„Growing Up" and the Environment

Wzrastanie i środowisko

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Abstract

Many factors in the natural, man-made and social environments can influence the physical growth and maturation and behavioral development of children and adolescents. Improved environmental conditions over the past century or so have contributed to positive secular changes in growth and maturation. More recently, however, technological advances have increased opportunities for sedentary behaviors and contributed to reductions in physical activity, both of which have potentially negative implications for the health of youth. Pollutants associa-ted with some industries also have implications for health. Children with elevated lead levels are at increased risk for impaired growth and maturation and for impairments in fine motor coordination. The impact of elevated lead on gross motor coordination in several tests of physical fitness is mediated through the influence of lead on growth in body size. Similarly, emissions from coal-fired power plants and other industries are associated with asthma, which has implications for the physical activity and fitness of youth.

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Streszczenie

Wiele czynników środowiskowych naturalnych, wytworzonych przez człowieka oraz społecznych może wpływać na na rozwój fizyczny, dojrzewanie i rozwój behawioralny, tj. zachowania się dzieci i młodzieży. Polepszenie warunków środowiskowych w ostatnim stuleciu przyczyniło się do pozytywnych sekularnych zmian we wzroście i dojrzewaniu.

Ostatnio jednak postęp technologiczny wzmógł łatwość zachowań sedentarnych i przyczynił się do zmniejszenia aktywności fizycznej, co potencjalnie niesie negatywne skutki dla zdrowia młodzieży. Zanieczyszczenia przemysłowe mają również wpływ na zdrowie. Dzieci z podwyższonym poziomem ołowiu w krwi mają podwyższone ryzyko zaburzenia wzrostu i dojrzewania, a także uszkodzenia koordynacji motorycznej. Wpływ podwyższonego poziomu ołowiu we krwi na powstawanie zaburzeń motorycznych jest badany za pomocą wielu testów sprawności fizycznej, jest wyrażony przez wpływ ołowiu na wzrost i wielkość ciała.

Podobnie emisje zanieczyszczeń z elektrowni węglowych i innych zakładów przemysłowych są związane z astmą, co ma również wpływ na aktywność fizyczną i sprawność młodzieży.

Słowa kluczowe: wzrastanie, dojrzewanie, ołów, koordynacja motoryczna, astma, aktywność fizyczna

„Growing Up"

„Growing up" is the universal business of infants, children and adolescents throughout the world. It includes three interrelated processes: growth, maturation and development [1]. The first two are biological while the third is behavioral. The processes occur simultaneously and interact, and are influenced by the environments in which individuals grow, mature and develop – the natural, man-made and social.

The importance of prenatal and early postnatal conditions for subsequent growth, maturation and development, and adult health cannot be overemphasized, but discussion is beyond the scope of this review. Research into these associations has spawned the developmental origins hypothesis for adult disease [2–4],

Growth refers to the increase in the size of the body as a whole and its parts. As children grow, size increases, physique and body composition change, and different parts of the body grow at different rates and times resulting in changes in proportions. Changes also occur in specific organs and related structures. Heart mass and volume follow a growth pattern like that for body weight, while the lungs and lung functions follow a growth pattern like that for height.

Maturation refers to progress towards the biologically mature state, an operational concept as maturity varies with body systems. All tissues, organs and systems mature. Skeletal and sexual maturation are used most often. Parameters of the growth curve in height are also used to estimate the timing of the adolescent growth spurt. Maturation varies in timing (when) and tempo (rate) among individuals.

Development refers to learning behaviors expected by society and are culture-specific. Children and adolescents develop cognitively, socially, morally and emotionally through life experiences at home, school, church, sports, recreation and other community activities. They are learning to behave in a culturally appropriate manner. The development of competence in movement skills (motor development), the acquisition and refinement of skillful performance in a variety of movement activities, is an important dimension of development that cuts across the biological and behavioral domains. Movement is the substrate of physical activity that has implications for health and physical fitness.

Physical growth, biological maturation and behavioral development occur simultaneously and interact during approximately the first two decades of postnatal life. The interval from birth to young adulthood is commonly partitioned into infancy, childhood and adolescence, and the demands of each process vary with chronological age. Infancy comprises the first year and is followed by childhood, which is often viewed in terms of early and middle phases which approximate the preschool and elementary school years. Adolescence is more difficult to pinpoint in time given inter-individual variability in age at onset, rate of progress and termination. Interactions among growth, maturation and development have the potential to influence self-concept, self-esteem, body image and perceived competence during childhood and adolescence. The interactions vary within and among individuals, especially during sexual maturation and the adolescent growth spurt.

The Environments of Man

Children grow up in different environments. The term environment, however, means different things to different people and academic disciplines. For convenience, the environment, or more appropriately, environments, can be viewed from a threefold perspective: the natural, the man-made and the human environments. Although somewhat arbitrary, the partition highlights different dimensions of a complex term.

Natural environments are reasonably obvious – climate, topography, altitude. These have been perhaps most important in shaping the evolution of the human species prior to the advent of agriculture – a significant man-made environmental modification.

