Body structure and maturation – the association with environmental factors

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ABSTRACT: The main objective of the study was to determine the relationship between physique, maturation and some environmental factors. The study was conducted in Warsaw, between 2012 and 2013 in randomly selected schools. The material included 171 girls, aged 12–20 years. Body height and weight, upper and lower extremity length, subcutaneous fat folds on arm, subscapular and abdominal, circumferences of arm, chest, waist and hip were measured. Body proportion indices were calculated. The questionnaire form provided information on parental education and profession, and the number of children in family. Girls were asked about age at menarche, number of daily meals, level of physical activity, participation is sport, and level of stress at home and at school. The principal component analysis was applied and 4 factors were extracted from the set of living condition characteristics (F1 – Parental education & father's occupation, F2 – Mother's occupation and the number of children, F3 – Stress, F4 – Physical activity and number of daily meals). Regression analysis allowed to evaluate the association of body build characteristics and age at menarche with the four factors. Factor 1 and 4 were the only ones which showed a statistically significant association with body build. The results showed that girls who were taller, with smaller arm and waist circumferences and less adiposity came from families with higher parental education and better father's profession. Taller stature, longer legs and less adiposity characterized girls who were more physically active and consumed more than three meals a day.

KEY WORDS: body build, socioeconomic factors, age at menarche

Introduction

Human height as a quantitative trait is controlled by many genes and environmental factors. Recent studies based on European twins have estimated stature heritability at 80–90 percent (Perola et al. 2007, Yang et al. 2010). Family studies usually show lower heritability of characteristics called "live history traits" (birth weight, age at menarche and at menopause, adult height, BMI) than twin stud-

ies. However, other research shows that twin studies could overestimate the proportion of heritability (Wells and Stock 2011). Studies on two different ethnic populations (Turkmenians and individuals from Volga riverside) reveled that genetic factors substantially influence inter-individual differences in body shape and its proportions, but pleiotropy and epigenetic effects may also play an important role on various aspects of the human physique (Livshits et al. 2002). Also, new studies, simultaneously considering 300,000 SNPs, increased the proportion of phenotypic variance explained to 45% (Yang et al. 2010). Numerous studies indicated that growth and development of children and youth are strongly related to socio-economic factors (Sobal and Stunkard 1989; Kaczmarek 1995; Salmon et al. 2005a; Salmon et al. 2005b; Youfa and Zhang 2005; Wolański 2012; Zsakai and Bodzsar 2014; Stojanoska et al. 2016). There were also reports that height, leg length, sitting height and some indices describing proportions of human body as: sitting height/stature, leg length/stature, were associated with risk of overweight, coronary heart diseases, diabetes and certain cancers. However, studies on non-pathological populations showed that environmental factors had more important impact on leg length and its proportions than genetic ones (Bogin and Varela-Silva 2010).

The second issue of growth and development which interested us was age of maturation. The question arises, how socioeconomic factors might moderate puberty. Menarche is the first menstrual period of a girl at puberty and the timing of this phenomenon is very important for health in later life. Many studies were the basis for further research on genetic determination of the age of menarche.

Contribution of genetic factors in the age at menarche was estimated at 57–82% (Morris et al. 2011). Slightly lower data for the inheritance of this characteristic (49–69%) were given by Khanna and Kapoor (2004), Cabanas et al. (2009) and Jones et al. (2009). However, genes responsible for this phenomenon have not been identified. There is a suggestion to expand this kind of research to different ethnicities, using various methodologies, including system approach (Dvornyk and Ul-Haq 2012). The girls maturing earlier were characterized by a more rapid growth rate than those maturing later (Kaliszewska-Drozdowska 2002). Also, the age at menarche revealed significant correlations with all characteristics of the growth spurt except for adolescent increment and adult height (Kaczmarek 2002). In the last two centuries, age at menarche has decreased in several European populations, whereas adult height has increased. Secular trend showed that more recent birth cohorts had their menarche earlier and grow taller. However, women with earlier menarche reached a shorter adult height compared with women who have menarche at a later age (Onland-Moret et al. 2005). There were findings on studies in Istanbul that in lower socioeconomic class age at menarche was significantly later and that this phenomenon was related to lower rates of growth in stature and weight, and of skeletal and sexual maturation (Onat and Ertem 1995). It has also been revealed that earlier entering the age of puberty is associated with endomorph physique and vice versa (Kaur and Pathak 2014). Later maturers had significantly more linear physiques than those experiencing menarche earlier. Late maturers also showed a tendency to lower values for the body mass index (BMI) and tri-

ceps skinfold (Wellens et al. 1992). The earlier occurrence of menarche might also be associated with the negative impact of environmental factors which include stress.

