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Secular trends in physical fitness between 2004 and 2022 in Belgian children aged 10–12 years: findings from a long-term school-based surveillance program

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Abstract

Background

Physical fitness (PF) is a key indicator of current and future health in childhood and adolescence. Monitoring long-term PF trends may help identify population changes relevant to public health. In Belgium, in the Province of Luxembourg, a large-scale annual campaign has assessed PF among children aged 10–12 years for more than three decades. This study aimed to analyze secular trends in PF between 2004 and 2022 according to grade and gender.

Methods

This retrospective study included 70,946 PF assessments collected annually from Grade 5 and Grade 6 children (49.5% girls) participating in a large-scale assessment campaign. PF was evaluated using eight standardized field tests assessing cardiorespiratory endurance, abdominal endurance, speed, flexibility, and upper- and lower-limb explosive strength. Group differences according to gender and grade were assessed using t-tests. Secular trends were analyzed using multiple linear regression models adjusted for grade, gender, and test year.

Results

Boys showed significantly higher scores than girls in all tests except flexibility (all $p < 0.001$). Grade 6 children performed better than Grade 5 peers (all $p < 0.001$). Significant secular declines were observed between 2004 and 2022 in cardiorespiratory endurance (− 39.6 m in the Cooper test), flexibility (− 0.79 cm in the sit-and-reach test), speed (+ 7.2% slower in the 20-m sprint and + 3.6% slower in the 4×5-m shuttle run), and lower-limb explosive strength (− 7.2 cm in standing long jump test) (all $p < 0.01$). Abdominal endurance declined until 2014 (− 3.5 sit-ups, $p < 0.01$) but improved after 2015 following protocol modifications (+ 5.6 modified sit-ups, $p < 0.01$). Vertical jump performance slightly increased over time (+ 4 mm, $p < 0.01$). Upper-limb explosive strength slightly declined between 2015 and 2022 (− 0.017 m in the seated medicine ball throw, $p < 0.01$).

Conclusions

PF levels among Belgian children aged 10–12 years declined across most parameters over the 18-year period. These findings support the need for targeted school- and public health-based interventions promoting physical activity and healthy lifestyles. Longitudinal surveillance programs should be maintained and extended to include behavioral, environmental, and socioeconomic determinants of children's health.

Contributions to the literature

- Long-term monitoring of children's PF can provide early indicators of population health changes and help identify priorities for prevention strategies.

- This study shows the importance of school-based surveillance systems to generate evidence on children's health trajectories over decades.
- Findings support integrating PF monitoring with behavioral, environmental, and socioeconomic factors to better inform education and public health policies.
- Sustained declines in several PF components reinforce the need for coordinated actions between schools, families, and policymakers to promote lifelong healthy behaviors.

Introduction

Physical fitness (PF) is a set of skills that individuals possess or acquire and that are linked to the ability to carry out a physical activity [1]. PF is an important health indicator in children and adolescents [2].

PF is determined a combination of genetical factors and the level of frequent physical activities (PA) [3]. Researchers have shown the existence of a relationship between regular PA and PF during childhood [4, 5]. Moreover, a physically active lifestyle during childhood continues during adolescence and adulthood [6]. Currently in Belgium, only a small percentage of the population meets the World Health Organization (WHO) recommendations for regular PA among 5–17-year-olds, i.e. moderate to sustained PA for at least one hour every day, combined with sport at least three times a week [7]. These results were mentioned in the latest Behaviour in School-aged Children (HBSC) survey report. This report, conducted in 2022 stated that in the French-speaking part of Belgium, 16.2% of the children (Grades 5 and 6, aged 10–12 years) of elementary school claimed to be sufficiently physically active; i.e. practiced moderate to sustained physical activity (MVPA) for at least 60 minutes every day, combined with sport at least three times a week [8]. These percentages decreased with age, reaching 9,8% between the ages of 14 and 18. In 2022, in the Dutch-speaking part among 11- to 12-year-old children, 21.9% practiced at least 60 minutes MVPA every day [9] and 18,5% reached this WHO recommendation at the age of 18.

In the past, several universities in Belgium have studied the PF in school-aged children and adolescents. A study measured secular trends in anthropometric characteristics, PF, PA and biological maturity adolescents were studied over the past 25–35 years [10], while another study has created PF barometers [11]. The barometer is an objective way of assessing the PF of every individual and monitoring their progress.

