

Original research article

BODY COMPOSITION, MOTOR PERFORMANCE, AND REACTION PERFORMANCE IN LOWER SECONDARY SCHOOL PUPILS IN TRNAVA, SLOVAKIA: A CROSS-SECTIONAL STUDY

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Abstract

Introduction: Physical fitness and health-related movement indicators are important determinants of children's health, influencing body composition, motor abilities, and long-term disease risk. Therefore, this study aimed to estimate associations and odds of selected outcomes related to body composition, motor performance, and reaction performance among lower secondary school pupils in Trnava.

Methods: A cross-sectional study of 444 pupils aged 11–16 years included anthropometric measurements and motor and reaction tests. Multiple logistic regression was applied with a significance level of $p < 0.05$ and 95% confidence intervals.

Results: Obesity was identified in 11% of pupils, low handgrip strength in 7%, and slower reaction performance in 21% of children. Obesity odds increased significantly with higher body fat mass (OR = 2.29; 95% CI: 1.60–3.27; $p < 0.0001$) and decreased with age. Low handgrip strength was associated with higher body fat percentage (OR = 1.70; 95% CI: 1.39–2.07; $p < 0.0001$), while girls had lower odds of low handgrip strength than boys (OR = 0.01; 95% CI: 0.0009–0.07; $p < 0.001$). Slower reaction performance was associated with lower skeletal muscle mass (OR = 0.95; 95% CI: 0.90–1.00; $p < 0.05$) and poorer performance in the tapping test (OR = 0.97; 95% CI: 0.96–0.99; $p < 0.001$), with boys showing higher odds (OR = 0.46; 95% CI: 0.26–0.80; $p < 0.01$).

Conclusion: The findings highlight significant associations between body composition, motor performance, and reaction performance. They emphasise the need to support physical fitness, motor competence, and active school environments from an early age.

Keywords: *Adolescents; Body composition; Children; Physical fitness; Reaction performance*

Abbreviations:

BFM – Body Fat Mass; BMI – Body Mass Index; CI – Confidence Interval; NSUT – Námestie slovenského učenia tovaríšstva (lower secondary school); OR – Odds Ratio; PBF – Body Fat Percentage; SMM – Skeletal Muscle Mass; VFL – Visceral Fat Level

INTRODUCTION

Physical fitness and related movement competencies represent key determinants of health in children and adolescents. Their level influences not only current health status but

also the long term risk of developing chronic diseases in adulthood, including obesity, type 2 diabetes mellitus, and cardiovascular diseases. The World Health Organization warns that insufficient regular physical activity is among the major global health threats, with

particularly pronounced negative effects in childhood and adolescence (WHO, 2022).

The concept of physical literacy is often used to describe a broader framework that extends beyond physical activity levels or motor performance alone, encompassing movement-related competencies and engagement in physical activity. Contemporary literature defines it as a lifelong developmental process that creates the foundation for sustained engagement in physical activities and the maintenance of an active lifestyle. Its significance extends beyond sport and physical education, as it plays an important role in the prevention of chronic diseases, the promotion of physical and mental health, and the enhancement of quality of life across the lifespan (Cairney et al., 2019; Caldwell et al., 2020; Cornish et al., 2020). Physical literacy is a multidimensional construct comprising four interrelated domains: affective, physical, cognitive, and behavioural. The affective domain includes motivation and confidence in physical activities; the physical domain reflects motor and movement competencies; the cognitive domain encompasses knowledge and understanding of the importance of movement for health; and the behavioural domain captures long term engagement in physical activities. These domains interact and evolve throughout life, making physical literacy a holistic approach to children's and adolescents' movement and health (Caldwell et al., 2020; Cornish et al., 2020). Although the concept includes cognitive and behavioural domains, our study focuses only on selected measurable indicators related to body composition and motor and reaction performance.

Research indicates that better body composition, handgrip strength, motor performance, and reaction processes are generally associated with higher physical activity and more favourable health indicators in children and adolescents (Cairney et al., 2019; Caldwell et al., 2020; Mendoza-Muñoz et al., 2021). Conversely, insufficient physical activity and poorer movement-related performance are associated with unfavourable body composition, reduced muscular strength, and weaker cognitive or school-related outcomes (Caldwell et al., 2020).

Global trends point to a long-term decline in physical fitness among children and adolescents, which is most pronounced in

economically developed countries and urbanised regions (Ortega et al., 2023). This adverse trend is primarily attributed to lifestyle changes characterised by increased sedentary time, reduced spontaneous physical activity, and greater use of digital technologies in both school and leisure environments (Lee et al., 2020; Ruan and Tang, 2024).