Stress was associated with the secretion of corticotropin, which stimulates the adrenal gland to produce glucocorticoids, and these are responsible for the rapid adaptation to the given conditions (Wolański 2012). Frequent stress can affect organism girls accelerating the maturation and somatic development. This is probably related to the fact that stressors increase the rate of stimuli in the limbic system and the central nervous system (Hulanicka 1986). Very interesting results showed that genetic predispositions toward later menarche were associated with fewer depressive symptoms and that genetic predispositions toward earlier menarche were associated with more depressive symptoms (Mendle et al. 2016).

The main objective of this work was to find out the relation between somatic structure of body, pubertal age of Warsaw girls, and some living condition characteristics.

Material and methods

The study was conducted in 2012–2013 in Warsaw and included 171 girls, aged 12 to 20 years. Warsaw is the biggest city in Poland, of 1744351 inhabitants and located in Mazowsze district. Population density equals 3372 persons per km^2 (GUS).

Junior high schools and high schools were randomly selected from all types of schools in Warsaw. However, because many of the girls or their parents refused to participate in these studies, the results do not represent the entire population of Warsaw.

Table 1. Age groups and number of studied Warsaw girls

Age group (years)	N
12 (11.5–12.49)	6
13 (12.5–13.49)	6
14 (13.5–14.49)	28
15 (14.5–15.49)	23
16 (15.5–16.49)	42
17 (16.5–17.49)	31
18 (17.5–18.49)	28
19 (18.5–19.49)	6
20 (19.5–20.49)	2
Total	171

Age groups and number of studied girls were presented in the Table 1.

The measurements included: body height (B-v) and weight, basion-acromion (B-a) height, basion-dactylion (B-da) height, seating height, subcutaneous fat folds on arm, subscapular and abdominal, arm, chest, waist and hip circumferences. The length of upper and lower extremities, trunk length, body mass index (BMI), waist-hip ration (WHR), lower extremity index, trunk length index, interextremity index were calculated. B-a and B-da were used to calculate the length of upper extremity. B-v and seating height were used to calculate the length of lower extremity. To eliminate age differences, each trait was transformed into "z" scores, based on their own cohort, for each age group separately. This was done according to the following formula.

Parents were asked to complete a questionnaire form, which included information about their education and profession and number of children in the family (1 – 15.2%; 2 – 50.3%; 3 – 22.8%; 4 – 7%; 5 – 2.9%; 6 – 0.6%; 7 – 0.6%; 9 – 0.6%). Parents' education was considered in four categories: elementary (fathers – 2.9%; mothers – 1.8%), vocational (22.8; 15.2), secondary (35.1; 40.3) and higher (39.2; 42.7). Parents'

profession was considered in five categories: unemployed (fathers – 2.9%; mothers – 5.8%), unskilled workers (4.1; 7.6), skilled workers (49.7; 24.0), technicians (14.6; 31.0), specialists (28.7; 31.6).

Daughters were asked about age at menarche, number of daily meals (snakes were not included), the level of physical activity, sports activities outside school, stress at home and at school. Girls evaluated the stress and physical activity levels in the three-step scale (1 – small, 2 – medium and 3 – high). Age at menarche was evaluated using a retrospective method.

Independent variables were presented as factors, after principal component analysis (PCA) of different socio-economic characteristics with Varimax rotation. PCA allowed the presentation of the groups of variables that were most correlated with each other (factors).

Multiple regression analysis was used to assess the influence of family living-condition characteristics, presented as factors on body structure characteristics and age at menarche of examined girls.