In recent years, there has been an increased interest in studying the PF levels of children and adolescents, in relation to their well-being, PA participation and health benefits. [12] PA and fitness are key elements in promoting and maintaining good health.

The way in which PF is measured varies from country to country, with a large diversity of test batteries. Many authors have developed their own battery of tests like ALPHA [13], EUROFIT [14], FITNESSGRAM [15]. In general, these batteries of tests cover several parameters such as cardio-respiratory endurance, lower limb explosive strength, flexibility, muscular strength and speed [16]. In Europe, the most widely used test battery is the Eurofit battery, developed in 1983 [17]. This test battery had excellent field-based

utility, a good reliability and was applicable in different contexts [18]. Gender-specific and age-specific normative values have been developed in European children and adolescents aged 7–17 years, who were tested from 1981 to 2015 with the EUROFIT battery [19].

Children's PF is assessed in a variety of contexts, such as research and school. In terms of research, PF tests provide reference measures for exploring the health-related PF of a population and are useful for analyzing the effect of PF training [20, 21]. Indeed, studying PF can help monitor fitness and combat disease risk, as well as using test results to set health goals and plan sustainable healthy behaviors. [22, 23]. The assessment of physical fitness in schools has been widely questioned. Little evidence has been found to support the idea that PF testing promotes healthy lifestyles and sustained PA practice, motivates school-age children and adolescents, or develops the knowledge and skills necessary for sustained engagement in an active lifestyle [24]. However, for these authors, if tests are used appropriately, and integrated into an educational program, they can play a role in promoting PA and in educating children about PA and FP [20].

PF is widely studied in the province of Luxembourg in Belgium. The province of Luxembourg located in the French-speaking part of Belgium is the southernmost region of the country, mainly rural and, with nearly 300,000 inhabitants. In 1991, the authorities the Province of Luxembourg have imagined and implemented a campaign to assess various parameters of PF, using a battery of 8 tests, inspired of the Eurofit test battery [17]. These tests measured cardiorespiratory endurance, flexibility, speed, abdominal endurance, lower body explosive strength and upper body explosive strength. This government action was part of the development of a sports education and culture within the Province of Luxembourg. From 1991 to 1995 around 2000 children aged 10 to 12 participated in this campaign, called "En sport aussi une ardeur d'avance"(A step ahead in sport). Year by year, the number of children has progressively increased. Since 2004, between 4,000 and 5,000 children have taken part in the testing campaign each year. More than 200 elementary schools attended this event, representing the two-thirds of all schools from the province. Since October 2023, the campaign has taken on a different format and a different objective. Only Grade 6 children are tested, which has reduced the number of participants by more than half. Each year, test results are sent to school principals on a report card. These results are forwarded to the physical education (PE) teacher. The latter gives the report card to each child. These results are not considered in the grading of the PE course.

The aim of the campaign was to measure the PF of school-aged children at the end of primary school (Grades 5 and 6; aged 10–12 years) and to encourage them to engage in appropriate, regular PA. The results of all these campaigns have not been used on a scientific basis. Only individual scores were effectively used, in the hope that PE-teachers would use them for initiatives to motivate their children to increase their daily physical activity and get involved in sporting activities. Excellent individual scores were also shared with the local sports club or association to detect future good talent. However, a more comprehensive analysis of the test results would provide important information on current weaknesses. Moreover, the results of these annual assessments would have an impact on public health and education. They would enable stakeholders in children's education to commit to projects to remedy

certain weaknesses and convince them about the need to act. Robust data will make it possible to verify the effectiveness of existing programs and interventions. Therefore, the aim of this article was to analyze secular trend, in Belgium, in the province of Luxembourg, among children in Grades 5 and 6 of elementary school, aged 10–12 years.

Methods

Study design and participants

This retrospective study analyzed data encoded from 2004 to 2022. Data from 1991 to 2003 have not been encoded in computer software and have not been retained. Only children in Grades 5 and 6 who had never repeated a year or had not advanced a year were included in this study. Participants were between 10 and 12 years old. Only their birth year was known. A total of 70,946 measurements were included (girls = 49,52%, boys = 50,48%). A total of 26,738 participants took the campaign tests only once, either in Grade 5 or Grade 6. Some children were ill, injured, changed schools, or their school did not take part in the tests every year. However, 44,208 participants carried out the tests twice, with a period of one year between the two tests.

