was also highest in rats adapted to high activity compared to other groups (Kvetňanský *et al.* 1975, Pařízková 1977).

6.13.3. Metabolic Activity of Adipose Tissue Due to Adaptation to Exercise

Adaptation to daily running not only reduced body weight and fat percentage, but moreover signifcantly changed metabolic properties of the adipose tissue, which were studied *in vitro*. Release of non-esterified, free fatty acids (FFA) both spontaneously and after addition of adrenaline *in vitro* was significantly highest from the adipose tissue of regularly exercising, adapted rats. FFA release from the adipose tissue of exercising rats during growth differed significantly not only from that of control, but also hypokinetic rats, in which the release was significantly lowest. In adult rats, no differences in FFA release between control and hypokinetic rats were found. As follows, *reduced activity was mostly effectively negative and significant metabolic stimulus during growth period*. At that time, increased activity is one of the most significant faculties of the organism, energy balance and turnover are on their highest level contributing to the stimulation of the development of essential vital organs, muscle and skeletal mass *etc*., and reducing the deposition of fat (Pařízková 1977, Pařízková and Staňková 1964). When measuring the reverse – the uptake of FFA by the adipose tissue *in vitro* after addition of insulin, glucose and/or their combination, lowest uptake was found for the adipose tissue of exercised animals. This indicated lower trend for depositing lipids in the adipose tissue of the animals adapted to exercise (Pařízková 1977).

6.13.4. Lipolytic Activity in Skeletal and Heart Muscles Due to the Adaptation to Exercise

The effect of increased activity was significant during all age periods. Along with the changes of the adipose tissue, an *increased lipolytic activity* was found in *skelatal muscles and in the heart,* indicating higher utilization of lipid metabolites including released FFA during muscle work. FFA after adaptation for exercise were found to be utilized more not only during work load and muscular activity, but also during rest conditions. This was revealed when measuring $^{14}CO_2$ in the expired air, as a result of the oxidation of FFA during palmitate- ^{14}C infusion into the femoral vein of anesthetized, 110-day-old male rats. Expired $^{14}CO_2$ was significantly highest in the animals adapted to exercise. On the other hand, it was lowest in the animals adapted to long term reduction of PA – hypokinesia, in which the $^{14}CO_2$ in expired air was lowest (Table **6.3.**; Pařízková and Poledne 1974). All these findings show an *increased activity of lipid metabolism, enhanced utilization of lipid metabolites including FFA, and resulting in reduced adiposity of the organism adapted to increased PA and exercise*. Reduction of activity has relatively more marked effects during growth period, and *vice versa* for adult age, when increased activity changes significantly many morphological, functional and biochemical parameters. The main underlying cause of this different effect are natural trends concerning the level of spontaneous physical activity during life span.

6.13.5. The Effect of the Adaptation to Exercise in Earliest Periods of Life

There was a question whether the effect of exercise can be effective in any life period, including the fetal one. Offspring of exercised and control rat mothers were followed up also from the point of view of lipid metabolism. It was shown that the effect of daily running during pregnancy was manifested by a change of some parameters of lipid metabolism of adult offspring which concerned the concentration, synthesis of cholesterol in the liver and synthesis of fatty acids in the small intestine (Pařízková and Petrásek 1978, 1979, Pařízková *et al.* 1980).

Table 6.3. The amount of $^{14}CO_2$ of the expired air as percent of applied activity / hour, indicating the oxidation of free, nonesterified fatty acids (FFA) during the infusion of of ^{14}C labelled palmitate into the femoral vein of anesthetized 110-days old animals adapted to different level of long term physical activity (daily exercise, control and hypokinetic animals living in reduced space) (Pařízková and Poledne 1974, Pařízková 1977).

	X	SD
Daily run on a tread-mill	10.57	1.41
Controls	6.40	0.31
Hypokinetic	5.50	0.45

Mentioned effects can be related also to other delayed consequences *of moderate dynamic exercise of pregnant mother* which *influenced* the programming of some parameters related to functional capacity in the offspring in their adult age. Microstructure of the heart is closely related to functional capacity of the organism, as *e.g.* the increased capilarization per mm^2, and positive, *i.e* higher ratio of the number of capillaries to the number of fibers in the heart muscle (capillary/fibre ratio) is increased in wild animals with higher PA, as compared to domesticated laboratory ones. Similar situation was found in animals adapted during postnatal life to exercise compared to control, inactive ones. Adaptation to exercise can have a significant influence even during fetal period : daily moderate exercise (1 hour per day) of pregnant mothers resulted in increased number of capillaries, muscle fibers and increased capillary/fiber ratio in the heart muscle of adult offspring. This positive effect was enhanced by additional exercise of the offspring during postnatal life ; however, relatively greater effect had the exercise of pregnant mother (Pařízková 1975, 1978, 1979a, 1998, 2010). As follows, prenatal influence of *e.g.* diet, but also exercise can have a significant effect which is positive from the functional point of view.

Offspring of exercised mothers had also lower damage of the heart after application of isoprenaline (which is used for the introduction of an experimental cardiac necrosis), and also lower spontaneous mortality after isoprenaline application (Pařízková and Faltová 1979, Pařízková *et al.* 1982). - At any age the resistence to isoprenaline was increased in laboratory rats adapted to increased exercise on a treadmill which reduced total body fat (Pařízková and Faltová 1970, Faltová *et al.* 1983, 1985, 1086).

6.13.6. Change of Nutrition in Early Life and Delayed Consequences in PA and Heart Sensitivity to Isoprenaline

Other models influencing PA were also followed up. Modestly reduced diet at the beginning of life, especialy that with a lower percentage of proteins (5 instead of 20 % in usual laboratory diet) resulted in spontaneously increased PA in rotation wheels during later life. Animals with modestly reduced diet also grew up, when offered after puberty normal laboratory diet, more economically – less food was needed for the same weight increment (g of diet/day for 1 g of weight increment/day) as compared to controls which had normal diet since weaning. When evaluating the level of cardiac damage after isoprenaline in adult age (evaluated with the method of assessing the counts /min after application of $^{203}HgCl_2$ one day before sacrifying the animals), the damage was lowest in animals with early modest diet, resulting in the increased spontaneous PA, greater economy of growth, slightly lower weight and fatness at the end of the experiement (Pařízková *et al.* 1982). These results indicate delayed effects of changed nutrition, resulting in higher spontaneous PA and their mutual relationships at the beginning of life, with regard to the changes of the development of different systems, organs and their function, as well as the resistence to noxi later in adult life.

Even when it is not possible to transfer findings and conclusions gained in an experimental model using laboratory animals to humans, some of the results on the effect of regular PA and exercise are comparable or the same - especially with regard to body composition, reduction of body fat and some changes of lipid metabolism. Therefore, it can be concluded that the prevention of negative changes of reduced PA concerning not only morphological, biochemical and functional status but concerning also health should be considered and applied since the very beginning of life. including the fetal period, and also with regard to the characteristics of the mother and her regime of life.

6.13.7. Conclusions

Experiments in laboratory animals enabled in greater detail the elucidation of the positive changes of body composition , adiposity, metabolic and biochemical changes of the adipose, heart and skeletal muscle tissue after adaptation to exercise and/or its interruption, and of long-term hypokinesia. since early age. Epigenetic factors – nutrition and exercise of the pregnant mother and of the offspring at the beginning of life were shown to have positive delayed effects concerning lipid metabolism, heart microstructure and its sensitivity to noxi in adult age.

