DE GRUYTER OPEN

10.2478/sjph-2018-0011 Zdr Varst. 2018;57(2):81-87

Lucovnik M, Starc G, Golja P, Verdenik I, Stucin Gantar I. Effects of perinatal factors on body mass index and physical fitness of school-age children. Zdr Varst. 2018;57(2):81-87. doi: 10.2478 /sjph-2018-0011.

EFFECTS OF PERINATAL FACTORS ON BODY MASS INDEX AND PHYSICAL FITNESS OF SCHOOL-AGE CHILDREN

VPLIV PERINATALNIH DEJAVNIKOV NA INDEKS TELESNE MASE IN GIBALNO UČINKOVITOST OSNOVNOŠOLCEV

Miha LUCOVNIK[1*], Gregor STARC[2], Petra GOLJA[3], Ivan VERDENIK[4], Irena STUCIN GANTAR[1]

[1]University Medical Centre Ljubljana, Department of Perinatology, Division of Obstetrics and Gynecology, Slajmerjeva 4, 1000 Ljubljana, Slovenia
[2]University of Ljubljana, Faculty of Sport, Gortanova 22, 1000 Ljubljana, Slovenia
[3]University of Ljubljana, Biotechnical Faculty, Jamnikarjeva 101, 1000 Ljubljana, Slovenia
[4]University Medical Centre Ljubljana, Clinic for Gynecology and Obstetrics, Division of Perinatology, Slajmerjeva 3, 1000 Ljubljana, Slovenia

Received: Jun 26, 2017
Accepted: Mar 7, 2018

Original scientific article

ABSTRACT

Keywords:
body mass index, pre-pregnancy obesity, physical fitness, preterm birth, maternal education

Objective: To examine the effects of various maternal and neonatal perinatal factors on the child's body mass index (BMI) and physical fitness at school-age.

Methods: Data from two registries, the SLOfit database (a national surveillance system of children's motor and physical development) and Slovenian National Perinatal Information System (NPIS) were analysed. Perinatal data for 2,929 children born in 2008 were linked to results of SLOfit testing of these children in 2016. Linear regression analysis was used to assess the potential relationship between several perinatal factors (very preterm birth, birth mass, maternal age, hypertensive disorders of pregnancy, gestational diabetes, parity, plurality, maternal pre-pregnancy BMI, mode of delivery, presentation, Apgar score at 5 minutes, and admission to a neonatal intensive care unit (NICU)) and child's BMI or child's physical fitness index (PFI) at the age of eight years. We also included child's school grade and maternal educational level in the analysis. A p value <0.05 was considered statistically significant.

Results: Children born to mothers with lower pre-pregnancy BMI and higher education had lower BMI and higher PFI (p<0.001) at school-age. Physical fitness was also inversely associated with nulliparity (p<0.001) and NICU admission (p=0.020).

Conclusions: Among all perinatal factors studied, higher maternal education and lower pre-pregnancy BMI seem to be the most significant determinants of child's BMI and physical fitness at school-age.

IZVLEČEK

Ključne besede:
indeks telesne mase, debelost, nosečnost, porod, gibalna učinkovitost, izobrazba matere

Namen: *Ugotoviti morebitne dolgoročne učinke perinatalnih dejavnikov na indeks telesne mase (ITM) in gibalno učinkovitost otrok v starosti osem let.*

Metode: *Analizirali smo podatke baze SLOfit (Nacionalnega sistema spremljanja telesnega in gibalnega razvoja otrok in mladine) in Nacionalnega perinatalnega informacijskega sistema Slovenije (NPIS). Perinatalne podatke za 2929 otrok, rojenih leta 2008, smo povezali z rezultati njihovih meritev SLOfit v letu 2016. Z linearno regresijo smo ugotavljali morebitne povezave med otrokovim ITM in indeksom gibalne učinkovitosti (IGU) ter naslednjimi perinatalnimi dejavniki: zelo prezgodnji porod, porodna masa, pariteta, število plodov, ITM matere pred zanositvijo, način poroda, vstava, ocena po Apgarjevi in potreba po neonatalni intenzivni terapiji. V analizo smo vključili tudi razred osnovne šole, ki ga je otrok obiskoval, in materino stopnjo izobrazbe. Za statistično značilno smo upoštevali vrednost p<0,05.*