International physical fitness monitoring systems document that countries in Northern and Western Europe, as well as Japan, achieve above average levels of aerobic capacity and muscular strength among children and adolescents (Ortega et al., 2023; Ruan and Tang, 2024). These favourable outcomes are attributed to systematic support for physical activity in schools, high participation in organised sports, accessible sports infrastructure, and a cultural emphasis on active living (Ortega et al., 2023). In contrast, countries in Southern Europe, Latin America, and urbanised regions of China consistently report lower physical fitness levels, particularly in aerobic capacity and muscular endurance (Lee et al., 2020; Ortega et al., 2023; Ruan and Tang, 2024). These differences are explained by a combination of factors, including a higher prevalence of sedentary leisure activities, lower frequency of regular physical activity, and limited opportunities for spontaneous movement in urban environments. Urbanisation, academic pressure, and changes in the organisation of children's daily routines contribute to reduced overall physical activity, which subsequently negatively affects their physical fitness (Lee et al., 2020; Ruan and Tang, 2024). In contrast to these regions, children and adolescents in rural areas of Africa maintain higher levels of physical fitness compared with the global average (National Sports Center, 2020). This phenomenon is primarily explained by high levels of natural daily physical activity, which forms an integral part of their lifestyle. Movement in these populations does not stem mainly from organised sports but from everyday activities such as walking long distances, manual labour, household tasks, and active transportation. Lower levels of sedentary behaviour, limited access to digital technologies, and the preservation of traditional lifestyles contribute significantly to the development of aerobic capacity, muscular strength, and overall physical fitness from early childhood (Monyeki et al., 2012).

In Slovakia, children's physical fitness is systematically monitored through the national Student Testing Information System, introduced by the Ministry of Education, Science, Research and Sport of the Slovak Republic in cooperation with the National Sports Centre. This legislatively established system enables regular assessment of motor abilities in pupils in the first and third grades of primary school and provides valuable data on the development of children's physical fitness at the national level. Monitoring results repeatedly indicate below average to markedly below average values, particularly in strength, speed strength, and speed coordination abilities, compared with generations from 20 to 30 years ago. Regional differences have also been documented, likely reflecting variations in access to sports infrastructure, socioeconomic conditions, and opportunities for physical activity across regions (National Sports Center, 2020). These trends may have negative consequences not only for children's current health but also for their long term quality of life.

Despite the existence of national monitoring systems, data on children's health risks related to body composition and physical fitness at the local level remain limited. Urban environments – characterised by higher levels of sedentary behaviour, greater prevalence of passive leisure activities, and restricted opportunities for spontaneous movement – may contribute to obesity and reduced physical fitness in children. Therefore, regional and local studies are needed to more precisely identify factors associated with adverse body composition and physical fitness outcomes, and to provide evidence for targeted preventive measures in school settings.

Consequently, the aim of this study was to examine associations and estimate the odds of selected outcomes related to body composition and physical fitness among lower secondary pupils in the city of Trnava, based on anthropometric measurements and motor performance tests. The study also sought to determine the prevalence of obesity, low handgrip strength, and slower reaction performance in the study population. Additional objectives included estimating the odds of obesity in relation to body fat mass, handgrip strength, foot-tapping frequency, sex, age categories, and school attended; estimating the odds of low handgrip strength in relation to

body fat mass, body fat percentage, sex, age categories, and school attended; and finally, estimating the odds of slower reaction performance in relation to skeletal muscle mass, foot-tapping frequency, sex, age categories, and school attended.

MATERIALS AND METHODS

This article is based on the diploma thesis entitled “*Health and physical literacy of elementary school students in Trnava*” (Vojteková, 2025).

Study design and sample

The study employed a cross sectional quantitative research design. Data were collected during the 2023/2024 school year in seven lower secondary schools in the city of Trnava that participated in the municipal programme “*Trnava v pohybe*” – “*Trnava in motion*” (We teach – methodological portal, 2025). Schools were included based on their participation in the municipal programme, and the study sample can therefore be characterised as a programme-based convenience sample at the school level. All lower secondary school pupils (grades 5–9) attending participating schools during the study period were considered eligible for inclusion. Participation in the study was voluntary and conditional upon written informed consent provided by the pupil's legal guardian. As only pupils with granted informed consent and availability during testing were included, this approach may have influenced the final composition of the study sample. To ensure methodological transparency, explicit inclusion and exclusion criteria were applied. Inclusion criteria were as follows:

- age between 11 and 16 years;
- attendance at one of the participating schools;
- provision of written informed consent by a legal guardian;
- availability of complete data for all variables included in the analysis.

Exclusion criteria were defined as:

- age outside the range of 11–16 years;
- non-attendance at participating schools or lack of informed consent;
- missing values in anthropometric, motor, or reaction test variables;

- incorrectly recorded measurement values identified during data validation;
- incomplete records for variables required in the multivariable regression models.

