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Secular trends in skill-related physical fitness among Slovenian children and adolescents from 1983 to 2014

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Abstract

It is vital from the public health and educational perspective to be familiar with changes in the fitness levels of individuals and populations since fitness is associated with several health outcomes and cognition. Skill-related physical fitness refers to performance in sports or occupation and is associated with motor skill performance. The aim of the present study was to examine secular trends in skill-related physical fitness of 16 678 participants in four youth generations of Slovenian children and adolescents in years 1983 ($n=3128$), 1993/94 ($n=3413$), 2003/04 ($n=5497$), and 2013/14 ($n=4640$). Using repeated cross-sectional design, we observed fitness level of all participants divided into three age groups: 6–10, 11–14, and 15–19 years. Skill-related physical performance was measured with seven fitness tests for speed, coordination, balance, and flexibility. Analysis of covariance was used to compare differences in fitness performance between decades in each age and sex group, adjusted for body height, body weight, and body mass index. Overall, large but inconsistent changes in coordination, a small improvement in speed, and a decline in flexibility were seen. The trends over the whole examined period were not linear throughout decades. Generally, positive trends were noticed in periods 1983–1993 (range 1.4%–17.9%; except flexibility) and 2003/04–2013/14 (range 0.2%–36.4%; except age group 15–19 years) while in the period 1993/94–2003/04 there are some particularities in secular trends according to individual components as well as age groups. In general, the secular trend showed a positive direction for both genders ($p<0.05$), except for gross motor coordination, which demonstrated positive trends in 1993 and 2013 compared with a decade earlier ($p<0.05$) and from 1983 to 2013/14, except for the youngest boys in 2003 and the youngest girls from 1993 to 2003 ($p<0.05$). Our findings call for exercise programs aimed at improving speed and gross motor coordination in both sexes and all age groups, especially in the group of 15–19 years old.

KEYWORDS
balance, coordination, flexibility, generation, health, speed, temporal trends, youth

1 | INTRODUCTION

Physical fitness refers to the ability to effectively carry out daily activities without premature fatigue and with sufficient energy.[1] For the past 40 years, the distinction between health-oriented and skill-related physical fitness has come into common use.[2] Health-related physical fitness is primarily focused on health outcomes and is the most researched area of physical fitness.[3] Skill-related physical fitness refers to performance in sports or occupation,[4] and is associated with motor skill performance.[5] It encompasses components such as speed, power, coordination, reaction time, agility and balance.[6] These components affect performance in health-related physical fitness, yet they have attracted less research interest. This is important also from the perspective of current fitness level of children and adolescents, since globally, nowadays generations are less fit[7] and more inclined to health risks associated with poor fitness.[8] Furthermore, trend dramatically worsened with COVID-19 pandemic. Namely, good physical fitness is associated with a healthier cardiovascular and metabolic profile, better quality of life,[9] a lower risk of cardiovascular disease later in life,[10] and also less fatal course of COVID-19 disease.[11] Moreover, childhood is a crucial period for the development of physical fitness, as individuals with better fitness tend to exhibit better physical activity profiles.[7] Therefore, it is vital to promptly detect negative pediatric fitness trends to react with proper policy measures and to develop interventions and programs aimed at supporting or increasing physical fitness.

Most studies on temporal trends in physical fitness among children and adolescents investigated only endurance.[12–14] In addition, many of them are limited to changes during a decade or two. Tomkinson and Olds[14] investigated trends only up to 2003, and Hanssen-Doose et al.[12] investigated secular trends exclusively after 2003. Only four studies with representative samples were found to investigate secular trends in skill-related physical fitness,[15–18] but are limited only to certain age groups. Global overview on trends in power and speed during the second half of 20th century, presented by Tomkinson[19] showed a slight annual improvement before 1985. After this period, fitness levels stabilized or declined.[19] Several national studies reveal trends also for other skill-related fitness components. German children performed significantly better in coordination between 1989 and 2007[20] and between 2005 and 2015,[21] whereas Slovenian children aged 7–9 years showed a slight improvement in coordination throughout the period from 1998 to 2019.[22] Initial positive trend of physical fitness (1991–1997) stabilized in Slovenia and began to decline slightly, but then showed a steep increase in 2011 through 2019.[23] Data from Lithuania showed that their adolescents improved performance in balance between 1992 and 2012, but at the same time their coordination deteriorated.[18] Flexibility decreased by 10% among German children and adolescents between 1975 and 2000.[16] Additionally, several studies reported a negative secular trend in sit-and-reach test[7,15,17,24] from 2006, while only one study noticed a positive secular trend between 1992/93 and 2006/07.[25]

In Slovenia, monitoring physical fitness is highly valued and is reflected in the development of a national system SLOfit for monitoring physical and motor development in children and adolescents. This system, which was first introduced in 1969 and revised in 1987,[26] involves the assessment of three anthropometric and eight motor tests in all primary and secondary schools (age 6–18 years) to monitor child development at the population level. By surveillance on national level, negative trends can be identified and addressed.[27] Studies comparing objectively and subjectively assessed physical activity data have shown that Slovenian school children and adolescents are among the most physically active in the world, with more than 80%[28,29] achieving the recommended 60 min of daily moderate-to-vigorous physical activity.[30–32] However, concerns exist about sedentary behaviors among Slovenian youth, such as watching television and using electronic devices.[33,34]

To summarize, previous findings suggest that country-specific differences in secular trends in skill-related fitness exist. Therefore, it is vital for countries to detect these trends in children and adolescents to promptly react by developing proper interventions aimed to support fitness performance and consequently better health outcomes. Therefore, the aim of the present study was to investigate secular trends in skill-related physical fitness among Slovenian children and adolescents between 1983 and 2014. For more comprehensive picture, flexibility was included in this study despite its controversy.[6] The information gained from our research can guide interventions, inform curricular development, and contribute to injury prevention and performance enhancement efforts in physical education and sports settings.

2 | METHODS

2.1 | Study design

The data were collected within the framework of the comprehensive study The Analysis of Children's Development in Slovenia (ACDSi).[35] ACDSi is an interdisciplinary, cross-sectional, decennial study that began in 1970 at the Faculty of Sport of the University of Ljubljana as a research project focusing on developmental trends in physical characteristics and motor performance of children and adolescents from Slovenia. In brief, ACDSi is a national repeated study performed in the same 11 primary schools across Slovenia, stratified according to four Slovenian settlement types (village, rural town, industrial town, and city) and regions, and in the same 16 upper secondary schools stratified by three types of programs (grammar/general, technical, and vocational). A sample of schools was selected using a multistage, stratified design. Thereafter, each research cycle included ~3500–5500 children aged ~7–19 years (Figure 1), representing ~2% of Slovenia's entire population in that age group. Specific sample sizes and means with standard deviations for body height and mass of children and adolescents for the current study are provided in Appendix in Table A1. Due to some data loss at the 1970 measurement wave, only data from 1983 onward are included in this study. The research project was repeated four times: the first time in 1983 and then every 10 years, in 1993/94, 2003/04, and 2013/14. In 1983, only primary schools were included, while from 1993/94 the sample was expanded with adolescents attending secondary schools (aged 15–19). The proportion of 6-year-old children has increased in the last two decades, as children started primary school 1 year earlier in Slovenia due to the change in the school system in 2000.[36] Details of ACDSi study are described elsewhere.[37]

ACDSi study was approved by the Slovenian National Medical Ethics Committee (ID: 138/05/13), following the Declaration of Helsinki.

2.2 | Participants

In total, a nationally representative sample included 16 678 participants (8518 boys; Figure 1) from four youth generations (1983, 1993–94, 2003–04, and 2013–14). We divided participants into three age groups: 6–10, 11–14, and 15 –19 years, in line with prior studies on physical fitness' secular trends.[38]

The participation of all students was anonymous and voluntary, and they could withdraw from the study at any time. After the children, adolescents, and their parents were informed about the goals of the study and its protocol, written consent was obtained from the parents or legal guardians of all participating children and adolescents. Note that there were no major risks associated with any of the tests.