Every year, tests were carried out in five sports centers in the Province of Luxembourg between October and November. Children went in one of these different sports centers to perform the tests, with their classroom teachers, PE-teacher and/or principals. Tests were administered by external assessors, such as retired PE-teachers, volunteer PE-teachers, PE- children, members of the sports department of the province. All assessors followed an assessment training before the campaign. Some assessors were present at the same test every year. Each child received a personal entry form, on which each assessor had to fill in the results after each test. Forms were kept by a member of the sports department of the province. All scores were coded in a software program belonging to this department. The computerized coding has been carried out every year, since 2004. A few months after the campaign, results were sent back to each school. Each child received a certificate with her or his own scores, from her or his classroom teacher or PE-teacher.

In 2011, no data was encoded due to an IT problem. Fewer children took part in the campaign in 2020. New restrictions linked to the Covid-19 pandemic prevented the campaign from being carried out in its entirety and testing conditions varied. Some children came to a sports center while others performed the tests in their school.

Only the year of birth of the children was known. It was not possible to determine the exact age of all pupils when they performed the tests justifying that the grade will be always used. Grade 5 comprised children aged 10 and nearly 11, and grade 6.

Ethics and privacy policy

Data were obtained from the test scores of the campaigns organized by the sport department of the Province of Luxembourg. Since 2004, all scores were computerized in a software owned by the Province of Luxembourg. A contract of collaboration was signed between the Province of Luxembourg, the Haute Ecole Robert Schuman (HERS, Luxembourg, Belgium) and the University of Liège (Liège, Belgium) to analyze the data. This retrospective study was approved by the hospital-faculty ethics committee of the University of Liege (2023/136). All data exported from the software were pseudonymized with a six-digit code before being treated by researchers.

Physical fitness assessments

PF was measured with a battery included 8 tests. The presentation of the tests below follows the order in which each test was proposed to the participants. All tests were recorded manually. The tests measured 6 PF's parameters.

1) Cardiorespiratory endurance was measured by the Cooper test. This test took place outdoors, on an athletics track. The evaluators counted the distance covered by the participants over a 12-minute period. Children were allowed to walk. However, they were not allowed to stop and leave the track during the test.

2) & 3) Lower limb (LL) explosive strength was assessed by two different tests, the standing long jump test (SLJT) and the vertical jump test (VJT). For the SLJT, participants stood behind a starting line with their feet slightly apart. They had to jump as far as possible, without any run-up, using the swing of their arms and the bending of their knees for propulsion. They had to land on both feet, without falling backwards. Children were allowed two attempts [14]. The best score was recorded. For the VJT, children stood facing a graduated board and held out both hands as high as possible, keeping their shoulders in a neutral position. The height of the fingertips was recorded and was the standing reach height. Participants had to jump as high as possible, without any run-up, using both arms and legs to assist in projecting the body upwards. The jump height was visually measured by the assessor. The difference in distance between the standing reach height and the jump height was the score. The best of two trials was recorded.

4) Flexibility was evaluated by the sit and reach test (SRT). The protocol came from the Eurofit test battery (Council of Europe Committee of Experts on Sports Research, 1993). Participants were sitting on the floor with legs stretched out straight ahead, and shoes off. The soles of the feet were placed against a box. Assessors might assist to hold both knees flat to the floor. With the palms facing downwards, and the hands side by side, participants leaned forward and slid a marker along the measuring line as far as possible. Participants were allowed two trials. The best trial was recorded.

5) & 6) Speed was the last parameter recorded by two tests, the 4x5-m shuttle run test and the 20-m sprint test. For the 4x5-m shuttle run test, the children had to run around cones over a distance of 4 x 5 meters. For the sprint test, the children ran in a lane of 20 meters. The start and finish lines were marked on the ground. For those two tests, participants had only one attempt.

