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No association between anthropometry and IQ in Czech preschool children

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Abstract

Background Previous research has suggested that body mass index (BMI) and body height are associated with intelligence quotient (IQ) in older children and adults. However, due to the limited number of studies in this age group, there is a lack of consensus on whether there are relationships between IQ and some anthropometric measures, including sex, among preschool-aged children.

Objectives This study aimed to assess whether there is a significant relationship between sex, BMI, height IQ, and subsets of IQ among preschool-aged children.

Sample and Methods 59 preschoolers aged 4.01 to 4.99 years were sampled from selected preschools in Prague. Data on sex, weight and height were collected, and IQ was assessed using the IDS-P. The data were processed using the St. Nicolas house analysis, t-tests and multiple regression.

Results Multiple Regression Analysis and St. Nicolas house analysis failed to show any significant relations between sex, BMI, height, and IQ subtests score ($p>0.05$).

Conclusion In this study, no significant associations were found between sex, BMI, height, and IQ in preschool-aged children. The relationships among sex, BMI, height, and IQ are more complex. For a better understanding, it is therefore essential to have larger sample sizes and to understand these interactions within context and with other confounding social-economic-political-emotional l (SEPE) variables, as suggested in previous studies.

Take-home message for students There is no association between sex, BMI, height, and IQ among the preschool-aged children. The relationship between sex, BMI, height, and IQ is more complex and should be understood within context and with other confounding social, economic, political, and emotional (SEPE) variables.

Introduction

Previous research has suggested that anthropometric parameters such as body height and body mass index (BMI) may be associated with a child's cognitive and executive functions and overall intelligence quotient (IQ) at different ages (height – positively; BMI – negatively) (Kanazawa and Reyniers, 2009).

Though interesting, findings on this topic are generally inconsistent. For instance, some studies showed inverse relationships between anthropometric parameters such as BMI, height, and IQ, others showed no associations at all (Kahn and Williamson, 1990; Lahmann et al., 2000).

Height and intelligence might be related due to assortative mating patterns (Kanazawa and Reyniers, 2009). Even after controlling for confounding factors such as health, ethnicity, and socio-economic status (SES), height was strongly associated with intelligence in both sexes (Kanazawa and Reyniers, 2009). Similarly, Beauchamp et al., 2011 discussed the robust positive correlation between height and intelligence, as measured by IQ tests, and found suggestive evidence of a shared genetic architecture with height. They also stressed the impact of assortative mating and highlighted the significant within-family correlation between height and intelligence (Beauchamp et al., 2011).

Benyamin et al. surveyed a cohort of young individuals and revealed a noteworthy link between stature and cognitive ability in 11-year-old Scottish children (Benyamin et al., 2005). Wheeler and co-workers (Wheeler et al., 2004) affirmed a positive correlation between height and intelligence quotient (IQ) in various age groups. Silventoinen et al. conducted a study in Sweden. They found a strong association between growth velocity and IQ and observed that men who were initially short at birth but ultimately achieved standard adult height displayed greater intellectual capacity than those who remained short throughout adulthood (Silventoinen et al., 2006).

Several authors emphasized the mutual impact of factors on height and intelligence, such as income (Bogin et al., 2017), early life environment (Case and Paxson, 2008), and shared genetic influences (Marioni et al., 2014; Silventoinen et al., 2006), while other data emphasize the importance of social-economic-political-emotional (SEPE) factors (Scheffler et al., 2021).

In contrast, BMI and intelligence seem to be negatively correlated, especially in adulthood. Some argue that obese people are more likely to develop an increased vascular risk that can worsen neurodegeneration, resulting in greater cognitive decline (Corley et al., 2010; Cournot et al., 2006; Dahl et al., 2013). Obesity has been associated with brain-derived neurotrophic factor (BDNF); however, the impact of this association remains unclear (Sandrini et al., 2018). Dahl et al. found that being overweight at 40 years predicted greater cognitive decline after the age of 60 (Dahl et al., 2013). More intelligent people may be more likely to eat a healthy diet and exercise more often (Halkjær et al., 2003; Nguyen et al., 2014). Other studies highlighted the mediating role of SESs in healthy behavior and its role in healthy eating and physical activity (Murray et al., 2012). In summary, the association between IQ, BMI, and body height is well established in older children and adults, but sufficient information on preschool-aged children is still lacking.