2.3 | Testing procedures

In each school, one of the physical education teachers was assigned as a coordinator. The coordinators helped with obtaining consent forms and parent questionnaires, with setting up the measurement schedule, informing other teachers and school staff about the organization of the measurements, etc. The measurements were organized between 8.00 and 14.00. A testing field leader led each of the three testing groups (anthropometry, motor testing, and questionnaires), and a measurement leader took care

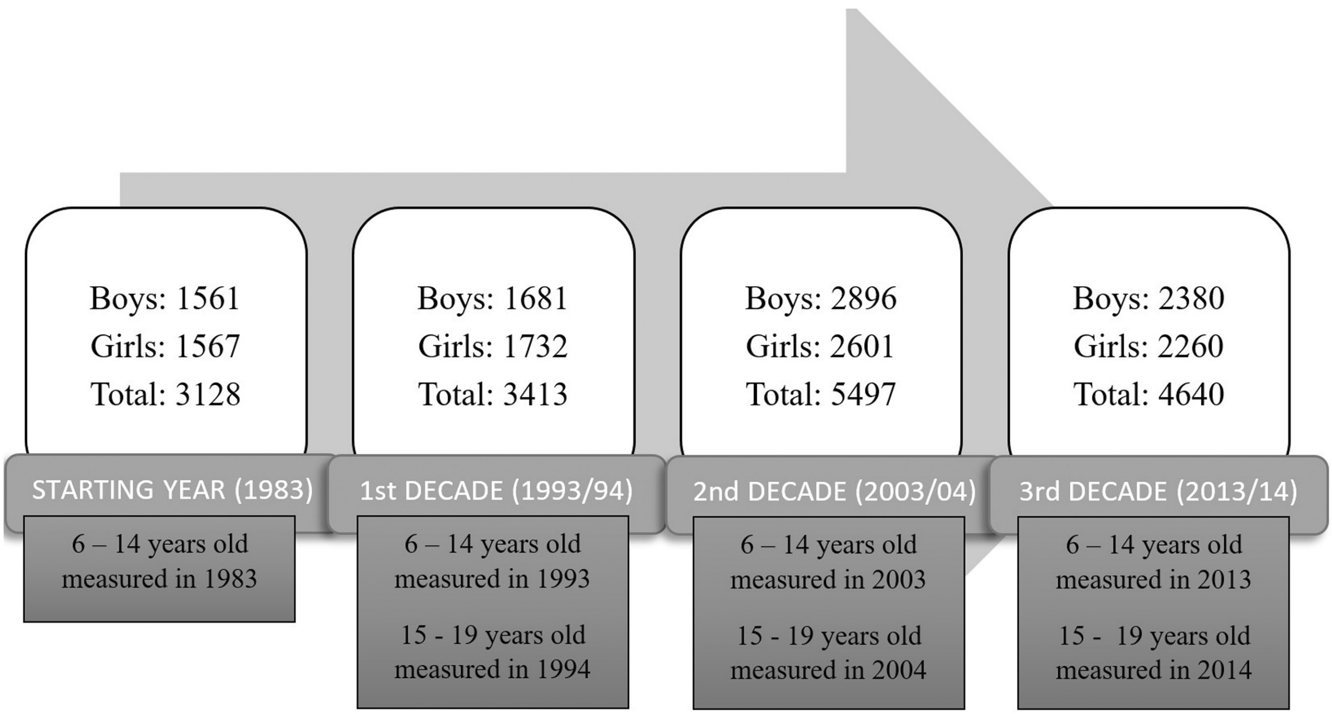

FIGURE 1 Number of participants by sex and age of measurement included in the study.

of the coordination between all three groups. All measuring equipment that was not part of the standard school gym equipment was brought to the school by the research team. All testing equipment was routinely calibrated every day throughout the testing period. The measurements were performed by researchers and students from the Faculty of Sport, the Faculty of Biotechnology, and the Faculty of Pedagogy at the University of Ljubljana. Between 20 and 25 student investigators participated in each testing session at each school. All student investigators received in-depth training from the SLOfit research team at the Faculty of Sport, University of Ljubljana. They all had previous experience with anthropometric measurements and motor testing. During the training, all measurement procedures were performed several times to ensure that all study participants were familiar with all tests and protocols assigned to them.

2.4 | Anthropometric measurements

Only standard noninvasive anthropometric measurements were taken. In all measurements, body height was measured to the nearest millimeter. Body weight was measured to the nearest 100 g. Participants were measured barefoot, wearing light clothing. The electronic scale was checked for accuracy every time it was moved. Body mass index (BMI) was calculated as body weight per square meter of height (kg/m^2). For the last two measurements (2003/04 and 2013/14), we used the GPM 101 anthropometer (Siber & Hegner) to measure body height and the Tanita BWB-800P portable electronic scale (Amsterdam, Netherlands) to measure body weight and the Harpenden fat caliper (Baty International Ltd.) to measure triceps muscle skinfold. For all previous measurements, the devices used were standardized with comparable accuracy.

2.5 | Skill-related fitness tests

All skill-related fitness tests were measured at four time points (1983, 1993/94, 2003/04, and 2013/14), except for the Flamingo and the shoulder flexibility test, which were measured three times (1993/94, 2003/04, and 2013/14). The tests utilized demonstrate adequate validity and reliability for implementation in the Slovenian youth population.[39,40]

2.5.1 | Speed

Speed was assessed with a 60-m dash test, in which participants had to run the distance of 60 m as fast as possible. Participants ran in small groups or in pairs and started from a standing position. At the first two measurement waves, time was measured with a stopwatch that had a division of 0.1 s, while in the last two decades time was measured using photocells. The result was recorded to the nearest 0.1 s. Students wore athletic footwear. The 60-m dash is also used in the annual national Slovenian national fitness surveillance system (SLOfit measurements) and has good measurement characteristics in age groups included in this study.[41]

2.5.2 | Coordination

Coordination is a very complex fitness component; therefore, it was examined with three tests: polygon backward, hand drumming, and hand tapping.

Coordination of whole-body movement was assessed with the *polygon backward* test, which required participants to crawl backward a distance of 10 m. The starting position for the participants was behind the starting line, while the participants crawl backward on all fours. The test leader gave the start signal. The test involved crawling backward (A) over 50 cm and (B) under the 50 cm high obstacles, which were (A) 3 m and (B) 6 m from the start line. The task was measured to the nearest tenth of a second (0.1 s), and the better of the two test performances was recorded. The polygon backward is also used in the annual national SLOfit measurements and has good measurement characteristics in those age groups.[41]

Arm coordination was measured with a specific sequence of hand drum movements, known as *hand drumming* test. While performing the test, participants sit on a chair in front of a table. In response to a signal, they perform the following sequence: strike the left side of the table twice with the left hand, cross the left hand with the right hand and strike the left side of the table twice, touch the forehead once with the right hand, and place the palm of the hand back on the right half of the table. The score is the maximum number of repetitions in 20 s performed in one of two trials. The Hands drumming test has been included in ACDSi study because of good measurement characteristics in included age groups.[41]

The speed and coordination of alternating arm movements were measured with the *hand tapping* test. The participant sits at a table with a hand tapping board and placed one hand in the center between the plates and the other hand on the plate on the opposite side. Participant feet should be on the ground. When the participant begins to touch the plates, the monitor begins to count the touches. Each touch of the two plates counts one repetition. The participant performs the task for 20 s. The hand tapping test is also used in the annual national SLOfit measurements and has proven measurement characteristics in observed age groups.[41]

2.5.3 | Balance

Balance was assessed with the *Flamingo test*, in which the participant stays upright with the fully extended leg on a special wooden beam (50 cm long, 5 cm high and 3 cm wide), bending the free leg at the knee and holding the foot with the hand on the same side. The measurer helps the participant to get into the correct position and starts timing as soon as the participant releases the hand of the timekeeper. The result is the maximum number of trials in 1 min, which is limited to 30. If the participant exceeds this number 15 times in the first 30 s, the participant's result is scored as 31. The Flamingo test is one of the Eurofit tests, which has shown good reproducibility, high reliability, and adequate validity in Slovenian children and adolescents.[40]

2.5.4 | Flexibility

Flexibility was examined with two tests: sit-and-reach and shoulder flexibility test.

