

ORIGINAL PAPER

Long-term trends in physical fitness and body mass among 10-year-olds in Gdansk: findings from a 12-year intervention programme

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ABSTRACT

Introduction: Physical fitness in childhood is a critical determinant of long-term health, influencing the risk of cardiometabolic and emotional disorders in adulthood. The Kasch pulse recovery test (KPRT) is a simple, non-invasive tool for assessing cardiorespiratory fitness (CRF) in population-based studies. This study evaluated the relationship between body mass index (BMI) and physical fitness in 10-year-old children from Gdansk, Poland, over a 12-year period (2011–2023), focusing on sex differences and the impact of the COVID-19 pandemic.

Material and methods: A total of 19,614 children (9,416 girls and 10,198 boys) participating in the health preventive programme were assessed. Body mass index was calculated using anthropometric measurements and categorized as underweight, normal weight, or overweight/obese according to the national centile grids. Physical fitness was evaluated using the KPRT, a 3-minute step test, with heart rate (HR) monitored post-exercise. Data were analysed using χ^2 tests and ANOVA ($p < 0.05$), comparing BMI categories, KPRT scores, and HR across study years and between sexes.

Results: Girls consistently outperformed boys in KPRT scores across all BMI categories ($p \leq 0.05$), with a higher proportion of 'good' ratings (e.g. 74.9% for girls vs. 61.5% for boys in 2019). Overweight children, especially boys, exhibited significantly poorer KPRT scores (57.1% 'poor' ratings in 2023) and higher post-exercise HR (e.g. 139 beats per minute (bpm) for overweight girls vs. 127 bpm for boys in 2023). A positive trend in fitness was observed in the 2015–2019 period, with lower HR (e.g. 114 bpm for girls, 106 bpm for boys in 2017), but fitness declined post-2020, with 'good' KPRT ratings dropping to 45.1% (girls) and 32.1% (boys) in 2023, alongside higher HR.

Conclusions: Overweight children, especially boys, are at a greater risk of reduced physical fitness, highlighting the need for targeted interventions. The Kasch pulse recovery test proved effective as a screening tool for assessing CRF in children.

KEY WORDS:

physical fitness, cardiorespiratory fitness, childhood obesity, Kasch pulse recovery test, preventive health.

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INTRODUCTION

Physical fitness in childhood is considered a key indicator of health, having a significant impact on reducing the risk of cardiovascular and metabolic diseases as well as emotional disorders in adulthood [1, 2]. High cardiorespiratory fitness (CRF), assessed using exercise tests such as the pendulum test or submaximal treadmill tests, correlates with lower levels of cardiometabolic risk factors such as hypertension, dyslipidaemia or insulin resistance, regardless of body weight [3–5]. Monitoring CRF in the school-age population allows for early identification of groups at risk of adverse health outcomes, which provides the basis for the development of effective prevention programmes promoting health and physical activity [6, 7]. The Kasch pulse recovery test (KPRT) is a simple tool for assessing children's fitness in population-based studies. This test, due to its simplicity, low invasiveness and low cost, enables a quick assessment of the cardiovascular system's ability to recover after physical exertion. Previous studies conducted in our centre have shown a strong relationship between KPRT results and body mass index (BMI), with overweight and obese children achieving significantly worse results [8, 9]. In the context of long-term epidemiological trends, long-term, systematic research is of particular importance. This article presents an analysis of the relationship between KPRT performance and BMI index of 10-year-old children participating in the city-wide preventive screening programme '6–10–14 for Health' between 2011 and 2023. We also consider the impact of the COVID-19 pandemic on fitness parameters and compare results by sex. The aim of the study was to assess the relationship between BMI and the level of physical fitness in a large population of school-age children, taking into account sex differences and years of study, as well as to verify the usefulness of KPRT as a screening tool in children's health prevention.

MATERIAL AND METHODS

PARTICIPANTS

This cross-sectional study included a total of 19,614 children aged 10 (9,416 girls and 10,198 boys) attending primary schools in Gdansk, who in the years 2011–2023 participated in the preventive programme '6–10–14 for Health' run by the local authorities. Estimates show that about half of all 10-year-olds were included in the study. All children underwent anthropometric measurements (height and weight) and a physical fitness test (KPRT).