Man-made environments are those associated with human activities, beginning with hunting and gathering during our evolutionary history, the beginnings of agriculture and associated environmental modifications, the origins of cities and in turn urban-rural contrasts, and quite recently in our evolutionary history, industrial and technological developments. Environmental and dietary modifications associated with agriculture and domestication did not occur without complications, or more specifically potential new stresses. These included threat of periodic crop failures and dietary deficiencies (nutritional stress), dependency on others for food production, problems associated with the removal of human and animal wastes (especially animal-borne diseases via the bowel-to-mouth route), population movement after crop failure or when productivity of soil declined, and infectious diseases. More specifically, progress in agriculture and domestication of plants and animals resulted in population size that approached numbers sufficiently large to maintain infectious diseases at endemic levels [5]. Skeletal and dental evidence from several regions of the world generally suggest a temporal decline in health status associated with the transition to agriculture [6, 7]. The association between climatic conditions and infectious diseases was especially important, with malaria being perhaps the most significant effect. Malaria requires ideal environmental conditions (tropical temperatures, standing or stagnant water) for the interactions of man, malaria parasite and mosquito.

Of course, people do not live in a social vacuum; human environments (social/behavioral) play an important role – parents, family, siblings, play and school mates, peers, teachers and other adults, among others. *Human environments* obviously impact behavioral development in its many dimensions, of course within the constraints of the culture within which the individual is reared. Given recent technological progress, however, cultures are increasingly interconnected.

Nutrition, food-related behaviors and nutritional status are important outcomes of the human environment that have received and continue to receive considerable attention. Eating is a social behavior as individuals consume food (culturally determined and prepared), not nutrients (energy, protein, minerals, vitamins). In the not too distant past and currently in some parts of the developing world, focus was on nutritional adequacy and specifically energy and protein deficiencies among young children. More recently, however, focus has shifted to energy excess as manifest in the worldwide epidemic of overweight and obesity. An important corollary of the epidemic is increased opportunities for physical inactivity.

Purpose

This review provides an overview of the influence of several environmental factors on the physical growth and biological maturation of children and adolescents and on aspects of behavioral development that have implications for health and physical fitness – movement proficiency and physical activity. The influences are addressed in the context of selected aspects of the natural, man-made and human environments.

The Natural Environment: High Altitudes

Among natural environmental conditions, residence at extreme high altitude (>3000 meters) imposes several stressors which influence growth and maturation, including hypobaric hypoxia, low temperatures and relative humidity, high cosmic radiation, and in some instances limited nutritional resources [8]. Areas of the world where populations have lived at high altitudes for several thousands of years include Peru and Bolivia in South America (3200 to 4800 m), Nepal in Asia (3400 to 4100 m) and Ethiopia in Africa (3000 m). Studies of children in Peru, Bolivia and Nepal generally indicate shorter statures, lighter weights and later maturity compared to peers of the same age, sex and ethnic group resident at low altitudes or at sea level [9–11]. Reduced stature may be due in part to smaller size at birth; infants born at high altitude often experience intrauterine growth restriction. Variation among high altitude populations within the same region is also apparent. Aymara children living at 3800 to 4000 meters in Bolivia tend to be taller and heavier than Quechua Indian children living at a slightly higher altitude. Children resident at moderately high altitudes in Ethiopia, on the other hand, tend to be slightly taller and heavier, and advanced in skeletal maturity compared to children of the same age, sex and racial ancestry at lower altitudes. It has been suggested that this observation is due in part to lack of malaria at moderately high altitudes.

Reduced growth at high altitudes is causally associated with chronic hypoxia, the result of reduced oxygen partial pressure, but observations are confounded in part by extreme cold temperatures, limited nutritional resources and poor health conditions. These conditions are associated with reduced growth independent of altitude. The potentially confounding influence of marginal health and nutritional conditions are superimposed on or interact with the specific physiological effects of high altitudes [12]. The confounders are of special concern because most high altitude populations are located in less developed regions of the world and high altitudes are often associated with limited flora and fauna as food resources.

Man-Made Environments: Improved Health and Nutrition

Man-made environments and environmental alterations associated with human activities have been and continue to be increasingly important in the context of the growth, maturation and development of youth. Perhaps most relevant to the well-being of children and adolescents have been improvements in food availability and quality and in living conditions. Nutritional and living conditions vary considerably across the globe so that the growth status of children is accepted as an indicator of the health and well-being of a population [13-15]. The variation reflects, to some extent, inequalities in living conditions and access to and/or distribution of resources. Although causes of inequalities are rooted in social, economic and political complexities, health and nutrition in marginal populations typically suffer and are documented in the growth status of children born and reared in such conditions. Societal improvements, in turn, are reflected in positive secular trends, i. e., taller height and earlier maturation [13, 15–19].

The majority of studies showing positive secular changes in growth of children and adolescents have been done in Europe, Japan and the United States. Data for developing or lesser developed countries are not as extensive. Secular gains have occurred in heights of children from better-off socioeconomic circumstances within a country whereas secular improvements in children from lower socioeconomic strata have been minimal or negligible [17].