Only a few studies addressed this issue but came to different conclusions. An earlier study by Pollitt and Mueller conducted in a well-nourished preschool population found that children with advanced physiological maturation tended to have high IQs (Pollitt and Mueller, 1982). Tabriz et al. alluded to the mediating role of SES when they found that low IQ score was associated with high BMI (Tabriz et al. et al., 2015). Yu et al. found an inverse association between IQ and obesity in a systematic review and meta-analysis, except for preschool children, that however disappeared when adjusting for educational attainment (Yu et al., 2010). Azurmendi et al. performed two subsets of the K-BIT test, namely, the matrices subtest and vocabulary subtest, and an IQ composite score of the two subtests to study the relation between various cognitive abilities (Azurmendi et al., 2005). They found inconsistent results and suggested that the most accurate predictors of certain cognitive capacities, particularly vocabulary abilities, affective labelling, and IQ composite, were BMI and androstenedione (Azurmendi et al., 2005). On the other hand, Patil et al. assessed anthropometry, dietary recall, and intelligence (Intelligent Quotient-IQ) in 3 to 7 year old children from rural Anganwadis in India and reported that despite high prevalence of malnutrition, there was no correlation between anthropometry and IQ (Patil et al., 2020).

Several studies showed a lack of correspondence between IQ and various anthropometric measures in preschool-aged children. To the best of our knowledge, only one study attempted to examine cognitive abilities in relation to anthropometric measurements. Most studies evaluated intelligence based on global IQ scores alone which may not capture the full range of associations between anthropometric measures such as height and BMI, and IQ in preschool children. Our study aims to investigate the association between height, BMI, sex, and cognitive abilities related to visual processing, selective attention, phonological memory, visual memory, auditory memory, conceptual thinking, constructive thinking and overall IQ in preschool-aged children in the Czech Republic. We hypothesized that height, BMI, and sex are positive predictors of cognitive abilities.

Sample and Methods

Participants

This cross-sectional study was conducted in 59 healthy 3.6–5 (mean=4.5, SD=0.4) year old preschool children (28 boys, 31 girls). The children attended four kindergartens in Prague. The study and consent procedures were approved by the Ethics Committee of the Faculty of Physical Education and Sports. All parents provided written informed consent to participate in this study of their child.

Study duration and time frame:

The study was conducted between 1st March and 30th June 2021.

Instruments

Anthropometric measurements

A qualified examiner assessed each anthropometric characteristic using the Eston and Reilly manual (Eston et al. 2009). Body height measurements were taken with a portable anthropometer P375 and recorded to the nearest 0.1 cm. Body weight was measured using a calibrated scale to the nearest 0.1 kg.

BMI was calculated as weight in kilograms divided by the square of height in meters and converted to BMI z-score based on Czech growth standards (Vignerova et al., 2006).

Measurement of cognitive function

IQ was evaluated using the IDS-P (Hagmann-von Arx et al., 2018). This test battery is a revised version of the Intelligence and Development Scale (Grob et al. 2009). The IDS showed high reliability and validity (Hagmann-von Arx et al., 2013, 2012, 2008), whereas the IDS-P has strong construct validity (Grieder and Grob, 2020). The IDS-P assesses cognitive ability and growth in several fundamental areas (e.g., executive functions, psychomotor skills, social-emotional competencies, scholastic skills and attitudes towards work). For the present study, seven subtests, namely visual processing, selective attention, phonological memory, visual memory, auditory memory, conceptual thinking and constructive thinking, were included. The global IQ score was obtained by adding all subset scores. Raw scores of all tests were transformed into standard scores normalized to age and sex.

We used St. Nicolas House Analysis (SNHA) (Hermanussen et al., 2021) to obtain a first impression of the data. The data set was analyzed using Shapiro-Wilk normality test to check for normal distribution. Subsequently, we used a correlation matrix (Spearman) and a multivariate regression model with the dependent variable IQ, including the subtests and the following predictors: BMI, height and sex. For data analysis, we used RStudio, an open-source program (R Core Team, 2021).