During the study period, a total of 1,159 students were recorded in the testing, representing all lower secondary schools involved in the city initiative. For the purposes of this study, data from two schools (Spartakovská and NSUT) were excluded due to a high proportion of missing tests and incomplete records, which prevented their inclusion in subsequent analyses. Following this step, the dataset was cleaned to ensure data quality and consistency. Records with missing data in key variables, implausible or incorrectly entered values, or incomplete results for variables included in the analytical models were excluded. Numerical data formats were verified, and obesity status was calculated using age and sex-specific BMI percentiles according to WHO standards (2007). After applying these procedures, the final analytical sample consisted of 444 pupils, indicating that 715 observations (61.7%) were excluded from the initial dataset. The majority of excluded records were removed due to incomplete data (i.e., missing at least one required variable), while a smaller proportion was excluded due to data entry errors. The minimum required sample size was calculated using the OpenEpi program to ensure a 95% confidence interval and a 5% margin of error (Sullivan et al., 2013). Given the total population of 6,172 lower secondary pupils in Trnava, the minimum required sample size was 362 respondents. The final analysed sample exceeded this threshold.

Data collection

Data collection was conducted within the municipal programme “*Trnava in motion*” and took place on the school premises during the 2023/2024 school year (We teach – methodological portal, 2025). Data collection was conducted in cooperation with trained staff from the Faculty of Physical Education and Sport, Comenius University in Bratislava. Prior to data collection, assessors were instructed in the use of measurement devices, test administration, recording procedures, and participant safety. The same standardised testing protocols were applied across all participating schools to ensure consistency and comparability of measurements.

The obtained data were recorded in a Microsoft Office Excel database.

Anthropometric measurements were performed using a multi-frequency bioelectrical impedance analyser InBody 370S, which estimates body composition based on the measurement of electrical impedance of body tissues. Measurements were performed under standardised conditions, with students barefoot, in underwear, and measured in an upright position before physical testing. The device was disinfected after each student. The parameters assessed included height and weight, from which body mass index (BMI) was calculated as weight (kg)/height (m²), as well as body fat percentage (PBF), body fat mass (BFM), visceral fat level (VFL), skeletal muscle mass (SMM), and protein and mineral content.

Physical fitness was evaluated using a battery of standardised motor tests assessing muscular strength, speed, coordination, and explosive power of the upper and lower limbs. All tests were administered according to a unified procedure, with clear instructions and demonstrations provided before testing. Where appropriate, two trials were performed, and the better result was recorded. Upper body strength was assessed using a handgrip dynamometer, with measurement performed on the dominant hand; pupils completed two attempts and the maximum value (kg) was used for analysis. Among boys, the number of pull ups was recorded, whereas among girls, the duration of maintaining a flexed arm hang was measured. Lower body performance and coordination were assessed using the tapping test, which evaluates the number of alternating foot contacts within a fixed time interval, and the countermovement jump, which records jump height and flight time. Speed and change-of-direction ability were assessed using the 10 m sprint, recorded as time in seconds, and the pro-agility test, also known as the 5–10–5 shuttle run, which assesses change-of-direction speed.

Reaction performance was assessed using a reaction task referred to as the INDEX_YN, designed to evaluate response flexibility under time pressure, as well as attention and response accuracy. The test is based on a paradigm of rapid decision-making in response to randomly generated visual stimuli. During

the assessment, pupils were exposed to stimuli presented via two photoelectric sensors, displaying varying combinations of colours and shapes. Within a limited time window, participants were required to determine whether the presented stimuli matched predefined criteria and to respond accordingly using two response sensors (“Yes”/ “No”). In the test, performance was expressed as a composite index reflecting both response speed and accuracy, thereby capturing the ability to respond quickly and accurately to stimuli under time constraints. Recorded parameters included reaction time and correctness of responses.

Data analysis

Prior to statistical analysis, the data were checked and cleaned. To identify potential extreme values resulting from measurement or recording errors, minimum and maximum values were calculated for each variable. Descriptive statistics were summarised using contingency tables. Multiple logistic regression was used to estimate odds ratios for obesity, low handgrip strength, and slower reaction performance in relation to selected explanatory variables. Selected anthropometric and motor indicators, along with basic demographic characteristics, were included in the regression models.

Statistical analyses were performed using R (version 3.6.2), with the significance level set at $p < 0.05$ (R Core Team, 2021). Results of the multiple logistic regression analyses were expressed as odds ratios with 95% confidence intervals. Dependent and categorical variables were coded accordingly. For categorical variables, reference groups were defined: boys for sex, the youngest age group (11–12 years) for age categories, and Bottová Lower Secondary School for schools. After constructing initial regression models, adjusted models were developed based on a combination of statistical significance and theoretical relevance of the variables, with consideration given to prior research, in order to identify the most meaningful predictors of the studied outcomes. Three multivariable logistic regression models were specified. The obesity model included body fat mass, handgrip strength, foot-tapping frequency, sex, age categories, and schools. The low handgrip strength model included body fat mass, body fat percentage, sex, age categories, and schools. The slower

reaction performance model included skeletal muscle mass, foot-tapping frequency, sex, age categories, and schools.