Results

Independent variables included 10 living-condition characteristics: mother's education and profession, father's education and profession, the number of children in the family, the level of stress at home and at school, sport classes outside school, the level of physical activity, the number of daily meals.

PCA extracted four factors which allowed to explain 66.5% of the variance of all independent variables (table 2).

The names of the four factors are: F1 – Parental education & father's occupation, F2 – Mother's occupation and the number of children, F3 – Stress, F4 – Physical activity and number of daily meals (table 3).

The table 3 shows that the mother's occupation was negatively correlated with number of children. This indicates that when women had a better profession they also had fewer children.

To determine association of somatic variables of Warsaw girls with four factors the linear regression was used. Only significant association between somatic

Table 2. Independent variables and total explained variance by four factors. Results of PCA

Components	Initial eigenvalues			The sum of the squares after isolation			The sum of the squares after rotation		
	Total	% of variance	% cumulative	Total	% of variance	% cumulative	Total	% of variance	% cumulative
Mother's education	2.68	26.85	26.85	2.68	26.85	26.85	2.37	23.74	23.74
Mother's occupation	1.47	14.75	41.60	1.47	14.75	41.60	1.48	14.77	38.51
Father's education	1.37	13.74	55.34	1.37	13.74	55.34	1.43	14.34	52.85
Father's occupation	1.11	11.14	66.48	1.11	11.14	66.48	1.36	13.63	66.48
Number of children	0.83	8.29	74.77						
Stress at school	0.73	7.27	82.04						
Stress at home	0.62	6.23	88.27						
Sports classes outside school	0.53	5.26	93.54						
Physical activity	0.38	3.81	97.35						
Number of daily meals	0.26	2.65	100.00						

Table 3. Rotated component matrix (variables most strongly correlated with each component are bolded)

Independent variables	F1	F2	F3	F4
Father's education	**0.845**	0.129	–0.040	0.043
Father's occupation	**0.809**	–0.068	0.038	–0.038
Mother's education	**0.702**	0.477	–0.032	0.134
Number of children	–0.023	**–0.839**	0.021	0.019
Mother's occupation	0.522	**0.606**	–0.047	0.030
Stress in school	–0.110	0.133	**0.847**	–0.078
Stress in home	0.103	–0.200	**0.821**	0.017
Sports classes outside school	–0.242	0.147	0.040	**0.734**
Physical activity	0.141	–0.011	–0.150	**0.722**
Number of daily meals	0.370	–0.278	0.109	**0.524**

variables and factors were considered (table 4). This showed that only two factors: F1 – Parental education and fathers' occupation and F4 – Physical activity and number of daily meals showed a significant association with somatic variables.

Body height was positively associated with the factor 1, and arm and waist circumferences, WHR, subscapular and abdominal subcutaneous fat folds and sum of three fat folds were negatively associated with the factor 1. This means that girls coming from families with better educated parents and better father's occupation were taller, with smaller values of circumferences and adiposity, and with more fat on the hips than on the waist.

There was also a positive association of body height and length of lower extremities with the factor 4 and a negative

Table 4. Results of multiple regression analysis of somatic variables on family living condition factors

Somatic variables (dependent variables)	F1 – Parental education and father's occupation			F4 – Physical activity and number of daily meals		
	B	Confidence intervals	T and PEV	B	Confidence intervals	T and PEV
Arm circumference	–0.142	–0.289–0.005	–1.907* PEV=2.1			
Waist circumference	–0.169	–0.316–0.022	–2.273* PEV=3.0			
WHR	–0.211	–0.357–0.005	–2.868* PEV=4.7			
Subscapular fat fold	–0.143	–0.291–0.005	–1.909* PEV=2.1			
Abdominal fat fold	–0.165	–0.312–0.017	–2.202* PEV=2,8			
Sum of three fat folds	–0.167	–0.315–0.019	–2.226* PEV=2,9	–0.142	–0.288–0.004	–1.925* PEV=2,1
Body height	0.181	0.036–0.326	2.445* PEV=3.4	0.158	0.013–0.303	2.471* PEV=2,6
Length of lower extremities				0.147	–0.002–0.297	1,946* PEV=2,2

PEV: percentage of explain variance of body structure variables by a factor with a significant T value.
Significance level: * $p<0.05$.

association of the sum of three fat-folds with the factor 4. This can be explained that girls more physically active who consume more than three daily meals were taller with longer legs and with less adiposity than girls who were less physically active and who consumed less than three meals daily.

