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Fitness trend analysis in male Austrian middle and high school students from 1975 to 2010

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Abstract: Considerable changes in the social and built environment contributed to alterations in physical activity, which potentially affect physical fitness. Long-term data on various components of physical fitness with multiple assessments in similar cohorts, however, remains limited. The present study, therefore, examined secular trends in physical fitness between 1975 and 2010 in adolescents living in a rural region in Tyrol, Austria. Data consisted of records from a physical education (PE) teacher that included a total of 2,998 cases of male adolescents between 11 and 18 years of age. Fitness assessments included sprint, long jump and an endurance run that were performed annually in 3 to 5 grades during regular PE classes. The results indicated three distinct eras during the observation period. There was an improvement in physical fitness until the mid to late 1980s with a subsequent decline until the mid-1990s and a final period of relatively consistent low physical fitness. Further, it was shown that aerobic fitness started to decline earlier and that the decline was more pronounced than the performance on anaerobic fitness tests. This is of particular concern due to the importance of aerobic fitness for general health and wellbeing. Accordingly, these results along with previous studies highlight the need to promote physical activities that contribute to an improvement of physical fitness in children and adolescents.

Introduction

Motor competence and physical fitness among children and adolescents are considered key health indicators (Barnett et al., 2016; Cattuzzo et al., 2016). Along with the association of physical fitness with physical activity (PA) and sports participation, which reduces chronic disease risk, there is evidence on an impact on social, psychological and cognitive development (Holfelder & Schott, 2014; Ortega et al., 2008). Physical fitness also tracks into adulthood, and, therefore, provides reasonable insight into future health (Ruiz et al., 2009). Given these benefits it is concerning that current data indicates low levels of motor competence in children and adolescents (Hardy et al., 2012; O'Brien et al., 2015; Sheehan & Lienhard, 2018), which may be attributed to changes in the social and built environment over the last several decades. There is also considerable evidence on changes in physical fitness and motor competence in European children and adolescents. Key studies along with their most important findings are summarized in Table 1. In most studies data collection, however, occurred at only two time points, which provides only limited insights into short-term changes (e.g. Mekota & Zahradnik, 2003; Müller et al., 2008; Peters, 1963) with only a few studies reporting multiple measurement times over a longer timespan (e.g. Crasselt, 1990; Greier et al., 2019; Raczek, 2002). Table 1 lists examination years separately, if they were available.

Table 1

Selected studies on national secular trends in physical fitness in male youth.

Author	Country	Years	Age (yrs)	Change
Peters, 1963	GER	1922, 1958	10–16	Jump, throw ↑ 10–20%
Crasselt, 1990	GDR	1958, 67, 71, 75, 85	6–16	Jump, sprint, endurance ↑ From 1985 →
Crasselt et al., 1998	GDR	1986, 81, 86, 91	6–16	Jump, sprint, endurance ↑ From 1985 →
Mekota, 1992	CZE	1965, 1986	7–17	Standing long jump, sprint, endurance ↑
Kasa, 1994	SVK	1966, 1987	8–18	Sprint, standing long jump, medicine ball push ↑
Dordel, 2000	GER	1970–1990	5–11	Endurance, flexibility ↓ Power, agility →
Bös & Mechling, 2002	GER	1976–1996	10	Strength, endurance ↓ (10–20%)
Raczek, 2002	POL	1965,75, 85, 95	8–18	until 1985 ↑ (5–10%), since 1985 ↓
Rusch, 2002	GER	1986–2001	11–14	until 1995 ↓, after ↑
Mekota & Zahradnik, 2003	CZE	1960/61, 2000/01	19–20	Power →, endurance ↓↓
Westerstahl et al., 2003	SWE	1974–1995	16	Endurance ↓, power →
Wedderkopp et al., 2004	DNK	1985–1997	9	Endurance ↓
Schott, 2005	GER	1976–1999	10	Endurance and power ↓↓, sprint (↓)
Reed et al., 2006	CAN	1981–2004	9–11	Endurance ↓
Hirtz, 2007	GER	1974–2004	7–16	until ca. 1985 ↑, from 1985 ↓
Bös et al., 2008	DEU	1996–2005	6–11	Endurance ↓, sprint (↓); jump →
Photiou et al., 2008	HUN	1975–2005	6–11	Endurance ↓
Müller et al., 2008	AUT	1995–2006	11–14	Strength, agility (↓), endurance →
Wyss et al., 2009	SUI	1982–2005	18	Endurance ↓, from 2002 →
Andersen et al., 2010	DNK	1983–2003	15–18	Strength ↓, VO max. →
Roth et al., 2010	GER	1973–2007	4–6	Power →, agility, throw ↓
Cohen et al., 2011	GBR	1978–2008	10	Strength (↓)
Krombholz, 2011	GER	1973–2001	4–6 6–11	→, Endurance ↓
Saczuk et al., 2012	POL	1986–2006	7–19	Endurance, Power ↓
Dyrstad et al., 2012	NOR	1969–2009	16–18	Endurance ↓
Sedlak et al., 2015	CZE	1977–2012	4–6	Power, throw ↓
Staub et al., 2015	SUI	1980–2012	18–20	Endurance in Swiss military recruits since 2002 →
Tomatis et al., 2013	SUI	2005–2011	6–7	Swiss children > intern. Norm from 1995–2010
Albrecht et al., 2016	GER	2003/06–2009/12	4–17	→, motor abilities ↑