6.14. SUMMARY STATEMENT

Secular problem of global epidemy of obesity along with comorbidities has been revealed more dangerous as has been considered until present. This is related to its earlier beginning than it used to be before some decades, and thus facilitating greater prevalence of obesity also in following periods of life. In spite of still existing differences in this epidemy and in eventual stabilization of this trend in different countries and continents, the problem is still threatening especially from the health point of view in the industrially developed, transition and developing countries. Studies of BMI – which has been consented internationally became the most used first approximation in the evaluation of overweight and obesity, however more exact evaluations – *i.e.* measurements of body composition - fat content in the organism, and eventually assessing the level of functional capacity and PF have been used more recently. Distribution of fat in the organism (increased mostly on the trunk and in the body cavities, especially abdomen) and the low level PF, especially of the arobic, cardiovascular one are related to cardiovascular and metabolic health risks which develop simultaneously or as delayed effects. Evaluation of secular trend revealed that these undesirable changes have appeared already in preschool age.

Musculoskeletal and orthopedic problems (flat feet, back and joint pains *etc*.) also complicate the situation of growing obese, especially when excess body fat has been laid down already at early age, and lasted during longer periods of growth.

Accidents – *e.g*. fractures, and joint pains, scoliosis, flat feet *etc*. are more frequent in the obese during growth. This situation results in chronic cases of obesity in further reduction of PA and exercise, and decreases the level of PF.

As a physiological approach not only monitored diet, but especially increased PA and exercise have been proved as efficient means for obesity intervention, which should be long term, uninterrupted and individually tailored, then mainly of aerobic character, and frequent and intense enough. This results in an increased activity of lipid metabolism, utilization of lipids as a fuel for muscle work, resulting in the reduction of fat depots in the organism, and along with that also in higher level of PF and reduction of health risks accompanying obesity.

CONFLICT OF INTEREST

The authors confirm that this chapter has no conflict of interest.

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CHAPTER 7

Personality and Problems of Obese Children and Adolescents

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Abstract: Obesity develops under complex internal and environmental influences affecting child's behavior from the beginning of postnatal life. Psychosocial factors accompanying increased body weight play the important role in forming personality of obese child, his attitudes towards world, society and to himself, as well as attitudes towards food, food choice, and eating behavior. Large scale of behavioral disturbances of the overweight children and adolescents have been reported, such as low self-esteem, depression, anxiety, shame of worse physical fitness, lower school performance, victimization from peers, withdrawal from social contacts, even lower financial evaluation. Many studies have been based on large population samples. However, many overweight and obese subjects are without behavioral problems, they don't suffer from social victimization, they are able to cope effectively with environmental stress. The question of causality of behavioral problems of obese individuals has been discussed. Deeper insight into the characteristis of personality of individual obese child and/or adolescent may help to reveal their specific behavioral problems, if any. This may be helpful in designing effective preventive programs or therapy of obesity.

Keywords: Appetite, Behavioral disturbances, Bullying, Childhood obesity, Child's personality, Daily rhythm, Eating behavior, Motivation, Self-concept, Social stigma.

7.1. INTRODUCTION

The concept of "Big two" provided important impuls to the study of health problems of the overweight child. Food intake which exceeds physiological requirements of the organism and the lack of adequate physical activity gradually

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increase body weight and result in obesity. It became soon evident, that these key factors were not able to explain all conseqences of the obesity and problems of the obese child (Cardel *et al.*, 2011). Genetic disposition may influence susceptibility to obesity to a substantial degree (Seal, 2011), however, increased prevalence of obesity is not accompanied with parallel changes in biological genetic equipment (Dunton *et al.*, 2009). From the beginning of postnatal life, child grows in the specific psychosocial and cultural milieu which forms basic features of his personality, as well as quantity and quality of food selection, eating behavior and attitudes towards food.

Extensive research has brought about relevant data concerning association between obesity and behavior in childhood and adolescence, however, many questions are open to future research such as: what is the role of food in the life of the overweight child? What determines his attitudes towards food, physical activity, body weight? What do we know about the individuality, personality of the obese child and adolescent? Are there differences in personality and in behavioral problems between obese and normal-weight children? How obese child perceives his physical handicap, does he suffer from emotional problems associated with his appearance? To a what degree obese child and adolescent are able to get adapted to the negative attitudes of peers and societal stigma? Does obesity affect specific (and which) mental/behavioral abilities or does it degrade globally the personality? Are there gender differences between obese subjects in the response to environmental stress?

Behavioral problems of obese child and adolescent may be classify as three inter-dependent main domains:

- **Attitudes of a child to food as the basis of increased weight and future health and behavioral problems.** On the one side, composition and quantity of ingested food determines growth and maturation of the organism including brain and therefore it exerts direct effect on behavioral development. On the other hand activity and spontaneous behavior of a child in food selection, in his eating behavior as well as in forming his attitudes towards food and the level of physical activity determine one’s own body weight.
- **Attitudes of the environment towards the child.** Family and influences from near environment are among the first agents organizing infant’s life, daily régime, food

intake, and physical activities. Child is the active participant in these interactions. By means of his behavior he influences attitudes of the environment and evaluation of his behavior.

- **Internalization of external and internal factors** represents complex process forming the attitudes of the child toward himself. They codetermine development of his body image, self-acceptance, self-evaluation, self-efficacy, physical and mental abilities. They influence his attitudes towards food and eating behavior. Disturbances in this domain may result in the excess food intake and later obesity.

7.2. FACTORS AFFECTING EATING BEHAVIOR IN THE OVERWEIGHT CHILD

Atitudes to food, eating behavior and regulation of food intake are regulated by the set of biological, psychosocial and cultural factors. Large number of stimuli and environmental cues might contribute to increased food intake in obese children (Barkeling *et al.*, 1992) and to the risk of obesity (Wardle *et al.*, 1992). Genetic and ontogenetic factors that take part in the food choice, regulation and utilization of the ingested food have been subjected to extensive research. Behavioral genetics studied the contribution of environmental sources of variability on the development of child adiposity (Faith, 2005). Variability as possible factor of food choice and preference, metabolization, and utilization of nutrients has been proposed (Pařízková, 2012; Widdowson, 1962).

Revealing associations between child's personality and his eating behavior is important for proposing effective strategy of preventing obesity. The thorough research has to find out, how internal and external cues exert their influences on feeding behavior and, whether obese children and adolescents differ in eating behavior from those with normal body weight.

7.2.1. Appetite as Motivational Factor in Eating Behavior

Hunger does not need to be the prime motive in the initiation of food intake. Yudkin and McKenzie (1964) defined hunger as the simple drive to eat food contrary to appetite as a drive to eat particular food. The concept of a drive as an unitary starter of specific behavior has been abandoned. No direct association between actual nutrient requirement and eating behavior exists at all events. Appetite may be one of the basic motives to increase eating. Individual differences in the appetite are known to appear soon after birth and they accompany entire life of the individual. Appetite might posses selective character in influencing food choice and hédonic reactivity of obese persons. Already (Stunkard and Koch 1955) reported that subjective feeling of hunger in adult subjects did not correspond to the objectively measured internal condition when compared with those of normal weight.

Food motivation is the extent of somatic development, cognitive-intellectual level, influences of prior experiences and various psychological traumas. It represents complex of intertwined internal and external food cues. All these cues give the basis of food motivated behavior of a child and of possible disturbance in regulation of food intake. Eating behavior is realized under specific sensory and psychological situations, it depends on eating habits and life style of the family. Wardle *et al.* (2001) proposed characteristics engaged in the attitudes to food and eating: satiety responsiveness, responses to external food cues (good or less good tasting), emotional eating, general interest in the speed of eating, and food fussiness. Overweight and normal-weight youngsters differ in the eating style (Braet *et al.*, 2008). Already the preschool overweight and normal-weight children have different attitudes towards food and they differ in their eating behavior. According to their parents, overweight children showed "great appetite" or even "enormous appetite" contrary to lean children, which often dawdled with food, ate without appetite (Fraňková, 2006, 2007). Higher score appeared in the Child Eating Questionnaire in Chilean children of both genders (6-12 years of age) compared to normal-weight controls. Food avoidance subscales were inversely associated with childhood obesity (Santos *et al.*, 2011).