There was no relation of studied somatic structure with mother occupation and number of children (Factor 2) and with stress at home and at work (Factor 3).

There was also not a statistically significant relation of age at menarche with the four-extracted factors.

Discussion

The most important result of this article showed that within the living conditions characteristics the factor 1 "parental education and father's occupation" has the most important impact on physique of young Warsaw girls. This was a part of widely understood socioeconomic status (SES). Several methods of measuring SES have been proposed, but most include family income (differently measured), parental education, and occupational status. SES is associated with a wide array of health, cognitive, and socioemotional outcomes in children, with effects beginning prior to birth and continuing into adulthood (Bradley and Corwyn 2002). It had also a very important impact on child growth and development in Polish living conditions, and thus the final dimensions of the body and its proportions (Kaczmarek 1995; Siniarska 1996; Wolański 2012). The present results showed that Warsaw girls from better off families had more slender body build (greater height, lower WHR, smaller arm and waist circumferences, less adiposity) than girls

raised in opposing conditions. This dependence is probably caused by the fact that higher educated parents have better knowledge about the health status of their children, and thus provide better and healthier food. On the other hand, better occupation usually means higher income which facilitates access to various resources, including, for example, extra-curricular sports (Drewnowski and Specter 2004, Kachi et al. 2015). Also in other countries studies revealed the similar results. In Iran higher overweight, abdominal obesity (BMI, WHR) and shorter stature were positively associated with father's' lower education level and his job (Farzianpour 2014). In Hungary, higher stature and lower relative fatness was found in better socio-economic conditions (Zsakai and Bodzsar 2014). In Turkey, parental education levels were more influential on body structure than the economic status of the family. Differences between the groups were marked in lower limb measurements, skinfold thicknesses and somatotype values, especially in endomorph component (Pelin et al. 2010). In Macedonia, the socioeconomic status affects the body weight, height, percentage of adipose tissue and some tests of motor performance (Gontarev et al. 2013). In Saudi Arabia, overweight and obesity among children were associated with low family income, low educational levels of both parents and big families (Al-Agha et al. 2015). Very interesting results have been obtained from studies on future effect of height and BMI on measures of SES, based on UK Biobank. High BMI plays very important role in women, lowering their income, and taller people are at an advantage (Tyrrell et al. 2016).

Another factor (F4) which showed a significant association with body build of studied Warsaw girls was "physical ac-

tivity and number of daily meals". Girls who were more physically active and consume more daily meals were characterize by more slim body build (they were taller, with longer legs and less adiposity – sum of 3 fat-folds). Unfortunately, there were no other data in the present study which would allow to describe nutritional status of studied girls in more details. However, referring to number of daily meals, nutritional experts said that we should eat 4–5 meals a day. This was also confirmed by our studies where daily meals were divided below and equal to three (less meals) and over three (more meals). Epidemiological studies had suggested that a "nibbling" pattern (pattern of eating) could help to prevent obesity. Obese people tent to eat little in the morning and much in the afternoon or/and evening, and even at night and significant correlation between the lack of eating breakfast and obesity was noted (Mushtaq et al. 2011). However, there was no clear evidence linking daily number of meals and body adiposity (Bellisle 2005).

Factor 4 (physical activity and number of daily meals) also significantly affected the length of the lower extremities of studied girls. Similar results indicating that lower body parts, including the length of lower limb, were especially sensitive to external factors reported Bogin et al. (2001). It was also observed that the length of the lower limbs might be a good biomarker of environmental factors contributing to the development of children. Poorer nutrition, type of physical activity, access to education and the level of health care might reduce leg length, which affects the stature (Bogin and Varela-Silva 2010; Pomeroy et al. 2012; Kozieł et al. 2016).