Performance: ↑ improving → constant ↓ declining

In addition, there are several cross-national reviews that provide an overview of physical fitness in children and adolescents (Bös, 2003; Bös et al., 2008). An international meta-analysis of 32 studies from 27 countries across 5 continents also provides global data on physical fitness throughout the second half of the 20th century along with descriptive statistics for the respective 10-year periods (Tomkinson, 2007; Tomkinson & Olds, 2007). Taken together there exists data on physical fitness from the 1950s to the beginning of the 21st century. Despite the fact that the repeated cross-sectional studies summarized in Table 1 have high internal validity, their short and limited measurement intervals cannot detect long-term trends. Large measurement intervals, on the other hand, are limited in the ability to determine the exact time when change in physical fitness occurred, which limits the ability to establish causal associations. Meta-analyses also reveal only global trends that potentially mask a wide variety of diverse local trends.

To the authors knowledge there are currently no time-series studies that cover a prolonged period of time with multiple similar measurements in the same location and with similar cohorts. The present study, therefore, examines changes in key components of physical fitness over a 35-year time span including short- and long-term changes in adolescents.

Materials and methods

Sample and data characteristics

The data for this analysis consists of records of a PE teacher at middle and high school level. The study population is from a predominantly rural district in the Federal State of Tyrol Austria with a total population of roughly 60,000. Data was collected as part of an evaluation for the Tyrolean Child Sports Badge and the Austrian Youth Sporting Badge during his 40-year tenure as PE teacher between the school years 1971/72 and 2010/11. Available data, therefore, is based on the requirements specified by the Austrian fitness badges, which have been widely used. The nature of the fitness assessments included in the analyses also closely resemble the tasks of various commonly used fitness testing batteries (Drenowatz & Greier, 2020), and the authors strongly believe that the data provides objective and reliable information on the the physical performance of secondary school students from the 1970s to the first decade of the 20th century (Baldauf, 2014). As boys and girls in Austrian secondary schools are separated during PE, data, however, was only available for male students. The study was approved by the Institutional Review Board of the Department of Sport Science at the University of Innsbruck.

The fitness test battery included assessments of linear speed (60 m and 100 m sprint), cardiorespiratory endurance (1,000 m run) and muscular power (long jump). Additional tasks included shotput, throwing for distance and swimming (50 m, 100 m, 200 m). Given the technical nature of these tasks, records for shotput, throwing and swimming were not included in the present analyses as the focus was on more general components of fitness (e.g. endurance, speed and power). Cardiorespiratory fitness and strength are also key components of health related fitness (along with flexibility, strength endurance and body composition; American College of Sports Medicine, 2017) and speed is critical for successful participation in various games that are popular in children. These components of fitness, therefore, are important aspects in the promotion of an active lifestyle (Barnett et al., 2009; Stodden et al., 2008). Available data are ordered by school grades and academic years (1971/72 to 2010/11). As middle school in Austria is typically entered at the age of 10 years and data collection occurred in most instances at the end of every school-year it was assumed that the initial middle school grade (grade 5) represents physical fitness for 11-year-old boys, the sixth grade represents performance of 12-year-old males and so on until the age of 18 years. The present analyses use data from grades 5 through 11 that were collected over a period of 35 academic years (1975/76 to 2009/10; Table 2).

