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Isolation by Distance Between Spouses and its Effect on Boys' Maturational Timing

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ABSTRACT

Heterosis is thought to be an important contributor to human growth and development. Marital distance (distance between parental birthplaces) is commonly considered as a factor favoring the occurrence of heterosis and can be used as a proximate measure of its level. It has already been shown that marital distance appears to be an independent and important factor influencing the height of offspring. However, there is no study showing this effect on maturational timing in boys. The aim of the study was to assess the effect of marital radius on age at peak height velocity in boys, controlling for midparental height and the socioeconomic status of family. Longitudinal, annual height measurements on 740 boys from 11 to 15 years of age from Ostrowiec Świętokrzyski, Poland, were analyzed along with sociodemographic data from their parents. Midparental height was calculated as the average of the reported heights of the parents. The SITAR model was applied to the longitudinal data of height in order to assess the age at peak height velocity (APHV). As the measurements were incomplete, the APHV was successfully estimated in only 298 boys. Multiple Linear regression showed the small, but significant effect of Marital distance on the maturation rate of boys (standardized beta=-0.14; p<0.05). According to the "isolation by distance" hypothesis, a greater distance between parental birthplaces may increase heterozygosity, potentially promoting heterosis. We propose that these conditions may result in reduced metabolic costs of growth among heterozygous individuals, and hence a lowered velocity of growth.

Key words: *maturation rate, heterosis, marital distance, boys, Poland*

Introduction

Many reports exploring longitudinal data have shown considerable variation in the tempo of maturation, indicated by the timing of the onset and the peak velocity of the growth spurt, and peak height velocity[1-5]. The estimated age at peak height velocity highly correlates with other measures of maturation rate[3], is independent from finally achieved adult stature[6], and it seems to be a reliable marker of general timing of puberty. It suggests that these two characteristics of growth: the time of adolescent growth spurt and end-result growth in stature, are unrelated features, probably controlled by two independent sets of genes[4,5].

Family and twin studies have evidenced that the genetic variation of the timing of puberty accounts to 57% – 100% of all variation on pubertal timing[7-11]. A few longitudinal twin studies have estimated the magnitude of the genetic effect on timing of adolescent growth spurt in height[8,9,12,13], but among them only Beunen at al. (2000)[8], using the novel twin genetic models, reported a reliable estimation accounting for 89%–93% in both sexes. A much smaller amount of research has focused on systematic studies of environmental factors that significantly affect the maturational timing in boys, mainly due to the requisition of longitudinal records or reliable palpation estimation of testicular enlargement only, which is difficult from a practical point of view. Among girls, the influence of various social factors on menarcheal age, as an easily assessable maturational timing marker, has intensively been studied[14]. Methodological and practical difficulties, as mentioned above, are the main reason for the lack of such studies in boys.

Assessing the possible role of heterosis, measured by distance of marital migration on the height of children, Koziel et al. (2011)[15] have found a significant effect on offspring's height, controlling for midparental height and socioeconomic status. The longer the distance between the place of birth of parents, the higher the stature of children. No possible effect of heterosis was assessed in relation to maturational timing in boys.

Marital distance can be expressed as the direct geographical distance between the birthplace of spouses[16] and

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to some extent, one can assume that it approximates the process of marital migration. It is suggested that short-range migrations, leading to the choice of mate, determine differentiation and genetic structure of populations[17]. A possible phenotypic effect of this process on fetal growth may be manifested through heterosis. Heterosis is a phenomenon firstly described by Shull (1914)[18] and regards the better vigour of offspring from crosses between two separate breeding lines[19,20]. Genetically possible benefits of heterosis are attributed to the positive effects of heterozygosity, such as suppression of deleterious recessive alleles and/or overdominance of heterozygotic genotypes over homozygotic ones[20,21]. Heterosis can be favoured by evolutionary processes, if fitness in crossbreeds is higher than in purebred individuals[22].

In humans, a good basis for heterosis can be constituted by regional micro differentation in gene frequencies and a higher probability of kinship[23-26], as well as consanguineous marriages between individuals living in close geographical proximity (e.g.[27-30]). By definition, such conditions may contribute to inbreeding, followed by a local increase in homozygosity[28]. Consequently, marital migration and mating between parents whose birthplaces are geographically distant, may result in higher offspring heterozygosity and a positive effect of heterosis.

The aim of the present study was to estimate the effect of marital distance, i.e. geographical distance between parental birthplaces, on the maturation rate of sons between the ages of 12-16 years.