Rezultati: *Otroci, rojeni materam z višjo izobrazbo in nižjim ITM pred zanositvijo, so imeli v starosti osem let nižji ITM in višji IGU (p<0,001). Otroci, ki so potrebovali neonatalno intenzivno terapijo (ne glede na gestacijsko starost) (p=0,020), in prvorojenci (p<0,001) so imeli slabšo gibalno učinkovitost.*

Zaključki: *Med vsemi preučenimi perinatalnimi dejavniki sta stopnja izobrazbe matere in njen ITM pred zanositvijo v največji meri vplivala na ITM in gibalno učinkovitost otroka v starosti osem let.*

***Corresponding author:** Tel. + 386 1 318 681; E-mail: mihalucovnik@yahoo.com

1 INTRODUCTION

Data on pregnancy complications, labour, delivery, and perinatal outcomes are being extensively collected in all developed countries. However, due to logistic difficulties of a long-term follow-up, only the short-term outcomes, such as Apgar scores, neonatal respiratory morbidity, admission to neonatal intensive care units (NICU), etc., are mostly analysed (1). Of all perinatal factors, prematurity has been the most studied in terms of its long-term consequences. Preterm birth has been shown in observational studies to be associated with decreased physical fitness and impaired cognitive functions in later life (2–9). Studies on impacts of other perinatal factors, such as hypertensive disorders of pregnancy, gestational diabetes, intrauterine growth restriction, plurality, parity, mode of delivery, etc., on long-term health are, however, lacking.

Studies on children born preterm suggest that childhood obesity and poor physical fitness could be among potential adverse long-term effects of complications in the perinatal period (2–14). Childhood obesity and poor physical fitness at school-age are associated with many preventable diseases and present a serious current and future public health problem, especially because they track well into adulthood and are associated with numerous adverse health outcomes (15–18). With global prevalence of childhood obesity continually growing, it is important to identify potential perinatal risk factors that could be effective targets of future public health initiatives tackling obesity (19, 20). Moreover, poor physical fitness in childhood has been associated with unfavourable psychological, social and cognitive development (21–32). It is, therefore, important to establish the impact of perinatal factors, such as preterm birth and others, on long-term physical development of children.

All births in Slovenia are being registered in the Slovenian National Perinatal Information System (NPIS) since 1987. The country also has a monitoring system of children's motor and physical development, the SLOfit system, implemented in all schools in 1987, which includes almost the entire school-going population from ages 6 to 18. The aim of the present study was to link the data from both registers in order to examine the potential relationship between several biological and environmental perinatal factors and child's body mass index (BMI) and physical fitness at school-age.

2 METHODS

We analysed the 2016 SLOfit data for children born at our institution in 2008, at their age of eight, and linked them to their NPIS perinatal data.

The SLOfit system is a national surveillance system of children's motor and physical development. Every April, qualified physical education teachers perform the measurements in all primary and secondary schools, following the official measurement protocol. The SLOfit test battery includes eight motor tests (arm-plate tapping, standing long jump, polygon course backwards, sit-ups, standing reach touch, bent arm hang, 60-meter run and 600-meter run), as well as measurements of child's height, weight and triceps skinfold thickness. Measurements are always organized in school gyms between 08:00 and 14:00. Subjects are weighed barefoot in their shorts and T-shirts to the nearest 0.1 kg with portable scales of various brands; height is measured with stadiometers of various brands to the nearest 0.1 cm. In order to include and evaluate the children's measurements in the SLOfit system, and to use the data for scientific purposes, children need the written consent of their parents; throughout the existence of this system, the response rates in primary schools have remained above 94%.

The Slovenian National Perinatal Information System (NPIS) registers all deliveries in Slovenia at ≥22 weeks of pregnancy or when the birth mass is ≥ 500 g. Registration is mandatory by law in the country's 14 maternity units and more than 140 variables are entered into a computerized database by the attending midwife and physician. To assure quality of data collection, controls are built in the computerized system, data is audited periodically, and comparisons are made with international databases, such as the Vermont Oxford network, in which Slovenia participates.