Every year, with the exception of 2 years, the PE teacher taught 3 to 5 different grades. As there are multiple classes in each grade, the available sample consisted of total of 135 classes and 2,998 available cases throughout the entire observation period (details of case numbers are shown in Table 2). The number of cases (data points) should not be confused with the number of students assessed over time as most students were measured repeatedly during consecutive years. Unfortunately, it is not possible to determine the exact number of students due to anonymization of the available records. Utilizing an assignment of birth cohorts (e.g., birth year of 1965 was assigned to grade 5 in the school year 1975/76) the minimum number of students measured would be 1,055.

Performance assessments were taken at the same sports facilities across the entire time span. Sprints were performed on a tartan track and the endurance run was performed on grass with time measurements taken by hand to the nearest 0.1 second for sprint and seconds for the 1,000 m run. Long jump performance was determined by the distance from the take-off bar in cm, after the approach to the take-off beam has been practiced sufficiently. As data collection occurred as part of a fitness assessment during regular PE classes no additional data, such as information on socio-economic status or migration background was collected.

Data treatment

In all but 7 classes (assessments only during fall), performance assessments were taken during fall and spring semester. When 2 assessments (fall and spring) were available, the better results were included in the analyses. In most cases performance was better during spring compared to fall (83% vs. 17%). For sprints, the requirements for the sports badge included 60 m or 100 m runs; accordingly, both distances were used as specified for specific grades. In order to establish uniformity across measurement times, linear regression was used to transfer 60 m results into 100 m times. The regression equation was based on 179 cases between grades 7 and 10 of the present study and an additional sample of 120 male students between 15 and 16 years of age who performed both 60 m and 100 m sprints. Data for the regression analysis was collected between the years 1979/80 and 2009/10 and partial correlation analyses indicated that time of data collection did not influence the association between 60 m- and 100 m-sprint performance. The obtained regression equation explained 80.3% of the variance:

By converting running times into average running speed (m/s) for sprints and the 1,000 m run all items showed positive associations between time measured and performance level.

Statistical analysis

The aim of the study was the generation of continuous time series over 35 years for physical fitness in male adolescents by summarizing all three test items into a total fitness score as well as analyzing each test item individually in order to allow for comparisons across specific contributors to physical fitness. As the data was skewed with a longer tail at lower performance scores, non-parametric measures were used for analyses.

Age- and test-specific percentiles were determined in order to summarize the data. Percentiles were based on all eligible cases of the 35 observation years. Time series analyses were based on median scores for each test item and a total fitness score across the separate age groups and observation years (see Table 3). Subsequently, data was smoothed by calculating weighted mean scores (based on sample size) across 5 continuous years (see Figure 1). Data processing and statistics were calculated via SPSS 23.0 and diagrams were created with MS Excel.

Results

Descriptive statistics (sample distribution and median) are shown in a 3 (test item) x 7 (age group) x 35 (year) matrix in Table 2 and Table 3. Percent rank scores are shown in Figure 1.

The y-axis in Figure 1 represents the percentiles across the entire sample, consisting of 8,493 test items. Scores below the 50th percentile represent below average performance, while scores above the 50th percentile represent above averageperformance. The measured values of the 50th percentile are shown in Table 3 in column *Total*. Due to the skewed distribution, equal distances across percentile scores do not represent equal differences in absolute performance.

The scatterplot of the median scores shows a high variability with largest differences observed for the 1,000 m run; in the year 2001 average performance was at the 10th percentile while in the year 1985 average performance ranked at the 93rd percentile. Higher performance percentiles were generally observed during the first half of the observation period (1977 and 1985), while lower percentile scores occurred in the second half of the observation period (1996, 1999 and 2001). Two distinct time spans are further shown by a more pronounced compression between percentiles 40 and 85 in the first half of the observation period as well as the 20th and 65th percentile during the second half of the observation period. This indicates a decline in performance by 20% scores after the 1980s. Due to the obvious lack of linear change across the time span no regression analysis was performed even though this is commonly done with scatterplots or time series analyses.

The change in performance may be even better indicated by the time series of the total fitness score (average across 7 grades and 3 test items, large marker), which highlights 3 distinct phases. During the early observation years, physical fitness was above average and continued to improve until the late 1980s. This phase was followed by constant decline in physical fitness below the 50th percentile until the mid-1990s and a final phase of relatively stable physical fitness at a low level.