For the obesity model, the dependent variable was the presence or absence of obesity, defined according to the 95th BMI percentile (WHO, 2007). Pupils below the 95th percentile were classified as non obese, while those at or above the 95th percentile were classified as obese. Independent variables included sociodemographic factors (sex, age, school), the anthropometric indicator (BFM), and motor performance tests (handgrip strength and number of foot taps).

The second logistic regression model examined the odds of low handgrip strength. The dependent variable was defined based on handgrip test results, categorised as low versus normal/above normal strength. Normative values for low handgrip strength were adopted from Wood (2012). Independent variables included sociodemographic factors (sex, age, school) and anthropometric indicators (PBF and BFM).

The final logistic regression model assessed the odds of slower reaction performance derived from the INDEX_YN test. For analytical purposes, performance was operationalised based on the distribution of reaction times within the study sample. Pupils with reaction times above the sample mean were classified as having slower reaction performance, whereas those with values at or below the mean were considered to have normal performance. This categorisation represents a relative measure of performance within the study population and does not correspond to a clinical assessment of cognitive impairment. Independent variables included sociodemographic factors (sex, age, school), the anthropometric parameter SMM, and the motor test tapping.

RESULTS

Characteristics of the study sample

A total of 444 lower secondary school pupils in Trnava were included in the study, comprising 248 boys (55.9%) and 196 girls (44.1%). The largest proportion of the sample consisted of pupils aged 13–14 years (248; 55.9%), followed by those aged 15–16 years (125; 28.1%) and 11–12 years (71; 16.0%). Seven

schools were represented in the sample, with the highest proportion of pupils coming from Lower Secondary School Bottová (91; 20.5%) and Lower Secondary School Kornel Mahra (84; 18.9%), whereas the lowest proportion was recorded at Lower Secondary School I. Krasko (32; 7.2%). The distribution of pupils across categories of the analysed variables (sex, age, school) is presented in Table 1.

Table 1 – Demographic characteristics of the study sample (N = 444)

Variable	N (%)
Sex	
Boys	248 (55.9)
Girls	196 (44.1)
Age category	
11–12	71 (16.0)
13–14	248 (55.9)
15–16	125 (28.1)
School	
Lower Secondary School Bottová	91 (20.5)
Lower Secondary School Gorkého	64 (14.4)
Lower Secondary School I. Krasko	32 (7.2)
Lower Secondary School Kornel Mahra	84 (18.9)
Lower Secondary School Kubina	70 (15.8)
Lower Secondary School and Nursery School Atómová	59 (13.3)
Lower Secondary School and Nursery School Vančurová	44 (9.9)

Obesity was identified in 51 pupils (11%), whereas 393 pupils (89%) did not meet the criteria for obesity. Among girls, obesity occurred most frequently in the 13–14-year age category, particularly at Lower Secondary School Kornel Mahra, Lower Secondary School and Nursery School Atómová, and Lower Secondary School Gorkého. Among boys, the highest prevalence of obesity was recorded at Lower Secondary School Gorkého (10 cases), with most cases also concentrated in the 13–14-year age group. The lowest occurrence was observed at Lower Secondary School I. Krasko, where obesity was identified in only one pupil aged 15–16 years.

Low handgrip strength was demonstrated in 29 pupils (7%), while the majority (415; 93%) achieved values within or above the normative range. Among girls, low handgrip strength was observed in only one pupil (Lower Secondary School and Nursery School Vančurová, aged 11–12 years). In boys, low handgrip strength was more common, par-

ticularly in the 13–14-year age group at Lower Secondary School Kornel Mahra (4 cases), as well as at other schools (Lower Secondary School Gorkého, Lower Secondary School Kubina, Lower Secondary School and Nursery School Atómová). Overall, reduced handgrip strength was relatively uncommon but still present in the study population.

Slower reaction performance was identified in 94 pupils (21%), while the majority (350; 79%) achieved average or above-average scores. Among girls, the highest occurrence was recorded at Lower Secondary School Kornel Mahra (11 cases), and Lower Secondary School and Nursery School Atómová (10 cases). Among boys, the highest number of cases was observed at Lower Secondary School Kornel Mahra (17 cases), followed by Lower Secondary School Gorkého and Lower Secondary School Kubina (14 cases each). In both sexes, the prevalence of slower reaction performance was highest in the 13–14-year age category.

The results of the multiple logistic regression analysis indicate the presence of several significant factors associated with the odds of obesity, low handgrip strength, and slower reaction performance among lower secondary school pupils. Separate analyses were conducted for each of the examined health-related outcomes. The results are presented as odds ratios (OR) with 95% confidence intervals and a significance level of $p < 0.05$.