7) Abdominal endurance was measured by the sit-up test (SUT) or the modified sit-up test (MSUT). From 2004 to 2014, children had to perform as many sit-ups as possible for 60 seconds following the Eurofit protocol of the SUT (Council of Europe Committee of Experts on Sports Research, 1993). Participants laid on their back, knees bent at right angles, feet flat on the floor and held by a partner. The fingers should be interlocked behind the head. The sit up was counted if the participant reached the vertical position without moving the position of the hands or arching the back and lifting the buttocks off the ground to raise the upper body, or if the knees exceed an angle of 90 degrees. From 2015, the protocol of the SUT was modified and called MUST. For the MUST participants lay on their back, with their head resting in the hands of a partner kneeling behind them. The participants' legs rested on a bench. For the starting position, they had to form a 90-degree angle between their trunk and thighs. To perform a valid sit-up, participants had to touch with fingertips, a marker placed on the bench, where their legs were resting. The result of the test was the number of sit-ups performed for 45 seconds.

8) Upper limb (UL) explosive strength was evaluated by the seated medicine ball throw test (SMBT). Participants sat with their backs against a wall, with their knees bent. The aim was to throw a medicine ball as far as possible, using both hands placed at chest height. The boys were given a medicine ball weighing either 2kg (before 2015) or 1.5kg (from 2015), and the girls a medicine ball weighing 1kg. This weight difference between girls and boys was established by the founders of the testing campaign and is not based on scientific evidence. Two attempts were allowed, with the best recorded.

Statistical analysis

R software was used for statistical analysis. Variables recorded in the database were the year in which the test was carried out, year of birth of participants, the name of the school, the location of the school (name of the town or village), the zip code, the gender, the age and the results in the eight tests. Basic analyses were performed to test normality, means, standard deviation, median and percentiles with the entire population. Subgroups were made by age and gender. Comparisons between subgroups were analyzed by a t-test: as some participants performed the test twice, a t-test based mixed models was used.

Multiple regression models were used to explore the influence of different independent variables on PF tests results [dependent variable (y)]. Various models were tested with four selected variables as the independent factors. These variables were the grade of primary school, gender, year of the test and zip code of the school. Analyses were performed for the global population. Regression coefficients (βIntercept, βvariable1, βvariable2, βvariable3,…) were used to show the association between independent factors and the PF test results. The level of statistical significance was < 0.05. Adjusted coefficients of determination (adjusted-R^2) were used to indicate the robustness of the model.

Results

Inferential statistics

The average scores for all participants and gender differences are presented in Table 1 across the PF components assessed.

Boys significantly outperformed girls in most PF tests, including cardiorespiratory endurance (Cooper test), lower-limb explosive strength (SLJT, VJT), speed (20-m sprint and 4×5-m shuttle run), abdominal endurance (SUT and MSUT), and upper-limb explosive strength (SMBT). However, girls achieved significantly higher scores in flexibility (SRT). All observed differences were statistically significant ($p < .001$), according to mixed-model t-tests. No statistical comparisons were provided for the SMBT because the weight of the medicine ball was different between gender.

Grade 6 children performed significantly better than their peers in grade 5 across all PF tests with unchanged protocols, including cardiorespiratory endurance, lower-limb explosive strength, speed, and flexibility. All differences reached statistical significance ($p < .001$).

For tests with protocol modifications introduced in 2015 (SUT, MSUT, and SMBT), Grade 6 children also showed significantly better performances than Grade 5 children within both sexes (all $p < .001$). Similar trends were observed across the two measurement periods (2004–2014 and 2015–2022). Overall, the results of the PF tests improved with age. Older children performed better, regardless of their gender.

Multiple linear regression

Multiple linear regression models were summarized in table 3. The selected independent variables were the grade of primary school, the gender and the test year. A similar analysis using linear mixed models (including the random effect of zip codes) was also considered, but it did not change the interpretations of the coefficients or their significance: consequently, these models were not integrated in this study. For seven physical tests, models were presented according to the following equation: $Y = \beta Intercept + \beta Grade + \beta Gender + \beta Year + e$. For SMBT, the protocol was different for boys and girls. Therefore, the independent variable gender was removed from the equation. Logarithm function was applied because the normality was rejected for the 20-m sprint test, 4x5-m shuttle run test and SMB 4–14.

Log-linear models measure the impact of a one-unit change in the independent variable X1 as a percentage change in Y, the dependent variable [$100(\exp(\beta 1)-1)\%$].