7.2.2. Circadian Rhythm and Speed of Eating in Obese Subjects

Increased speed of eating may be responsible for totally higher energetic input. Obese children (11 years old) eat more quickly than normal-weight ones and they don't decrease the speed of eating by the end of meals (Barkeling *et al.*, 1992). Both obese children and their mothers consume larger quantity of food within shorter time than the lean subjects (Birch *et al.*, 1981).The cause of more rapid eating has not be satisfactorily explained. It is not clear, whether it is the consequence of defect signaling the satiety or disturbed response to satiety signals. Eating too fast may disturb saturity feeling in the course of meals.

Interaction between circadian rhythm of food intake were studied also in adult obese persons (Stunkard, 1957; Stunkard & Wolff, 1956). Bellisle *et al.* (1988) investigated circadian rthythm in 7-12 years old children in association with their BMI. Total daily energetic intake was not substantionally affected by body weight, however, intergroups difference appeared in time distribution of food intake. Obese children take lesser amount of food as breakfast than normal-weight peers, however, they compensated the deficit by more heavy dinner. Children with mean BMI took more snacks between main meals during the day. Research studies gave evidence that overweight adolescents were less able to adapt their energy intake through the day (Ebbeling *et al.*, 2004).

7.2.3. Food Intake in the Absence of Hunger

Eating not motivated by actual hunger is a phenomenon observed often in adults as well as in children.There are various reasons for overeating: by means of food free time is filled, when waiting or because the lack of the opportunity or motivation to physical or mental activities. It may be used as the instrument to compensate for acute or chronic stress. Parties and various social events are good opportunities to consume large amount of food, usually of high caloric density. By means of eating, feeling of frustration, tension, anxiety, and mental tension may be temporarily reduced. Inhibition of overt manifestation of aggression by eating may be also effective (one of the reasons why people take chewing gum).

In the study of children aged 10-13 years, aimed on revealing actual reasons for taking food without hunger, discrepancies appeared between reports of parents and of their children. According to parents, hunger was the cause of eating, while according to children, they often ate without hunger because of the boredom. Some of them ate when perceived anger, sorrow, or depression. Older children reported these reasons more often than younger ones. In boys often feelings of hunger appeared while in girls sadness, anger, depression prevealed (Moag-Stahlberg *et al.*, 2003). As evident, children solve different unpleasant as well as pleasant or even emotionally neutral situations with useless or authomatic eating. They often consume various snacks, pop corns or ice cream while waching TV

(Dietz & Gortmaker, 1985; Fisher & Birch, 2002). Eating without hunger used to be associated with sedentary way of life, watching TV, sitting at Internet, computer *etc*. (Robinson, 2001).This way of unnecesary caloric intake is common in children and adolescents regardless their body weight. Sedentary way of passing free time accompanied with eating without hunger (even without an appetite) increases risk of overweight. In children it results in the habit of overeating. Lack of knowledge of the effects of overeating may contribute to excessive caloric intake, namely in young children which are not able to recognize effects of overeating at larger time axis.

7.2.4. Traumatic Experience as the Motive for Eating in the Absence of Hunger

Various actual negative experience as well as early traumas may be the cause of food intake without physiological needs (Kaplan & Kaplan, 1957, Varness *et al.*, 2009; Včelařová & Bendová, 2012). Overeating of the child may signalize behavioral problems and troubles. Situation in the family may appear which the child perceives as threatening, such as conflicts between parents, death of the close relative, disintegration of the family, but also the birth of the sibling. According to the child, his parents give all their love only to the infant, they are no more interested in him. The easiest solution of this situation consists in the refrigerator, the child takes some food to his bedroom and by excessive eating tries to drive his troubles away.

Overeating may be used as behavioral defence strategy of children, mostly in boys. It appears in situations where the boy is affraid of physical punishment or maltreating from his parents or bullying from peers. He is convinced that by excessive eating he increase his body size and therefore higher physical power and predominance over father and peers.

7.2.5. Sensory Characteristics of Food and Eating Behavior of Obese Child

Individual physiological properties of sensory receptors and sensory systems may influence food choice and food intake. Mere exposition to food and to the eating situation may stimulate appetite for the presented meal. Sensory stimuli from food may be of priority in decision making for food acceptance and formation of attitude toward it. External cues associated with meal may be more stimulating for obese subjects than for normal-weight subjects. They are not able to resist eating food when it is accompanied with aggreable sensory stimuli (Braet & VanStrien, 1997; Herman & Polivy, 2008).

Hédonic response to certain meals may be elicited by higher sensitivity of receptors to olfactory, visual, haptic, and accoustic stimuli from the meal, from its texture, palatability, aesthetical value. Sensory signals from perifery are represented in the brain and associated with past memories and emotional experiences with the given meal. Adult obese persons have increased sensitivity to sensory stimuli which accompany eating situation, they are over-responsive to external cues of food such as smell and taste and less responsive to internal stimuli signalizing satiety or hunger (Schachter 1968; Stunkard & Wolf, 1956). In obese children high significance of sensory perceptions associated with the presentation of food and its consumption was reported (Schachter, 1968).

7.2.6. Influence of Mass Media and Marketing on Attitudes Towards Food

The offer of meals with high energetic density, provided convincingly by advertising may be one of the causes of prevalence of obesity in children and adolescents (Villani, 2001). Food marketers are well familiar with the psychology of the child and the means how to influence this target group. Advertising has greater effect on small children than on the older age groups and adolescents, which are critical to everything associated with environmental pressure. Young children are not yet able to differentiate between reality and what they see on the television screen, billboards, in leaflets addressed to their mothers, *etc*. They believe them namely if presented by somebody to whome they trust, who is good looking, who resembles mother, grandmother, who is connected with the positive role of the model (Ray & Klesges, 1993). Children models presenting or consuming meal are particularly effective, since they are perceived as real friends or peers.

If overweight children are more sensitive to external sensory cues, they are more open to develop liking for products with attractive color, shape, accompanied with illustrations of cute animals (kittens, dogs). The offer of such products, usually containing high percentage of sugar, fats, unhealthy but good looking and tasting ingredients contributes to establish preference even dependence on it. The aim of producers is not only to sell their products immediately, but by means of the target object, the children, they prepare their future customers (Nestlé, 2002).

7.2.7. Gender Difference in Attitudes Towards Food in Obese Children

Wardle *et al.* (2001) pointed the possibility of different attitudes and eating behavior between boys and girls. The sources of the these differences may be of various nature. Genetic characteristics in sensitivity of sensory systems and perception of taste, color, smell *etc*. may be responsible for the differences (if any). They may influence food selection, eating behavior and attitudes towards individual foods. Boys usually prefer calorically more dense, fatty meals, girls may like more sugar and sweets and, they may pay more attention to the aesthetic properties of meals. Role of genetic factors in processing informations from individual receptors has not been explained so far.

Gender difference in attitudes towards food is not sole property of genetics. Social pressure on physical attractiveness is culture- dependent and the acceptance of obesity differs for boys and girls. Psychosocial norms have developed the model of strong superman. Boys accepted the idea that food gives them power and stength (not being able to differentiate fatness from physical strength). Girls are more critical to physical appearance of their mothers, attitude towards food which was rather positive in early infance get changed as they get older. Attitude towards sweet meals is repudiated, however, many adolescent girls and young women are in danger to develop obesity because their preference for sweet foods as the remedy is helpful in solving their problems.

7.2.8. Disturbance of Attitudes to Food and Eating Behavior in Obese Children and Adolescents

Disturbances of eating behavior in obese children and adolescents are in some respects similar to those typical for mental anorexia and bulimia. Fairburn *et al.* (1997) reported that odds of being obese in child was three times higher among bulimics compared with healthy subjects. Obese adolescent girls practice similar methods to reduce body weight as anorectic and bulimic girls: they use pills, induce vomiting; starvation used to be alternated with bulimic episodes. Dieteting in obese adolescents may paradoxically result in obesity (Haines & Neumark-Sztainer, 2006). Breakdown of dietary restraints may lead to the loss of ability to control eating, to bingeing and overeating (Shunk & Birch, 2004).