Factors associated with obesity

The regression analysis identified several factors associated with the odds of obesity (Table 2). Body fat mass was strongly associated with increased odds of obesity (OR = 2.29, 95% CI: 1.60–3.27). A significant association was also observed for handgrip strength (OR = 1.30, 95% CI: 1.09–1.54). In terms of sex, girls had 93% lower odds of obesity than boys (OR = 0.07, 95% CI: 0.01–0.53). Older age acted as a protective factor, with pupils aged 13–14 years (OR = 0.01, 95% CI: 0.00–0.18) and 15–16 years (OR = 0.0002, 95% CI: 0.00–0.02) showing lower odds of obesity than the reference age group of 11–12 years. Significant differences were also observed between schools. Compared with the reference school (Lower Secondary School Bottová), higher odds of obesity were recorded among pupils at Lower Secondary School I. Krasko (OR = 41.52, 95% CI: 1.12–1532.50),

Lower Secondary School and Nursery School Atómová (OR = 21.55, 95% CI: 1.43–325.27), and Lower Secondary School and Nursery School Vančurová (OR = 44.94, 95% CI: 1.68–1204.60). These estimates were, however, accompanied by very wide confidence intervals, indicating low precision and potential instability of the estimates. The findings may be influenced by different subgroup sample sizes or variability in the data structure and should therefore be interpreted with considerable caution. The model demonstrated an exceptionally high level of explained variance (Nagelkerke $R^2 = 0.8738$). We interpret this result with caution, as a high Nagelkerke R^2

does not necessarily indicate strong predictive validity, particularly when predictors are conceptually related to the outcome variable. In the present model, obesity was defined according to BMI percentiles, while several included predictors reflected closely related aspects of body composition, particularly body fat mass. This overlap may have inflated the apparent explanatory capacity of the model. Therefore, the observed associations may be better interpreted as reflecting consistency between closely related anthropometric and body composition indicators rather than as evidence of strong independent predictive relationships.

Table 2 – Adjusted odds ratios for factors associated with obesity among lower secondary school pupils, based on multivariable logistic regression (N = 444)

Factors associated with obesity	Adjusted OR (95% CI)	p-value
Physical and motor performance indicators		
BFM (kg)	2.29 (1.60–3.27)	<0.001
Handgrip (kg)	1.30 (1.09–1.54)	0.0037**
Tapping	0.99 (0.94–1.05)	0.8112
Sex		
Boys	Ref.	
Girls	0.07 (0.01–0.53)	0.0102*
Age category		
11–12	Ref.	
13–14	0.01 (0.00–0.18)	0.0025**
15–16	0.00 (0.00–0.02)	0.0004***
School		
Lower Secondary School Bottová	Ref.	
Lower Secondary School Gorkého	12.08 (0.74–197.95)	0.0808
Lower Secondary School I. Krasko	41.52 (1.12–1532.50)	0.0430*
Lower Secondary School Kornel Mahra	21.25 (0.95–475.27)	0.0539
Lower Secondary School Kubina	3.82 (0.35–42.20)	0.2739
Lower Secondary School and Nursery School Atómová	21.55 (1.43–325.27)	0.0266*
Lower Secondary School and Nursery School Vančurová	44.94 (1.68–1204.60)	0.0233*
Model parameter	Nagelkerke R^2 : 0.8738	
<i>Note:</i> * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; CI – confidence interval; BFM – Body Fat Mass; Ref. – reference category		

Factors associated with low handgrip strength

The results of the subsequent multiple regression analysis showed that the odds of low handgrip strength were significantly associated primarily with body composition parameters (Table 3). Body fat mass was identified as a protective factor (OR = 0.49, 95% CI: 0.37–0.65), whereas body fat percentage was associated with increased odds of low hand-

grip strength (OR = 1.70, 95% CI: 1.39–2.07). A pronounced effect was also observed for sex. Girls had 99% lower odds of low handgrip strength compared with boys (OR = 0.01, 95% CI: 0.0009–0.07). The odds of low handgrip strength increased with age; with pupils aged 13–14 years (OR = 7.69, 95% CI: 1.52–38.86) and 15–16 years (OR = 28.69, 95% CI: 3.83–214.80) showing higher odds than the reference age group (11–12 years). We interpret

these estimates with caution, particularly in the older age groups, where some associations were accompanied by relatively wide confidence intervals. This suggests reduced precision and possible instability of the estimates. Therefore, these subgroup-specific findings should be considered with appropriate caution. No statistically significant differences

were observed between schools when compared with Lower Secondary School Bottová. The overall model exhibited moderate explanatory capacity (Nagelkerke $R^2 = 0.3815$), indicating that the included predictors accounted for a meaningful, though not dominant, proportion of the variance in low handgrip strength.