Cooper test. The regression coefficients of the multiple linear regression model associated with this test showed that participants who were in grade 6 had an average score 35m higher for this endurance test compared to participants in grade 5. This increase was highly significant ($p<.001$). In addition, boys had a higher score of 266.2m than girls ($p<.001$). Between 2004 and 2022, a highly significant decrease of 2.2m was observed each year ($p<.001$). Eighteen years of measurements were recorded for this study, as the year 2011 was removed. A decreased of 39,6m was measured between 2004 and 2022. Residuals from this linear regression model were normally distributed. The adjusted coefficient of determination (adjusted R2) was very low, close to 0 (0.142). Hence, this model explained 14.2% of the variability in the results of the Cooper test.

SLJT. For this test, the regression coefficient βGrade was highly significative (p<.001) and showed on average a superior length of 5.90cm in participants in grade 6. Boys had a jump significantly longer of 7,60cm compared with girls (p<.001). For each additional year between 2004 and 2022, there was a highly significant reduction of 4mm (p<.001), which corresponded to a loss of 7.2 cm in length over the 18 years recorded. The residuals of this model followed the normality. Adjusted R2 was also close to 0 (0.070), meaning that this model described 7% of the variability in the results of the SLJT.

VJT. βGrade indicated a significantly higher average height (2.17cm) for children in Grade 6 (p<.001). Boys had a significantly higher average jump (0.92cm) than girls (p<.001). From 2004 to 2022, VJT-results have increased by 4mm (p<.001). The normality of the residuals for this model was maintained. Adjusted R2 was low (0.041) and explained 4.1% of the variability in the results of the VJT.

SRT. The flexibility was significantly superior for girls (on average 4.58cm) compared with boys (p<.001). Over an 18-year period, the participants lost an average of 0.79cm of flexibility in their posterior chain. This decrease was highly significative (p<.001). The difference in flexibility between Grades 5 and 6, in other words, between children aged 10–11 and 11–12, was not significant (p = 0.76). The normality was maintained for the residuals of this model. Twelve-point one percent of the variability in the results of the SRT were explained by this multiple linear regression model.

20-m sprint test. The sprint test result decreased by -2.6% when the age range of the children was increased from 10–11 to 11–12 years (from Grades 5 to 6). This variation was highly significant (p<.001). This negative variation expressed a shorter sprint test time, i.e. an increase in speed with age. Boys showed a significantly faster speed than girls (p<.001). The result differed from − 3.7% when the test was performed by the boys. The result of this sprint test varied from 0.4% when a calendar year increased, i.e. a change of 7.2% over the period 2004–2022. This variation was highly significative (p<.001). This positive change meant that the children took longer to complete the test. Over a period of 18 years, their speed decreased. The normality of the residuals was respected for this model. Adjusted R2 was 0.108, meaning that this model expressed 10.8% of the variability in the results of the 20-m sprint test.

*4*5-m shuttle run test.* This test followed the same variations as the sprint test. Results decreased by -2.1% when the grade of the children increased from one year. This variation was highly significant (p<.001). Boys were significantly faster compared with girls (p<.001), indicating a variation of -4,4% when they realized the test. A significant increase of 0.2% was measured every calendar year (p<.001). Between 2004 and 2022, there was a 3.6% increase in the time (s) taken to perform the shuttle test, marked by a reduction in speed. Residuals from this linear regression model were normally distributed. Adjusted R2 was very low (0.093). This multiple linear model explained 9.3% of the variability of the results for the 4x5-m shuttle run test.

SUT & MUST. This test showed that grade was a determining factor. Grade 6 children performed an average of 2.2 (SUT 4–14) and 3.7 (MSUT 15–22) more sit-ups than grade 5 children. These increases were highly significant (p<.001). A significantly higher average number of sit-ups was observed in boys

(3.1 sit-ups SUT 4–14, p<.001; 2.6 sit-ups MSUT 15–22, p<.001) compared with girls. SUT showed a decrease of 3.5 sit-ups over the 10-year period between 2004 and 2014. From 2015 to 2022, there was an increase of 5.4 sit-ups in the MSUT. These two multiple linear models for SUT and MSUT had normally distributed residuals. Adjusted R2 was very low (0.065 SUT 4–14, 0.061 MSUT 15–22).

SMBT. Children in grade 6 showed a greater distance of 0.34m (p<.001) compared to their Grade 5 peers, for SMBT 04–14 and SMBT 15–22. A significant reduction was recorded only for the period 2015 to 2022 (0.017m; p<.001). For the two multiple linear regression models associated with the SMBT, the residuals were normally distributed. The adjusted R2 values associated with these models were close to 0 (0.080 SMBT 4–14 and 0.096 SMBT 15–22).