Figure 1 further shows that the improvement in sprint and long jump performance was almost identical during the first phase, while the decline was slower in the long jump compared to sprint and endurance in phase 2. Long jump performance, however, continued to decline into phase 3 and, therefore, achieved comparable low levels as those observed for sprint in phase 3. Changes in physical fitness were most pronounced for the 1,000 m run (i.e. aerobic fitness). Aerobic fitness exceeded percentile scores of sprint and jumping in the first phase of the observation period but showed a faster decline during phase 2 and ranks below long jump and sprinting performance at phase 3.

In addition, the evaluation of individual test items reveals that the decline in endurance performance started earlier (1984) than the decline for sprint and long jump (1987/88). There was, however, an accelerated decline in endurance performance starting in 1987/88.

Finally, an assessment of the performance decline was made for periods that were defined by the highest and lowest median score. Change in performance was calculated across test items and by grade relative to the median of the *Total* column in Table 3 (shown in Table 4, relative performance change in percent).

Table 4
Maximum decline (absolute and relative to total median respectively) in sprint, endurance and long jump performance (%)

Age	100 m sprint		1,000 m run		Long jump		Total
Y	m/s	%	m/s	%	m	%	%
11	0,96	16,7	0,83	22,4	0,76	23,8	21,0
12	0,59	9,8	0,59	15,0	0,51	15,1	13,3
13	0,76	12,1	0,72	18,1	0,55	15,3	15,2
14	0,71	10,8	0,72	17,4	0,69	17,8	15,3
15	0,88	12,6	0,92	21,4	0,88	20,8	18,3
16	0,74	10,2	0,81	18,3	0,89	20,1	16,2
17	0,53	7,0	0,91	19,6	0,69	14,7	13,8
Mean		11,3		18,9		18,2	16,1

Best performances at the 1,000 m run were achieved around the year 1984 with an average score at the 73rd percentile (Figure 1). Towards the end of the 1990s average performance fell below the 40th percentile. The maximum relative decline in performance was 18.9% with a variation between 15.0% (grade 6 - 1982: 4.13 m/s, 1997: 3.55 m/s) and 22.4% (grade 5 - 1983: 3.98 m/s, 1991: 3.14 m/s) across individual age groups. The decline in relative long jump performance was similar with 18.2% and a variation between 14.7% (grade 11 - 1979: 5.05 m, 2000: 4.50 m) and 23.8% (grade 5 - 1979: 3.52 m, 2000: 2.76 m) across age groups; percentile ranks ranged from 61 in 1989 to 43 in 1998. The smallest decline occurred in sprint performance with 11.3% and a variation between 7.0% (grade 11 - 1979: 7.75 m/s, 2000: 7.43 m/s) und 16.7% (grade 5 - 1981: 6.24 m/s, 1996: 5.28 m/s) across age groups; percentile ranks for the sprint ranged from 62 in 1988 to 46 in 1993.

Discussion

This study examined change in key components of physical fitness (endurance, speed, power) in 11- to 18-year-old male students in a rural region in Tyrol, Austria from the school year 1975/76 to 2009/10. There was considerable variability in physical fitness across the observation period with annual average performance scores between the 10th and 93rd percentile. Long-term and medium-term changes in physical fitness were examined by smoothing measures of central tendency with weighted means. The results revealed that physical fitness was generally high during the early years of the observation. Peak values for aerobic fitness were observed in 1984 and peak values for anaerobic fitness occurred in 1988. Following a steady improvement until these peak values a steady decline was observed, which ended with below-average scores after the years 1993, 1995 and 1998 for sprint, endurance and long jump, respectively. Since the late 1990s physical performance remained below average, with the exception of long jump performance during the years 2003 and 2004. The maximum drop in performance relative to the respective cohort's norm values was most pronounced for aerobic fitness (19%), followed by long jump (18%) and sprint performance (11%).In order to compare the results of the present study with previous research, only studies with a prolonged observation time, including Bös (2003), Bös et al. (2008), Greier et al. (2019), Hirtz (2007), Raczek (2002) and Tomkinson (2007) were considered. By comparing physical fitness across the years 1965, 1975, 1985 and 1995, Raczeck (2002) showed a significant decline after 1985 in physical fitness in adolescents at the age of 14 and older; the decline was particularly pronounced in endurance and strength performance with a reduction of 20% between 1985 and 1995. These results align in timing and magnitude with the results of the present study. Tomkinson (2007) showed a transition from an increase in power and speed to a decline in performance around the year 1988. For aerobic fitness, the highest performance occurred in 1965 and remained relatively stable until 1970. Starting from the 1970s aerobic fitness started to decline until 2003. The present study also showed a transition from increased to decreased performance in long jump and sprint performance in 1988, which aligns with the global data shown by Tomkinson. As was shown by Tomkinson alterations in speed were also less pronounced compared to power in the present study, while changes in aerobic fitness were most pronounced. Three test items (20 m sprint, standing long jump, 6- or 12-minute run) from the review by Bös (2003) covering the years from 1965 to 2002 can be used for comparison with the results of the present study. The results by Bös can be summarized with two distinct eras: 1965-1985 and 1985-2002. Running performances generally improved until 1985 and declined subsequently until 2002, while standing long jump performance started to decline already in 1965. In 12- to 17-year-old male and female adolescents performance for the endurance run, sprint, sit ups, long jump and stand-and-reach test declined by an average of 12.5% (Bös et al., 2008). It is conceivable that the studies considered by Bös may not have shown possibly existing lowest performance scores before 2002 and, a decline of 16%, as shown in the present study, therefore, appears to be plausible.