Table 3 – Adjusted odds ratios for factors associated with low handgrip strength among lower secondary school pupils, based on multivariable logistic regression ($N = 444$)

Factors associated with low handgrip strength	Adjusted OR (95% CI)	<i>p</i> -value
Physical and motor performance indicators		
BFM (kg)	0.49 (0.37–0.65)	<0.001
PBF (%)	1.70 (1.39–2.07)	<0.001
Sex		
Boys	Ref.	
Girls	0.01 (0.00–0.07)	1.40e-05***
Age category		
11–12	Ref.	
13–14	7.69 (1.52–38.86)	0.0136*
15–16	28.69 (3.83–214.80)	0.0011**
School		
Lower Secondary School Bottová	Ref.	
Lower Secondary School Gorkého	0.61 (0.11–3.25)	0.5609
Lower Secondary School I. Krasko	2.03 (0.36–11.29)	0.4198
Lower Secondary School Kornel Mahra	0.76 (0.19–3.04)	0.6931
Lower Secondary School Kubina	0.51 (0.10–2.46)	0.3989
Lower Secondary School and Nursery School Atómová	1.01 (0.21–4.79)	0.9872
Lower Secondary School and Nursery School Vančurová	1.17 (0.18–7.42)	0.8706
Model parameter	Nagelkerke R^2 : 0.3815	
<i>Note:</i> * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; CI – confidence interval; BFM – Body Fat Mass; PBF – Percent Body Fat; Ref. – reference category		

Factors associated with slower reaction performance

The analysis of the final multiple logistic regression model also identified factors significantly associated with slower reaction performance (Table 4). A protective effect was observed for higher skeletal muscle mass 95% CI and better performance in the foot-tapping test (OR = 0.97, 95% CI: 0.96–0.99). Compared with boys, girls had approximately 54% lower odds of slower reaction performance (OR = 0.46, 95% CI: 0.26–0.80). Age

categories were not statistically significant in this model. A mild but significant effect was observed for school (OR = 1.13, 95% CI: 1.01–1.28), indicating variation across schools compared with Lower Secondary School Bottová. The overall model displayed limited explanatory capacity (Nagelkerke $R^2 = 0.08188$), indicating that the included predictors accounted for only a small proportion of the variance in reaction performance. This suggests that additional unmeasured factors may contribute to variability in this outcome.

Table 4 – Adjusted odds ratios for factors associated with slower reaction performance among lower secondary school pupils, based on multivariable logistic regression (N = 444)

Factors associated with slower reaction	Adjusted OR (95% CI)	p-value
Physical and motor performance indicators		
SMM (kg)	0.95 (0.90–1.00)	0.0390*
Tapping	0.97 (0.96–0.99)	0.0009***
Sex		
Boys	Ref.	
Girls	0.46 (0.26–0.80)	0.0057**
Age category		
11–12	Ref.	
13–14	0.74 (0.39–1.41)	0.3552
15–16	0.81 (0.36–1.82)	0.6135
School		
Lower Secondary School Bottová	Ref.	
Other schools	1.13 (1.01–1.28)	0.0407*
Model parameter	Nagelkerke R ² : 0.08188	
Note: * p < 0.05; ** p < 0.01; *** p < 0.001; CI – confidence interval; SMM – Skeletal Muscle Mass; Ref. – reference category		

DISCUSSION

The findings highlight a complex interaction between physical functioning and reaction performance in children and adolescents, and support the importance of a multidimensional approach to assessing their health status (Cairney et al., 2019). The prevalence of obesity in the study sample reached 11%, which is comparable to results from European monitoring studies reporting obesity rates among children and adolescents ranging from approximately 8–18%, depending on age, sex, and socioeconomic conditions (Ortega et al., 2023; Tomkinson et al., 2018; WHO, 2024). This prevalence indicates that obesity remains a significant public health concern even within urban environments in Slovakia. The higher prevalence of obesity among boys is consistent with previous findings and may be related to differences in physical activity levels, sedentary behaviour, and dietary habits between sexes (Ahmad et al., 2010; Jebeile et al., 2022). Given that childhood obesity frequently persists into adulthood, the observed pattern provides an important impetus for targeted preventive interventions during the school years.

Our results indicated a low prevalence of reduced handgrip strength, which was observed in 7% of pupils and occurred almost exclusively among boys. Such an outcome is par-

tially inconsistent with most available studies, which consistently report higher average handgrip strength values in boys compared with girls, particularly during prepubertal and pubertal periods. For example, in the study of normative handgrip strength values among Polish children and adolescents, Górecki et al. (2024) demonstrated significantly higher values in boys across all examined age categories. Similar findings were presented by Shetty et al. (2019), who established reference values for handgrip strength in an Indian population of children and adolescents and reported a marked increase in strength during puberty – again more pronounced in boys. In contrast, the present findings suggest that low handgrip strength occurred more frequently among boys in the studied sample, which may be associated with specific factors influencing muscular strength, such as lower levels of physical activity levels, lifestyle-related determinants, or differences in somatic development. It is also important to emphasise that these results relate to a specific sample and should therefore be interpreted with caution. Further research should focus on identifying determinants of reduced muscular strength in children.

Another important finding of our study was the occurrence of slower reaction performance in 21% of pupils, again more frequently observed among boys. This proportion is

broadly consistent with findings from the longitudinal Finnish study by Heiskanen et al. (2024), which examined the development of cognitive abilities from childhood into adulthood. The authors highlighted that lower cognitive performance in childhood represents a significant predictor of future educational attainment and that boys, on average, more frequently achieve lower scores in cognitive function tests. However, it should be noted that our study assessed reaction performance rather than broader cognitive functioning. Therefore, we interpret comparisons with previous findings cautiously.