Discussion

On a global scale, society is faced with a recent downward trend in PF [16]. This trend of declining is linked to changes in the lifestyles of children and adolescents, physical inactivity and the increase in time spent in front of a screen [25]. Physical inactivity can lead to multiple health problems. Inactive young populations such as children and adolescents are at risk of developing certain serious non-communicable diseases sooner or later (e.g. cardiovascular diseases, diabetes, metabolic disorders, mental health problems…) [26].

In order to implement measures in the health sector, in the promotion of PA, in education and in active transportations, it is important to have strong data on changes in a population.

A major strength of this study is the number of participants, with annual cohorts ranging from 4,000 to 5,000. Identical assessments have been repeated over a long period of 20 years, for the same age group of participants (10–12 years), for 6 PF tests. The robustness of these results can be used to understand changes in the population and to develop evidence-based recommendations. The results of this study have a considerable potential impact on public health policy.

The main results of this study show a downward trend identified for the majority of PF parameters measured in PF tests between 2004 and 2022.

General trends of these PF parameters were compared with other studies mentioned by Masanovic et al. (2020) in this recent systematic review on trends on PF among school-aged children and adolescents. These trends comparisons were made between studies using different study designs and methodologies. The inter-study variance is therefore a limit to consider for studies comparisons. In addition, some studies reported data for the whole population and did not differentiate results according to age samples (e.g. 8–10, 10–12, 12–14,…). Moreover, results in some studies were either calculated for both genders or split for boys and girls.

The decline in PF is caused by multiple factors. Inappropriate health behaviors (lack of sleep, lack of energy expenditure, poor diet, reduced PA, etc.) have a negative impact not only on endurance but also

on other fitness parameters such as speed, strength and flexibility [27]. The slight decrease of endurance measured in this study followed the worldwide trend of the last decades [16, 28]. Lack of PA correlates with reduced cardiorespiratory endurance [2]. In French-speaking Belgium, the HBSC surveys [8] revealed that the overall level of PA among children at the end of primary school has fallen in recent years. In 2010, 21.5% of children in Grades 5 and 6 practiced a sport outside school at least twice a week, compared with 16.2% in 2022.

Regarding speed, direct comparison with other studies assessing children aged 10 to 12 was limited by differences in testing protocols, particularly the sprint distance used—50 m in Ao et al. (2019), Dong et al. (2019), and Bi et al. (2020), and 40 m in Costa et al. (2017), compared to the 20-m sprint test in the present study. Furthermore, the contradictory trends observed in these studies highlight the potential influence of geographical, socio-economic and educational disparities. Beyond methodological differences, speed performance is highly sensitive to multiple factors including age-related neuromuscular development, training background [29], and surface or testing environment. These elements underline the need for standardized protocols and contextual analysis when interpreting secular trends in sprint performance.

In our study, flexibility levels also declined over time. This finding is consistent with studies conducted in Europe on children of the same age group, which reported a downward trend in flexibility [12, 30]. In contrast, data from Canada showed a stable evolution in flexibility among children aged 6 to 10 years [31]. Interestingly, other international studies have reported an increase in flexibility over time [32, 33], suggesting that secular trends may vary by region, measurement protocol, or population characteristics.

For the LL explosive strength, a declining trend was also observed in four other studies for boys and girls aged 12 [34], 7–18 [35, 36] or 11–18 [30], between 1985–2014 or 1992–2012. These studies used only the SLJT. In our study, SLJT showed a decline in explosive strength (7.2 cm) while VJT revealed a slight increase of 4mm. Both tests measure explosive leg strength, but according to different movement planes and coordination requirements. However, in the present study, the trend in the results of these two tests was divergent. The accuracy of the VJT has been questioned in the literature. Compared with measurement systems using platform contact or optical system, the visual and manual method of the VJT (or Sargent test) tended to overestimate the results [37]. The reliability and accuracy of this test was also questioned in the present study. Indeed, the VJT boxplot for each year showed a sharp increase in results between 2016 and 2017. After 2017, the trend was downwards again, but the average results remained higher than those recorded in 2016 and before (see Appendix 1). A revision of the protocol or a change of equipment could perhaps have been reviewed in 2017. Several tests such as squat jump, countermovement jump with optical measurement system, vertical jump on mat contact and SLJT were the most reliable and valid tests to assess LL explosive strength in children aged 6–12 years [38]. But for practical applications, SLJT seems to be the most time efficient test with low cost and equipment requirements. SLJT is widely used in PF test batteries to assess UL explosive strength [38, 39], despite the impact of technical level, which can explain large differences in children's performance [40].