Insights into recent secular changes in less developed countries can be gleaned from studies of the growth status of indigenous school children and conditions in the state of Oaxaca in southern Mexico [20–22]. The state of Oaxaca has the highest number of indigenous residents in Mexico compared to other states. Heights of large samples of indigenous school children 6–14 years from four regions of Oaxaca measured in the 1970s and in 2007 were compared [23]. Secular gains in stature over 3.2 decades (assuming 1975 as the mid-point for the 1970s) were similar in boys and girls 6–9 years, 1.10 and 1.05 cm/decade, and slightly greater in boys and girls 10–14 years, 1.35 and 1.15 cm/decade. Although positive secular change in growth status has occurred, mean heights of indigenous school youth in 2007 approximated the 5th percentiles of United States reference data [23]. National reference data for Mexico are not available. Of interest, indigenous school children in the 1970s were, on average, shorter at all ages between 6 and 14 years compared to school youth in Mexico City in the 1920s, while indigenous school children in 2007 were, on average, generally similar in height to the school children in the 1920s.

The improved growth status of indigenous youth between the 1970s and 2007 reflects better health and nutritional conditions in indigenous communities of Oaxaca over 30–40 years [23]. Though improving, the growth status of indigenous children remains marginal compared to that of better off children in Mexico and other countries. This reflects the rankings of the state of Oaxaca on community-specific indices of nutritional status, marginalization and human development compared to other Mexican states [20–22].

An issue that has not been satisfactorily addressed is the potential role of lead (Pb) as a factor affecting the growth status of indigenous children in Oaxaca and perhaps other regions of Mexico (the influence of elevated blood lead on growth is discussed in the next section). Oaxaca has a long tradition of producing lead-glazed pottery and using the pottery for storage and cooking. Leaching of lead into foods stored or cooked in lead-glazed pottery is potentially a problem, but current data indicate considerable variation [24]. Of interest, the problem of lead poisoning associated with making pottery was noted in the 1870s [25]. Blood lead levels of school children in Oaxaca across time are not available, but elevated blood levels have been reported in adults [26] and school children [27] in Oaxaca. Among school children 8-10 years in the city of Oaxaca (not from pottery making families), mean blood lead level was 10.5 μg/dL while levels for individual children ranged between 1.3 and 35.5 μg/dL [27]. Growth status of the children was not considered, but family use of lead-glazed pottery, animal fat in cooking and family income accounted for 25% of the variance in blood lead levels.

In response to elevated blood lead levels and lead poisoning among children of immigrants from Oaxaca residing in California, detailed examinations of sources of lead was undertaken [28, 29]. Initial observations suggested dried grasshoppers (*chapulines*), a food item regularly available in Oaxaca markets, as an important source. Levels of lead in samples of grasshoppers ranged from 3 to 2500 ppm [28]. In a subsequent study of food items among immigrants in the U.S. and of the region of Oaxaca from which they emigrated, lead was found in several foodstuffs, glazed cooking ware and mine wastes [29]. The region historically had a silver mine. An important factor facilitating transfer of lead into foods was use of a specific piece of lead-glazed cooking ware (*chirmolera*) for grinding spices that were not heated [29]. The cooking ware is a bowl for grinding spices (mortar and pestle); it has grooves cut into the bottom to facilitate grinding. Although limited to a single region of Oaxaca, the results highlight the need to expand studies of the potential role of lead in the growth and function of indigenous children. Recently, a program was instituted by the Mexican government that provides a lead-free glaze compound for pottery manufacturers, and it is apparently being adapted, perhaps because it is provided free of charge [30].

A related issue may be the use of lead-based folk remedies in the treatment of gastrointestinal problems (*empacho*) in Oaxaca and other regions of Mexico [31] and also among immigrants in the United States [32, 33]. *Curanderos* (folk healers) and *parteras* (midwife) „…believe that *empacho* is balls of food that are stuck in the stomach, with resulting cramps, bloating, etc." [32, p. 107]. Case studies of Mexican American infants and young children in the United States have been described [32, 33]. The infants were given two folk remedies that are almost entirely comprised of lead, *azarcon* (a bright orange powder) and greta (a yellow powder). *Greta* and *azarcon* contain up to 90%–100% lead oxide [34, 35]. Cautionary information for Hispanic and other immigrants on the use of these and other culture-specific practices associated with elevated blood lead in children is provided by the United States Centers for Disease Control and Prevention. In addition, refugee children often have elevated blood lead levels on arrival in the United States [36].

Man-Made Environments: Lead Pollution

More recent man-made environmental alterations, specifically environmental pollutants and toxicants associated with power generation and industry have major consequences for the growth, maturation and development of youth. Lead and lead compounds are common in the earth's crust, ~70 ppm [37] and are associated with power generation and several industrial processes. Lead and lead-compounds are well-known toxic agents to developing humans, contributing to growth retardation, delayed sexual maturation and neurobehavioral delays [38].