ANTHROPOMETRIC MEASUREMENTS

Body height was measured in the Frankfurt position using a height gauge to the nearest 1 mm, and body weight was measured using a scale to the nearest 100 g (scale

SECA 799, stadiometer SECA 216). The measurements were taken with the children barefoot and wearing only underwear or gym clothes. Body mass index was calculated based on the anthropometric measurements. According to Polish criteria based on the OLAF national centile charts, BMI $\geq 85^{\text{th}}$ and $< 95^{\text{th}}$ percentile was classified as overweight, and BMI $\geq 95^{\text{th}}$ percentile as obesity [10].

KASCH PULSE RECOVERY TEST

To evaluate physical fitness, we utilised KPRT, a 3-minute step test. The test required participants to step up and down on a 0.305-meter-high step at a set cadence of 24 steps per minute for three minutes, followed by one minute and five seconds' rest in a sitting position. Throughout the test and recovery period, we continuously monitored the heart rate (HR) using the 'Polar' electronic analyzer (Finland). The average pre- and post-exercise HR was recorded for one minute, starting five seconds after the test ended [9]. The Kasch pulse recovery test result for 10-year-olds should be interpreted by comparing post-exercise HR with age- and sex-specific centile charts: HR < 105 beats per minute (bpm) (boys) or < 114 bpm (girls) indicates very good fitness ($< 25^{\text{th}}$ centile), 105–117 bpm (boys) or 114–125 bpm (girls) indicates average/good fitness (25^{th} – 75^{th} centile), and > 126 bpm (boys) or > 138 bpm (girls) indicates poor fitness ($> 75^{\text{th}}$ centile).

STATISTICAL ANALYSIS

The data were analysed using χ^2 and ANOVA tests, assuming a significance level of $p < 0.05$. The results were stratified by sex, BMI category and changes occurring over the years. Figures were created using Python Software (Wilmington, USA).

RESULTS

The study included 19,614 children (9,416 girls, 10,198 boys) in the period 2011–2023 and analysed the following variables: BMI categories (underweight, normal weight, excess body weight), physical fitness (KPRT score: poor, adequate, good) and post-exercise heart rate. The results showed significant differences between sexes and clear time trends.

BODY MASS INDEX CATEGORIES BY SEX, PER STUDY YEAR

The distribution of BMI categories showed significant sex differences in most years ($p < 0.05$ in 2011–2016, 2018–2019, 2021–2022), except for 2017, 2020 and 2023 ($p \geq 0.05$), as shown in Figure 1. Among girls, the percentage of underweight ranged from 14.7% in 2016 to 18.8% in 2023, of excess body weight from 9.8% in 2023 to 15.9% in 2011. In boys, underweight ranged from 10.0% in 2014 to

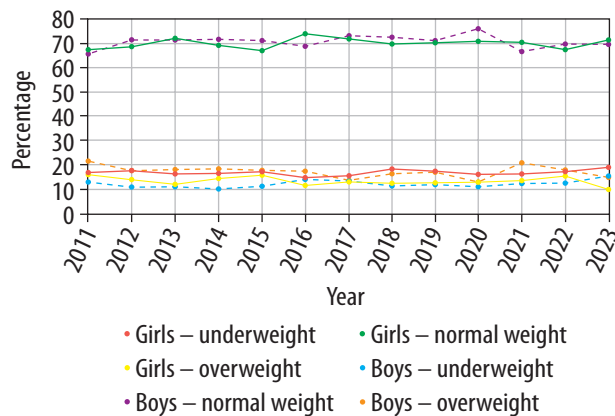


FIGURE 1. Distribution of body mass index categories by sex (2011–2023)

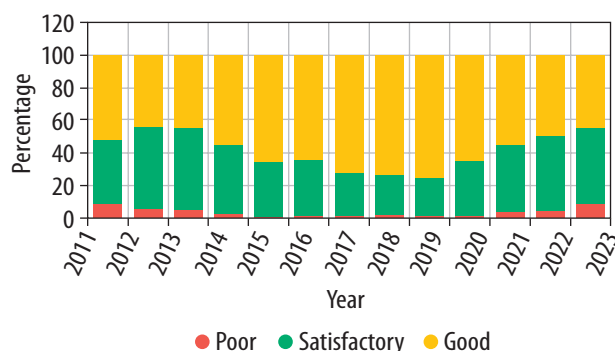


FIGURE 3. Distribution of Kasch pulse recovery test categories for girls (2011–2023)

15.3% in 2023, and excess body weight ranged from 12.9% in 2020 to 21.5% in 2011. Normal body weight dominated in both sexes, reaching the highest values in 2016 for girls (73.9%) and in 2020 for boys (76.2%). There was a downward trend in the percentage of girls with excess body weight (from 15.9% in 2011 to 9.8% in 2023) and a greater stability in boys (approx. 16–18% in most years after 2014).