In his review of numerous national and international studies Hirtz (2007) also found in almost all studies an increase in physical fitness until 1985. These improvements in physical fitness, however, were subsequently attenuated by an increase in BMI. The observed performance declines in the present study, therefore, may also be attributed to an increase in body weight in adolescents. In fact, Freedman et al. (2012) showed a sharp increase in obesity rates in boys after 1985. Given that the fitness assessments required using the own body weight, it is not surprising that increased body weight would impair performance on these tasks. Changes in lifestyle and leisure-time choices during the last decades may also have contributed to a decline in physical fitness. Increased urbanization, for example, has been associated with a more sedentary lifestyle due to lack of space for play, safety concerns and passive transportation (Collins et al., 2012; Romero et al., 2001). Further, time spent outdoors has declined, which is also an important correlate of habitual PA (Collins et al., 2012; Gray et al., 2015). Another consideration may be the emergence of informal youth sport activities like skateboarding or BMX-biking, which focused more on style than physical performance. These changes in PA characteristics may also influence attitudes towards physical fitness and potentially affected motivation during the fitness tests.

Given the long-observation period and the fact that data was collected during PE, changes in the curriculum should be considered as well. Since the 1990s PE curricula shifted from a sports orientation towards a stronger focus on educational aspects, which potentially affected intensity of PE classes. This change may also have affected the teaching style and content during PE classes. Sports facilities, however, did not change throughout the observation period and the fact that the fitness assessments were part of the grading process indicate that the promotion of physical fitness remained a priority of the teacher and that fitness-related content was included in PE lessons at all times. The high regard for the sports badges also ensured consistent actions by the teacher in preparing his students for the fitness assessments. The implementation of the results in the grading process, further should have contributed to a comparable motivation of the students performing the tests across the entire observation period.

In Austrian adolescents Greier et al. (2019) reported change in physical fitness in 10- to 14-year-olds in the years 1972, 1987 and 2015. Out of the 6 test items, results from the 20 m sprint, the 800 m run and the jump-and-reach test can be used for comparison with the present study. Some caution, however, is warranted as performance on the 20 m sprint and jump-and-reach test may not be exactly comparable with 100 m sprint performance and the long jump of the present study. A considerable strength of the study by Greier et al. (2019) is that data collection occurred in the same schools using the same methodology throughout the entire observation period. This is currently the only study, except the project *Klug und Fit* (Müller et al., 2008), which is still ongoing, that provides data on Tyrolean adolescents. An additional advantage is that data collection occurred in 1987, which appears to be in close proximity to the previously reported flipping point of physical fitness. Greier et al. (2019) showed an incremental improvement in jumping performance from 1972 to 2015, which resulted in a 12% improvement since the year 1972. For the sprint peak performance was observed in 1987, which was 8% better than in 1972. Subsequently there was a small decline in sprinting performance. For the 800 m there was an incremental decline since 1972 of roughly 7% across each era, resulting in an endurance performance that was only 85.5% of that shown in 1972. These results are different from those shown in the present study: only for the sprint there was an increase in performance until 1987 followed by a decline, while jumping performance continued to increase after 1987. Endurance capacity, on the other hand, already started to decline prior to 1987 while there was considerable improvement in the jump and reach test until 2002. The reported decline in sprint performance was also relatively small. These discrepancies may be explained by the reliance on different test items and differences in study population (rural/urban). As has been addressed at the beginning of the results section there is considerable variability in physical fitness within a given population. Given the limited available data, both studies, nevertheless, add new insights into the fitness state of adolescents in Tyrol, Austria. For more generalizable statements, additional research, however, is warranted.