The Copper Basin in Southwestern Poland

The copper mine region in Lower Silesia, southwestern Poland, has major smelting and refinery facilities near Legnica and Głogów, the Copper Basin. Mines, plants and smelting works associated with the copper industry generate large amounts of industrial wastes and heavy metals, including lead. This has been a primary industrial activity for about two generations or more. Recent intensive environmental interventions have reduced emissions of harmful substances in areas with potential health hazards. Interventions were targeted to maximize health-related benefits for the population resident in or close to the industrial zones [39]. Observations from studies of the influence of elevated blood lead levels associated with industrial pollution in the Copper Basin on the growth, maturation and physical fitness of school children in the region are subsequently considered.

Lead and Growth

Elevated blood lead levels adversely affect prenatal growth [40, 41], but this has not been noted in all studies [42, 43]. A frequent finding among children is reduced length/stature in association with increased blood lead levels. Age at exposure, duration and season of exposure, and nutritional status are related to the degree of growth stunting, with younger, chronically exposed, undernourished children at greatest risk [44]. The stunting effect of blood lead on linear growth follows a dose-related pattern of reduction in height by about 1 to 3 cm for each 10.0 μg/dL increase in blood lead level (Table 1).

Table 1. Estimated decrements in height per 10 μg/dL blood lead levels in children
Tabela 1. Szacunkowe obniżenie wzrostu na 10 μg/dL poziomu ołowiu w krwi dzieci

Study	Age range	Stature decrement
Cincinnati Lead Study [100]	3 to 15 months	2.0 cm
Cincinnati Lead Study [101]	33 months	1.5 cm
Dallas Lead Project I [102]	1 to 10 years	1.6 cm
Dallas Lead Project II [103]	2 to 12 years	2.1 cm
Three Greek Cities [104]	6 to 9 years	0.9 cm
NHANES II [105]	1 to 7 years	1.2 cm
NHANES III [44]	1 to 7 years	1.6 cm
Lower Silesia, Poland [45]	7 to 14 years	3.1 cm
Unweighted Mean		2.5 cm

Reduced height was associated with elevated blood lead levels in school children of the Copper Basin observed in 1995 [45]. The negative effects of elevated blood lead were more apparent in growth of the extremities (arms, estimated leg length) than in growth of the trunk. Greater reductions in linear growth were observed at higher blood lead levels. The observations were consistent with experimental data suggesting a major influence of lead on linear bone growth, specifically proliferation of chondrocytes, hypertrophy and matrix calcification at the growth plates of long bones [46]. Other potential targets for lead are reduced osteoblast activity and bone remodeling [47].

Lead and Sexual Maturation

Information on the influence of elevated blood lead levels on indicators of biological maturation commonly used in growth studies is limited largely to age at menarche and to a lesser extent stages of puberty (breast and pubic hair development in girls, genital and pubic hair development in boys) using criteria described by Tanner [48]. Data relating blood lead to skeletal maturation, the only maturity indicator that spans childhood through adolescence, are apparently not available. Longitudinal data for height that span adolescence are required for estimates of the timing and magnitude of the adolescent growth spurt associated with elevated blood lead.

Blood lead levels 3 μg/dL were associated with later estimated attainment of stages of breast and pubic hair maturation in American girls from the Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III). Later attainment of stages of puberty was most apparent in American Black girls and to a lesser extent in Mexican American girls with 3.0 μg/dL of blood lead compared to those with 1.0 μg/dL. Later pubertal maturation was noted in American White girls with 3.0 μg/dL of blood lead, but the effect was not statistically significant [49]. Corresponding data for lead and sexual maturation of boys are limited to a prospective study of testicular volume and stages of pubic hair and genital maturation in Russian boys. Later onset of puberty was associated with blood lead levels $\geqslant 5.0$ μg/dL compared to boys with < 5.0 μg/dL in two separate analyses of the same data base [50, 51]. Another analysis of the data set considered maternal serum concentrations of PCBs and dioxin and noted inconclusive associations with pubertal onset in the boys [52].

Age at menarche is an indicator of maturational timing which occurs late in the sequence of pubertal events [1]. It occurs later in girls with elevated blood lead levels, but studies relating age at menarche to blood lead are limited to three, two analyses of the same national data set for American girls from NHANES III [49, 53] and one of American Indian girls [54]. The two analyses of NHANES III data have noted later menarche with elevated lead levels in American girls. In one analysis, menarche was later by approximately 3.6 months for each 1.0 μg/dL increase in levels of blood lead > 3.0 μg/dL [53]. In the other analysis, menarche was delayed by 3.6 months with blood lead concentrations above 3.0 μg/dL in African American girls, but the association between blood lead and later in menarche was not significant in American White and Mexican American girls with lead concentrations of above 3.0 μg/dL [49]. In contrast, menarche was delayed at blood lead levels > 0.5 μg/dL (geometric mean) among American Indian (Akwesasne Mohawk) girls [54]. This study was unique in that the analysis controlled for other pollutants (*p, p'*-DDE, HCB, mirex and mercury). In contrast to lead, four potentially estrogenic PCB congeners were associated with a higher probability of having attained menarche in this sample of American Indian girls [54], indicating earlier menarche with PCB exposure. Of relevance, the effects of blood lead on age at menarche may be influenced by other toxicants in the blood.