There were two more factors of a living condition character for which the association with girls' physique was not found. Mother occupation and number of children within a family (Factor 2) and the level of stress at home and at school (Factor 3). The matric of rotated components (tab. 2) showed that there was a negative correlation between number of children and five categories of mother's profession. However, this does not have any relation to somatic development of studied girls.

Earlier studies on girls studying in the Welsh Collage have revealed that family size tends to diminish height whereas position in family increases height (Dann and Roberts 1969). A multidisciplinary explanation for the findings on family size suggests that family resources become "diluted" as family size increases and the result is the various developmental deficits reported by researchers. There was substantial documentation indicating that children from small families have a better developmental prognosis than children with many siblings (Falbo and Polit 1986). Studies in the mountainous regions of Poland (Podkarpacie and Podbeskidzie region) revealed that the development of girls aged 7–11 years was strongly influenced by family size and parental education (Zadarko-Domaradzka and Tlałka 2006). The differences found between girls in Warsaw and from mountainous regions of Poland could be caused by different levels of economic development of these regions and worse living conditions in mountainous areas. Similar living conditions found in many Warsaw families and a small number of children in the family is perhaps the main reason for the lack of association of somatic development with family size.

Present results revealed that also stress was not associated with physique.

This can be explained by the low level of stress reported by the girls surveyed. High stress level in school was reported by 5.8% of girls and stress at home manifested only 3.5% of the respondents. In addition, the small sample size did not allow to assess the impact of stress on possible changes in body structure. However, is very well known that stress can have lasting effects on the brain and behavior, and in some cases, can lead to psychopathology. Evaluation of the impact of stress on biological development is difficult to carry out. Mechanisms which protect the organism against early-life stress can promote resilience and positive outcomes (Gee and Casey 2015). Children who experienced trauma often felt out of control. In home, occupational therapy practitioners should create predictable routines that allow children to have a sense of control. In school, occupational therapy practitioners should promote social interactions among peers and support the teachers to create a safe and nurturing environment that enhances learning (Petrenchik 2015).

The last part of the discussion refers to an absence of relationship between age at menarche and four extracted socioeconomic factors in the present study. Noteworthy was the fact, which we have already mentioned, that this material is not random and that most of the studied girls had parents with higher education. In other countries, the association of age at menarche with SES was observed. In Chile, low socioeconomic status was associated with delayed menarche (Amigo et al. 2012). Comparing White and Black girls the results reveal that White girls in the lowest quartile of household income were at a significantly lower risk of early menarche, whereas Black girls in the highest quartile of household income were at an increased risk of early menarche (Braithwaite et al. 2008). Also, Black and Hispanic girls experienced menarche earlier than whites. SES indicators were associated uniquely with earlier menarche and included mother's unmarried status and lower family income (Deardorff et al. 2014). However, the other polish studies (female university students) from Szczecin showed that there were no significant differences in the number of the early, average and late maturing students between the socioeconomic groups (Olszewska et al. 2015).

Finishing the part devoted to living condition characteristics we can quote indications of the American Academy of Pediatrics saying that race/ethnicity, gender, and socioeconomic status are important mediators of childhood health, and as predictors of adult health status. Only effective preventive intervention strategies by their implementation during childhood can improve the health of children and the adults into which they will grow (American Academy of Pediatrics 2000).

Conclusions

Shorter stature, larger values of WHR, adiposity (subscapular, abdominal fat folds, the sum of 3 fat-folds), arm and waist circumference were observed in girls from families with a lower parental education and a worse father's profession.

More physically active girls, who consume more than three dishes daily were taller, with longer legs and less adiposity (the sum of 3 fat-folds).

There was no association between age at menarche and four extracted factors.

Aknowledgement

Authors' contributions

AnnaS designed the research and statistical analyses, interpreted the results, and wrote the paper; JND gave support and conceptual advice, collected the data, commented the initial draft of the manuscript; AnetaS collected the data. The final version of paper was prepared by AnnaS and approved by both authors, SK was the project manager.

Conflict of interest

The authors declare that there is no conflict of interests.

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