PHYSICAL FITNESS

The assessments of physical fitness based on the KPRT results demonstrated significant sex differences in all years of the study ($p \leq 0.05$) as illustrated in Figures 2, 3. Girls consistently performed better, with a higher percentage of 'good' scores, especially in 2015–2019, with this percentage increasing from 65.6% in 2015 to 74.9% in 2019, with a very low percentage of 'poor' scores (0.9% in 2015, 1.6% in 2019). In boys, the percentage of 'good' scores reached a maximum of 61.5% in 2017, with 'poor' scores of 3.0% in 2017 and 3.2% in 2019. After 2020, especially after the pandemic, a deterioration was observed: the percentage of 'good' scores fell to 45.1% in girls and 32.1% in boys in 2023, with a simultaneous increase in

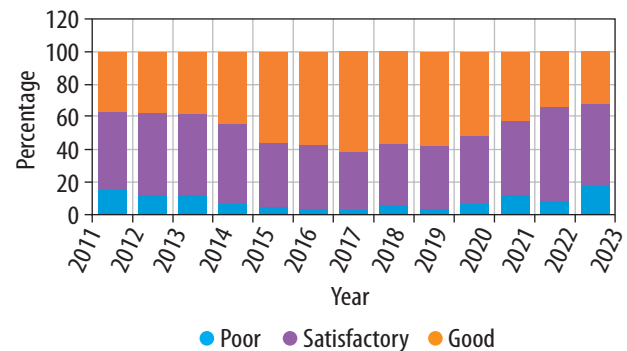


FIGURE 2. Distribution of Kasch pulse recovery test categories for boys (2011–2023)

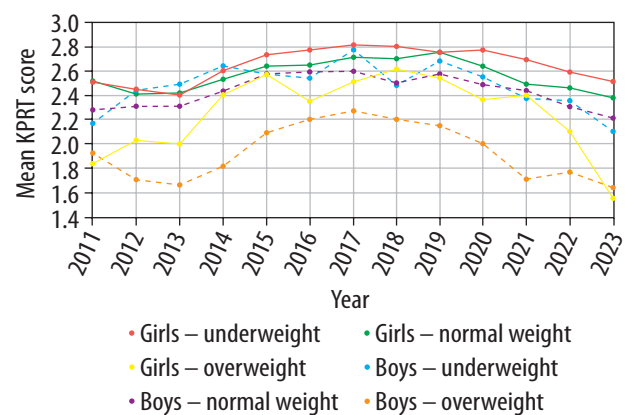


FIGURE 4. Mean Kasch pulse recovery test scores by body mass index category and sex (2011–2023)

'poor' scores to 9.2% for girls and 17.3% for boys. Figure 4 confirms an improvement in the 2015–2019 period and a decrease after 2020.

POST-EXERCISE HEART RATE

The average post-exercise HR is the average HR measured for a period of one minute starting 5 seconds after the end of the 3-minute test. It reflects cardiorespiratory fitness: low values indicate good condition and low health risks, while high values indicate poor fitness. Significantly higher values were observed in girls than in boys in all years ($p < 0.001$, except for 2023: $p = 0.001$), as shown in Figure 5. In 2011–2017, a decrease in HR was observed, with the lowest values in 2017 (girls: 114 bpm, boys: 106 bpm), which indicates better cardiovascular fitness. In the period 2015–2019, the HR remained relatively low (interpolated values for 2015: girls 119 bpm, boys 111 bpm; 2019: girls 116 bpm, boys 109 bpm), with medians closely tracking the means (e.g. 2017: girls 112 bpm, boys 103 bpm). After 2020, the HR increased, reaching 122 bpm for girls and 118 bpm for boys in 2023, which suggests a deterioration in cardiovascular fitness. The interquartile range indicated

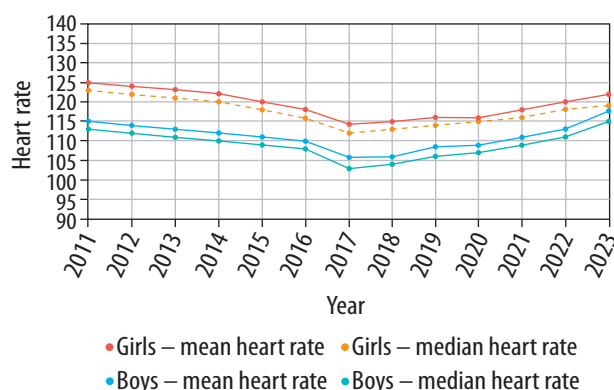


FIGURE 5. Mean and median heart rate by sex (2011–2023)

greater HR variability in girls (e.g. 103–125 bpm in 2017) than in boys (e.g. 97–112 bpm in 2017).