SLOfit data of the eight motor tests were used to calculate the physical fitness index (PFI). The z-score of each test was computed and the PFI was computed as the mean of all eight z-scores as: mean of eight z-scores x ten + 50. Child's height and weight measurements were used to calculate the body mass index (BMI). By definition BMI (both in children and in mothers) was calculated as an individual's weight in kilograms, divided by the height in metres squared. BMI was categorized according to the Institute of Medicine criteria as underweight (<18.5 kg/m2), normal (18.5–24.9 kg/m2), overweight (25–29.9 kg/m2) or obese (≥30 kg/m2) (33).

Student's T test was used to compare maternal and neonatal characteristics in the study group (the group for which SLOfit and NPIS data could be matched) and in the group in which SLOfit and NPIS data could not be matched. Linear regression analysis was used to assess the potential relationship between several perinatal factors (very preterm birth (<32 0/7 weeks), small for gestational age (SGA; birth mass of <10th percentile for gestation), large for gestational age (LGA; birth mass of >90th percentile for gestation), maternal age at birth, hypertensive disorders of pregnancy (diagnosed in 2008 in Slovenia as blood pressure of ≥140/90 mmHg after 20 weeks' gestation with or without proteinuria), gestational diabetes mellitus (diagnosed in Slovenia in 2008 using a two-step approach: screening with 50g oral glucose load and, when indicated, performing a 100g oral glucose tolerance test based on Carpenter and Coustan criteria), parity (nullipara vs. multipara), plurality (singleton vs. twin pregnancies), maternal pre-pregnancy BMI, mode of delivery (caesarean vs. vaginal delivery), presentation (cephalic vs. breech), Apgar score at 5 minutes <6, and admission to a neonatal intensive care unit (NICU)) and child's BMI and PFI at the age of eight years. We also included child's school grade and maternal educational level (defined as primary or vocational school; high school or college, and university degree or higher) in the regression analysis.

A p value of <0.05 was considered statistically significant. The software used for statistical analysis was IBM SPSS Statistics for Windows Version 21.0 (Armonk, NY: IBM Corp.).

3 RESULTS

A total of 6,894 neonates were born at our institution in 2008. Ninety stillbirths and early neonatal deaths were excluded leaving 6,804 children for analysis. We were able to match 2,929 (43%) of these children from SLOfit database to NPIS data due to unavailability of complete identifiers in the NPIS register. In other words, NPIS includes mothers' data for identification of children and the initial names of children are later often changed. The SLOfit database only includes children's data from official school records.

Table 1 presents the comparison between maternal and neonatal characteristics in the study group (the group for which SLOfit and NPIS data could be matched) and in the group in which we were unable to match the SLOfit and NPIS data.

Table 1. The comparison between maternal and neonatal characteristics in the study group and in the group in which SLOfit and NPIS data could not be matched.

	Matched study group	Non-matched group	P
Low maternal educational level (primary or vocational school degree)*	133 (4.6%)	135 (3.5%)	0.03
High maternal educational level (university degree or higher)	1,225 (42.0%)	1,665 (43.0%)	0.40
Very preterm birth (<32 0/7 weeks)*	39 (1.3%)	101 (2.6%)	<0.001
SGA	79 (2.7%)	134 (3.5%)	0.08
LGA	108 (3.7%)	133 (3.4%)	0.56
Maternal age (years)*	30.4±4.6	30.0±4.8	<0.001
Hypertensive disorders of pregnancy	93 (3.2%)	125 (3.2%)	0.93
Gestational diabetes	130 (4.5%)	175 (4.5%)	0.90
Nulliparity*	1,223 (41.9%)	2,298 (59.3%)	<0.001
Twin pregnancy*	122 (4.2%)	210 (5.4%)	0.02
Maternal pre-pregnancy BMI*	23.4±4.2	23.0±4.2	<0.001
Cesarean section	454 (15.5%)	666 (17.2%)	0.07
Breech presentation	147 (5%)	212 (5.5%)	0.43
Apgar score at 5 min <6	14 (0.5%)	21 (0.5%)	0.72
NICU admission*	205 (7.0%)	371 (9.6%)	<0.001

Data are shown as mean ± SD, or as N (%); BMI body mass index; NICU neonatal intensive care unit; * represents statistical significance (p<0.05) (Student's T test)

Tables 2 and 3 present the results of the regression analysis. Children born to mothers with lower pre-pregnancy BMI and higher education had lower BMI and higher PFI (p<0.001). Physical fitness was lso inversely associated with nulliparity (p<0.001) and NICU admission (p=0.020), but not with other factors, including very preterm birth (p=0.719).