TABLE 1.
PERCENTAGE OF BOYS IN RELATION TO MARITAL DISTANCE AND SES CATEGORIES

Factors	Numbers	Percentages
Marital distance		
<25 km	157	52.9
25-100 km	74	24.9
101-300 km	36	12.1
>300 km	30	10.1
SES		
High	104	35.0
Medium	108	36.4
Low	85	28.6

TABLE 2.
MEANS AND SDS OF AGE AND HEIGHT IN 5 SUBSEQUENT MEASUREMENTS IN 298 BOYS

Age classes	Age [years]	SD	Height [cm]	SD
12	11.79	0.28	149.37	6.96
13	12.78	0.28	156.19	7.77
14	13.78	0.28	163.65	8.18
15	14.78	0.28	167.30	7.74
16	15.78	0.29	170.01	7.43

Material and Methods

Data was obtained from a semi-longitudinal survey conducted between 1994-1999 in primary and secondary schools in Ostrowiec Świętokrzyski, a town located in the Swietokrzyskie voivodship with the capital city Kielce. The survey included four birth cohorts which were followed up annually for 5 years. The present study was limited to only 740 boys born in the year 1983, and during the study were followed from 12 (mean=11.77; SD=0.28) to 16 years of age (mean=15.79; SD=0.29). However, only boys with the complete 5 measurements and with successfully estimated age at peak height velocity (APHV) were included in further analysis, which resulted in the final number of subjects dropping to 298 boys.

Distance between birthplaces of parents (marital radius) was scored in four categories as follows: fewer than 25 kilometers, between 25 and 100 kilometers, between 100 and 300, and more than 300 kilometers. Socio-economic status (SES) was presented by first factor scores derived from the principal component analysis (PCA), encompassing such factors as parental education, family size, living conditions and household possessions. The eigenvalue of the analyzed factor amounted to 2.73 and explained 54.62% of common variation in SES. The scores of the first factors were then used as an independent variable in further analysis.

An APHV was the estimated means of the SITAR model – a mixed effects model for estimation timing and intensity of pubertal growth developed by Cole et al. (2010)[31]. The SITAR model was executed by running the package „Sitar", version 1.0.9 by R application. The method estimates a single mean growth curve as a regression B-spline, plus a set of up to three fixed and random effects (a, b and c), defining how individual growth curves differ from the mean curve. Next, b as a measure of the fraction difference in age at peak height velocity from the mean was converted into age (APHV) for each individual.

Multiple linear regression was used to assess the effect of marital distance on APHV, controlling for SES of family and midparental height. These calculations were done by using Statistica 13.1[32] (Dell Inc. 2016).

Results

The estimated mean APHV and mean peak velocity using the SITAR model for 298 boys accounts for 13.03 years and 8.991 cm/year, respectively. Table 1 presents numbers and percentage distribution in each of the categories of marital distance and socio economic status of the family. Table 2 shows the means and SDs for age and height in five subsequent measurements of all boys.

The results of multiple regression is shown in Table 3. Only marital distance had a significant, but rather weak, effect on APHV in boys, controlling for SES of family and midparental height. Means of APHV by categories of marital status are presented in Figure 1.

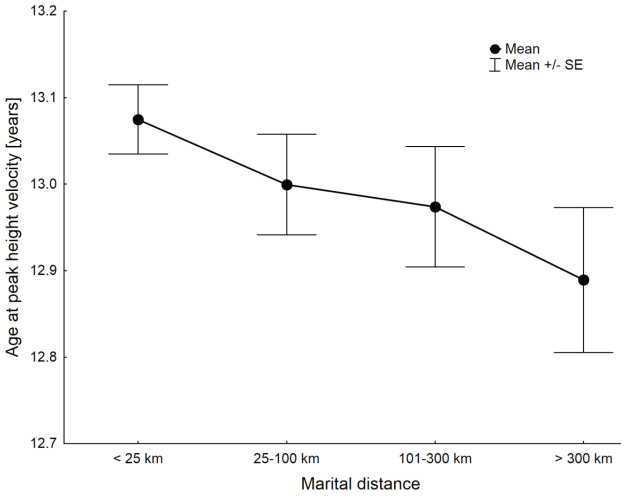

Fig 1. Means and ± standard errors of mean for age at peak height velocity for 298 boys by categories of marital distance.

TABLE 3.
RESULTS OF MULTIPLE LINEAR REGRESSION

Factors	Stad. beta	SE of beta	t	p
SES	–0.013	0.07	–0.195	0.8459
Marital Distance	–0.141	0.06	–0.220	0.0287
Mid-parental height	0.035	0.06	0.555	0.5795

Discussion

Our data confirms the weak but significant effect of geographical distance between the birthplaces of the parents on the maturation rate of sons, allowing for SES of the family and midparental height as a genetic component. To our knowledge this is the first study describing such findings.