7.2.9. Attention Deficit (ADHD) in Obese Children

Certain studies demonstrated the association between ADHD and obesity (Lam & Yang, 2007). Higher prevalence of ADHD was reported for overweight individuals than for normal-weight ones. In obese children with psychiatric diagnosis more than 5% displayed ADHD (Vila *et al.*, 2004). Children and adolescents with ADHD aged 5 to 17 years had approximately 1,5 times the odds of being overweight (Waring & Lapane, 2008). However, mechanisms of the association between overweight and ADHD were not explained convincingly. It is not clear, whether ADHD contributes to obesity or *vice versa*, obesity leads to ADHD or whether they share common mechanisms (Cortese & Penalver, 2010). It was suggested, that impulsivity typical for children with ADHD may induce impulsive eating and the excessive food intake may contribute to obesity.

7.2.10. Summary

Many factors contribute to food choice, food intake, to attitudes towards food and, to eating behavior of a child. Increased food intake and overeating of obese child may be the result of complex influences from the internal an external impacts. The obese children are more than the normal-weight ones sensitive to sensory cues and to the actual psycho-social situation associated with food. Besides somatic causes, sensitivity of sensory receptors, both positive and negative early experience and traumas affect motivation to food, rhythmicity of eating, food intake without hunger, what may contribute to the development of obesity.

7.3. FAMILY INFLUENCES ON WEIGHT AND EATING BEHAVIOR OF OBESE CHILDREN

Role of family and attitudes of parents to the overweight child have been the object of numerous studies (Golan & Crow, 2004; Hodges, 2003; Klesges *et al.*, 1983; Klesges *et al.*, 1991; Striegel-Moore & Kearny-Cooke, 1994, Werner *et al.*, 1994 and others). The role of parents in the development of body weight, food choice, eating behavior and behavioral patterns associated with food in child has been well documented.

7.3.1. Attitudes of Parents to the Overweight and their Influence on Eating Behavior of Obese Child

Attitudes of parents to overweight and obesity of their children have various reasons. One of them is their own body weight which may influence their attitudes to overweight (Lumeng, 2003). Some adults consider increased body weight as being normal for adult age and put up with it. Positive correlation exists between BMI of parents and of their child (Vignerová & Bláha, 2007). Obesity of mother used to be the predictor of her child's obesity. Difference exists between father and mother in their attitudes towards weight. Mothers have the tendency to overestimate their own body weight and they possess critical attitude to body proportions of the overweight child. Negative evaluation of child's weight may influence their interactions and to contribute to mental disorders of a child. Already five- years old girls perceive negatively critical views of their parents on their body weight. They result in her negative self-evaluation (Hill & Pallin, 1998). Attention deserves father's attitude to body weight of his daughter. His critique did not influence behavior of 5 years old daughter, however, she had low self-evaluation at school age (Davison & Birch, 2002). It was also reported, that attitude of parents affected negatively self-esteem of girls aged 9 to 11 years.

7.3.2. Life and Education Style of Parents and Control of Eating Behavior of Obese Child

The life style and attitudes of parents towards food influence development of eating behavior in children and their body weight. If food becomes the centre of the family life, object of disproportionate interest or expression of high social status, the child take over these attitudes. Gifts, visits of friends, feasts,parties and celebrations contribute to overeating and to habits of eating caloric meals. Educational style of parents manifests itself in their strategies of coping with food and modulation of children's behavior (Epstein *et al.*, 1994). Parents may influence eating behavior of child directly, by means of their own eating habits but also by means they can not influence and which don't allow the control of eating behavior and food choice of child, such as long time spent out of home, their working duties, health condition, *etc*.

Small child has limited responsibility for control his weight and food choice. In the course of childhood the living space get enlarged, he is exposed to more external stimuli, the ability to chose his food independently gradually increases.

Parental attitudes and parental feeding practices may influence body weight of the child in several directions, aimed either to increase or to decrease his body weight. The first motivation is to force the child to increase food intake by means of positive appreciation of his appetite. Higher food intake has been interpreted as advantageous behavioral strategy in human evolution, since increased nutrient intake helped to survive periods of food shortage. This strategy has persisted, it has been transmited from one to the next generation, its traces may be seen even in modern society. There are generations which have experienced one or two world wars accompanied with hunger and starvation. Adults had the tendency to rear next generation in the conviction that energetic reserves through increased food intake may be useful. This behavioral strategy documents its cultural roots.

Opposite educational strategy restricts quantity of meals in the effort to prevent over-weight and to struggle with possible obesity of the child. However, the overrestrictive strategy may paradoxically contribute to positive energy balance by negative impact on the development of child's ability to regulate food intake independently and to become responsible for his eating régime. This point is important namely in older children (Epstein *et al.*, 1994). Excessive preoccupation with food may support elevation of food motivation, consequently it increases body weight (Ray & Klesges, 1993).

Unfavorable education strategy also may appear in parents who deside not to restrict child's eating behavior and food choice. They suppose it would be sufficient if they provide him with money and they leave the decission what to eat on him.

7.3.3. Attitudes of Mother to Child's Obesity

More attention has been paid to attitudes of mother to the obese child when compared with that of father. Mother is supposed to be the predictor of child's overweight, of the success or failure of the prevention or the therapy (Arluk *et al.*, 2003). Correlation between body weight of mother and child was revealed (Lumeng, 2003; Whitaker *et al.*, 1997). In the prospective study on Danish children the odds of overweight increased if mother was not aware of the preference for sweets in her child. The risk of obesity further increased, if mother has also the habit of eating more sweets and if she spent more money in purchasing them (Lissau & Sorenson, 1993). On the other hand, reduction of food intake may have negative impact on the child. Practicizing high restraint in girl 5-years old resulted in higher food intake at the age 7-9 years.

Many data were obtained by studying the ability of mothers to rate body size and body weight. Obese mothers were found to be unable to perceive small child as strong, their ability increased with child's age. From the study of Jackson *et al.* (1990) it appeared that 72 % mothers were accurate in their estimation of child's weight status, 17% under-estimated children's weight. Mothers with high BMI had the tendency to underestimate weight of their children, while mothers with low BMI were more likely to evaluate their children as being "overweight" than "about the right weight" or "underweight" (Maynard *et al.*, 2003).

The ability of accurate estimation of child's body by mothers depends on more factors. One of the factors is the education of mother (Baughcum *et al.*, 2000). Mothers of lower income groups described sometimes the preschoolers with less negative connotation. They were satisfied with the child which was playful, happy and had good appetite (Jain *et al.*, 2001).

Attitudes of mother to body weight of children are gender-dependent. They are more critical towards overweight girls than to that in boys.They have the tendency to overestimate weight of girls and they are able to detect it sooner than of boys. Correct estimation of body weight of girls is easier because they mature faster than boys and they are perceived as more strong. Maynard *et al.* (2003) argued, that difference in sociocultural standards for acceptable body size determines mother's attitude to body weight of the child. Research studies demonstrated cultural difference in mother's evaluation of body shape of her child (Hill & Pallin 1998; Hodges 2003).

7.3.4. Influences of Mental Problems of Mother on Child's Body Weight

Many researchers discussed the question whether mental condition of mother could influence the development of obesity and behavioral disturbances of her child (Epstein *et al.*, 1987, 1996). It has been accepted, that psychopathology of mother (but also of father) predicts psychological problems of child. Mental state of mother predicts also success or failure of the therapy of obesity (Epstein *et al.*, 1987). Burdette *et al.* (2003) studied interactions among obesity, depression, time spent in television viewing and their consequences on 3-4 years old children. Obese and depressive mother spent 50mins. more by watching TV when compared with mentally health and normal-weight mothers. From the studied sample of children it appeared that 42% of their mothers were both obese and depressive, 30% were depressive and 29% were only obese. The authors suggested that depressive mothers my have decreased cognitive level and lower moti-vation to educate and to solve problems of their children. Mentally healthy mothers may provide child with more stimuli suppporting his cognitive development and promoting his physical activity.