Table 2. The relationship between perinatal factors and child's body mass index (BMI) at the age of eight.

	Unstandardized B	SE	Standardized B	p
High maternal educational level (university degree or higher)*	-0.484	0.102	-0.091	<0.001
Very preterm birth (<32 0/7 weeks)	-0.873	0.516	-0.036	0.091
SGA	0.089	0.310	0.006	0.773
LGA	0.430	0.266	0.031	0.106
Maternal age	-0.016	0.011	-0.029	0.150
Hypertensive disorders of pregnancy	0.337	0.278	0.022	0.226
Gestational diabetes	-0.098	0.234	-0.008	0.677
Nulliparity	0.147	0.105	0.028	0.159
Twin pregnancy	-0.119	0.270	-0.009	0.659
Maternal pre-pregnancy BMI*	0.153	0.012	0.241	<0.001
Cesarean section	-0.022	0.145	-0.003	0.878
Breech presentation	-0.208	0.236	-0.017	0.378
Apgar score at 5 min <6	0.653	0.737	0.017	0.376
NICU admission	-0.090	0.248	-0.009	0.718

B regression model coefficient; SE model's coefficient standard error; BMI body mass index; NICU neonatal intensive care unit; * represents statistical significance (p<0.05)

Table 3. The relationship between perinatal factors and child's physical fitness index (PFI) at the age of eight.

	Unstandardized B	SE	Standardized B	p
High maternal educational level (university degree or higher)*	1.598	0.255	0.120	<0.001
Very preterm birth (<32 0/7 weeks)	-0.455	1.266	-0.008	0.719
SGA	-0.735	0.773	-0.018	0.342
LGA	-0.550	0.666	-0.016	0.409
Maternal age	-0.044	0.029	-0.031	0.121
Hypertensive disorders of pregnancy	0.224	0.682	0.006	0.743
Gestational diabetes	-0.672	0.574	-0.021	0.241
Nulliparity	-1.528	0.261	-0.115	<0.001
Twin pregnancy	0.564	0.677	0.017	0.405
Maternal pre-pregnancy BMI*	-0.105	0.031	-0.066	<0.001
Cesarean section	0.223	0.365	0.012	0.541
Breech presentation	-0.110	0.586	-0.004	0.851
Apgar score at 5 min <6	-0.815	2.024	-0.008	0.687
NICU admission	-1.432	0.618	-0.056	0.020

B regression model coefficient; SE model's coefficient standard error; BMI body mass index; NICU neonatal intensive care unit; * represents statistical significance (p<0.05)

4 DISCUSSION

Our findings emphasize the importance of maternal education and lifestyle on children's motor and physical development. Higher maternal education and lower pre-pregnancy maternal BMI were associated with lower BMI and higher physical fitness of children at age 8. Children's physical fitness was also linked to parity (first-borns having lower physical fitness than their siblings) and NICU admission irrespective of gestational age.

These results are in accordance with several previously published studies. Finger et al. showed lower parental education level to be associated with higher BMI and lower fitness capacity among adolescents (34). Parental education and occupation were more strongly related to adolescents' physical activity and fitness outcomes than to family income (31). Two other studies reported similar results, but they were both based on surveys and not on objective fitness capacity measurements (35, 36). Children from families with lower socioeconomic status have also been shown to have higher rates of metabolic syndrome, impaired fasting glucose and type 2 diabetes in adulthood (37). Special preventive measures for these families with programs focused on healthy nutrition and fitness stimulation could effectively decrease the burden of metabolic syndrome in adulthood.