In our study, the trend of abdominal endurance declined first from 2004 to 2014, and was followed by a growth trend from 2015 until 2022. This trend was not generalized in other existing studies. Results of previous studies were also divergent [12, 30, 34–36]. In our study, the increasing trend observed after 2015 may be partially explained by a change in testing protocol. Specifically, the range of motion was reduced, as children no longer performed full sit-ups. In addition, the test duration was shortened by 15 seconds (from 60 to 45 seconds) shifting the test's physiological demand from muscular endurance to more explosive strength. This modification likely influenced the nature of the effort required and may have contributed to the improvement observed performance.

In the literature, UL explosive strength is most commonly assessed using handgrip, bent-arm hang, or pull-up tests [16]. In contrast, the present study evaluated UL explosive strength using the SMBT, a test frequently employed in sports settings to assess functional performance in athletes, but not reported in school-aged populations [41]. From 2004 to 2014, an upward trend was observed in SMBT performance. However, since 2015, performance has declined, coinciding with a reduction in the weight of the medicine ball used for boys. It is worth noting that object manipulation skills developed during PE lessons, reactional PA, and sports enhance coordination, agility, and precision [42], but may not directly translate into improvements in muscular strength. Moreover, modern behaviors involving increased use of digital devices place greater demands on fine motor skills and upper limbs without contributing to actual strength gains [43].

The practical implications of our results are that upper and lower body strength, endurance, speed and flexibility should be given particular attention in PE or PA interventions. Regarding education, the current reform in the Wallonia-Brussels Federation (French-speaking part of Belgium) provides for an extra 50 minutes of PE in the timetable of Grade 5 children from the start of the 2024–2025 school year. At the beginning of the 2025–2026 school year, grade 6 will also have an extra 50 minutes per week [44].

This study highlighted the influence of both age and sex on children's physical fitness (PF). From a developmental perspective, significant improvements were observed between Grade 5 (ages 10–11) and Grade 6 (ages 11–12) in most PF parameters, including cardiorespiratory endurance, abdominal endurance, speed, and upper and lower limb explosive strength. These improvements are consistent with previous findings in children of similar age groups [33, 45, 46].

However, no significant change was observed in flexibility. This stability may be explained by the fact that changes in flexibility are closely linked to biological processes such as rapid bone growth, hormonal changes, and maturation of connective tissues and muscles, which generally occur over several years [47–49]. Thus, in the present study, a one-year period between the two assessments may be too short to observe measurable changes in flexibility.

Gender was also found to be a determining factor for several components of PF. Boys outperformed girls in cardiorespiratory and abdominal endurance, speed, and explosive strength of the limbs. These differences are likely related to physiological changes occurring at the onset of puberty, which typically

begin between ages 10 and 12 [50]. During this period, boys experience increases in fat-free mass and testosterone levels, while girls tend to accumulate more fat mass [51].

Beyond biological factors, PA levels are also strongly associated with PF in children and adolescents. Data from nine countries indicate that boys engage more frequently in moderate-to-vigorous physical activity compared to girls [52–54], which may further explain their superior performance in PF measures.

Limits

A limitation of this study is that no data was measured on the participants' level of PA, body mass index, height or body composition. Data such as lifestyles and their daily or weekly PA, health-related factors (e.g., nutrition), socio-economic status are missing. The influence of these factors on children' level of PF could not be studied in this research. The relationship between these factors and PF is relevant and widely studied (Drenowatz et al., 2010; Gu et al., 2016; Janssen & LeBlanc, 2010; Larsen et al., 2017; Milanese et al., 2020). However, these factors were not considered when the PF measurement campaigns were launched. Certain lifestyle habits like skipping breakfast or short sleep periods and bad sleep quality might be related to lower PF in children. These conclusions were observed in adolescents but were not controlled in this study [55, 56].

Each test was recorded manually and was subject to measurement error. Measurement errors influence the accuracy of test results. This may also be a limitation of the study. Encouragements from peers and teachers [57], motivation [58] as well as the amount of regular training could influence the results of fitness tests [59]. These factors were not analyzed in this study as in most of the similar research.