Menarcheal status and blood lead levels were considered in two surveys of school girls in the Copper Basin separated by 12 years, 1995 and 2007 [55]. Blood lead level and age at menarche declined, on average, over this interval (Table 2). Menstrual status (0 = no, 1 = yes) was the dependent variable in the logistic regression analysis for each year, while age, height (linear growth), BMI (weight-for-height), and lead group (binary variable, 0 = Pb $\leqslant 5.00$ and 1 = Pb $\geqslant 5.10$ μg/dL) were independent variables. The odds ratio for 1995 was not significant ($p < 0.48$) indicating that lead group did not affect the odds of a girl having attained menarche. The odds ratio for 2007 approached significance ($p = 0.057$) suggesting that increased blood lead was associated with later menarche (decreased odds of attaining menarche).

The major difference in the specific logistic regression analyses of the two years was in the contributions of BMI and blood lead to the probability of attaining menarche. The BMI was less important to attaining menarche in 2007 than in 1995, while the opposite was true for lead, which had a smaller effect in 1995 than in 2007. It may be possible that the influence of blood lead on menarche in 1995 was through its effect on weight-for-height (BMI). The decline in age at menarche between 1995 and 2007 may thus reflect attenuation of multiple environmental stressors in addition to blood lead level. It may

Table 2. Blood lead levels and ages at menarche in school girls resident in the Copper Basin in 1995 and 2007*

Tabela 2. Poziomy ołowiu w krwi i wiek menarche u dziewcząt szkolnych zamieszkałych w Zagłębiu Miedziowym w roku 1996 i 2007*

Year	N	Blood Lead Level, g/dL		Age at Menarche, years	
		Mean	SE	Median	SD
1995	436	6.57	0.13	14.36	1.16
2007	346	4.24	0.14	12.73	1.22

*Adapted from Sławińska et al. [55]

be possible that somewhat marginal nutritional and health conditions and unstable social and economic conditions in Poland in the 1980s and early 1990s masked the influence of lead on the process of sexual maturation in the 1995 sample so that a significant effect of lead on age at menarche was masked or diminished to statistically non-significant.

Observations for girls in the Copper Basin in 1995 beg the following question. Given the elevated blood lead levels in the sample, why was an association between lead levels and age at menarche not observed in 1995? The broad range of blood lead values (2.0–33.9 μg/dL) contributed to unusually wide 95% confidence intervals and in turn a non-significant association. A much larger sample size was likely needed for the influence of lead on menarcheal status to reach statistical significance.

Environmental and economic conditions of the 1980s (birth years of girls in the 1995) may be significant confounders in the relationship between blood lead and sexual maturation. The decade between 1978 and 1988 in Poland included political turmoil and eventual changes which had major economic and social consequences. National and regional surveys of the growth and maturation of Polish children and adolescents suggested unstable health and nutritional conditions in the 1970s and 1980s, i.e., prior to and during the turmoil associated with the fall of communism [56]. Inadequate nutrition as in regularity of meals, estimated intakes of specific nutrients and clinical symptoms of deficits was often noted in Poland in the 1970s, especially among children resident in rural areas and children of semiskilled manual workers [57].

Specific information on dietary calcium and iron (both of which are chemically similar to lead) in the villages surveyed in the Copper Basin during the 1980s and early 1990s is not available. Limited data indicated lower dietary intakes of calcium and iron than recommended in rural more so than urban adolescent Polish girls [58]. It is reasonable to assume that the trends apply to girls resident in the villages surveyed in the Copper Basin. Among adolescents and young adults 13–25 years in Glogów and Lubin in 1995, dietary calcium approximated only 45% and 62% of the norm, respectively, and intakes of females relative to the norms were lower than those of males of the same age [58]. Iron intakes of school girls in Glogów and Lubin in 1995 were, respectively, 64% and 75% of recommended; corresponding estimates for boys were higher than recommended. Estimated iron intakes for random samples of girls 11–15 years resident in villages throughout Poland were 79% of recommended in 1995, while for random samples of girls 11–18 years in several specific regions of Poland in the late 1990s varied between 62% and 67% of recommended values [58]. A synergistic interaction between lead and marginal nutritional conditions may explain the large but statistically not significant effect of elevated blood lead on menarche noted in the 1995 survey.

Differential effects of lead on linear growth and sexual maturation have also been suggested [53]. Height of the total sample of girls and boys in the 1995 survey decreased with increasing blood lead levels [45]. As noted, some experimental data have suggested an influence of lead on the proliferation of chondrocytes, hypertrophy and matrix calcification at the growth plates of long bones and in turn on linear bone growth [46]. Menarche, in contrast, is a single point in time and ages at menarche based on status quo surveys (as in the surveys in the Copper Basin) are sample estimates. Specific information dealing with the effects of elevated blood lead on neuroendocrine processes leading to delayed onset of menses is lacking. Marginal nutritional status and subpar calcium and iron intakes may be contributory factors masking the influence of elevated lead on menarcheal status. These effects may operate through socioeconomic status which is highly correlated with blood lead levels [44].