The multiple logistic regression analysis enabled the identification of factors associated with obesity among primary school pupils in an urban environment. The results highlight the dominant role of body composition parameters, particularly body fat mass, as well as differences related to age and the school environment. Body fat mass was strongly associated with higher odds of obesity, which is consistent with the biological basis of obesity and supports the use of more detailed indicators of body composition beyond body mass index alone. Similar conclusions were reported by Williams et al. (2007), who demonstrated the high sensitivity of bioelectrical impedance in identifying elevated body fat levels among children and adolescents. The present analysis therefore suggests that assessing body fat may be an important tool for the early identification of individuals with an unfavourable body composition profile.

A noteworthy pattern was the positive association between handgrip strength and the odds of obesity. Traditionally, higher muscular strength is considered a protective factor in relation to obesity and cardiometabolic risks. In our case, however, this may reflect higher absolute handgrip strength among pupils with greater body mass, which is not accompanied by better functional fitness. This phenomenon was also described in the study by Cossio Bolaños et al. (2020), who noted that children with higher body fat percentages may achieve higher values of absolute muscular strength, yet simultaneously exhibit poorer muscle quality and reduced motor performance. Such findings underscore the need to interpret handgrip strength in conjunction with body composition and to incorporate relative indicators of muscular strength.

Sex emerged as a factor associated with differences in obesity prevalence, with girls showing lower odds of obesity than boys. This trend aligns with findings from several studies that indicate higher caloric intake, lower regulation of dietary habits, and greater levels of sedentary behaviour among boys (Shah et al., 2020). Biological and hormonal differences between sexes which already influence body composition and energy requirements during childhood, must also be considered. Age was also associated with obesity, with the highest odds observed in the youngest age category. With increasing age, the odds of obesity were lower, which may be related to changes in body composition during puberty, increased energy demands, and greater independence and physical activity among older pupils.

Significant differences in the odds of obesity between schools suggest that the school environment may play an important role in shaping children's body composition. However, given the wide confidence intervals observed in the regression model, these differences should be interpreted with caution, as they may partly reflect variability due to sample size or data structure rather than true underlying differences. Similar findings were presented by Cossio Bolaños et al. (2020), who reported differences in body fat percentage among children depending on regional and environmental conditions. Schools therefore represent a key setting for implementing preventive programmes that promote healthy lifestyles.

The results of the second multiple logistic regression analysis highlighted the role of body composition parameters, sex, and age in relation to low handgrip strength among primary school pupils. The findings further confirm that handgrip strength in childhood and adolescence is influenced by a complex interaction between fat mass, muscle mass, biological factors, and lifestyle-related determinants. The analysis revealed a contrasting effect of absolute body fat mass and body fat percentage. While higher body fat mass appeared to act as a protective factor against low handgrip strength, higher body fat percentage was associated with higher odds of reduced handgrip strength. This suggests that absolute fat mass alone may not necessarily impair muscle function; however, a higher proportion of fat relative to muscle mass may neg-

actively affect muscle quality. Similar conclusions were reported by Nara et al. (2023), who observed lower relative muscular strength in children with overweight and obesity despite their higher body mass.

In our sample, boys exhibited higher odds of low handgrip strength than girls. This finding differs from other studies; for example, Elezi et al. (2021), in their study examining handgrip strength differences among 9–10 year-old children in North Macedonia, found that boys achieved higher handgrip strength values than girls, with differences increasing with age.

These discrepancies may be related to the structure of the study sample, differences in physical activity levels, or lifestyle characteristics of the examined population.

Age was also associated with differences in handgrip strength, where higher odds were observed among older pupils. This trend may reflect a decline in spontaneous physical activity during adolescence, an increase in sedentary behaviour, and the growing demands of the school environment. Similar findings were presented by Nara et al. (2023), who reported decreasing muscular strength among adolescents with low levels of physical activity.

The analysis of factors associated with slower reaction performance highlighted a close interconnection between physical characteristics, motor performance, and reaction performance in children and adolescents. The findings support a multidimensional perspective on health, in which not only physical but also motor and neurological components of development play an important role. Higher skeletal muscle mass was associated with lower odds of slower reaction performance, supporting hypotheses that suggest a positive relationship between muscle mass and brain health. This relationship may be explained by biological mechanisms through which skeletal muscles produce myokines with neuroprotective effects that promote neuroplasticity and cognitive functioning (Sui et al., 2020).

Motor coordination, assessed through the tapping test, was identified as another factor associated with reaction performance. Better performance in the test was associated with lower odds of slower reaction performance, confirming existing evidence on the close relationship between motor and reaction processes. A systematic review by van der Fels et

al. (2015) demonstrated that motor tasks requiring coordination, speed, and precision are closely linked to working memory, attention, and executive functioning.