Limitations and strength of the study

Some limitations of this study, however, need to be considered when interpreting the results. In comparison to other longitudinal studies the sample size was small. This may have contributed to the lack of normal distribution of the data, which warranted a non-parametric statistical approach that potentially limits comparability with large-scale studies that used other time-course analyses. In addition, only male students from a single school in Tyrol, Austria, were included in this study and, therefore, data may not be representative of the Austrian population. There was also no data for time series for upper grades between 1990 and 1995. Further, comparison of secular trends in physical fitness with other studies is limited due to differences in test items. In addition, students were stratified by grade rather than chronological age. The lack of information on height and body weight along with additional correlates of physical fitness, including leisure time PA, sports participation, family background, socio-economic status, also did not allow to examine potential longitudinal associations of these aspects with changes in physical fitness. Considerable strengths of the present study, on the other hand, include the long observation period along with annual fitness assessments in 3 to 5 different classes within the same school and consistent methodology under similar conditions that were performed by the same person. This allowed to explore short-term and long-term changes in physical fitness and a quite accurate determination of time points when trends in physical fitness start to shift, which could provide important insights for the examination of causality. An additional strength of this study, according to the authors, is the utilization of percentiles across different test items in addition to the determining percent change based on performance scores, which provide additional information and clarity.

Perspective

The present study along with previous research indicates a decline in physical fitness since the late 1980s. Even though this decline has been attenuated in more recent years, fitness levels of todays' children and adolescents are considerably lower than those of children 3 to 4 decades ago. The pronounced decline in aerobic fitness along with low current levels is of particular concern as low aerobic fitness has been associated with an increased risk for various chronic diseases (Ortega et al., 2008). Beyond a general encouragement for engagement in physical activity in children and adolescents, it is also necessary to ensure activities of sufficient duration and intensity that contribute to an improvement in physical fitness. Accordingly, school-based high-intensity interval training (HIIT) appears to be a viable option for improving physical fitness in children and adolescents (Garcia-Hermoso et al., 2020). A higher physical fitness may also facilitate a more active lifestyle beyond childhood and adolescents as it provides sufficient energy reserves to pursue and enjoy active recreational pursuits (Fraser et al., 2019). The promotion of physical fitness in children and adolescents, therefore, can also have a significant impact on future public health.

Table 2

Number cases by grade/age across test items and measurement years.

			Year of test																																		
	Grade	Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
			Number of cases tested																																			
100 m sprint	5	11		16	16	15		13		29				18		13	23	18	52			21	14			35	33	14	23	10	16	27	21	9			14	450
	6	12			15	40		21	38		46		25		20	18	29	24	18	49			22	13			46	31	16	23	10	16	28	20	33		15	616
	7	13				13	17		49	19		31		26		12	16	40	24	16	45			22	13			48	33	13	22	11	17	24	18	32	16	577
	8	14	24					16	17	14	19	33	26		11					18		47		10	32	20			34		13	13	17	16	25	19	9	433
	9	15		21	24						7	17			18								26	14	25	20				24			14	22	23			255
	10	16	16	22	21	20	25				30	12	27			28							24	20	22	18	17			21	22	18			14	33	20	430
	11	17	15	16		22	23	23				22	23	26			21										16	11										218
	Sum		55	75	76	110	65	73	104	62	102	115	101	70	49	71	89	82	94	83	45	68	86	79	92	93	112	104	106	91	83	85	97	91	113	84	74	2.979
1,000 m run	5	11				14		13		32						13	23	17	51				14			36	29	15	23	10	16	28	21	8			13	376
	6	12				33		21	37		41		21		20	18	29	23	18	50			22	13			46	32	15	22	11	16	28	21	35		16	588
	7	13				12	16		45	19		31		25		12	9	36	24	15	38			22	13			47	32	14	22	10	15	26	19	33	21	556
	8	14	27					16	17	12	17	32	26		11					18		47		12	35	20			33		13	22	19	16	25	20	9	447
	9	15	16								15	17			16								26	14	25	22				24			14	20	25			234
	10	16					13				20	9	27			27							23	20	22	18	18			19	24	20			15	32	19	326
	11	17	14					20				15	21	20													17	14										121
	Sum		57			59	29	70	99	63	93	104	95	45	47	70	61	76	93	83	38	47	85	81	95	96	110	108	103	89	86	96	97	91	119	85	78	2.648
Long jump	5	11		15	13	15		13		32				17		13	23	18	49			21	13			34	25	15	23	10	15	27	18	9			14	432
	6	12			15	39		20	35		46		26		20	17	29	24	18	49			22	13			48	30	16	23	11	15	27	21	33		17	614
	7	13				14	17		49	15		32		22		12	17	39	24	17				21	13			50	28	14	22	10	13	26	17	31	17	520
	8	14	25					17	17	14	19	31	25		11					17		46		11	32	20			29		13	22	19	16	24	19	9	436
	9	15	23	20	23						14	17			18								26	14	20	22				24			14	21	19			275
	10	16	19	18	21	18	19				25	10				28							24	20	21	18	16			21	21	17			13	31	20	380
	11	17	17	16		22	22	20				21	18	25			21										16	11										209
	Sum		84	69	72	108	58	70	101	61	104	111	69	64	49	70	90	81	91	83		67	85	79	86	94	105	106	96	92	82	91	91	93	106	81	77	2.866
	Total Sum		196	144	148	277	152	213	304	186	299	330	265	179	145	211	240	239	278	249	83	182	256	239	273	283	327	318	305	272	251	272	285	275	338	250	229	8.493