Hip joint flexibility was assessed with *sit-and-reach test* using a specially constructed box that had a ruler attached to the top. For practical reasons, the box is placed on a raised platform against a wall so that the participant can sit facing the box with his legs straight out in front of him and his bare feet against the box. With knees extended, the participant grabs the slide, gently pushes it as far away as possible, and then holds the position for 2 s. After one practice attempt, the best score out of three attempts is recorded. A higher score means better performance. The sit-and-reach test is also one of the Eurofit tests, which has shown overall moderate criterion validity for estimating hamstring extensibility.[41]

The mobility of the shoulder girdle was measured with *shoulder flexibility test*. For the execution of the test, a wooden stick of 1.5 m length and 3 or 2 cm diameter is needed. Measurer is holding a stick behind his back with both hands wide apart and palms facing downwards. The participant's task is to make a twist while carrying the stick behind his back, so (s)he should not drop the stick and extend his palms as little as possible. (S)he performs the task twice. The result was read from the stick on the right little finger in centimeters where lower number read represents better result. Shoulder flexibility test is a part of ACDSi testing protocols and has shown satisfactory validity and reliability in Slovenian children and adolescents.[41]

2.6 | Statistical analyses

Statistical Package for the Social Sciences-SPSS v 28.0 for Windows (IBM) was used for data processing and analysis. Boys and girls were analyzed separately. We restricted our analysis to participants with complete data for the variables of interest. However, it is important to note that there were instances of missing data for specific variables across the study years, ranging from 10.2% to 14.1%. To maintain the integrity and accuracy of our results, we excluded these missing data points from the analysis. Values that fell outside the interval of ±3 SDs by sex and each age group were marked as outliers and were excluded from further analysis. Data were tested for normality using Shapiro–Wilk analysis for each age group ($n=3$) and for both sexes separately. Analysis of covariance (ANCOVA) was used to compare differences in skill-related fitness between decades in each age and sex group. To eliminate the effect of body size and age, height, weight, BMI, and exact age of participants were used as covariates, with the decade being the fixed factor. The Tukey's post-hoc test was used multiple times for comparisons in both types of analyses. Statistical significance was determined using an alpha level of 0.05. Results in the figures are presented as raw means, while results in the tables are presented as raw values (Table A1) and percentages (relative differences; Table A2).

3 | RESULTS

In this section, we present secular trends in particular skill-related fitness tests over the three decades stratified by age group and sex. Graphs present the raw values, while Table A1 presents the raw values for height and weight of included children and adolescents.

Figure 2 displays the secular changes in the time taken to complete a 60-m dash. Overall, there was an improvement in speed from 1983 to 1993, followed by a decline in the next two generations, and a subsequent improvement from 2003 to 2013 for children aged 6–14 years. However, for the oldest children aged 15–19 years, there was a decline in speed from 2004 to 2014 ($p<0.05$). The largest relative decline in speed was observed in children aged 6–10 years from 1993 to 2003, in boys aged 6–14 years (−9.5%; $p<0.05$) and youngest girls (−9.1%; $p<0.05$) from 1993 to 2003. The greatest relative and significant improvement was observed in the youngest boys (10.6%; $p<0.05$) and girls (10.6%; $p<0.05$) between 2003 and 2013, respectively.

Figure 3 displays the changes over the three decades in coordination tests. The coordination performance improved in all age groups and both sexes, except for

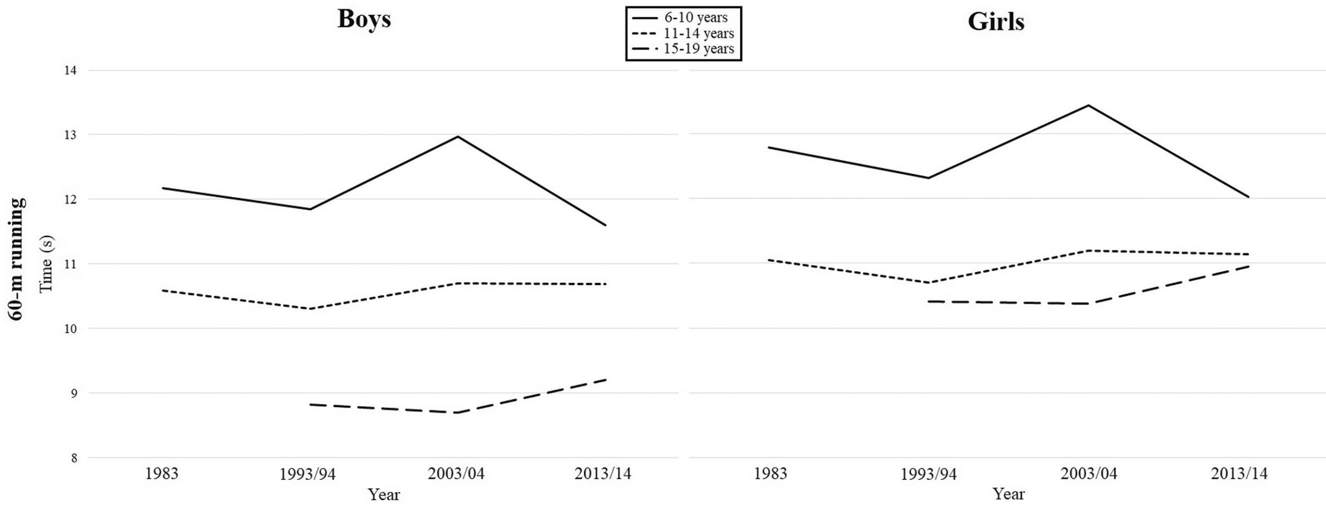

FIGURE 2 Secular changes in the 60-m dash among Slovenian children and adolescents from 1983 to 2014.

11–14-year-old boys, during the last period (2013/14; $p<0.05$).

The hand drumming test showed a significant positive trend in all age groups and both sexes, with the greatest relative improvement among all skill-related tests, especially from 1983 to 2013 (38.2% in boys and 29.7% in girls; $p<0.05$). In contrast, the trends for hand tapping were more complex, with a decline in performance for the middle age group (11–14 years) between 1983 and 1993 ($p<0.05$). The polygon backward test, which measures gross motor coordination, showed positive trends in scores for most age and gender groups between 1983 and 2013/14, except for the youngest boys (6–10 years) and the youngest girls from 1993 to 2003 ($p<0.05$). The biggest relative decline in polygon backward was observed in children aged 11–14 years from 1983 to 1993, while the greatest relative improvement was observed in children aged 11–14 years between 1983 and 1993 in boys (15.5%) and between 1983 and 2013 in girls (21.8%). Both tests indicating fine motor coordination had similar trends, with the hand drumming test showing a larger improvement across decades. Interestingly, younger age groups of girls (age 6–10 and 11–14 years old) performed significantly better than boys at the same age in the hand drumming test at all time points ($p<0.05$). Overall, there was no deterioration in performance in the hand drumming test over the past 30 years. In Figure 3, the changes in gross motor coordination measured by the polygon backward test over time are presented. Positive trends were observed in 1993 and 2013 compared with the preceding decade ($p<0.05$). Overall, we found a positive trend in the scores of these tests for most age and gender groups between 1983 and 2013/14, with some exceptions. Specifically, the youngest boys (6–10 years) showed a decline in their scores in 2003 compared to 1983, and the youngest girls showed a decline from 1993 to 2003 ($p<0.05$). The largest relative decline in polygon backward was observed in children aged 11–14 years from 1983 to 1993, for both youngest boys (−20.3%) and youngest girls (−12.9%). On the contrary, the greatest relative improvement was observed in children aged 11–14 years, with boys improving by 15.5% between 1983 and 1993 and girls improving by 21.8% between 1983 and 2013.