Results

We conducted Spearman's correlation analysis to determine the relation among the variables (Figure 1). Weight and height correlated best (r=0.87), followed by weight and BMI (r=0.56). Among the cognitive functions, IQ and selective attention (r=0.57), and IQ and visual processing memory (r=0.53) correlated best. But the correlations between anthropometric and cognitive data were generally very weak or did not exist at all.

To further elucidate the relationships between the variables, we visualized the results using SNHA (Figure 2). The analysis revealed that anthropometric data and cognitive function formed distinct clusters. BMI, weight, and body height were positively correlated and formed one cluster that was independent of IQ. Cognitive functions, with the exception of auditory and phonological memory, were also positively correlated among each other and formed a second cluster with IQ situated at its centre. Notably, we found no correlation between anthropometric data and cognitive function or between anthropometric data and IQ. Sex did not correlate with either cluster.

A multiple regression analysis was conducted to study whether anthropometrics can predict cognitive function and to evaluate the predictive accuracy of sex, BMI and height on visual processing, selective attention, phonological memory, visual memory, auditory memory, constructive thinking, conceptual thinking and intelligence quotient. Multiple regression analysis revealed that sex, BMI, and height were not statistically significant predictors of the model ($p>0.05$) (Table 1).

Discussion

Substantial research suggested a relationship between anthropometric measurements and intelligence. Yet, most studies were performed in older children and adults. We studied preschool children and used the IDS-P assessment battery to assess the relationships between sex, BMI,

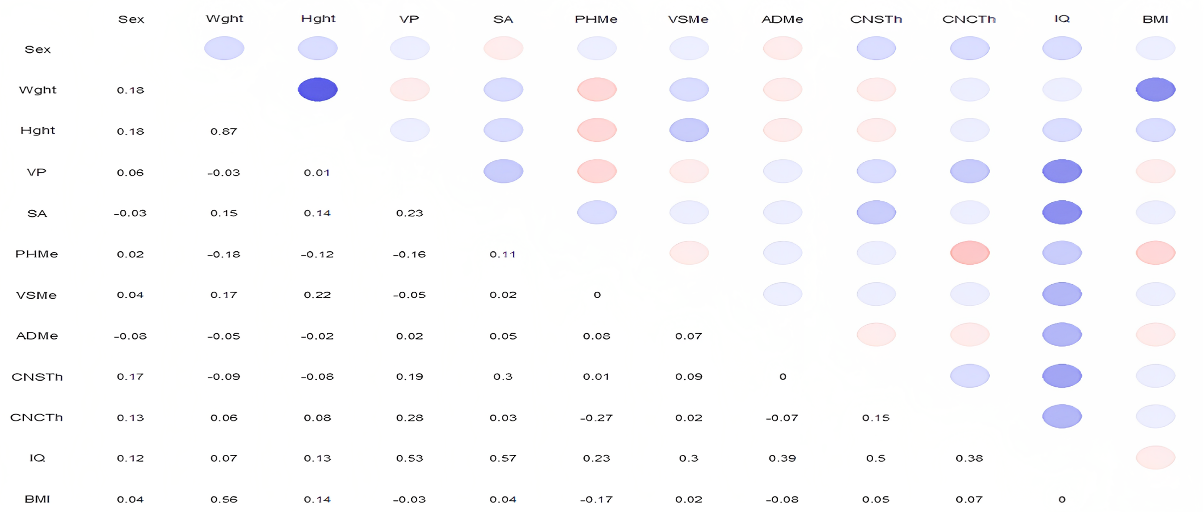

Figure 1 Spearman's correlation matrix for pairwise correlations between anthropometric and cognitive measurements. Blue circles indicate positive correlations; red circles indicate negative correlations. BMI=Body Mass Index; Wght=weight; Hght=height; VP=visual processing; SA=selective attention; PHMe=phonological memory; VSMe=visual memory; ADMe=auditory memory; CNSTh=constructive thinking; CNCTh=conceptual thinking; IQ=intelligence quotient.