Improved health, nutritional and general living conditions, decreased environmental exposure to lead and socioeconomic conditions in the Copper Basin between 1995 and 2007 have contributed to a reduction in the age at menarche. It is difficult, however, to partition the secular decline in age at menarche from the decline in blood lead levels between 1995 and 2007. Comparisons of estimated ages at menarche in subsamples of girls with high ≥5.1 μg/dL) and low (≤5.0 μg/dL) levels of blood lead in 1995 and 2007, respectively, provide some insights (Table 3). The difference between estimated median ages at menarche for girls with high and low blood lead levels was 0.35 year in 1995 while that between estimated medians ages in 2007 was 0.69 year. The difference between estimates in 1995 was slightly greater than that noted in rural girls with inadequate and adequate nutrition in the 1970s, 0.2 year [59]. The secular decline between 1995 and 2007 was due in large part to a reduction in age at menarche in girls with low blood lead in 2007 compared to girls with low blood lead in 1995 (0.49 year), while the difference in ages at menarche in girls with high lead in both years was small (0.15 year).

lead concentrations in the air and sediment; blood lead levels of individual girls were not considered. Air contamination is only an indirect indicator of lead load in individuals.

Unfortunately, data on infiltration of lead and other toxicants into food crops and perhaps on the nutrient quality of crops were not available. Moreover, other potential toxicants in the blood were not considered. In addition to lead, age at menarche was sensitive to several polychlorinated biphenyl (PCBs) congeners in the sample of Akwesasne Mohawk girls described earlier [54]. The results highlight the need to expand future studies to include simultaneous analysis of other toxicants that may influence the process of sexual maturation.

Lead and Behavioral Development

Negative influences of blood lead on intellectual function were evident at levels <10.0 μg/dL [41,62–66]. Of interest, the United States Centers for Disease Control and Prevention recently stipulated 5 μg/dL blood lead for medical intervention in children [67]. Blood lead levels are also associated with impaired performances on tests of fine motor coordination and visual integration in children. Among 6 year old children, for example, elevated blood lead levels had a negative influence on visual-motor control, bilateral coordination, and upper limb speed of movement, dexterity and fine motor coordination [68], and on finger tapping speed [69]. Visual-motor integration, eye-hand coordination and spatial relations were reduced among 8–10 year old children with elevated blood lead [70]. Elevated dentin lead levels in deciduous teeth (i. e., in early childhood) were also associated with long term deficits in reduced finger tapping rate, poorer eye-hand coordination and slower reaction time at 18 years of age [71]. Thus, neurobehavioral effects of

Table 3. Estimated ages at menarche (years) in girls with low and high blood lead levels in 1995 and 2007*
Tabela 3. Szacunkowy wiek menarche (w latach) dziewczynek z niskim i wysokim poziomem ołowiu w krwi w latach 1995 i 2007*

Year	Blood Lead Level						Difference High – Low
	Low (≤5.0 μg/dL)			High (≥5.1 μg/dL)			
	N	Median	SD	N	Median	SD	
1995	133	13.10	1.00	303	13.45	1.19	+ 0.35 yrs
2007	250	12.61	1.27	96	13.30	1.10	+ 0.69 yrs
Difference 2007–1995		–0.49 yrs			–0.15 yrs		

*Adapted from Sławińska et al. [55]

An indicator of maturity status was not available for boys from the Copper Basin. It is reasonable to assume similar secular declines among boys seeing as blood lead levels also declined significantly in boys [60]. However, percentages of youth with blood lead levels ṛ6 μg/dL were higher in boys than girls in both years (1995, 77% vs 52%; 2007, 33% vs 17%).

Corresponding data considering the relationship between blood lead and age at menarche for other samples of Polish girls are limited. Urban Polish girls resident in areas with high and low lead pollution in the early 1990s did not differ in ages at menarche, 13.0 ± 1.0 and 13.1 ± 1.1 years, respectively [61]. Groups were defined on the basis of lead seemingly persist and perhaps the deficits may be irreversible, i. e., they do not diminish or disappear as the child grows.

With few exceptions, tasks requiring muscular strength and endurance, speed, power, balance and coordination in gross movement tasks have not been systematically evaluated in children and adolescents with elevated blood lead levels. Gross balance at 6 years of age [68] and performance on rail balance tests at 8–10 years of age [70] were not influenced by blood lead levels, while elevated blood lead was negatively associated with teacher ratings of agility defined as „…the ability to execute motor activities such as running and jumping with precision and rapidity," in 7–9 year old children [72]. Movement tasks which involve movement precision and coordination are thus adversely affected by elevated blood lead levels. Elevated blood lead was associated with an increase in postural sway in children [73, 74], although the association between postural sway and balance was not addressed. If postural sway is related to dynamic and static balance, the results may suggest a potential influence of early lead exposure on the vestibular system and/or proprioception. Elevated blood lead was also associated with hearing deficits in children [75]. It is perhaps possible that lead affects function of the otolithic complex related to maintenance of equilibrium (vestibular system).

Corresponding analyses of gross bodily movements as in standard physical fitness tests are limited to an evaluation of relationships between blood lead levels and measures of fitness in school children 7–15 years from the Copper Basin in 1995 [76]. Of relevance is the question: are indicators of physical fitness directly related to blood lead levels? Alternatively, is physical fitness indirectly affected through reduced body size given the influence of elevated lead on linear growth? Smaller body size is generally associated with poorer performances on a variety of physical fitness tests in youth [77, 78].