RELATIONSHIP BETWEEN BODY MASS INDEX AND PHYSICAL FITNESS

Cross tabulations showed a strong relationship between the BMI category and the KPRT score ($p < 0.05$ in most years) (Figure 4). In boys with excess body weight, the percentage of ‘poor’ scores was much higher (e.g. 57.1% in 2023 vs. 28.6% for underweight and 11.0% for normal body weight). In girls, the relationship was less pronounced, but in years such as 2023, the percentage of ‘poor’ scores in overweight children was 63.6% compared to 2.6% for underweight and 6.5% for normal body weight. Children with excess body weight had a higher post-exercise HR ($p < 0.001$): in 2023, overweight girls had an average HR of 139 bpm (median: 140 bpm) vs. 118 bpm (median: 117 bpm) for underweight, and boys 127 bpm (median: 130 bpm) vs. 120 bpm (median: 119 bpm) (Figure 5). Figure 4 confirms that overweight children had lower average KPRT scores in all years, with the largest sex difference in this category (e.g. 2023: girls 1.55 vs. boys 1.64).

SUMMARY OF RESULTS

Improvement of physical fitness in the period of 2015–2019: an improvement in the physical fitness of children occurred in the period between 2015 and 2019, especially in girls, where the percentage of ‘good’ KPRT scores increased from 65.6% in 2015 to 74.9% in 2019. In boys, the improvement was the most noticeable in 2017 (61.5% of ‘good’ scores). A decrease in post-exercise HR in this period, with the lowest values in 2017, confirms improvements in cardiovascular fitness, which correlates with higher average KPRT scores.

Post-pandemic deterioration: after 2020, especially in 2021–2023, a deterioration in fitness was observed. The percentage of ‘good’ KPRT scores fell to 45.1% in girls and 32.1% in boys in 2023, with a simultaneous increase in ‘poor’ scores (9.2% for girls, 17.3% for boys). An increase in post-exercise HR and a decrease in the average

KPRT score indicate worse cardiovascular adaptation, probably related to physical activity limitations during the pandemic.

Sex differences: girls showed better physical fitness as measured by KPRT than boys in all years, with a higher percentage of ‘good’ scores. Boys were more likely to have excess body weight, especially in 2011–2014, which partly explains their worse KPRT results. The decrease in excess body weight in girls confirms their better results compared to boys.

The relationship between BMI and HR and fitness: Excess body weight was associated with a higher post-exercise HR and worse KPRT scores especially in boys, where the percentage of ‘poor’ scores reached 57.1% in 2023 for overweight boys. Children with normal body weight and underweight achieved better KPRT results and had lower heart rate, which confirms the beneficial effect of normal body weight on physical fitness.

DISCUSSION

The present study provides a detailed analysis of the fitness of children aged 10 years as assessed by KPRT in relation to BMI and sex. Mintjens *et al.* [1] results confirm that physical fitness in children is an independent prognostic factor for the risk of chronic diseases, such as metabolic, cardiovascular and emotional difficulties in adulthood. In particular, overweight children had worse scores on the KPRT, which is consistent with the observations of Lemanowicz-Kustra *et al.* [8], who reported inverse correlation between BMI and aerobic fitness, particularly clear in boys ($r = -0.41$). Similarly, Raghuveer *et al.* [11] have shown that high CRF protects against cardiometabolic risk factors such as hypertension or insulin resistance, independently of body weight. Moreover, in another study from our centre, we confirmed that interventions promoting physical activity in overweight children lead to improvements in both body composition and KPRT results, which emphasises the value of this test as an assessment tool in health programmes [12].