Figure 4 illustrates the secular changes in balance. Balance improved significantly in 2013 for primary schoolchildren (6–14 years old; $p<0.05$) and in 2003/04 for teenagers (11–19 years old; $p<0.05$). However, it worsened in 2014 for secondary school children (15–19 years old; $p<0.05$) and in 2003 for the youngest children (6–10 years old; $p<0.05$). No significant changes were observed in balance between 1983 and 1993 ($p>0.05$). There was a positive trend in balance for both sexes in the youngest children (6–10 years) and a negative trend in the oldest children (15–19 years) after 1993/94. The largest relative decline in Flamingo test scores was observed from 2003 to 2013 in children aged 6–10 years, in both boys (−3.1%, $p<0.05$) and girls (−3.9%; $p<0.05$). The greatest relative and significant improvement was observed from 2004 to 2014 in the oldest boys (44.0%) and the oldest girls (26.8%).

Figure 5 displays the secular changes in shoulder flexibility and sit-and-reach tests for different age groups. The most favorable results were found in both tests in the last decade ($p<0.05$) for both sexes. In the sit-and-reach test, the largest decrease was observed in the youngest and middle-aged children (6–14 years old), while in the older children (15–19 years old), the trend turned positive between 2003/04 ($p<0.05$) and 2013/14 ($p<0.05$). Shoulder flexibility worsened for all age groups through all three decades, except for the youngest children (6–10 years) in 2003–2013 ($p<0.05$). In elementary school children

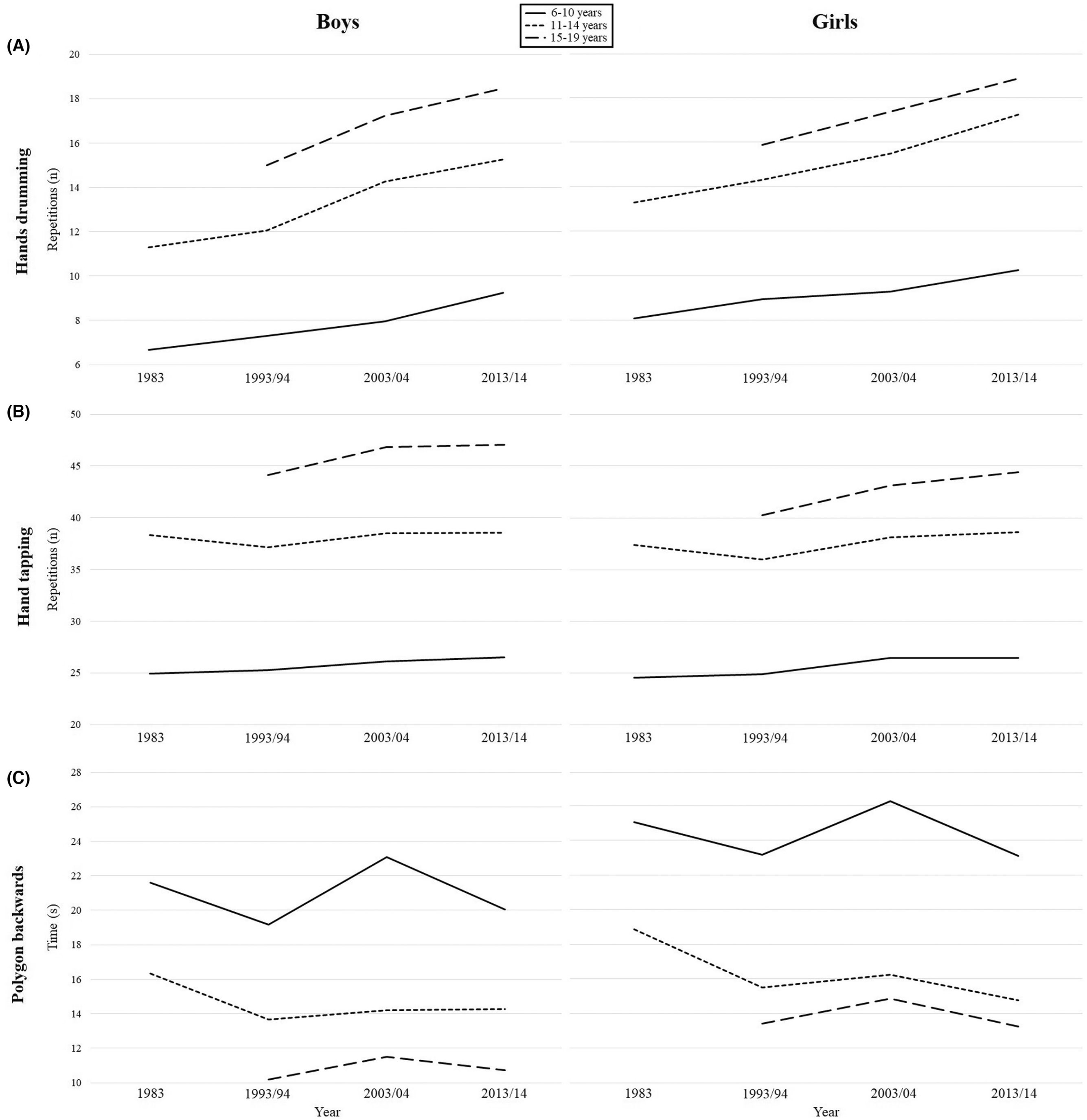

FIGURE 3 Secular changes in the coordination among Slovenian children and adolescents from 1983 to 2014: (A) Hands drumming (fine coordination), (B) hand tapping (fine coordination), and (C) polygon backward (gross coordination).

(6–14 years), a positive trend was observed between all decades for shoulder flexibility. A significant relative negative trend in shoulder flexibility was observed from 2003/04 to 2013/14 in the oldest boys (15–19 years −2.1%) and the youngest girls (−1.1%), while the largest relative increase from 1983 to 2013 was in 11- to 14-year-old children (boys 27.3% and girls 26.6%). Figure 6 compares the relative changes in individual fitness components over time. The largest relative improvement was observed from 1983 to 1993 in polygon backward among children aged 11–14 years (boys 15.5%, girls 17.0%; $p<0.05$) and shoulder flexibility test (boys 16.0%, girls 19.2%; $p<0.05$). In this period, a relative decrease was observed only in the hand tapping for 11- to 14-year-olds (boys −3.1%, girls −3.9%; $p<0.05$). From 1993/94 to 2003/04, the largest relative increase was observed in hand drumming for boys aged 11–14 years (18.3%; $p<0.05$) and 15–19 years (14.8%). In this period, the largest relative decrease was

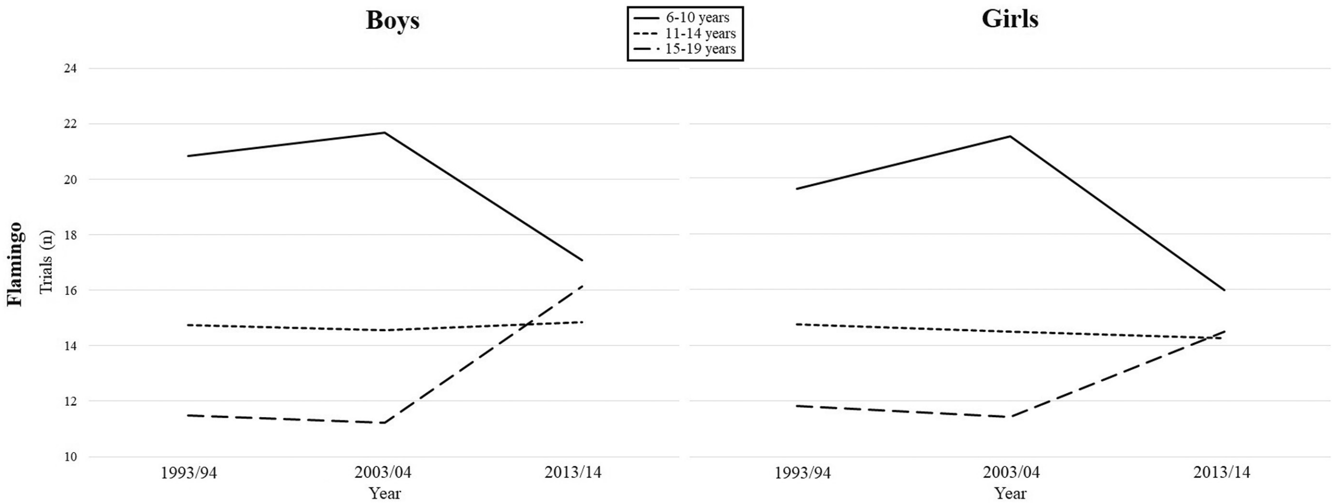

FIGURE 4 Secular changes in balance among Slovenian children and adolescents from 1993 to 2014: Flamingo test.