Table 3

Average performance across 3 disciplines indicated by the median performance score of each grade by the respective years.

	Grade	Age	Year of test: 1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
			Median																	
100 m sprint (m/s)	5	11		5,63	5,82	6,17		6,24		5,82				5,93		6,10	5,82	5,59	5,66	
	6	12			5,96	6,06		6,17	6,35		5,93		6,10		6,28	6,24	6,10	5,86	5,86	5,96
	7	13				5,96	6,21		6,37	6,62		6,39		6,24		6,72	6,57	6,39	6,17	6,13
	8	14	6,69					6,76	6,90	7,04	6,67	6,71	6,80		6,49					6,42
	9	15		7,63	7,12						6,85	7,35			7,04					
	10	16	7,35	7,66	7,41	7,43	7,30				7,14	7,35	7,63			7,46				
	11	17	7,46	7,58		7,75	7,58	7,52				7,55	7,63	7,97			7,63			
1,000 m run (m/s)	5	11				3,97		3,80		3,98						3,95	3,85	3,14	3,64	
	6	12				3,99		4,00	4,13		4,00		3,97		3,85	4,02	4,00	3,76	3,59	3,82
	7	13				3,93	4,10		4,31	4,42		4,03		4,07		4,35	3,92	4,14	4,07	3,70
	8	14	3,79					4,03	4,29	4,36	4,50	4,45	4,42		4,37					4,07
	9	15	4,11								4,59	4,93			4,64					
	10	16					4,61				4,67	4,85	4,93			4,63				
	11	17	3,92					4,58				4,74	4,83	4,80						
Long jump (m)	5	11		3,12	3,20	3,52		3,18		3,22				3,29		3,38	3,29	3,33	3,19	
	6	12			3,33	3,46		3,40	3,61		3,31		3,54		3,41	3,52	3,40	3,30	3,48	3,42
	7	13				3,63	3,66			3,67		3,51		3,73		3,71	3,77	3,89	3,63	3,55
	8	14	3,92					4,04	3,92	3,97	4,35	3,90	4,03		4,17					3,81
	9	15	4,41	4,50	4,27						4,19	4,73			4,39					
	10	16	4,32	5,06	4,67	4,54	4,51				4,62	4,56				4,62				
	11	17	4,54	4,68		5,05	4,78	4,36				4,59	4,79	4,79			4,53			