7.3.5. Summary

Parents play the key role in child nutrition and way of life. It manifests itself in family traditions of preparing and serving meals, in time spent in physical and/or mental activities. Among other factors body weight of father and mother, attitudes towards obesity and their educational style may contribute to body weight of the child. More attention deserves personality of mother. Her health difficulties and obesity- related mental problems negatively influence child rearing, organization of its activities, stimulation of physical and cognitive development.

7.4. PERSONALITY AND BEHAVIORAL DISTURBANCES IN OBESE CHILDREN

One of the keys to the personality of the child and to behavioral problems linked with overweight is in understanding his attitudes to himself and to the world in which he lives. It is important to know how the child perceives his body, physical properties, appearance, how he evaluates his cognitive abilities, physical fitness, and how he is able to communicate with the social environment. His self-confidence, and the ability to cope with stress may affect the response to overweight and the tolerance of negative influences from the environment. The attitudes to himsef, perception of different domains of his personality have been described using terms such as self-concept, self-worth, self-estimation, self-evaluation, self-adequacy, self-image, self-meaning, *etc*. These terms refer to most various domains of personality dealing with the Self as a base of self-efficacy. The range of terms expressing various, sometimes identical characteristics of the personality indicates the complexity of behavior, but also vagueness and inconsistency in using these concepts (Bailey, 2003). Nevertheless, many behavioral studies of obese children and adolescents have indicated possible risks of unfavorable behavioral accompaniment and/or the consequences of overweight.

7.4.1. Self-Concept, Self-Esteem, Self-Evaluation

The concept of the Self and terms like self-esteem and self-evaluation express important characteristics of child's personality. They may be good predictors of mental problems of obese adult and adolescent subjects (Allgood- Merten & Stockard, 1991). The self-concept has been used more often in association with physical appearance and motor activity than with cognitive part of child's personality and sociability. It develops from the early age in the interactions with the environment. Davison and Birch (2002) reported negative self-evaluation already in five-years-old girls. The child creates the image of himself in the process of contacts and perceiving external world (Harter, 1993). The satisfaction of the own's body gives the basis to the self-concept. According to several authors absence of this satisfaction is responsible for behavioral disturbance (Hill *et al.*, 1994). Many studies have demonstrated the association between lower or negative self-evaluation and body weight both in boys and girls (Braet & VanStrien, 1997; French *et al.*, 1996; Friedlander *et al.*, 2003, Keel 2001 and others). Some research studies failed to reveal correlation between self-esteem, self-evaluation and body weight (Hill & Silver 1995; Klesges *et al.*, 1992). In adolescents self-concept and feeling of shame related to body size did not correlate (Bornholt *et* *al.*, 2005). Gender difference were revealed in self-evaluation. While in boys low self-evaluation was associated with the idea they were too slim, in girls it was connected with adiposity (Pierce & Wardle, 1993). Age proved to be the important independent variable. Both overweight boys and girls displayed low level of self-evaluation at the age of 10 -11 years when compared with that of normal-weight children, but in older boys (14-15 years) difference between normal and overweight boys disappeared, but not between normal-weight and overweight girls (Fraňková *et al.*, 2013).

Consequences of negative self-concept (regardless the term used by different authors) manifest themselves in many areas of mental state and behavior :

- in the ability to cope with difficulties resulting from health complications associated with overweight,
- in lower ability to cope with negative experience and with minor failures, that don't mean serious problems for healthy children with normal weight,
- in the lack of ability to overcome negative attitudes of peers,
- in the disturbed cognitive, emotional and social development.

Certain studies have indicated that higher incidence in consumption of alcohol and in drug abuses. Smoking and deliquency have appeared more often in children with low self-evaluation (Wang & Veugelers, 2008). Differences in opinions on personality of obese children may be influenced by the concept of the self (Bailey, 2003). Certain consent was reached in regarding the self-concept and self-evaluation as being the intrapsychic results, representations of extrapsychic influences, and in their accent on the multidimensionality of the term self-concept (Harter & Baumeister, 1993; Marsh, 1990). From large body of studies it has appeared that the self-concept may cover dimensions:

- physical appearance, satisfaction with the own's body weight (Bornholt *et al.*, 2005),
- global view of the child on himself (Kimm *et al.*, 1991; Pierce & Wardle,1993; Strauss *et al.*, 1985),
- evaluation of physical and mental abilities by the child,
- perception of physical appearance as a result of social impacts (Marsh, 1990),
- quality of life in association with health status (Friedlander *et al.*, 2003).

This classification may be helpful in the analysis of personality of obese child, since not all domains of personality may be associated with obesity. As an important preventive means, positive view on himself/herself was proposed. Effect of positive self-evaluation manifests itself in behavior patterns as well as in eating behavior later in life (Murnen & Smolak, 1996).

7.4.2. Cognitive Performance and Education of Obese Child and Adolescent

Intelligence, level of cognitive performance and success at school have been objects of many research programs. Low level of cognitive performance has been found in obese children both in cross-sectional and prospective studies (Braet & VanWinckel, 2000; Kanazawa, 2013) in conventional tests of intelligence, *e.g.* in Wechsler Intelligence test (Campos *et al.*, 1996).

Cognitive performance has been connected with school performance and with the level of education. Results of researches realized in different countries on large population samples give almost uniform evidence on the disadvantage of obese children and adolescents (Datar *et al.*, 2004; Lissau & Sorensen, 1993; Mikkilä *et al.*, 2003; Puhl & Latner, 2007; Taras & Potts-Datema, 2005; Teasdale *et al.*, 1992). Overweight children were found to be worse in math, reading (Datar *et al.*, 2004), gymnastics, general knowledge, foreign languages (Li, 1995). Reduced motor, verbal, cognitive, and social skills were found in obese preschool (Cawley & Spiess, 2008) and school children (Mond *et al.*, 2007). Contrary to the finding on worse school performance, no association between obesity and classroom failure was also reported (Tershakovec *et al.*, 1994). Obesity influenced negatively college admission (Canning & Mayer, 1966). Relations among obesity, intelligence and school performance are not simple. Intelligence can't be the absolute predictor of good results at school. Some children (regardless their body weight) may have pronounced special interests, *e.g.* in arts, sport, architecture, history *etc*. School is boring for them or it is underestimated, or simply they have not time enough to study all subjects. In adulthood, many men and women obese as children or adolescents become excellent scientists, artists, doctors, attorneys *etc*. Independet variables which could confound school achievements are most divers, such as:

- ***Personality characteristics and health conditions***. Of various reasons, obese child may have lowered motivation to learn. Higher fatigueness of obese children may decrease their attention span and concentration on the subject for longer time. Obese adolescents may miss school days because of being ill more often than the general population (Schwimmer *et al.*, 2003). At school, obese children may suffer from examination fever, they are affraid of misconduct and blaming as the consequence of negative attitudes of peers toward them.

- Family influences. Recent studies try to control family factors and to eliminate some of them. Some were neglected despite they may influence school performance, like worse economic situation, lack of money for books, worse nutrition, but also lack of time to help the child with learning, less cognitive stimulation, loss of interest in school achievements of the child, *etc*.

- Age factors. Worse results reported studies, in which obesity was diagnosed at early age. It is difficult to compare findings of research studies performed in children of different age, with different life history, duration of increased body weight, actual dietary régime, *etc*. Wang and Veugelers (2008) argued, that by excluding confounding factors, association between obesity and intelligencee disappeared.

