

eISBN: 978-1-60805-946-1

ISBN: 978-1-60805-947-8

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**

Edited by

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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.

Marie Françoise Rolland-Cachera

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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 satisfactorily 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 development of this important topic.

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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.

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 proportionality.

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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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 pointed 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

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 reactivity¹ 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 $^2\text{H}_2$, 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 $^2\text{H}_2$ 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).

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 14th 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 triiodothyronin T3. Some authors demonstrated BAT also in the healthy adult humans (Cypess *et al.*, 2009, Virtanen *et al.*, 2009).

The differentiation of the multipotential 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 released from CNS, catecholamines, growth factors as growth hormone, and IGF-1 insulin, glucagon and others influence the activity of AT.

Thyroid Hormones (TH) and Thyrotrophin 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 patients and

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 countries; 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 Development

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 ("Barker's 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

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 epidemic 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 sedentarism 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 reaction 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 following 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 epidemic 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 (inadequate 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

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 characteristics 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 consequences 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

Attitudes 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 dif-

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 influencing 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 guaranteeing 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, biochemical, hormonal, and psychological, *etc.* complications of obesity have been already followed up in greater detail – relatively more than the functional, motor and orthopedic 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 accompanying 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 predispositions, 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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