Very preterm birth (at <32 weeks' gestation) was not an independent risk factor for increased child's BMI at the age of eight years. This is not in accordance with the results from Vasylyeva et al., who showed preterm birth to be associated with the highest risk for excessive weight gain during childhood (10). However, late preterm birth, and not very preterm birth, was the main factor contributing to excessive weight gain in their study (10). A possible explanation for this could be that altered appetite regulation or altered insulin secretion are responsible for childhood obesity only in preterm infants with higher birth mass, i.e., those born in the late preterm period (11, 12). Physical fitness was also not associated with very preterm delivery. However, admission to the NICU was an independent risk factor for decreased physical fitness at school-age. This may be explained by increased pain sensitivity, increased avoidance behaviour, and social hypervigilance, which are all possible consequences of untreated NICU associated pain in early infancy and are unrelated to gestational age at NICU admission (13). Decreasing stress in the NICU and active encouraging of parents to stimulate their NICU children to participate in regular childhood physical activities and sports could, therefore, be very important to decrease the negative influence of NICU on physical fitness in childhood.

The association between birth order and physical fitness has not been well studied to date. We found first-born children to have lower exercise capacities, in contrast to Barclay and Myrskyla, who reported the opposite, i.e., better physical fitness in first-borns (38). It is important to notice that they analysed only males, who were born in a different time period (1965–1977). They interpreted their findings as being the consequence of social upbringing within the family rather than prenatal experience. Our results seem to suggest that older siblings positively influence the physical activity of their younger brother or sister. The important influence of peer stimulation is supported by the fact that children who attended higher school grades at the same age had better PFI in our study.

The main limitation of the study is its retrospective observational nature, which does not allow accounting for all potential confounders. It also does not allow deriving definitive conclusions on causal relations between factors studied and children's BMI and physical fitness. Moreover, we were not able to match the data of all children from the SLOfit database and NPIS. The group in which we were unable to link children's data from SLOfit to NPIS differed in many maternal and neonatal characteristics from the group for which data from these databases could be matched. Many of these differences were statistically important due to large numbers, but clinically irrelevant, e.g., the 94 g difference in birth mass between the two groups. Other differences, such as higher proportion of nulliparous women in the non-matched group, however, could indicate a systemic bias. Our results should, therefore, be interpreted with caution. To allow this, we decided to present also maternal and neonatal characteristics of pregnancies of the non-matched data. We have not stratified BMIs in subgroups, but only determined a correlation between maternal and child's BMI and other factors. Further studies will, therefore, be needed in order to more exactly determine which BMIs (in which subgroups) are correlated with which outcomes. We believe, however, that our results highlight the importance of maternal pre-pregnancy BMI and will lead to additional studies in this field.

In conclusion, our results seem to suggest that factors such as high maternal pre-pregnancy BMI and low maternal education level seem to be among the most important determinants of worse child's physical health at school-age. These public health domain factors seem to be of greater importance for child's long-term development than many perinatal outcomes, such as very preterm birth, SGA, LGA or low Apgar scores, on which perinatal medicine is currently mostly focused. Finally, our study shows that social factors seem to significantly determine the developmental outcome of children, which gives lots of opportunities for effective interventions in the pre-school and school age.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

FUNDING

The study was not financed.

ETHICAL APPROVAL

Received from the National Medical Ethics Committee (approval number 102/03/15).