School children of both sexes from the Copper Basin in 1995 [45] were on, average, shorter that a national sample of Polish youth in a 1999 physical fitness survey [79]. On the other hand, children from the Copper Basin tended to weigh slightly less than the national sample between 7 and 11 years, while differences were negligible at older ages.

Several indicators of physical fitness were measured in school children from the Copper Basis region using the EUROFIT battery [80]: right and left grip (static strength), sit-ups in 30 seconds (abdominal muscular strength and endurance), flexed arm hang (upper body functional strength), plate tapping (speed of upper limb movement), shuttle run (running speed and agility), standing long jump (explosive power of the lower extremities) and medicine ball throw (explosive power of the upper extremities). Simple reaction time was measured in a subsample.

Standing long jump performances of boys and girls from the Copper Basin were, on average, slightly lower than those of the national sample from 7–13 years, while differences at 14–15 years were negligible. A similar age-related pattern was apparent for speed of upper limb movement (plate tapping). Performances in an agility shuttle run did not differ, on average, between children of both sexes in the Copper Basin and the national sample. In contrast, the number of sit-ups completed in 30 seconds was consistently lower in Copper Basin children of both sexes across the age range 7–15 years. Grip strength was, on average, greater in boys and girls from the Copper Basin than in the national sample. However, this comparison must be tempered because it was not clear what type of dynamometer was used in the national survey.

Results of regression and path analyses indicated that blood lead level did not directly affect the physical fitness of the school youth from the Copper Basin. The effects of blood lead were indirect through a negative influence of high blood lead levels on growth in body size in this sample [45, 76]. Blood lead level was also not related with reaction time in the subsample of children. However, diet and family circumstances (except for maternal education) and level of habitual physical activity were not considered. Nutritional status and familial factors (e. g., common environment, sibling interactions, etc.) can independently influence both growth physical fitness [81, 82] while physical activity is an important correlate of fitness [1].

The Human Environment: Physical Activity and Physical Inactivity

In the past two generations (~50 years), the pace of cultural, specifically technological development has accelerated. Many changes in lifestyle associated with the technological revolution, though beneficial for society, have resulted in an increase in opportunities for physical inactivity or sedentary behavior. School and related activities (study, reading) have historically been highly valued by society. Though important, school is largely a socially sanctioned form of physical inactivity – attendance for 5–6 hours per day involves primarily sitting and very light activity (except for physical education and recess). The advent of the radio, telephones and motorized transport in the first half of the 20th century has provided additional opportunities for physical inactivity. The widespread availability of television since the 1950s was followed by personal computers (1980s), cell phones and internet (1990s) and subsequently CDs, DVDs and video games, all of which have contributed to an increase in physically inactive behaviors and/or to behaviors with potential for inactivity.

Technological advances have contributed to significant changes in the lives of children and perhaps in parental expectations. Between 1981 and 1997, for example, time spent in school or day care, time reading and studying at home, and time in organized activities including hobbies, arts and sports increased among American children 3–12 years of age; on the other hand, discretionary (free) time, television time and time in unstructured activities (play) decreased [83]. In 2005, the majority of American children in grades 3–5 (77%) and 6–8 (80%) participated in after-school programs with a high potential for physical inactivity: academic activities, arts, clubs, community service, religious activities and scouts at least once per week. In contrast, about 34% of children in both grade groups participated in after school sport programs at least once per week [84].

In addition to increased opportunities for physical inactivity, the preceding implies that American children are increasingly involved in organized activities beginning at relatively young ages. About one-third of children 3–4 years of age in the United States were enrolled in preschool in 1993 [85], while about 47% and 74% of 3 and 4 year old children, respectively, were enrolled in public and private preschool programs in 2007 [86]. Among organized sport participants ≤18 years of age in the United States, children ≤6 years of age comprised 9% in 1997 and 12% in 2008 [87], suggesting negligible change in potential for one form of physical activity. Sport at young ages is typically aimed at all youth – sport for all, whereas with increasing age, sport becomes highly select and exclusive [88, 89].

The increase in organized activities for children has implications for physical activity and play. Reduction in discretionary and play time have resulted in a reduction in informal play, especially physically active play in the form of „street" games, sports and other activities. Informal activities and associated behaviors generally involve frequent repetitions, trial and error, experimentation and repetition, variable settings, and exposure to different conditions, skills and rules, and are often done in groups. Peer interactions are central to the activities. Many physical and behavioral skills are learned without awareness and are likely adaptable to variety of activity and social circumstances.

The increase in opportunities for physical inactivity over the past generation or so has been accompanied by a general decline in physical activity and fitness of youth [90–92]. Like physical inactivity, physical activity is a multi-dimensional behavior. It is viewed analytically most often in terms of energy expenditure and the stresses and strains associated with weight bearing and ground reaction forces. It is clear that physical fitness and motor skill are important aspects of activity, but an important dimension of physical activity that is often overlooked is context. It refers to types and settings of activity, and includes play, physical education, exercise, sport, work, and others. Contexts and meanings attached to them vary among and within different cultural groups and influence patterns of habitual physical activity.