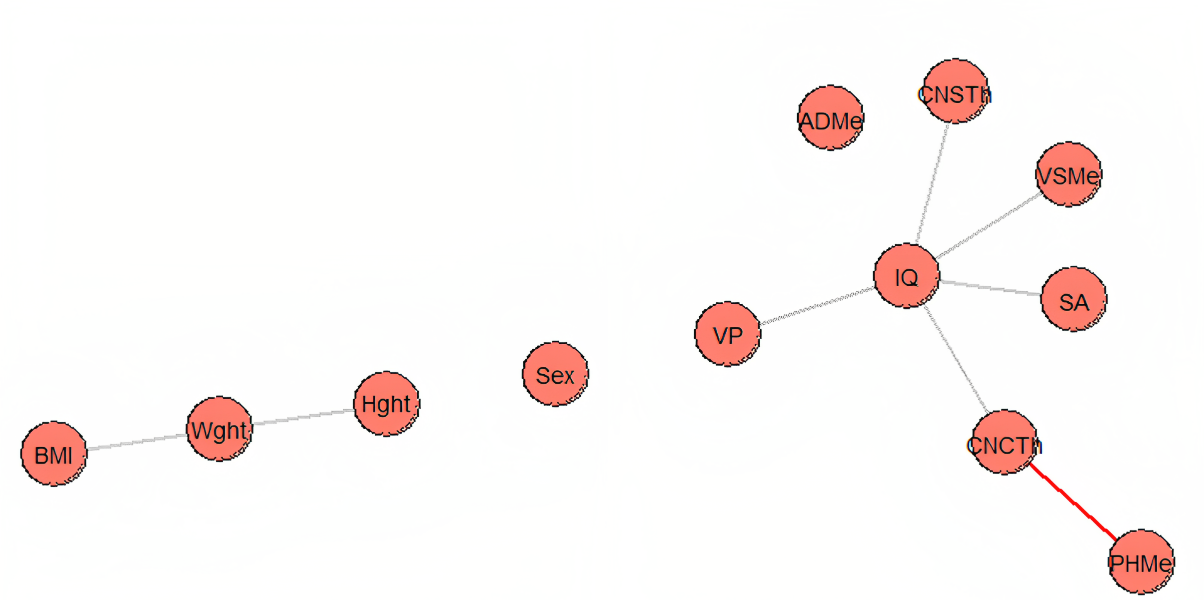

Figure 2 St. Nicolas House Analysis (SNHA) for anthropometric and cognitive measurements. alpha=0.05, threshold=0.001. Red lines indicate negative associations; gray lines indicate positive associations. BMI=Body Mass Index; Wght=weight; Hght=height; VP=visual processing; SA=selective attention; PHMe=phonological memory; VSMe=visual memory; ADMe=auditory memory; CNSTh=constructive thinking; CNCTh=conceptual thinking; IQ=intelligence quotient.

height, visual processing, selective attention, phonological memory, visual memory, auditory memory, constructive thinking, conceptual thinking and intelligence quotient (IQ). We hypothesized that height, BMI and sex are positive predictors of these cognitive abilities.

Our study revealed strong associations between height and weight as well as weight and BMI. Additionally, we observed moderate associations between individual cognitive parameters of the IDS-P tests and total IQ scores. However, we did not identify any significant correlations between anthropometric measurements and any of the IDS-P subtest scores, including total IQ score. Thus, we rejected our initial hypothesis. Our findings contradict previous reports that suggested positive associations between BMI and IQ scores (Tabriz et al., 2015), and positive correlations between height and IQ during early childhood (Silventoinen et al., 2006), and an association between short stature and low mean intellectual performance (Tuvemo et al., 1999). It is important to note that most of the studies that report an association between anthropometric measures and cognitive function also highlight the confounding influence of SES. Our study lacks a thorough examination of socioeconomic factors, but our conclusions are consistent with Patil et al. who failed to detect any significant correlation between anthropometric measures and IQ (Patil et al., 2020). Nonetheless, it is crucial to acknowledge that SES could have influenced the outcomes of our investigation. Previous studies emphasized the critical role of SES in the understanding of the intricate associations between sex, anthropometric measures and IQ.

The negative correlation between BMI and IQ does not only indicate that obesity may increase the risk of cognitive decline in adults (Corley et al., 2010), but also underscores the socioeconomic dimension of this relationship (Pollitt and Mueller, 1982; Tabriz et al., 2015). Kahn and Williamson further demonstrated that families with low education or income levels are more likely to experience obesity and have limited access to mentally stimulating activities that support cognitive development (Kahn and Williamson, 1990). Murray et al. utilized a multiple mediator model to examine the intricate connection between SES, beliefs and behaviour which further elucidates the link between anthropome-

Table 1 The associations between anthropometric and cognitive measurements of 59 children (standard deviations from the mean) assessed by regression model.