REFERENCES

1. EURO-PERISTAT Project. The european perinatal health report 2010. Accessed June 18th, 2017 at: http://europeristat.com.
2. Hille ET, den Ouden AL, Saigal S, Wolke D, Lambert M, Whitaker A , et al. Behavioural problems in children who weigh 1000 g or less at birth in four countries. Lancet. 2001;357:1641-3. doi: 10.1016/S0140-6736(00)04818-2.
3. Bhutta AT, Cleves MA, Casey PH, Cradock MM, Anand KJ. Cognitive and behavioral outcomes of school-aged children who were born preterm: a meta-analysis. JAMA. 2002;288:728-37. doi: 10.1001/jama.288.6.728.
4. Saigal S, den Ouden L, Wolke D, Hoult L, Paneth N, Streiner DL , et al. School-age outcomes in children who were extremely low birth weight from four international population-based cohorts. Pediatrics. 2003;112:943-50. doi: 10.1542/peds.112.4.943.
5. Hack M, Taylor HG, Drotar D, Schluchter M, Cartar L, Andreias L, et al. Chronic conditions, functional limitations, and special health care needs of school-aged children born with extremely low-birth-weight in the 1990s. JAMA. 2005;294:318-25. doi: 10.1001/jama.294.3.318.
6. Marlow N, Wolke D, Bracewell MA, Samara M. Neurologic and developmental disability at six years of age after extremely preterm birth. N Engl J Med. 2005;352:9-19. doi: 10.1056/NEJMoa041367.
7. Litt J, Taylor HG, Klein N, Hack M. Learning disabilities in children with very low birthweight: prevalence, neuropsychological correlates, and educational interventions. J Learn Disabil. 2005; 38:130-41. doi: 10.1177/00222194050380020301.
8. Moster D, Lie RT, Markestad T. Long-term medical and social consequences of preterm birth. N Engl J Med. 2008;359:262-73. doi: 10.1056/NEJMoa0706475.
9. Svedenkrans J, Kowalski J, Norman M, Bohlin K. Low exercise capacity increases the risk of low cognitive function in healthy young men born preterm: a population-based cohort study. PLoS One. 2016;11:e0161314. doi: 10.1371/journal.pone.0161314.
10. Vasylyeva TL, Barche A, Chennasamudram SP, Sheehan C, Singh R, Okogbo ME. Obesity in prematurely born children and adolescents: follow up in pediatric clinic. Nutr J. 2013;12:150. doi: 10.1186/1475-2891-12-150.
11. Gaskins RB, Liu J, Shankaran S, Lester BM, Bada HS. Small for gestational age and higher birth weight predict childhood obesity in preterm infants. Am J Perinatol. 2010;27:721-30. doi: 10.1055/s-0030-1253555.
12. Rother E, Kuschewski R, Alcazar MA, Oberthuer A, Bae-Gartz I, Vohlen C. Hypothalamic JNK1 and IKK beta activation and impaired early postnatal glucose metabolism after maternal perinatal high-fat feeding. Endocrinology. 2012;153:770-81. doi: 10.1210/en.2011-1589.
13. Page GG. Are there long-term consequences of pain in newborn or very young infants? J Perinat Educ. 2004;13:10-7. doi: 10.1624/105812404X1725.
14. Kovač M, Jurak G, Zaletel Kragelj L, Leskošek B. The secular trend in the prevalence of overweight and obesity in the population of primary school children from Ljubljana (Slovenia). Zdr Varst. 2014;53:188-98. doi: 10.2478/sjph-2014-0019.
15. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. Pediatrics. 1998;101:518-25. doi: 10.1542/peds.101.3.s1.518.
16. Yang X, Telama R, Leskinen E, Mansikkaniemi K, Viikari JSA, Raitakari OT. Testing a model of physical activity and obesity tracking from youth to adulthood: the cardiovascular risk in young Finns study. Int J Obes. 2007;31:521-7. doi: 10.1038/sj.ijo.0803459.
17. Steinberger J, Daniels SR, Eckel RH, Hayman L, Lustig RH, McCrindle B, et al. Progress and challenges in metabolic syndrome in children and adolescents: a scientific statement from the american heart association atherosclerosis, hypertension, and obesity in the young committee of the council on cardiovascular disease in the young; council on cardiovascular nursing; and council on nutrition, physical activity, and metabolism. Circulation. 2009;119:628-47. doi: 10.1161/CIRCULATIONAHA.108.191394.
18. Kotnik P, Fischer Posovszky P, Wabitsch M. Endocrine and metabolic effects of adipose tissue in children and adolescents. Zdr Varst. 2015;54:131-8. doi: 10.1515/sjph-2015-0020.
19. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. Int J Pediatr Obes. 2006;1:11-25. doi: 10.1080/17477160600586747.
20. Centers for Disease Control (CDC). Childhood obesity facts. Accessed June 18th 2017 at: http://www.cdc.gov/healthyschools/obesity/facts.htm.
21. Owen CG, Nightingale CM, Rudnicka AR, Sattar N, Cook DG, Ekelund U, et al. Physical activity, obesity and cardiometabolic risk factors in 9- to 10-year-old UK children of white European, South Asian and black African-Caribbean origin: the Child Heart And health Study in England (CHASE). Diabetologia. 2010;53:1620-30. doi: 10.1007/s00125-010-1781-1.
22. Fox KR. The self-esteem complex and youth fitness. Quest. 1988;40:230-46. doi: 10.1080/00336297.1988.10483903.
23. Backmand H, Kaprio J, Kujala UM, Sarna S, Fogelholm M. Physical and psychological functioning of daily living in relation to physical activity: a longitudinal study among former elite male athletes and controls. Aging Clin Exp Res. 2006;18:40-9. doi: 10.1007/BF03324639.
24. Hassmen P, Koivula N, Uutela A. Physical exercise and psychological well-being: a population study in Finland. Prev Med. 2000;30:17-25. doi: 10.1006/pmed.1999.0597.
25. Kjonniksen L, Anderssen N, Wold B. Organized youth sport as a predictor of physical activity in adulthood. Scand J Med Sci Sports. 2009;19:646-54. doi: 10.1111/j.1600-0838.2008.00850.x.
26. Trudeau F, Laurencelle L, Shephard RJ. Is fitness level in childhood associated with physical activity level as an adult? Pediatr Exerc Sci. 2009;21:329-38. doi: 10.1123/pes.21.3.329.
27. Telama R, Yang XL, Hirvensalo M, Raitakari O. Participation in organized youth sport as a predictor of adult physical activity: a 21-year longitudinal study. Pediatr Exerc Sci. 2006;18:76-88. doi: 10.1123/pes.18.1.76.
28. Strauss RS, Rodzilsky D, Burack G, Colin M: Psychosocial correlates of physical activity in healthy children. Arch Pediat Adol Med. 2001;155:897-902. doi: 10.1001/archpedi.155.8.897.
29. Gibbons SL, Ebbeck V, Weiss MR. Fair play for kids - effects on the moral development of children in physical-education. Res Q Exercise Sport. 1995;66:247-55. doi: 10.1080/02701367.1995.10608839.
30. Sallis JF, McKenzie TL, Kolody B, Lewis M, Marshall S, Rosengard P. Effects of health-related physical education on academic