7.4.3. Psychological Problems Associated with Physical Activity

From biological and evolutional points of view, physical activity represents one of the most important self-preservation mechanism operating from the beginning of postnatal life. It serves to insure both intake of vital nutrients and security. Be means of physical activity the infant acquires motor skills, experiences, knowledge of physical characteristics of objects in its surroundings, it enlarges its living space, he gains stimuli supporting the development of cognitive processes as well as the ability to communicate actively with the environment. Normal, physically and mentally healthy child is highly movable, he has need for physical activity; sometimes it gives he problem, how to keep him quiet.

This evolutionary proved strategy fails in modern society, which rather suppress than stimulates physical activity, instead it provides many ways how to eliminate it. The opportunity for sedentary way of life is supported. This behavior pattern is comfortable, it does not require either physical or mental efforts. Virtual situations enabled by social networks, Internet games, and mobile phones replace natural social contacts with peers in collective games, competitions, sporting activities. Spontaneous physical activity in normal natural and social environment is compensated by organized physical education at school, by preventive and therapeutical programs outside school aimed to increase physical fitness. They are effective only if they are long term and children are motivated enough to cooperate (see Pařízková, this book).

Many research programs have studied various forms of physical activity and exercise that may be effective in developing harmonic personality. They contribute to better health, physical fitness and prevention of obesity. These programs are important because they have also relevant psychological consequences, such as:

- they support cognitive, emotional and social competences of the child,
- they teach the child to realize that physical activity is **normal** compound of the life. It must become the need, the **internal motivation** for physical activity, excercise, sport,
- physical activity,fitness contributes to general well-being, it enriches the life.

7.4.4. Dependence of Obese Child

Dependence and attachment to parents are characteristics in which difference between overweight and normal-weight children have been observed (Turner *et al.*, 2005). Already preschool overweigtht boys (not girls), aged 3-6 years, prefered games, walks and other activities under the presence of parent or other adult when compared with lean boys (Fraňková & Chudobová, 2000). Dependence on adults was found to be most striking characteristics of personality of preadolescent and adolescent boys (Fraňková *et al.*, 2013). Separation of young children from near persons may result in anxiety, even in social phobias. It appears more often in obese children than in normal-weight ones (Isnard-Mugnier *et al.*, 1993). Dependence and fear of separation of obese children deserve more attention since they may predispose them for serious behavioral problems even later in life.

7.4.5. Summary

Research studies on child obesity have been performed most often on large population sample. They have contributed with valuable, generally acceptable findings, supported by careful statistical analyses. However,they are not able to explain all influences on individual overweight child and formation of his personality.The relationship between obesity and child's personality is two way: on the one side, overweight affects body shape, emotional experience, physical and mental performances *etc*., on the other side, specific characteristics of the individual obese child determines the way of coping with stress of being fat,of the ability to overwhelm negative influence from the environment (see 7.4) and they help him to increase self-confidence and the quality of his life.

7.5. DISTURBANCES OF BEHAVIOR IN OVERWEIGHT CHILD AND ADOLESCENT

No exact boundaries exist between unusual behavior which is not yet considered as pathological and of that where real psychopathological symptomatology appeared. It is not clear whether normal-weight and obese children share the same behavioral problems, or whether there are disturbances that characterize obese population of children and adolescents and/or whether differences between normal-weight and obese subjects exist in the intensity of behavioral displays classified as psychopathological.

First fundamental clinical experience with behavioral disturbances of obese children reported Bruch (Bruch & Touraine,1940). Recently, large number of studies has demonstrated behavioral problems which appeared in obese children. Some of them were found even in youg children. In preschool overweight Australian children teachers observed more behavioral disturbances than in normal-weight peers (Sawyer *et al.*, 2006). Another study did not find association between behavioral problems and obesity at the age of 5 years, but at the age of 14 the overweight girls had more than twice the odds of disturbances when compared with the normal weight ones (Lawlord *et al.*, 2005).

In obese children and adolescents, many studies have reported decreased self-worth, low self-esteem, depression, anxiosity, loneliness, disturbed interpersonal contacts, worse success in professional life, lower financial evaluation, lesser sexual partners, lesser marriage *etc*. (Anderson *et al.*, 2006; Beane & Lipka, 1983;

French *et al.*, 1996; Harter & Baumeister, 1993; Mendelson & White, 1982; Pine *et al.*, 2001; Puhl & Latner, 2007; Strauss & Pollack, 2003). Certain behavioral problems deserve more attention.

7.5.1. Depression, Anxiosity

Depression has been most often discussed in connection with obesity in children and adolescents (Goodman & Whitaker, 2002; Pervanidou & Chrousos, 2011; Pine *et al.*, 1997; Pine *et al.*, 2001). Great part of behavioral displays of obese child and adolescents was described as depression. Typical symptoms of depression manifest themselves as sadness, loneliness, pessimism, suicidal thougths or even attempts to commit suicide,and hostility. (Weinberg *et al.*, 1973). Several studies revealed association between children's obesity and depression associated with lower self-esteem (Sheslow *et al.*, 1993; Wang & Neugelers, 2008), however, other studies did not confirm these findings (Renman *et al.*, 1999). Different forms of social stigmatizing such as bullying (see below) may also be the cause of children's depression (Puhl & Latner, 2007), with the consequences like separation from peers, fear of school, loss of interest in any form of physical activity. Sjøberg *et al.* (2005) reported stigmatizing in subjects 15-17 years old as feeling of shame.

Symptoms of depression in children and adolescents were revealed by means of Rohner's Personality Assessment Questionnaire PAQ (Rohner *et al.*, 1978). In obese girls 13-15 years old high score was found in emotional lability and in responses expressing pesimistic, negative world view. In boys neither pessimism nor greater emotional lability appeared in their responses (Fraňková *et al.*, 2013).

Ontogenetic factors seem to be important in the association with childhood depression and adult BMI (Pine *et al.*, 2001). Higher BMI displayed subjects in which depression appeared at an early age (Anderson *et al.*, 2006). Thinking about the causality of the link between early children's behavior and depression, Goodman and Whitaker (2002) argued that depression predicted obesity but there was no evidence for obesity predicting depression. The causes and displays of depression are in many respects different from those that appear in adults. Besides others, they depend on the level of mental deve-lopment and specificity of children's life and social conditions in which they grow. Problems may arise how to detect them at age when child is not yet able to express and to verbalize them (Krejčířová, 2001).

Clinical studies refer depression usually in connection with anxiosity (Vila *et al.*, 2004). Anxiosity, as one of the dominant behavioral problems of obese child may be associated with emotional overeating and loss of control over food intake (Goossens *et al.*, 2009). Emotional eating might help to cope with anxiety since it provides certain comfort from negative emotions (Pervanidou & Chrousos, 2011).

7.5.2. Aggression and Hostility

Many attention has been paid to aggressive behavior and hostility in overweight and obese children. Discussions have been held, whether obese child is more aggressive or rather submisive, whether he is more often aggressor or the victim and whether aggression really means pathological deviation from normal behavior. Aggression was defined as every activity aimed to harm or to injure (Johnson & Meddinus, 1965). Developmental psychologists argue that aggression is the integral part of developmental processes (Diamond, 1957), education has to regulate and to suppress overt manifestations of violent tendencies. Aggression in obese children may be the consequence of frustration, reaction to hostile environment and to various traumatic events.

7.5.3. Summary

In obese children symptoms of disturbed behavior have been observed from mild deviations to relevant pathological displays.The onset of some behavioral problems may be detected as early as at preschool age. Depression as most striking behavioral problem of obese children has been reported, the symptoms being age-dependent, they may manifest themselves by different means in young children than in schoolers and adolescents. As reported, negative attitudes to peers and to the environment, fear of the life and of the world as well as depression may precede more serious behavioral disturbances in adult age.There are doubts whether disturbed behavior appears more often also in obese, not clinically treated children when compared with peers of normal weight.