Independent variables	Dependent variables							
	Visual processing	Selective Attention	Phenomenological Memory	Visual memory	Auditory Memory	Constructive thinking	Conceptual Thinking	IQ
Constant	11.40 (8.31)	2.32 (8.05)	17.90* (7.6)	-5.84 (6.81)	12.68 (8.79)	13.94* (6.57)	5.54 (7.77)	84.66 (27.67)
Sex	0.40 (0.80)	-0.34 (0.78)	0.13 (0.74)	0.34 (0.66)	-0.42 (0.85)	0.86 (0.64)	0.60 (0.75)	1.50 (2.68)
BMI	-0.06 (0.32)	0.15 (0.31)	-0.17 (0.30)	0.13 (0.27)	-0.03 (0.34)	0.20 (0.26)	0.02 (0.30)	0.26 (1.07)
Height	-0.01 (0.08)	0.05 (0.07)	-0.05 (0.07)	0.13 (0.07)	-0.01 (0.86)	-0.07 (0.06)	0.02 (0.08)	0.10 (0.27)
R-squared	0.01	0.02	0.02	0.09	0.01	0.05	0.02	0.01
Adjusted R^2	-0.05	-0.03	-0.03	0.44	-0.05	-0.00	-0.04	-0.04
F-statistic	0.10	0.35	1.9	1.9	0.11	0.98	0.31	0.26
DF	55	55	55	55	55	55	55	55
p	0.97	0.79	0.14	0.14	0.95	0.41	0.82	0.86

Standard errors in parentheses
* Indicates significance at the 95% level

try and cognitive abilities (Murray et al., 2012).

Students attending better SES schools are more likely to get better test scores on the Programme for International Student Assessment (PISA) (Flores-Mendoza et al., 2021). This confirms observations that children raised under medium to high SES have better chances to be exposed to quality education (Azurmendi et al., 2005). The importance of SESs was highlighted by (Bogin et al., 2017) who suggested that greater income equality is more likely to predict greater average height for both sexes and that gradients in height reflect gradients in social disadvantage. Vietnamese children born in Germany are taller than their immigrant parents (Scheffler et al., 2021) may serve as an example of the importance of social-economic-political-emotional (SEPE) factors (Bogin, 2021).

The question remains as to how BMI, height, and sex influence the IQ. Assessments and interpretations of the relationship between anthropometric parameters and IQ should include SEPE factors to shed more light on the complex interaction between anthropometry and cognition.

A limitation of this study was the fact that it was conducted on a relatively small sample of preschool children from four kindergartens in Prague and that it did not include information on family SES. Therefore, the results may not be generalized to other populations or age groups. Due to the cross-sectional design of the study the causal relationships between the variables could not be established. Further research with larger and more diverse samples as well as longitudinal designs is needed to confirm and extend our findings.

Conclusion

Contrary to earlier research, this study failed to provide evidence for any association between sex, BMI and height in preschool children on one side, and IQ and IQ subtests on the other side. The relationship between sex, BMI, height, and IQ is complex; its assessments must include social, economic, political, and emotional factors.

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References

Azurmendi, A. /Braza, F./ Sorozabal, A./ García, A./ Braza, P. /Carreras, M.R./ Muñoz, J.M./Cardas, J./ Sánchez-Martín, J.R. (2005). Cognitive abilities, androgen levels, and body mass index in 5-year-old children. Hormones and Behavior 48, 187–195. https://doi.org/10.1016/j.yhbeh.2005.03.003.

Beauchamp, J.P./Cesarini, D./Johannesson, M./Lindqvist, E./Apicella, C. (2011). On the sources of the height–intelligence correlation: New insights from a bivariate ACE model with assortative mating. Behavior Genetics 41, 242–252. https://doi.org/10.1007/s10519-010-9376-7.

Benyamin, B./Wilson, V./Whalley, L.J./Visscher, P.M./Deary, I.J. (2005). Large, consistent estimates of the heritability of cognitive ability in two entire populations of 11-year-old twins from scottish mental surveys of 1932 and 1947. Behavior Genetics 35, 525–534. https://doi.org/10.1007/s10519-005-3556-x.