achievement: project SPARK. Res Q Exerc Sport. 1999;70:127-34. doi: 10.1080/02701367.1999.10608030.

31. Carlson SA, Fulton JE, Lee SM, Maynard LM, Brown DR, Kohl HW, et al. Physical education and academic achievement in elementary school: data from the early childhood longitudinal study. Am J Public Health. 2008;98:721-7. doi: 10.2105/AJPH.2007.117176.
32. Trudeau F, Shephard R. Physical education, school physical activity, school sports and academic performance. Int J Behav Nutr Phys Act. 2008;5:10. doi: 10.1186/1479-5868-5-10.
33. Finger JD, Mensink GBM, Banzer W, Lampert T, Tylleskär T. Physical activity, aerobic fitness and parental socio-economic position among adolescents: the German Health Interview and Examination Survey for Children and Adolescents 2003–2006 (KiGGS). Int J Behav Nutr Phys Act. 2014;11:43. doi: 10.1186/1479-5868-11-43.
34. Institute of Medicine. Weight gain during pregnancy: reexamining the guidelines. Washington DC: National Academic Press, 2009.
35. McMurray RG, Harrell JS, Deng S, Bradley CB, Cox LM, Bangdiwala SI. The influence of physical activity, socioeconomic status, and ethnicity on the weight status of adolescents. Obesity. 2000;8:130-9. doi: 10.1038/oby.2000.14.
36. Sallis JF, Zakarian JM, Hovell MF, Hofstetter CR. Ethnic, socioeconomic, and sex differences in physical activity among adolescents. J Clin Epidemiol. 1996;49:125-34. doi: 10.1016/0895-4356(95)00514-5.
37. Puolakka E, Pahkala K, Laitinen TT, Magnussen CG, Hutri-Kähönen N, Tossavainen P, et al. Childhood socioeconomic status in predicting metabolic syndrome and glucose abnormalities in adulthood: the cardiovascular risk in young Finns study. Diabetes Care. 2016;39:2311-7. doi: 10.2337/dc16-1565.
38. Barclay K, Myrskylä M. Birth order and physical fitness in early adulthood: evidence from Swedish military conscription data. Soc Sci Med. 2014;123:141-8. doi: 10.1016/j.socscimed.2014.11.007.