Between 2015 and 2019, we observed a favourable-trend marked by decreasing post-exercise heart rates, indicating an improvement in cardiovascular fitness. This pattern reversed after the onset of the COVID-19 pandemic, when a clear increase in post-exercise HR was noted. Our findings are consistent with the observations of Calcaterra *et al.* [13] and Welling *et al.* [14], who reported that lockdown-related lifestyle changes – including reduced physical activity and increases in excess body weight – adversely affected children’s health behaviours. Similar conclusions were drawn by Runacres *et al.* [15] and Chambonniere *et al.* [16] who emphasised that pandemic restrictions contributed to deteriorating cardiorespiratory fitness, particularly among children with higher BMI. Growing evidence suggests, however, that lifestyle

changes alone do not fully account for the post-pandemic decline in fitness observed in our cohort. Recent international studies indicate that SARS-CoV-2 infection itself may exert an additional, independent impact on exercise tolerance. The virus can impair the function of ACE2-expressing cells, leading to endothelial dysfunction, inflammatory activation, coagulation disturbances and myocarditis, and in some paediatric cases can trigger multisystem inflammatory syndromes resembling Kawasaki disease [17]. These mechanisms may compromise cardiovascular adaptation to exertion. At the same time, meta-analyses show that persistent abnormalities in pulmonary function are uncommon in children following infection, whereas chronic symptoms – most frequently fatigue and exertional dyspnoea – occur considerably more often, pointing to cardiovascular and systemic rather than respiratory limitations as the key contributors to reduced performance [18–20]. The trends we observed in Gdansk align closely with reports from Austria, Germany and other European countries, where increases in BMI and declines in cardiorespiratory fitness, agility and flexibility have been documented in both sexes after the pandemic [21–24]. When interpreted alongside these international data, the reduced fitness levels and elevated post-exercise heart rates identified in our 12-year screening programme appear to form part of a broader, multifactorial pattern shaped by substantial pandemic-related lifestyle disruptions as well as potential longer-term consequences of SARS-CoV-2 infection in the paediatric population.

Sex differences in our analysis indicate that girls achieved higher physical fitness than boys in all BMI categories, which is especially visible in the overweight group, where boys had more than twice the percentage of ‘poor’ scores. These findings may be due to physiological differences as well as different patterns of physical activity [25], the perception of physical activity by parents and teachers may affect the involvement of children, with girls more often preferring moderate activity, positively affecting CRF [26]. However, other studies indicate the opposite trends – Moore *et al.* [27] have shown that boys (58.8%) more often than girls (41.2%) meet the recommendations for physical activity, and their level of moderate-to-vigorous physical activity is significantly higher, and what is important, the study concerned the pandemic period. These discrepancies suggest the need for further research on the relationship between sex and physical activity, which supports Kretschmer *et al.*’s demand for sex specific programmes [28].

From the methodological point of view, the high correlation between post-exercise HR and fitness measured with KPRT ($r = -0.95$ in boys, $r = -0.97$ in girls) confirms the diagnostic value of this test, which is consistent with the results of Gronwald *et al.* [29] and Plaza-Florido *et al.* [30], who indicated that the resting HR is a more reliable indicator of fitness than HR variability. The Kasch pulse recovery test as a simple and non-invasive screening test

was also confirmed in the research of Jankowski *et al.* [9]. In addition, Ekelund *et al.* [3] in the European Youth Heart Study showed that CRF measured by various tests, including heart-rate-based tests, is a strong predictor of long-term cardiometabolic health, regardless of BMI. Similarly, Ortega *et al.* [5] confirmed that regular physical activity and high CRF in childhood reduce the risk of obesity and cardiovascular disease in adulthood, which further strengthens the importance of KPRT as a tool in health prevention [30].

In addition to numerous advantages, the study has limitations. The data are cross-sectional and do not allow for the assessment of individual changes over time. There is a lack of information about diet, extracurricular activity, sleep time and stress levels that could affect fitness. Subjective assessments of well-being or motivation of participants were also not measured, which limits the interpretation of the results in the psychosocial context. These aspects go beyond the framework of our analysis and encourage new research.

Overweight children are characterized by significantly lower physical fitness regardless of sex, with overweight boys being at the highest risk of reduced physical fitness. Girls perform better in each BMI category, which may be the result of physiological differences, activity levels or health behaviours. The results indicate the need for regular monitoring of children’s physical fitness using simple, objective tools such as KPRT and HR measurement. Overweight children, especially boys, should be included in early preventive interventions that can significantly improve their health prognosis. Further longitudinal studies are needed to assess the long-term effects of physical activity and the effectiveness of intervention programmes implemented in the paediatric population.

CONCLUSIONS

Our research, in accordance with most of the literature, confirmed that children with excessive body weight are characterized by lower physical fitness. Thanks to a detailed analysis, we identified boys as a group particularly vulnerable to the long-term complications of obesity. It was shown that girls, regardless of the BMI category, achieved better results in fitness tests.

In addition, we demonstrated that KPRT seems to be a useful and accessible tool for quickly assessing physical fitness of children, helping to identify those who need additional support.

DISCLOSURES

1. Institutional review board statement: Not applicable.
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

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