Bogin, B. (2021). Social-Economic-Political-Emotional (SEPE) factors regulate human growth. Human Biology and Public Health 1. https://doi.org/10.52905/hbph.v1.10.

Bogin, B./Scheffler, C./Hermanussen, M. (2017). Global effects of income and income inequality on adult height and sexual dimorphism in height: Bogin et al. American Journal of Human Biology. 29, e22980. https://doi.org/10.1002/ajhb.22980.

Case, A./Paxson, C. (2008). Height, health, and cognitive function at older ages. American Economic Review 98, 463–467. https://doi.org/10.1257/aer.98.2.463.

Corley, J./Gow, A.J./Starr, J.M./Deary, I.J. (2010). Is body mass index in old age related to cognitive abilities? The Lothian Birth Cohort 1936 Study. Psychology and Aging 25, 867–875. https://doi.org/10.1037/a0020301.

Cournot, M./Marquié, J.C./Ansiau, D./Martinaud, C./Fonds, H./Ferrières, J./Ruidavets, J.B. (2006). Relation between body mass index and cognitive function in healthy middle-aged men and women. Neurology 67, 1208–1214. https://doi.org/10.1212/01.wnl.0000238082.13860.50.

Dahl, A.K./Hassing, L.B./Fransson, E.I./Gatz, M./Reynolds, C.A./Pedersen, N.L. (2013). Body mass index across midlife and cognitive change in late life. International Journal of Obesity (London) 37, 296–302. https://doi.org/10.1038/ijo.2012.37.

Eston, R./Hawes, M. M./Reilly, T. (2009). Human body composition (from Eston and Reilly, 3rd ed. 2009). pp. 3–53.

Flores-Mendoza, C./Ardila, R./Gallegos, M./Reategui-Colareta, N. (2021). General intelligence and socioeconomic status as strong predictors of student performance in latin american schools: Evidence from PISA Items. Frontiers in Education 6. https://doi.org/10.3389/feduc.2021.632289

Grieder, S./Grob, A. (2020). Exploratory factor analyses of the intelligence and development scales–2: implications for theory and practice. Assessment 27, 1853–1869. https://doi.org/10.1177/1073191119845051.

Grob, A./Meyer, C./Hagmann-von Arx, P. (2009). Intelligence and Development Scales (IDS).

Hagmann-von Arx, P./Grob, A./Petermann, F./Daseking, M. (2012). [Concurrent validity of the HAWIK-IV and the Intelligence and Development Scales (IDS)]. Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie 40, 41–50. https://doi.org/10.1024/1422-4917/a000148.

Hagmann-von Arx, P./Lemola, S./Grob, A.. (2018). Does IQ = IQ? Comparability of intelligence test scores in typically developing children. Assessment 25, 691–701. https://doi.org/10.1177/1073191116662911.

Hagmann-von Arx, P./Meyer, C.S./Grob, A. (2008). Intelligenz- und entwicklungsdiagnostik im Deutschen sprachraum. [Intelligence and developmental scales in German-speaking countries.]. Kindheit und Entwicklung: Zeitschrift für Klinische Kinderpsychologie 17, 232–242. https://doi.org/10.1026/0942-5403.17.4.232.

Hagmann-von Arx, P./Petermann, F./Grob, A. (2013). Konvergente und diskriminante Validität der WISC-IV und der Intelligence and Development Scales (IDS) bei Kindern mit Migrationshintergrund. Diagnostica 59, 170–182. https://doi.org/10.1026/0012-1924/a000091.

Halkjær, J./Holst, C./Sørensen, T. (2003). Intelligence test score and educational level in relation to bmi changes and obesity. Obesity Research 11, 1238–45. https://doi.org/10.1038/oby.2003.170.

Hermanussen, M./Aßmann, C./Groth, D. (2021). Chain reversion for detecting associations in interacting variables—St. Nicolas House Analysis. International Journal of Environmental Research and Public Health 18, 1741. https://doi.org/10.3390/ijerph18041741.

Kahn, H.S./Williamson, D.F. (1990). The contributions of income, education and changing marital status to weight change among US men. International Journal of Obesity 14, 1057–1068.

Kanazawa, S./Reyniers, D.J. (2009). The role of height in the sex difference in intelligence. The American Journal of Psychology 122, 527–536. https://doi.org/10.2307/27784427.