7.6. PSYCHOSOCIAL FACTORS PARTICIPATING IN BEHAVIORAL PROBLEMS OF OBESE CHILD AND ADOLESCENT

The child adopts opinions of adults and peers concerning his behavior and appearance. In his response to the perceived attitudes he behaves so to strenght the feedbacks and stereotypes from the environment. He reacts according to his feelings, these feelings are fixed and internalized. Obese children are more sensitive to negative attitudes of other persons than normal weight ones (Neumark-Sztainer *et al.*, 2002).

7.6.1. Attitudes of Peers to Obese Child and Adolescent

For psychosocial life and well being, opinions of the other children are most important. Attitudes of peers to obese children are referred almost uniformly as being negative. Their aim is to degradate the overweight individual. They appear already among preschool children.The overweight peers are described as being lazy, stupid, uggly *etc*. (Staffieri, 1967). The attitudes of peers to overweight children were studied experimentally using the description of pictures, photos, models of children with different body size, from lean to obese ones. The 3-4 years-old children were not yeat able to use terms like obese or overweight, however, they described picture of a lean child as “small” and “big” of the obese model, despite their height was identical (Fraňková & Chudobová, 2000). When girls and boys five-years- old evaluated the models of lean and obese children of the same or opposite gender, they used negative expression for the model respresenting obese girl or boy and they told they would never choose them as friends (Fraňková *et al.*, 2013). Similarly children and adolescent 8-16years old only seldom chose obese models as “the best friend” (Goldfield & Chrisler, 1995; Maddox *et al.*, 1968; Robinson, 2006; Strauss & Pollack, 2003).

Obese children were often reported as ones, excluded from social life. They suffer from isolation, they are rejected as partners in common activities, sports and exercise (Kraig & Keel, 2001; Latner & Stunkard, 2003; Neumark-Sztainer *et al.*, 2002; Puhl & Latner, 2007). Obesity related stigma may pass through adolescence and adulthood. It was reported, that obese individuals were less suitable for marriage partners (Vener *et al.*, 1982).

7.6.2. Teasing and Bullying Overweight Children

Teasing, makes jokes of some physiological or mental characteristics, clothes, and language, are common among adults as well as among normal-weight children; they don't take them as harmful. The adults tend to underestimate them if they appear towards overweight children. The risk of adverse response to teasing increases with age. Contrary to normal-weight children, the obese subjects are much more sensitive to teasing and they perecived them with greater intensity than normal- weight peers (Janssen *et al.*, 2004; Pearce *et al.*, 2002).

Increased body weight as marked physical handicap gives promising opportunity to various forms of peer aggression (Baum & Forehand, 1984; Pearce *et al.*, 2002). Studies of aggression toward obese children provided almost unambiguous results. Obese children are more often submitted to aggressive behavior from the peers (Janssen *et al.*, 2004; Goldfield *et al.*, 2002; Olweus, 1993).

Aggression and other forms of violence against other person are shared under common term "**bullying"**. Bullying appears also in normal- weight children and adolescents, however, obese children represent especially suitable target. Bullying exists irrespective of gender, race, socioeconomic status and other factors (Harrison, 2010; Lumeng, 2003). Lumeng (2003) found, that obese children were 1,6 times more often the victims of bullying when compared with children of normal weight; children with the risk of obesity were 1,1times more often bullied than the controls. Bullying has various intensity, duration, dynamics, sophistication, it may be direct as well as indirect (Olweus, 1978).

Physical bullying manifests itself often as physical attacks,torture, hitting, kicking, chasing and destruction of things (books,workbooks, cloths), violent enforcement of food or money. Physical form of bullying affects rather lower age groups. Small obese children used to be clumsy, they lack physical fitness, they try to avoid situations in which their deficit becomes evident and would gives the peers oportunity for bullying. They also try to avoid collective games and competitions despite these activities could help them to increase their ability of self-defense and self-confidence. In older obese boys their increased body size may elicit rather respect, therefore the peers use other forms of bullying. On the contrary, older obese boys become often aggressors than victims. In three age-groups of obese and normal-weight boys and girls, age and gender appeared to be the important factors in bullying (Janssen *et al.*, 2004).

Verbal bullying represents dangerous form of hurting obese children and adolescents. It appears as insults, threats, harassment, derogatory even vulgare nicknames, critics of the appearance, cloths, hair-do, personality, *etc*. Ridicule at the expense of body weight are most often form of bullying obese children (Eisenberg & Aalsma, 2005; Lagerspetz *et al.*, 1982; Pearce *et al.*, 2002; Sjøberg *et al.*, 2005).Verbal form of bullying appears already in preschoolers, it is often accompanied by nonverbal displays such as sneer, grimace, and parodying.

Relational bullying affects children and adolescents of all age categories. It represents non directed, dangerous,captious form of making harm. It manifests itself as spreading rumors, lies. It is difficult to fight back, since the perpetrator is unknown. Recently, new form- ***cyberbullying*** has appeared, such as threats, harassment, extortion, black mailing and other attacks by means of Internet, sending e-mail messages, SMS notices, photos with intimate content, messages on social net works, *etc*. Usually, cyberbullying is not exhausted by one attack, it spreads very rapidly, it hits the child's on most sensitive place. It is not possible to prevent and to preclude cyberbullying because the sender can't be identified.

Sexual bullying does not belong to typical form of bullying obese subjects. Janssen *et al.* (2004) reported somewhat higher incidence of sexual bullying in overweight and obese groups when compared with normal-weight subjects, including making sexual jokes, comments, or gestures toward others, however, intergroup difference was not significant.

Despite the form, consequences of bullying may be unfavorable, even tragic. In victims various behavioral disturbances were observed such as depression, loneliness, mood disorders, powerlessness, suicidal attempts, isolation, negative attitudes towards school, peers, avoidance of social contacts and communication, decreased self-worth, psycho-somatic disturbances *etc*. (Storch *et al.*, 2007). Attemps have been reported to prevent consequence of bullying (Olweus, 1993; Vemberg & Biggs, 2010). It was reported that cognitive stimulation of 4- years old child may protect unfavorable response to bullying at the age 6-11 years (Zimmerman *et al.*, 2005). Family and school may contribute to the prevention of bullying by talking about and explaining its danger.

7.6.3. Summary

From the range of psychosocial factors shaping formation of personality of obese child, adverse attitudes of peers deserve attention. Their negative comments on body weight of the obese child could contribute to behavioral disturbances such as depression, anxiety, loss of self-confidence, fear of being ridiculed. Obese childs are often target of aggression and of various forms of bullying. Negative stereotypes and prejudices concerning abilities and qualities of the obese children result in excluding them from games and parties. Teasing concerning overweight may result in dieting, restricting food intake and to disturbed health. All these factors may lead to the withdrawn of obese children from social life and they may result in negative attitudes towards the environment, people,and world.

7.7. METHODICAL COMMENTS ON BEHAVIORAL STUDIES OF OBESE CHILDREN AND ADOLESCENTS

Associations between child's obesity and behavior are extremely complex, being codetermined by many independent variables, only some of them may be predicted and controled. They influence mehods and interpretation of research data. The extensive research has contributed to the insight into behavioral problems of the obese child in respect to the society and, peers and adults, as well as to himself. Quality of research projects and methods used in the study of behavior of obese child may influence validity and reliability of findings. Many methodical problems are still open for discussion, such as:cross-sectional *versus* longitudinal projects,materials, selection of the research sample,ontogenetic, age factors,population based *vs.* individual approach, *etc*.

Selection of research sample may be the important source of inconsistent findings. Different results were reported when compared clinical and nonclinical samples, mentally health *vs.* children medically treated for accompanying physical or mental problems. Recent studies try to eliminate these confounding variables. Better control of psycho-social, cultural, economic, nutritional and other factors increases their value.