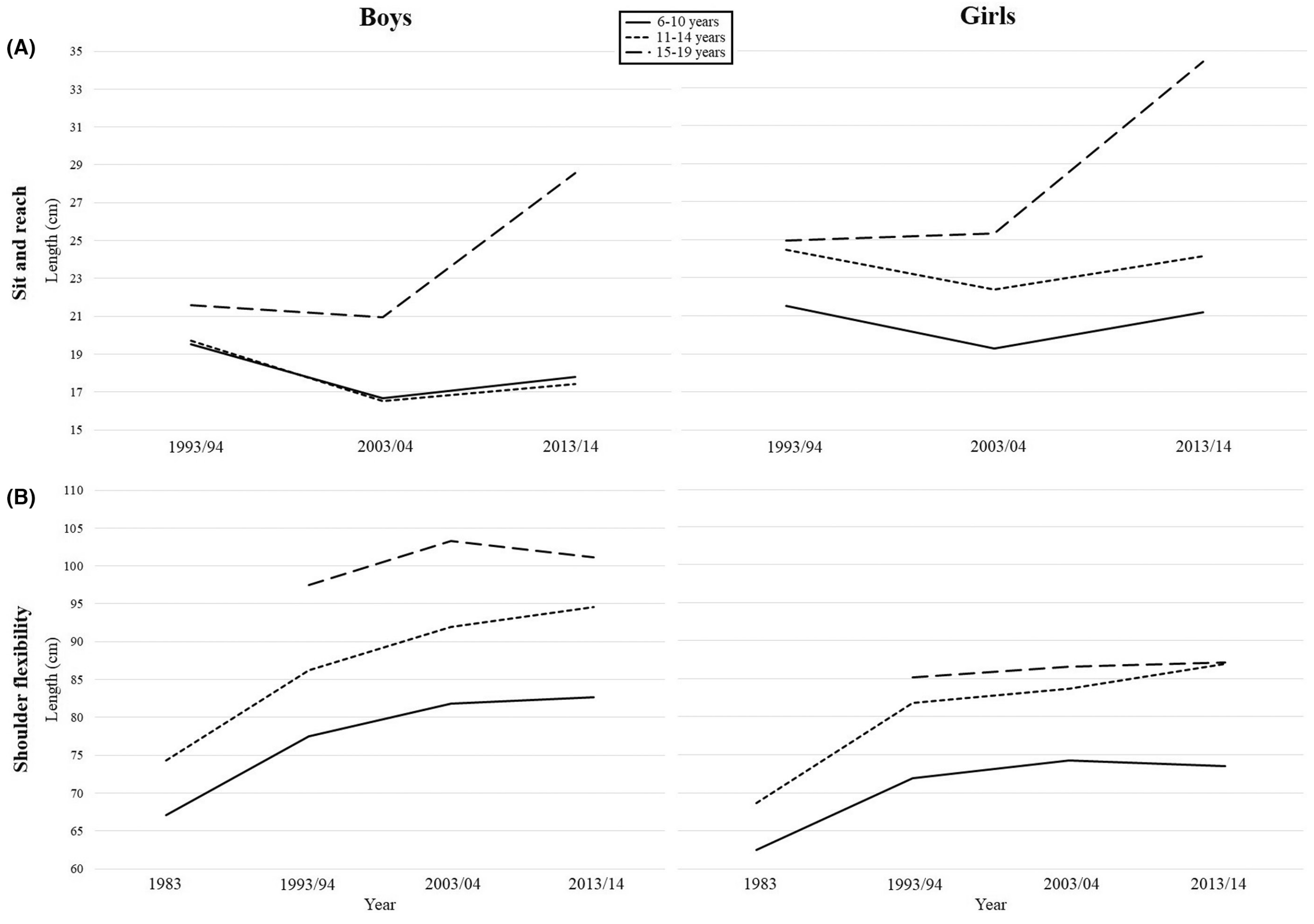

FIGURE 5 Secular changes in flexibility among Slovenian children and adolescents from 1983 to 2014: (A) sit-and-reach and (B) shoulder flexibility test. Higher result (in cm) in shoulder flexibility test presents worse result.

observed in the sit-and-reach test. From 2004 to 2014, the largest improvement was observed in the sit-and-reach test in children aged 15–19 years (boys: 36.4%; girls: 35.7%; $p < 0.05$), whereas the largest deterioration in the same decade was observed for the Flamingo test in 15- to 19-year-old boys (26.8%).