Girls were found to be less likely to exhibit slower reaction performance than boys. This difference may be related to the greater variability in cognitive performance among boys, as reported by Heiskanen et al. (2024), as well as behavioural, attentional, and school related differences between sexes. The analysis also indicated that the school environment may play an important role in supporting or hindering pupils' reaction performance. Factors such as instructional organisation, the availability of physical activity opportunities, and overall support for a healthy lifestyle may be associated with children's overall developmental and motor processes.

It is important to emphasise that several regression estimates showed wide confidence intervals, reflecting limited precision and potential instability, particularly in subgroup analyses. These findings should therefore be interpreted as indicative rather than definitive evidence of associations.

Limitations of the study

Several limitations should be considered when interpreting the findings of this study. The study was conducted exclusively in lower secondary schools administered by the city of Trnava and participating in the municipal programme "Trnava in motion". Schools were therefore not randomly selected but included based on their involvement in the programme. Consequently, the study used a non-probability, programme-based convenience sampling strategy at the school level. This limits the representativeness of the sample, and the findings cannot be generalised to all lower secondary school pupils in Trnava or to the wider population of children and adolescents in Slovakia.

An important limitation relates to the sampling strategy and data availability. From the initial sample of 1,159 pupils, only 444 were included in the final analysis following data cleaning procedures. A substantial proportion of participants was excluded, primarily due to missing or incomplete data, as well as the exclusion of two schools with insufficient data quality. Although these exclusions were driven mainly by data completeness rather than

predefined participant characteristics, the lack of detailed comparison between included and excluded pupils means that selection bias cannot be fully ruled out.

Another limitation is the cross sectional design of the study, which does not allow causal relationships between the examined variables to be established. The identified associations between body composition, motor performance, and reaction performance should therefore be interpreted as relational rather than causal.

Further limitations arise from the measurement of reaction performance. The INDEX_YN test primarily assesses reaction speed, attention, and response flexibility under time pressure, rather than broader or higher-order cognitive functions. Moreover, the operationalisation of slower reaction performance was based on the sample mean, reflecting a relative classification within the study population rather than clinically validated or standardised thresholds. This limits the interpretability of the findings and their comparability with studies assessing broader cognitive functioning.

In addition, we interpret certain results of the regression analyses with caution. In the obesity model, some estimates, particularly those related to differences between schools, were characterised by wide confidence intervals, indicating limited precision and potential instability. Furthermore, the high explanatory power of the obesity model, as indicated by Nagelkerke R^2 , may be partly attributable to conceptual overlap between the outcome variable, obesity defined according to BMI percentiles, and closely related anthropometric and body composition predictors, such as body fat mass. This overlap may have inflated the apparent explanatory capacity of the model and should therefore be considered when interpreting the strength of the observed associations.

The study may also be affected by unmeasured confounding variables, such as socioeconomic status, dietary habits, levels of habitual physical activity, or pupils' individual motivation during testing, which were not included in the analysis and may have influenced the observed associations. Despite these limitations, the study provides important empirical data on health-related characteristics of children in an urban environment, offering a

valuable foundation for further longitudinal research aimed at clarifying the directionality of the observed relationships and improving the assessment of health and performance indicators in school populations.

CONCLUSION

This study provides a comprehensive overview of selected health indicators among lower secondary school pupils in an urban environment, highlighting observed associations between body composition, physical fitness, and reaction performance. The obesity prevalence of 11% confirms that elevated body weight remains a relevant public health concern even within Slovak urban settings. Additional important adverse health-related outcomes were also identified, particularly low handgrip strength among a subset of pupils and slower reaction performance in one fifth of the study population.

The results of the multiple logistic regression analyses suggested associations with body composition parameters – especially body fat mass, body fat percentage, and skeletal muscle mass – as well as differences related to sex, age, and school environment, emphasising the need for targeted and differentiated prevention strategies. The observed relationship between motor performance and reaction measures supports the importance of considering physical and reaction-related processes in an integrated manner in children and adolescents.

The insights gained highlight the potential importance of supporting physical fitness, motor competence, and muscular strength development, as well as promoting an active lifestyle from an early age. The school environment represents a key setting for implementing preventive and intervention programmes that may contribute to improving both physical and reaction performance in children, while reducing long term health risks in adulthood.

Ethical considerations

Participation in the research was voluntary. Prior to the start of the study, parents were provided with informed consent regarding their child's participation in the "Trnava v pohybe" programme. The study was conducted

in accordance with general ethical principles for research involving children. The research was conducted with full anonymity and in accordance with principles of personal data protection. Data collection was conducted as part of the municipal programme “Trnava v pohybe”, within which ethical approval for the implementation of measurements in schools had been granted by the representative of the Municipal Office in Trnava, PhDr. Eva Nemčovská, PhD., MPH. The present study represents a secondary analysis of these data; therefore, no additional independent ethical approval was required.

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Conflict of interest

The authors have no conflict of interest to declare.

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