	Grade	Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
100 m sprint (m/s)	5	11		6,03	5,28			5,69	5,82	5,89	5,63	5,89	5,63	5,63	5,76	5,76			5,82	5,76
	6	12			6,20	5,76			5,99	6,24	6,10	6,31	5,99	5,99	5,79	5,89	5,89		5,89	6,03
	7	13	6,39			6,39	6,10			6,35	6,31	6,31	6,39	6,24	6,31	6,10	6,35	6,39	6,17	6,31
	8	14		6,61		6,58	6,73	6,54			6,60		6,54	6,71	6,49	6,73	6,33	6,94	6,71	6,62
	9	15			6,76	6,92	6,99	7,19				6,94			7,04	6,80	7,14			6,94
	10	16			7,46	7,19	6,92	7,22	7,04			7,30	7,12	7,30			7,22	7,35	7,22	7,30
	11	17							7,43	7,52										7,63
1,000 m run (m/s)	5	11			3,31			3,62	3,58	3,75	3,80	3,63	3,59	3,59	3,72	3,48			3,48	3,72
	6	12			3,91	3,55			3,69	3,68	4,00	3,82	3,94	3,77	3,77	3,75	3,82		4,00	3,91
	7	13	3,83			4,11	3,75			3,75	3,84	3,99	3,82	3,85	3,73	4,00	3,95	3,98	3,79	3,98
	8	14		4,05		4,10	4,26	3,82			4,13		4,12	4,37	4,12	4,14	3,92	4,18	3,91	4,12
	9	15			4,23	4,29	4,26	4,31				4,08			4,42	4,01	4,22			4,28
	10	16			4,44	4,26	4,29	4,19	4,21			4,50	4,19	4,59			4,12	4,42	4,24	4,42
	11	17							4,39	4,05										4,65
Long jump (m)	5	11		3,16	2,86			2,98	2,76	3,25	3,16	3,26	3,26	3,19	3,26	2,88			2,79	3,19
	6	12			3,50	3,10			3,25	3,34	3,28	3,35	3,40	3,45	3,34	3,46	3,23		3,35	3,38
	7	13				3,57	3,41			3,61	3,61	3,75	3,62	3,34	3,81	3,39	3,72	3,50	3,48	3,59
	8	14		3,95		3,84	3,98	3,66			4,02			3,93	3,84	4,02	3,83	3,97	3,90	3,88
	9	15			3,99	3,93	4,26	4,34				4,11			4,23	3,85	4,33			4,24
	10	16			4,41	4,46	4,37	4,43	4,26			4,55	4,41	4,43			4,21	4,29	4,17	4,43
	11	17							4,50	4,51										4,65

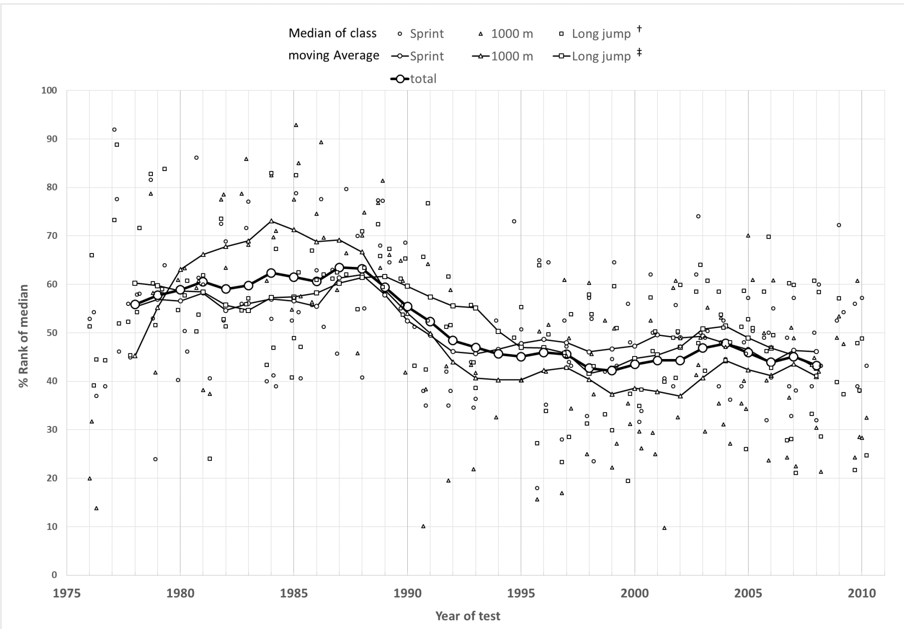

Figure 1

Scatterplot of percentiles of median for 100 m sprint, 1,000 m run and long jump and percentile based time series.

† in order to avoid overlap of similar percentile marks of year, grades 1-3 are shown slightly left and grades 5-7 are shown slightly right of the grid respective year of test.
‡ represent the smoothed percentile-based time series using the weighted (based on sample size) average of 5 consecutive years for sprint, long jump and 1,000 m run.

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