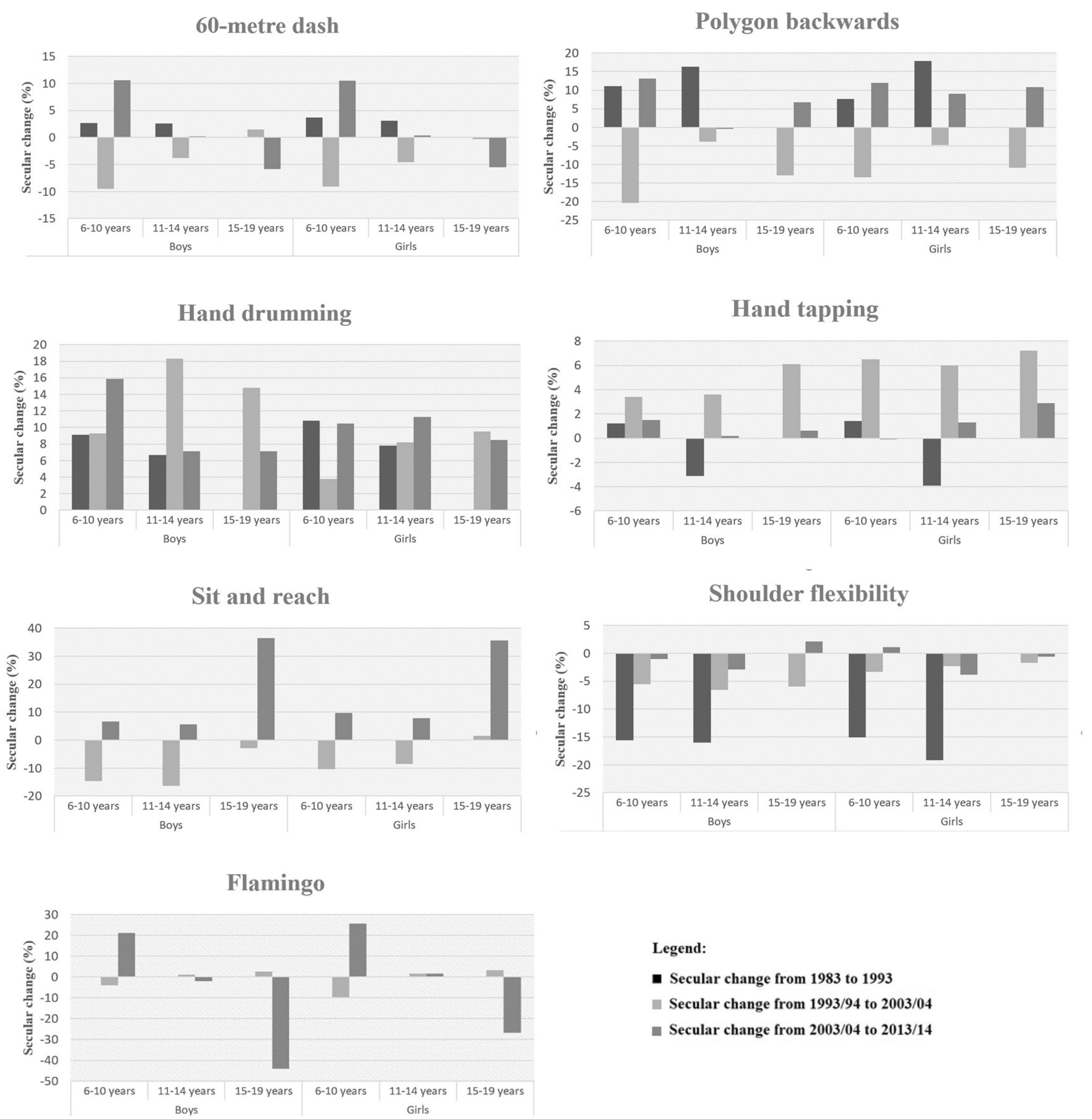

FIGURE 6 Secular changes (%) among Slovenian children and adolescents from 1983 to 2014 for 60-m dash, polygon backward, hand drumming, hand tapping, sit-and-reach, shoulder flexibility test, and Flamingo. Secular changes are presented in % change in 10 years.

4 | DISCUSSION

The aim of the present study was to analyze secular trends in skill-related physical fitness among Slovenian children and adolescents between 1983 and 2014. The main findings are as follows: (a) The individual components of skill-related fitness had different trends during the observed period. Overall, large but inconsistent changes in coordination, a small improvement in speed, and a decline in flexibility were noticed; (b) the trends over the whole examined period (i.e., 1983–2013/14) were not linear throughout decades. Generally, positive trends were noticed in periods 1983–1993 (except flexibility) and 2003/04–2013/14 (except age group 15–19 years) while in the period 1993/94–2003/04 there were some particularities in secular trends according to individual components as well as age groups; (c) the secular trend generally had the same direction for both sexes, except for gross motor coordination; (d) the shape of the secular trend curve for all tests in both sexes and for all generations has changed the most in the middle age group (11–14 years).

Secular changes indicate diverging trends in individual skill-related fitness components during period 1983–2014. Defining general trend in coordination, we can notice that fine motor coordination has improved over all decades, while gross motor coordination increased in the period 1983–1993 and then decreased in boys in the period 1993/94–2013/14. Increase in fine coordinative skills over decades in all age groups for both sexes is consistent with the results of other studies.[7,18,21] The greatest improvement in secular trends among all observed tests was seen in the hand drumming test, where all age groups of both sexes showed improvement in performance over time. We assume this happened likely due to more hand-oriented daily activities in the last decades (e.g., playing video games and using smartphone), which stimulate fine arm coordination.[42] In contrast, there was an overall negative trend for polygon backward among boys over the past 20 years and a positive trend for this test in girls. This sex difference could be attributed to lifestyle changes that effected negatively gross coordination of Slovenian boys, but not girls. According to Clements,[43] in 1990s boys spent more time outdoors, performing different strength and coordination-based physical activities (e.g., playing games outdoors and climbing on the threes). Moreover, during the same period (1993/94–2003/04), an extremely negative trend in strength of upper body has been previously recorded.[38] Since in polygon backward the subject has to combine strength, power and agility when regulating movement, such a negative trend could be expected. Moreover, boys tend to perform this test by relying more on their hand than girls; therefore, a decrease in upper body strength would have affected their performance more. At the same time, girls were exposed to more positive impulses for the development of coordination. Namely, physical education curricula adopted in 1998,[36] and implemented in the next decade, were designed to better tailor physical education classes to the needs and interests of girls. This was possible due to the fact that in Slovenia in grades 6–9 physical education classes are performed in groups of up to 20 children of the same gender.[36] Paralleled, many out-of-school sports programs for girls emerged in 2000s (especially dance, guided group aerobics).

Secular trend in speed was nonlinear and cubic-shaped and showed improvement in the period 1983–1993 and then deterioration in the next two decades, Our findings are not fully in line with the results of a large meta-analysis, which was based on 164 studies and reported the first improvement of speed performance in 1980, the negative inflection from 1990 to 2002, and a second improvement after 2002.[44] We noticed a similar trend for 6–10 years age group, but in 15–19 years age group a deterioration was noted. Other authors speculated that recent positive trends are a result of higher participation in organized sports programs, which focus more on games and exercises suitable for young children, and are more likely to improve speed and coordination instead of aerobic fitness.[45] However, this may be the case elsewhere, where less time is available for physical education, while in Slovenia, schools have the greatest influence on children physical activity and physical fitness.[22] The implementation of new curricula in Slovenian schools in 2000 could potentially explain the divergent trends in speed performance observed between the youngest age group (6–10 years) and the oldest age group (15–19 years). Initiated in 2000, the introduction of revised curricula in primary schools specifically focused on nine-year-olds. These curriculum updates placed significant importance on athletic content and integrating fundamental movement skills. Nevertheless, it was not until 2007 that these changes were fully integrated into the education system. The decline in performance among 15–19 year-olds can be attributed, in part, to a reduction in the number of physical education lessons per week. Specifically, in 2005, the first 2 years of technical and vocational upper secondary programs saw a reduction from 3 h to only 2 h of physical education per week. Additionally, some schools, including those offering physical education, chose to allocate hours and incorporate them into an open curriculum structure. This approach allowed each school to tailor their curriculum to their specific needs. While sports programs remained an option, schools opted to utilize these hours for subjects that focused on developing future occupational competencies and preparing students for vocational high school diplomas. However, an attempt to introduce a similar approach in gymnasiums faced strong opposition from physical education teachers; therefore, it was not implemented. The largest negative secular trend was observed for flexibility, which is consistent with previous studies in similar age groups.[7,17,18,24] Shoulder flexibility decreased linearly, while hip flexibility decreased until 2003/04 and then improved over the last decade. Since we controlled for between-year differences in BMI, the aforementioned decline in flexibility cannot be explained by a relationship between increased BMI and a negative trend in flexibility, as has been explained elsewhere.[18] Saranga and colleagues[46] have attributed the deterioration in flexibility to a decline in physical activity and unstructured play.[46] Indeed, there is a consensus that flexibility gradually declines in children and adolescents,[7] mostly measured with a similar methodological testing procedure and using the sit-and-reach test as an indicator of flexibility. Secular trends for tests measuring different types of flexibility have been very similar over the years, with the exception of the last decade.[7] We hypothesize that the improvements in flexibility over the last decade in all age groups are indicative of decreased muscle tone as a result of a decrease in strength over this period.[38]

In our study, balance increased in the 1993/94–2003/04 period, except for the youngest group of both sexes, and then decreased in the next decade. If we compare the generations 20 years apart, we can see that the younger age groups of both sexes have better balance skills, while the 15–19 age group of both sexes have significantly worse balance skills. The largest change in the trend direction of balance was observed in 2003, as the largest decline occurred a decade earlier and the largest improvement occurred a decade later. In contrast to our results, Venckunas and colleagues[18] found better relative balance performance of Lithuanian children on identical tests in the same decades. There are several factors that explain such discrepancies between findings due to trends that differ from population to population such as geographical and socioeconomic characteristics and the wider age range of the children in our study—from 6 to 19 years in our study and from 11 to 18 years in the study reported by Venckunas—may partially explain a secular decline that was only found in our study.[18]