Prospective research plans are of great value, since they cover longer life trajectory as the consequence of early impacts. However, the 20th century, especially last 30 years have brought great changes in nutrition, social, economic, even in political system in many countries (namely in so-called postcommunist countries). The life style has been changed, necessity of physical work decreased, the time spent in sedentary employment has increased. The ways of preparing and consuming meals tend to purchase ready-to eat foods; ways of serving meals in the "fast food" restaurant change social function of food. Time spent in common family meals declined, children are prematurely dependent on the own's food choice, the amount of consumed food is not controled.

Ontogeny and age factors contribute to problems with interpretation of the findings dealing with behavioral problems in obese child and adolescent. Some studies covered great age range, differences were in the onset and duration of obesity, age of the apearance of disturbed behavior, they combined results of boys and girls despite gender differences in timing of physical and mental maturation. Discussions have been conducted about what was cause and what was the result, whether firstly mental health was disturbed and obesity followed or *vice versa*, whether obesity predicted later behavioral problems. As argued, deeper behavioral problems appeared when overweight or disturbed behavior appeared in early ontogeny (Mills & Andrianopoulos, 1993).

Findings on behavioral disturbances as the consequence of obesity should be treated with certain caution. Not all obese children suffer of depression and other behavioral problems and not every depression results in obesity. Certain controlled population-based study did not reveal behavioral differences between obese and normal-weight subjects (Renman *et al.*, 1999). In one research program (Dreyfus, 1993), 25% obese children were found without behavioral problems, in 58% no severe personality disorders appeared, 15% displayed some disturbances and 2% had psychotic symptoms.

Research on behavior of obese children and adolescents has been based on extensive population samples. Statistically significant correlation between obesity and the large scale of behavioral disturbances has been demonstrated, however it could not reveal always problems of the concrete, individual child. Already Williams (1956) observed enormous differences in various biochemical characteristics in adult subjects. Widdowson (1962) defined "nutritional individuality" according food preferences, metabolism, utilization of nutrients. Lát (1967) demonstrated individual, genetically determined differences in preferences for basal nutrients in experimental animals. It was also found, that behavioral responses to the change in food composition depended on genetic difference in central nervous activity (the "excitability") of laboratory rats (Fraňková, 1966). Pařízková (2012) demonstrated individual difference in the effect of physical activity and exercise on children. Lesser attention has been paid so far to individuality of obese child and adolescent in their responses to obesity and the odds of possible behavioral problems as the consequence of being overweight. From both theoretical and practical reasons it would be important to reveal, what is specific for a given obese child, where are sources of his difficulties and which therapeutical and educational means have to be used. This raises the need to initiate more studies concentrated on the personality than on population.

If the statements concerning behavioral pathology in overweight and obese children and youth would be valid in the situation of increasing prevalence of obesity in children and adolescents, it would represent great threat for the quality of life of both contemporary and namely next generations. Fortunatelly, many overweight children are well being, mentally healthy, self-confident and well adapted. This raises the need for further detailed studies of the development of personality of children and the prevence of negative or harmful influences from the environment.

7.8. SUMMARY STATEMENT - CONCLUSIONS

Empirical observations, experimental studies as well as clinical experience have demonstated complex relations in the effects of nutrition, activity and physical fitness on the development of organism, structural and functional changes due to overnutrition. Early age is important as the critical period in which individual long-term physiological and behavioral characteristics and personality are formed. Responses to internal and external stimuli shape the personality of the child. This chapter reviewed some of the influences of nutrition on growing child as the part of complex biological and psychosocial environment.

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CHAPTER 8

Conclusions, Perspectives and Recommendations

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Adequate balance between energy intake and expenditure is one of the conditions of an optimal somatic growth, body composition, adiposity and physical fitness resulting also in a desirable health status and its positive prognosis for later life. "Health of children is the key to health of the whole population" (WHO 2010a,b,c, 2011, 2013). As shown by previously mentioned chapters, favourable factors influencíng the growing organism should start to be applied in optimal mutual relationship since the very beginning of life including fetal period. This has been revealed not only by previous practical experience, but also by more numerous recent observations, and applies also to the energy balance and turnover resulting first of all from proper nutrition and physical activity régime (PA).

As proved by presented results, children adapted to exercise who are more skillfull, fit and less burdened with superflous fat are usually more interested and willing to continue with higher level of PA and exercise later in their life. Adaptation to higher PA since childhood is at present recommended as one of the most important factors for the prevention and treatment of obesity and other diseases of civilization later in life, resulting from inactivity (WHO 2010a,b,c, 2011). Unfortunately, along with technological progress, life style includings edentarism and increased stress has been exported to most countries of the world.

Adaptation to proper regime of physical activity started as early as possible, however, very difficult under present environmental conditions, especially in larger urban agglomerations; development of "homo sedentarius" with all undesirable functional and health consequences is initiated at the very beginning of life. Nevertheless, active life must be promoted, as the results are worth of any effort - not only for the prevention of "diseases of civilisation", but also for the

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development of “positive health” - *i.e.* a higher level of physical and overall fitness, optimal lasting health and predisposition for active longevity. Previous chapters included results of many studies focusing attention and contributing to the solution of this urgent problem.

It is necessary to comment that this has been considered and applied in certain populations – however very rarely - during previous historical periods. Early beginning of the proper way of life including exercise and nutrition and starting with the pregnant mother and young child was defined already in the seventeenth century by the founder of pedagogics, John Amos Comenius (Schola infantiae, 1667). Much of his wisdom has not been accomplished yet, and moreover it seems that environment and lifestyle of the present civilization has been guaranteing the adherence to them even less than as it was not so long ago in our past. Then, the effects of past social media with regard to nutrition and PA might have been also more positive than at present.

Secular changes of the global prevalence of obesity, especially those started during early growth, emphasize the increasing importance of efficient early interventions so as to prevent accompanying negative health, economic, and further undesirable consequences. Morphological, clinical, nutritional, bio-chemical, hormonal, and psychological, *etc.* complications of obesity have been already followed up in greater detail – relatively more than the functional, motor and othopedic deviations resulting from excessive fatness. This was therefore more introduced in selected chapters of this monograph.

Even when in some populations this undesirable health deterioration accom-panying excess fatness seems to be reduced, present status is still threatening. In many countries the increase of obesity prevalence still continues, and also concerns subjects at a very young age. This in spite of the knowledge on long living populations who – *inter alia* – preserve high level of physical activity through the whole life, and especially in children (Benet 1996, Kozlov 1972 *etc.*). Some inspiration from the experiences of these populations should be worth to be still implemented.

However, it has been until present difficult to compare the results of individual studies on the relationship of PA to PF and health, due to the lack of homogenous approach - *i.e.* following and comparing groups with similar number of individuals, of identical age range, gender, level of sexual development, skeletal age, nutrition and dietary intake, using the same methodology and criteria, at least comparable morphological and functional parameters, period of measurements, *etc.* The same applies for secular changes and their comparison. Many studies have been partly similar and overlapping, but not identical and of the same character, Only general guidelines could have been therefore implemented at present.

During recent years, the studies concerning this particular topic have been increasing, but efficient treatment resulting in a permanently long lasting improvement of physical fitness along with adequate body composition and health status of the growing obese child, *under present environmental situation and possibilities* have not yet been defined – and therefore more attention should be paid to this problem also in the future. For the definition and elaboration of treatment and prevention of excess adiposity along with reducing physical fitness it is necessary – as follows from previous chapters - to consider age, gender, duration and degree of obesity, individual functional predipositions, possible adaptations, psychological traits, *etc.* Studies have been increasing continuously and it was too difficult to encompass them all until present. In this respect, it is indispensable even more to gain much more informations.

This depends, in addition, also on economic, social, cultural and other conditions, the changes of which are not within the reach of health and pedagogic specialists. However, *complex approach especially using exercise along with a monitored diet* which is not only *physiological but also economic* seems to be still the most usable and available approach, to prevent not only obesity, but also to achieve high level of overall fitness and “positive health”, as one of the most important aims of the whole society.

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SUBJECT INDEX