The weakness of this effect might be caused, firstly by the relative small number of subjects. However, this consideration would be difficult to improve since the estimation of APHV is possible only based on a longitudinal study, at least in boys. Secondly, the maturation rate seems to be a highly determined genetic component, so environmental variation is relatively low. Beunen at al. (2000)[8] explored the semi-annual measurement set throughout puberty of 99 twin pairs. Based on the novel twin genetic model, the team estimated the genetic contribution to the timing of adolescent growth spurts in height, found to be 89%-93%, in both genders – it seems to be relatively high. Similar results were reported by Wehkalampi et al. (2008)[13], who used an indirect measure of pubertal timing – an assessment of change in relative height – estimated the genetic effect on variance of APHV to 86% and 82% in boys and girls. On the other hand, since the mid-19th century, a secular trend towards earlier menarcheal age has been observed in many countries in Europe and North America[33]. However, studies on female puberty have been prioritized because of the easy and precise assessment of menarcheal age. Much less data concerns secular trends in pubertal timing in boys. However, we can conclude that improved environmental conditions, such as better nutrition and hygiene, lower morbidity, less psychosocial stress, and better living standards are mainly responsible for the acceleration of pubertal timing in boys and girls.

In order to interpret our results, we refer to two possible mechanisms. Firstly, possible heterosis has increased metabolic efficiency, reducing basal, sometimes called maintenance, energy costs, and thus, allocating more energy to growth and development. Homozygous individuals, through better enzyme activity, could achieve energy conservation, and consequently more saved energy could be spent on faster growth[34,35]. It also could be possible that heterosis favors better physiological efficiency and the developmental stability of individuals, and hence better growth performance. It is especially important since earlier maturation is associated with higher growth velocity[2]. The molecular effect of heterosis might lead to the suppression of deleterious recessive alleles from one parent by the dominant alleles from the other and superiority of heterozygotes over homozygotes at given loci[21].

The second mechanism, which does not exclude that which is described above, is a selective spatial migration of parents. Several studies on migration have shown that it is often related to numerous costs like genetic, somatic, cultural, and involves a long process of adaptation to a new environment, which itself is costly and could have biological consequences[17,36,37]. Thus, one could expect that individuals who decided to migrate might have been distinguished by both psychological and somatic features, which facilitate their mobility. Fishberg (1905)[38] was the first who showed that Jewish immigrants to New York were taller than their nationals from native population. More recently, Chen et al. (1999)[39] found a simple association between the variation in the frequency of DRD4 7R+ (certain polymorphism in allele of gen dopamine receptor 4) and the distance to which a population has moved from its original location. These findings were also confirmed by Matthews and Butler (2011)[40], taking into account the neutral gene structure. We can conclude that it is highly plausible that the longer distance the have parents migrated, the more selective the pressure was and the higher level of heterosis was achieved. This was the biological consequence of growth in height of offspring, as was shown by Koziel et al. (2011)[15] on maturational timing.

Some limitations of the study should be taken into account when analyzing its results. Firstly, we used geographical distance between parental birthplaces as the proxy measure of offspring heterozygosity. We were not able to use a more direct examination of individuals' allele diversity and its influence on physiological processes. Secondly, the sample size is relatively small and limited to the local population. A larger sample of individuals from different geographical regions of Poland would straightforward the effect marital distance on maturation rate.

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IZOLACIJA UDALJENOSTI IZMEĐU SUPRUŽNIKA I NJEZINOG UTJECAJA NA MATURNO MJERENJE KOD DJEČAKA

SAŽETAK

Smatra se da je heteroseksta važan doprinos rastu i razvoju čovjeka. Bračna udaljenost (udaljenost između roditeljskih rodnih mjesta) obično se smatra faktorom koji favorizira pojavu heterozija i može se koristiti kao neposredna mjera njezine razine. Već je pokazano da bračna udaljenost izgleda kao nezavisan i važan čimbenik koji utječe na visinu potomstva. Međutim, ne postoji studija koja pokazuje ovaj učinak na maturni vremenski raspored dječaka. Cilj istraživanja bio je utvrditi utjecaj bračnog polumjera na dob u vršnoj visinskoj brzini kod dječaka, kontrolirajući srednjoškolsku visinu i socioekonomski status obitelji. Analizirane su uzdužne, godišnje mjerenje visine na 740 dječaka od 11 do 15 godina iz Ostrowiec Świętokrzyski, Poljska, uz sociodemografske podatke svojih roditelja. Središnja je visina izračunata kao prosjek prijavljenih visina roditelja. SITAR model primijenjen je na uzdužne podatke visine kako bi se procijenio dob u vršnoj visinskoj brzini (APHV). Budući da su mjerenja nepotpuna, APHV je uspješno procijenjen u samo 298 dječaka. Višestruka linearna regresija pokazala je mali, ali značajan učinak bračne udaljenosti na stopu sazrijevanja dječaka (standardizirani beta = -0,14, p <0,05). Prema hipotezi „izolacije po udaljenostima“, veća udaljenost između roditeljskih rodnih mjesta može povećati heterozigotnost, potencijalno potičući heterozu. Predlažemo da ti uvjeti mogu rezultirati smanjenim troškovima metabolizma rasta među heterozigotnim pojedincima, a time i smanjenom brzinom rasta.