Physically active and inactive behaviors occur in many contexts which are important avenues for learning, enjoyment, social interactions and self-understanding. Activity and inactivity have important implications for child and adolescent health. Increased physical inactivity and reduced physical activity in an environment with a readily and easily available and accessible food (energy) supply underlie the current epidemic of obesity in many parts of the world and the emergence of risk factors for cardiovascular and metabolic disease in youth.

The beneficial effects of regular physical activity for the health and fitness of youth are well-documented [93, 94]. Studies of the influence of regular physical activity seem to differentiate between „healthy" and „unhealthy" youth [93]. Among „healthy" children and adolescents (normal weight, normotensive blood pressure), the evidence for beneficial effects of physical activity is strongest for skeletal health, aerobic fitness, and muscular strength and endurance, with relatively small effects on lipids, adiposity and blood pressures. A greater volume of activity may be needed to improve the lipid, adiposity and blood pressure profiles of healthy youth. On the other hand, beneficial effects of systematic physical activity are generally more apparent among „unhealthy" youth – the obese, hypertensive, and those with indicators of the metabolic syndrome. Physical activity intervention programs have a beneficial effect on adiposity in the obese, on blood pressures in the hypertensive, and on insulin, triglycerides and adiposity in obese youth with the metabolic syndrome.

Many indicators of health and fitness, in particular metabolic risk factors are affected by obesity in children and adolescents. A key intervention, therefore, is the prevention of unhealthy weight gain, specifically in the context of reducing overweight/obesity and associated risks (diabetes, cardiovascular disease). Given the individuality of growth and maturation [1], „unhealthy weight gain" is difficult to define and diagnose. Limited longitudinal data indicated smaller gains in the BMI in physically active youth [95]. Maintenance of smaller gains in the BMI through physical activity over time may prevent unhealthy weight gain and in turn reduce risk of overweight/obesity. Note, however, the BMI does not differentiate between the fat-free mass and fat mass. Two longitudinal studies suggested that physical activity may play an important role in the prevention of excess weight gain during different phases of growth. More active children between 4 and 11 years had less fatness in early adolescence and may also have had a later adiposity rebound [96], while increase in physical activity during adolescence apparently limited the accrual of fat mass in males though not females [97].

An issue that requires more attention is the influence of polluted environmental conditions on the physical activity and fitness and in turn health of children. Nitrous oxide, ozone and/or particulate matter are specifically related to respiratory health, including aggravation of asthma in children and adults, stunted lung development in children, and chronic obstructive pulmonary disease and lung cancer in smokers and adult non-smokers [98]. Coal-fired power plants and industries with environmental emissions are major contributors to the development and exacerbation of asthma in youth. The state of Texas, for example, has 19 coal-fired power plants. Among Texas youth ≤18 years of age in 1998, 61/1000 who lived within a ~50 km radius of a coal-fired power plant had asthma [99] compared to the background rate of 10–12/1000.

Further research on physical activity and fitness of children with asthma is urgently needed. Comparisons of physical activity levels of asthmatic and non-asthmatic youth have shown inconsistent results, i. e., no differences versus higher or lower activity levels in asthmatic youth. On the other hand, higher levels of activity were associated with greater reporting of asthma or asthma-related symptoms (whistling, wheezing) in asthmatic youth. Some, but not all, studies indicated lower levels of aerobic and anaerobic fitness in youth with asthma. Finally, controlled aerobic programs (2 to 3 sessions per week for at least 6 weeks) can improve the aerobic and anaerobic fitness of asthmatic youth, but the activity programs were not associated with systematic improvements in pulmonary function or exercise-induced bronchoconstriction [93]. The inconsistent results are likely confounded by the level of control of asthma. One would expect that youth with well-controlled asthma would be more physically active and fit compared to youth with poorly managed asthma. However, this remains to be investigated.

Summary

The environments in which children physically grow and mature and behaviorally develop influence these processes and the biobehavioral interactions among them. The influence of several dimensions of the natural, man-made and social environments on aspects of growth, maturation and development were briefly considered. Improved environmental conditions over the past century or so have contributed to positive secular changes in growth and maturation, although the magnitude of secular improvements vary in different parts of the world. On the other hand, recent technological developments have increased opportunities for sedentary behaviors and have contributed to reduced physical activity, both of which have negative effects on the health of children and adolescents.

The impact of elevated levels of blood lead on growth and maturation and on movement proficiency and physical fitness was considered. Children with elevated lead levels are at increased risk for impaired growth and maturation and for impairments in aspects of fine motor coordination. The impact of elevated lead on gross motor coordination in several tests of physical fitness is mediated through the influence of lead on growth in body size. Similarly, air emissions from coal-fired power plants and other industries are associated with asthma, which has implications for the physical activity and fitness of youth. Although not considered in this review, chronic exposure to environmental contaminants (ozone, PCBs, mercury, carbon monoxide) also has unfortunately serious detrimental effects on the health and well-being of children and adolescents.

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