Lahmann, P.H./Lissner, L./Gullberg, B./Berglund, G. (2000). Sociodemographic factors associated with long-term weight gain, current body fatness and central adiposity in Swedish women. International Journal of Obesity 24, 685–694. https://doi.org/10.1038/sj.ijo.0801219.

Marioni, R.E./Batty, G.D./Hayward, C./Kerr, S.M./Campbell, A./Hocking, L.J./Porteous, D.J./Visscher, P.M./Deary, I.J. (2014). Common genetic variants explain the majority of the correlation between height and intelligence: The generation scotland study. Behavior Genetics 44, 91–96. https://doi.org/10.1007/s10519-014-9644-z.

Murray, T.C./Rodgers, W.M./Fraser, S.N. (2012). Exploring the relationship between socioeconomic status, control beliefs and exercise behavior: a multiple mediator model. Journal of Behavioral Medicine 35, 63–73. https://doi.org/10.1007/s10865-011-9327-7.

Nguyen, J.C.D./Killcross, A.S./Jenkins, T.A. (2014). Obesity and cognitive decline: role of inflammation and vascular changes. Frontiers in Neuroscience 8, 375. https://doi.org/10.3389/fnins.2014.00375.

Patil, S./Joglekar, C./Sonavane, S./Chavan, R./Bhat, P./Mohite, R./Deorukhakar, P./Jadhav, D./Dervankar, O. (2020). Relationship between anthropometric parameters and intelligence in preschool children from rural konkan. International Journal of Clinical and Biomedical Research 30–34. https://doi.org/10.31878/ijcbr.2020.62.08.

Pollitt, E.,/Mueller, W. (1982). The relation of growth to cognition in a well-nourished preschool population. Child Development 53, 1157–1163.

R Core Team. (2021). R: The R Project for Statistical Computing [WWW Document]. URL https://www.r-project.org/ (accessed 23–04-22).

Sandrini, L./Di Minno, A./Amadio, P./Ieraci, A./Tremoli, E./Barbieri, S.S. (2018). Association between obesity and circulating brain-derived neurotrophic factor (BDNF) levels: Systematic review of literature and meta-analysis. International Journal of Molecular Sciences 19, 2281. https://doi.org/10.3390/ijms19082281.

Scheffler, C./Nguyen, T./Hermanussen, M. (2021). Vietnamese migrants are as tall as they want to be. Human Biology and Public Health 2. https://doi.org/10.52905/hbph.v2.12.

Silventoinen, K./Posthuma, D./van Beijsterveldt, T./Bartels, M./Boomsma, D.I./ (2006). Genetic contributions to the association between height and intelligence: Evidence from Dutch twin data from childhood to middle age. Genes Brain and Behavior 5, 585–595. https://doi.org/10.1111/j.1601-183X.2006.00208.x.

Tabriz, A.A./Sohrabi, M.-R./Parsay, S./Abadi, A./Kiapour, N./Aliyari, M./Ahmadi, F./Roodaki, A. (2015). Relation of intelligence quotient and body mass index in preschool children: a community-based cross-sectional study. Nutrition and Diabetes 5, e176–e176. https://doi.org/10.1038/nutd.2015.27.

Tuvemo, T./Jonsson, B./Persson, I. (1999). Intellectual and physical performance and morbidity in relation to height in a cohort of 18-year-old Swedish conscripts. Hormone Reseach 52, 186–191. https://doi.org/10.1159/000023459.

Vignerova, J./Riedlová, J./Bláha, P./Kobzová, L./krejčovský, L./Brabec, M./Hrušková, M. (2006). 6. celostátní antropologický výzkum dětí a mládeže 2001, Česká Republika.

Wheeler, P.G./Bresnahan, K./Shephard, B.A./Lau, J./Balk, E.M. (2004). Short stature and functional impairment: a systematic review. Archives of Pediatrics and Adolescent Medicine 158, 236–243. https://doi.org/10.1001/archpedi.158.3.236.

Yu, Z.B./Han, S.P./Cao, X.G./Guo, X.R. (2010). Intelligence in relation to obesity: a systematic review and meta-analysis. Obesity Reviews 11, 656–670. https://doi.org/10.1111/j.1467-789X.2009.00656.x.