In general, boys performed better in speed and gross motor coordination, whereas girls performed better in flexibility, balance, and fine motor coordination. However, secular trend generally has the same direction for both sexes. The exception is the trend in gross motor coordination, which was discussed before. The shape of the secular trend curve has changed the most in the middle age group (11–14 years) for most tests in all generations. In particular, the change in trend direction around the age of 11 years was noticed. In Slovenia, in this age children transit from primary to lower secondary level according to international standard classification of education (ISCED).[36] It is typical for primary level (6–10 years) that physical education is taught by generalist teachers while on lower secondary level (11–14 years) by physical education specialists. The latter have better competencies for teaching physical education due to more specialization during initial teaching education. In addition, class size in physical education in Slovenia is smaller at the lower secondary level (up to 20 children per class) compared with the primary level (up to 28 children per class). These two characteristics affect physical education learning outcomes and could also have influence on the observed fitness trends.[47]

4.1 | Strengths and limitations

The greatest strength of our study is ecological validity of our analysis. Namely, we included representative samples of children examined at four points over three decades using the same methodology, always from the same environments (schools). In addition, the components of body size (height, weight, and BMI) were considered in the analysis of skill-related fitness trends, since verified increase of BMI among youth in the last decades is an often proposed reason for a simultaneous decline in physical fitness.[48,49] Furthermore, the present study is the only one that covers a wider age range (6–19 years) and allows comparison of trends between age groups. Moreover, for some fitness components we analyzed different aspects, like fine and gross coordination and shoulder and hip flexibility, which allowed us to see that the secular changes in skill-related fitness were not equal across all dimensions of these fitness components. On the contrary, several limitations of the current study should be noted. First, we lacked data on the maturity level of the children, which could influence trends in fitness.[50] Second, we used only one data point per decade. If we had more frequent data points (e.g., one per 5 years, or one per year), this would enable a more detailed description of fitness trends. Third, data for the sit-and-reach and Flamingo were not available in the year 1983 and thus slightly less completed trends on this part of flexibility and balance were available. Fourth, the last data collection in this study happened well before COVID-19 pandemic; therefore, contemporary trend is most likely much worse, as frequently shown by recent post-COVID fitness data.[34] Fifth, the nested or clustered data structure may lead to biased results when using ANCOVA.[51] Sixth, we did not track the response/consent rate for all included years, which may have influenced the overall analysis and interpretation of our findings.

5 | PERSPECTIVE

The individual components of skill-related fitness showed different trends during the observed period. The biggest improvement occurred in fine motor coordination. Additionally, we noticed positive secular trends in skill-related fitness during the last period. Education, public health, and sport sector efforts should focus on providing more skill-related exercising with an emphasis on speed and gross motor coordination skills in both sexes, especially in the group of 15–19 years old adolescents. Moreover, regular and standardized monitoring of physical fitness is critical to develop personalized interventions for 24-h movement behavior changes and improvement of skill-related fitness, notably due to the negative consequences of COVID-19 closure of society on children and adolescents' fitness.[34] This is enabled in Slovenia through SLOfit Student program supported by My SLOfit web-based application.[23] The next measurement cycle of

ACDSi in 2023 and 2024 will provide further information about secular fitness trends.

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CONFLICT OF INTEREST STATEMENT

There is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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APPENDIX A

TABLE A1 Specific sample sizes and body height and mass of children and adolescents included in the study.

Year			1983		1993/1994		2003/2004		2013/2014	
Age	Variable	Sex	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
6	Height (cm)	Boys	31	120.7 ± 4.5	82	122.1 ± 5.0	238	119.9 ± 5.4	229	121.6 ± 5.4
		Girls	27	121.9 ± 8.5	95	123.5 ± 5.8	212	119.5 ± 5.4	248	121.5 ± 5.6
	Weight (kg)	Boys	31	22.4 ± 2.3	82	23.9 ± 3.5	238	23.7 ± 4.2	229	24.6 ± 5.4
		Girls	27	23.5 ± 4.4	95	24.1 ± 4.4	212	23.8 ± 4.7	248	24.0 ± 4.9
7	Height (cm)	Boys	179	123.5 ± 5.8	183	127.7 ± 5.4	248	126.2 ± 5.8	217	128.2 ± 5.6
		Girls	214	124.3 ± 5.3	229	126.9 ± 5.7	241	126.1 ± 5.6	221	127.5 ± 5.6
	Weight (kg)	Boys	179	23.8 ± 3.4	183	26.7 ± 4.8	248	27.0 ± 5.5	217	27.2 ± 4.7
		Girls	214	24.2 ± 3.9	229	26.1 ± 5.4	241	27.2 ± 6.0	221	27.2 ± 6.1
8	Height (cm)	Boys	197	130.0 ± 5.5	220	132.6 ± 6.0	235	132.0 ± 5.6	206	133.6 ± 5.3
		Girls	211	129.7 ± 5.6	212	132.8 ± 6.4	232	131.3 ± 6.0	207	133.1 ± 6.3
	Weight (kg)	Boys	197	27.4 ± 5.0	220	29.8 ± 5.8	235	31.2 ± 6.6	206	31.4 ± 6.3
		Girls	211	26.7 ± 5.0	212	29.8 ± 6.4	232	30.0 ± 6.2	207	31.3 ± 6.4
9	Height (cm)	Boys	183	136.2 ± 5.6	224	138.5 ± 5.6	229	137.8 ± 6.1	171	139.1 ± 7.0
		Girls	181	135.2 ± 5.8	240	138.0 ± 6.4	247	137.9 ± 6.1	197	139.7 ± 5.9
	Weight (kg)	Boys	183	30.6 ± 4.9	224	33.7 ± 6.9	229	34.3 ± 7.1	171	35.2 ± 7.8
		Girls	181	30.2 ± 5.4	240	32.3 ± 6.8	247	34.8 ± 7.8	197	35.0 ± 7.8
10	Height (cm)	Boys	208	140.9 ± 7.4	215	143.6 ± 6.8	235	142.2 ± 7.2	177	145.1 ± 6.8
		Girls	201	140.6 ± 6.8	201	144.1 ± 7.2	225	143.1 ± 7.1	160	145.5 ± 7.0
	Weight (kg)	Boys	208	33.2 ± 6.3	215	37.1 ± 7.6	235	37.3 ± 8.9	177	40.3 ± 9.0
		Girls	201	33.6 ± 6.9	201	37.0 ± 7.6	225	37.7 ± 8.0	160	40.7 ± 9.5
11	Height (cm)	Boys	176	146.5 ± 6.5	192	148.4 ± 6.2	226	148.4 ± 6.7	196	150.5 ± 7.3
		Girls	184	147.5 ± 6.6	212	150.7 ± 7.1	221	150.5 ± 7.2	202	152.5 ± 6.9
	Weight (kg)	Boys	176	37.5 ± 8.2	192	40.8 ± 9.3	226	41.4 ± 8.3	196	44.5 ± 10.8
		Girls	184	38.5 ± 8.1	212	42.3 ± 9.6	221	43.8 ± 9.4	202	45.9 ± 10.9
12	Height (cm)	Boys	203	152.5 ± 8.3	220	155.0 ± 7.6	256	154.6 ± 8.6	168	156.7 ± 7.8
		Girls	194	153.4 ± 6.5	204	156.6 ± 6.9	223	156.0 ± 7.3	132	158.4 ± 6.3
	Weight (kg)	Boys	203	42.9 ± 9.0	220	45.5 ± 10.1	256	46.7 ± 11.1	168	49.9 ± 12.8
		Girls	194	43.8 ± 9.1	204	46.7 ± 9.3	223	48.3 ± 10.4	132	51.6 ± 11.6
13	Height (cm)	Boys	205	158.2 ± 9.2	200	162.6 ± 9.9	231	161.8 ± 8.3	177	164.3 ± 8.3
		Girls	181	157.7 ± 6.1	241	160.6 ± 7.0	191	160.3 ± 6.3	164	161.7 ± 5.9
	Weight (kg)	Boys	205	48.0 ± 10.4	200	52.5 ± 12.1	231	53.1 ± 10.5	177	56.7 ± 12.8
		Girls	181	48.2 ± 10.0	241	51.5 ± 9.5	191	53.9 ± 9.6	164	53.4 ± 8.7
14	Height (cm)	Boys	181	164.9 ± 8.0	175	168.2 ± 8.4	200	169.5 ± 7.8	209	169.6 ± 7.6
		Girls	175	161.4 ± 5.5	165	163.7 ± 6.5	179	162.3 ± 5.7	181	163.9 ± 5.9
	Weight (kg)	Boys	181	53.2 ± 8.6	175	58.1 ± 11.8	200	60.5 ± 11.6	209	61.5 ± 12.0
		Girls	175	52.5 ± 7.8	165	55.4 ± 8.4	179	54.7 ± 8.3	181	57.2 ± 10.0
15	Height (cm)	Boys			150	173.3 ± 7.5	200	174.4 ± 7.2	184	175.9 ± 7.0
		Girls			169	162.7 ± 5.3	160	165.1 ± 6.2	193	165.4 ± 6.7
	Weight (kg)	Boys			150	61.5 ± 9.8	200	65.2 ± 11.1	184	67.3 ± 10.9
		Girls			169	54.9 ± 7.6	160	56.9 ± 8.2	193	59.6 ± 11.3