Another limitation is the test preparation or familiarization that might have differed from one school to another. This could have influenced the results of the tests. Some teachers who are used to taking part in the campaign were more familiar with the tests and others were free to prepare their pupils for the tests or not.

In addition to the results of the eight physical tests, only a few data were available (birth year, gender, zip code, test year, name of the school). Multiple linear regression models were used included only three independent variables (test year, gender and Grade). Significant changes observed in each multiple linear regression model were sometimes minimal, e.g. an increase of 35.1m in the Cooper test between Grade 5 and 6, or a decrease of flexibility of 0.792cm during the same period. All multiple linear regression models explained only 4–15% of the variance of the PF parameter, and hence 85–96% of the variance remained unexplained by the covariates. This important unexplained variance means that other correlates than age, time and gender have an influence on the evolution of PF parameters. These results should be interpreted with caution. Many measured and unmeasured factors not studied in the study may influence the results of PF parameters.

Conclusions

The aim of this study was to assess changes in the physical fitness of 10- and 12-year-old Belgian children in large cohorts between 2004 and 2022. During this measurement period, a decrease was observed in most PF parameters (cardiorespiratory endurance, LL explosive strength, flexibility and speed), when the test was unchanged, and its protocol was reliable and accurate. Beyond its scientific relevance, this large-scale fitness assessment campaign offers clear benefits for multiple stakeholders. For teachers, it provides objective indicators to monitor children' physical PF and support pedagogical adjustments. This approach remains formative and encourages children to focus on personal needs, improvements and health. For parents, individual feedback enhances awareness of their child's physical capabilities and can encourage engagement in PA outside of school, especially when weaknesses or strengths are identified. For policymakers, the longitudinal nature of the campaign generates robust data that can inform public health strategies, educational reform, and targeted interventions to address observed weaknesses. Overall, the campaign represents a valuable tool for education, prevention, and policy development in the promotion of PA, child and adolescent health.

In future, for this type of large-scale fitness assessment campaign, more factors should be exploited to better interpret the determinants of PF. This will be relevant with a view to establishing a policy of action and prevention for the provincial government.

Abbreviations

ALPHA
Assessing Levels of Physical Activity and Fitness test battery
COVID
19–Coronavirus Disease 2019
HBSC
Health Behaviour in School–aged Children
HERS
Haute École Robert Schuman
LL
Lower Limb
MSUT
Modified Sit–Up Test
MVPA
Moderate–to–Vigorous Physical Activity
p
p–value
PA
Physical Activity
PE
Physical Education
PE

teacher–Physical Education Teacher
PF
Physical Fitness
Q1
First Quartile (25th percentile)
Q3
Third Quartile (75th percentile)
R^2
Coefficient of Determination
adjusted R^2
Adjusted Coefficient of Determination
SD
Standard Deviation
SLJT
Standing Long Jump Test
SMBT
Seated Medicine Ball Throw Test
SRT
Sit–and–Reach Test
SUT
Sit–Up Test
UL
Upper Limb
ULiège
University of Liège
VJT
Vertical Jump Test
WHO
World Health Organization
β
Regression Coefficient

Declarations

Ethics approval and consent to participate

Ethical review and approval were waived for this study due to the fact that the Hospital-Faculty Ethics Committee of the University of Liege determined it did not fall within the scope of the Belgian law of 7 May 2004 relating to experiments on the human person and therefore raised no ethical objection to its conduct. Study reference: 2023/136

Consent for publication

Patient consent was waived for this retrospective study because the data had been previously collected as part of a provincial fitness assessment campaign, were pseudonymized prior to analysis, and did not involve any direct intervention or experimentation on human participants.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

A.B., A.M. and B.V. contributed to the conceptualization and design of the study. Data collection was performed by B.M., A.-M.F., V.G., and A.F. Statistical analyses were conducted by G.B. and A.B., while data interpretation was undertaken by A.B., M.C., G.B., and B.J. A.B. carried out the literature review and prepared the first draft of the manuscript. Funding acquisition was provided by B.V. and B.M. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for the integrity and accuracy of the work.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available, as the Province of Luxembourg does not wish to publish this public health data; but are available from the corresponding author on reasonable request.

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