TABLE A1 (Continued)

Year			1983		1993/1994		2003/2004		2013/2014	
Age	Variable	Sex	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
16	Height (cm)	Boys			192	176.7 ± 6.3	242	177.0 ± 6.9	157	178.3 ± 6.4
		Girls			203	164.0 ± 5.9	157	165.0 ± 6.1	174	164.6 ± 6.6
	Weight (kg)	Boys			192	67.1 ± 9.4	242	68.7 ± 10.7	157	71.9 ± 11.6
		Girls			203	57.2 ± 7.6	157	57.7 ± 7.4	174	60.0 ± 11.2
17	Height (cm)	Boys			203	177.2 ± 6.8	202	178.7 ± 6.2	165	178.8 ± 6.1
		Girls			216	165.3 ± 5.8	164	164.9 ± 5.8	168	165.8 ± 6.4
	Weight (kg)	Boys			203	67.5 ± 8.5	202	72.2 ± 10.9	165	75.4 ± 13.5
		Girls			216	58.4 ± 7.8	164	59.2 ± 8.5	168	59.9 ± 9.3
18	Height (cm)	Boys			110	177.7 ± 6.3	173	178.5 ± 6.3	130	179.0 ± 6.1
		Girls			123	165.0 ± 6.0	134	165.5 ± 6.4	112	165.7 ± 5.8
	Weight (kg)	Boys			110	70.4 ± 9.7	173	75.3 ± 13.2	130	73.6 ± 11.0
		Girls			123	58.2 ± 8.0	134	59.8 ± 9.6	112	60.6 ± 11.0
19	Height (cm)	Boys			8	178.6 ± 6.1	56	177.4 ± 6.5	34	178.8 ± 8.6
		Girls			12	164.4 ± 5.5	40	165.8 ± 5.8	22	164.0 ± 4.9
	Weight (kg)	Boys			8	77.0 ± 6.5	56	74.3 ± 11.5	34	76.7 ± 13.6
		Girls			12	57.9 ± 4.7	40	59.5 ± 9.0	22	62.5 ± 12.0

TABLE A2 Relative secular changes in all included motor tests, separated by sex and age groups.

				Secular changes					
				1983–1993/94	1983–2003/04	1983–2013/14	1993/94–2003/04	1993/94–2013/14	2003/04–2013/14
FC	**Test**	**Sex**	**Age group**	**10 years**	**20 years**	**30 years**	**10 years**	**20 years**	**10 years**
Speed	60-m dash	Boys	6–10 years	2.7%**	−6.5%**	4.8%**	−9.5%**	2.10%	10.6%**
			11–14 years	2.6%**	−1.0%	−0.9%	−3.8%**	−3.6%**	0.2%
			15–19 years				1.5%	−4.2%**	−5.8%**
		Girls	6–10 years	3.7%**	−5.1%**	6.0%**	−9.1%**	2.4%	10.5%**
			11–14 years	3.1%**	−1.3%	−0.9%	−4.6%	−4.1%**	0.4%
			15–19 years				−0.3%	−5.2%**	−5.5%**
Coordination	Polygon backward	Boys	6–10 years	11.1%**	−6.9%**	7.1%**	−20.3%**	−4.5%**	13.1%**
			11–14 years	16.3%**	13.1%**	12.7%**	−3.9%	−4.3%	−0.4%
			15–19 years				−12.9%**	−5.3%	6.7%
		Girls	6–10 years	7.6%**	−4.8%**	7.8%**	−13.4%**	0.3%	12.0%**
			11–14 years	17.9%**	14.0%**	21.8%**	−4.7%	4.8%	9.1%**
			15–19 years				−10.9%**	1.3%	10.9%**
	Hand drumming	Boys	6–10 years	9.1%*	19.2%**	38.2%**	9.3%**	26.7%**	15.9%**
			11–14 years	6.7%**	26.3%**	35.2%**	18.3%**	26.7%**	7.1%**
			15–19 years				14.8%**	23.0%**	7.1%**
		Girls	6–10 years	10.8%**	14.9%**	26.9%**	3.8%	14.6%**	10.5%**
			11–14 years	7.8%**	16.6%**	29.7%**	8.2%**	20.3%**	11.3%**
			15–19 years				9.5%**	18.8%**	8.5%**
	Hand tapping	Boys	6–10 years	1.2%	4.6%**	6.2%**	3.4%*	5.0%**	1.5%
			11–14 years	−3.1%**	0.3%	0.5%	3.6%**	3.7%**	0.2%
			15–19 years				6.1%**	6.7%**	0.6%
		Girls	6–10 years	1.4%	8.0%**	7.9%**	6.5%**	6.4%**	−0.1%
			11–14 years	−3.9%**	1.9%	3.2%*	6.0%**	7.4%**	1.3%
			15–19 years				7.2%**	10.3%**	2.9%**
Balance	Flamingo	Boys	6–10 years				−4.0%	−18.1%**	21.3%**
			11–14 years				1.3%	−0.6%	−1.9%
			15–19 years				2.5%	−40.4%**	−44.0%**
		Girls	6–10 years				−9.6%**	−18.5%**	25.7%**
			11–14 years				1.7%	3.2%	1.6%
			15–19 years				3.2%	−22.7%**	−26.8%**

TABLE A2 (Continued)

FC	Test	Sex	Age group	Secular changes 1983–1993/94 10 years	1983–2003/04 20 years	1983–2013/14 30 years	1993/94–2003/04 10 years	1993/94–2013/14 20 years	2003/04–2013/14 10 years
Flexibility	Sit-and-reach	Boys	6–10 years				−14.6%**	−8.9%**	6.7%**
			11–14 years				−16.3%**	−11.6%**	5.6%*
			15–19 years				−2.9%	32.5%**	36.4%**
		Girls	6–10 years				−10.4%**	−1.6%	9.8%**
			11–14 years				−8.5%**	−1.5%	7.8%**
			15–19 years				1.6%	37.8%**	35.7%**
	Shoulder flexibility test	Boys	6–10 years	−15.6%**	−22.0%**	−23.2%**	−5.5%**	−6.6%**	−1.0%
			11–14 years	−16.0%**	−23.7%**	−27.3%**	−6.6%**	−9.7%**	−2.9%
			15–19 years				−6.0%**	−3.8%*	2.1%*
		Girls	6–10 years	−15.1%**	−18.9%**	−17.6%**	−3.3%*	−2.2%	1.1%
			11–14 years	−19.2%**	−21.9%**	−26.6%**	−2.30%	−6.2%**	−3.8%**
			15–19 years				−1.7%	−2.3%	−0.6%

Note: FC, fitness component; sign + (no sign in table) denotes improvement and sign—describes deterioration. For 60-m dash, polygon backward, Flamingo and shoulder flexibility test the omen has been changed since higher score represents a worse result and vice versa.

*$p < 0.05$; **$p < 0.01$.