

Changes in motor competence over four decades in 10 to 14-year-old Austrian boys

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ABSTRACT

Background: Data on secular trends in motor competence in children and adolescents have been inconsistent. While several studies showed a decline in motor competence over the last several decades there is also research that showed no change or even an increase in motor competence in youth. **Methods:** In the present study motor competence was assessed via 6 test items in 10- to 14-year-old Austrian boys in the years 1972 (n=694), 1987 (n=138) and 2015 (n=222). At each measurement time participants performed 20m sprint, 800m run, sit ups, jump and reach, one-leg stand and stand and reach tests in the school gymnasium during regular school time. Data across measurement times was compared using weighted means across 5 age groups with pooled standard deviations. **Results:** Average performance on the 20m sprint, jump and reach test and one leg stand improved significantly ($p < 0.05$) from 1972 to 2015 by 0.3 seconds, 3.9 cm and 3.5 seconds, respectively. Time for the 800m run increased significantly by 15% ($p < 0.01$), indicating a decline in cardiorespiratory endurance. Flexibility, measured by the stand and reach test, also declined significantly ($p = 0.02$) from 1972 to 2015. There was no significant difference in the number of sit ups performed at the 3 measurement times. **Conclusion:** Results of the present study do not show a general decline in motor competence in male middle-school students over the last 4 decades. Rather, secular trends differ by specific components contributing to overall motor competence with declines in flexibility and endurance but increases in power, speed and balance.

Keywords:

motor skills – secular trends – physical fitness – youth – adolescents

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Introduction

Regular physical activity (PA) and high motor competence are important determinants of physical and psychological health and well-being in youth (Andersen, Sardinha, Froberg, Riddoch, Page & Anderssen, 2008; Brosnahan, Steffen, Lytle, Patterson & Boostrom, 2004; Deforche, Lefevre, De Bourdeaudhuij, Hills, Duquet & Bouckaert, 2003; Janssen & Leblanc, 2010). Well-developed motor competence further facilitates learning

of sport-specific skills, which play a crucial role in a person's development (Bös & Brehm, 2004; Dencker, Thorsson & Karlsson, 2006; Logan, Robinson, Wilson & Lucas, 2012; Morgan, Barnett, Cliff, Okely, Scott, Cohen & Lubans, 2013; Ortega, Ruiz & Castillo, 2013; Starker, Lampert, Worth, Oberger, Kahl & Bös, 2007). Over the last several decades there have been significant changes in physical activity levels of children and adolescents, particularly in highly developed countries, leading to increasingly sedentary behavioral choices (Hills, King & Armstrong, 2007). Watching

TV, playing computer games and surfing the internet have become popular leisure time behaviors (Greier & Drenowatz, 2018; Greier, Drenowatz, Ruedl, Lackner, Kroell & Feurstein-Zerlauth, 2018; Kaiser-Jovy, Scheu & Greier, 2017; Mathers, Canterford, Olds, Hesketh, Ridley & Wake, 2009). Accordingly, various studies have shown that a majority of youth are not meeting current physical activity guidelines of 60-minutes of moderate-to-vigorous PA (Krug, Jekauc, Poethko-Müller, Woll & Schlaud, 2012; Reilly, Jackson, Montgomery, Kelly, Slater, Grant & Paton, 2004; WHO 2010).

The decline in physical activity levels in youth may also contribute to a decline in motor competence. Several studies have shown reductions in motor competence in children and adolescents (Albon, Hamlin & Ross, 2010; Klaes, Cosler, Rommel & Zens, 2003; Muellerova, et al., 2015; Raczek, 2002; Runhaar, Collard, Singh, Kemper, van Mechelen & Chinapaw, 2010; Tomkinson & Olds, 2008). A review and meta-analysis by Bös (2003) using 54 studies with more than 100 000 children and adolescents between 6 and 17 years of age from 20 countries indicated a 10% decline in motor competence between 1965 and 2002. A follow-up study supported this alarming trend (Bös et al. 2008). Similarly, a meta-analysis by Tomkinson, Léger, Olds und Cazorla (2003) using 55 studies with roughly 130 000 children and adolescents from 11 countries indicated an annual decline of 0.4% in cardio-respiratory endurance from 1981 to 2000. A more recent study also showed a decline in cardio-respiratory endurance of school children from 1998 to 2008 (Sandercock, Voss, McConnell & Rayner, 2010). There are, however, also studies that show limited change in motor competence or even an increase in motor performance in youth (Dordel, 2000; Klein, Emrich, Schwarz, Papathanassiou, Pitsch, Kindermann & Urhausen, 2004; Gaschler, 2001; Kretschmer & Giewald, 2001; Roth, et al., 2010; Rusch & Irrgang 2002). Possible explanations for these inconsistencies may be methodological differences (i.e. test batteries, evaluation criteria) and differences in the characteristics of the study population (i.e. age, sex, socio-economic status).

Given these inconsistent findings regarding secular trends in motor competence in youth additional research is warranted. Even though large-scale studies indicate a decline in motor competence over the last decade (Bös 2003; Tomkinson et al. 2003), a more diverse approach may be warranted and the authors hypothesize that secular trends differ by specific parameters of motor competence (e.g. strength, endurance, flexibility).

Methods

The present study uses data collected by the Department of Sports Science of the University of Innsbruck. Specifically, data from 1970 was taken from a dissertation study while data from 1987 was from a Master thesis. In 2015 the same research design was used to obtain current comparable data on motor competence. Motor competence was assessed in 10- to 14-year old male middle-school students (Gymnasium, Sekundarstufe

l) at the same schools in Tyrol, Austria at each measurement time using the Fetzer and Kornexl test battery from the year 1970. Validity, reliability and objectivity of this test battery have been extensively studied (Fetzer & Kornexl 1970; 1978). Data collection occurred during regular school times in the school gymnasium. The research protocol was approved by the University of Innsbruck and the principal of the selected schools. Parents received written information about the testing procedures and provided written informed consent while participants provided oral assent at the time of data collection. All male students in grades 5 to 8, willing to participate were recruited from the same 2 middle-schools in Tyrol at each measurement time. Exclusion criteria for participation were injuries or health problems prohibiting participation from the motor competence test as well as missing parental written informed consent or oral assent.

Motor Competence

Participants performed six motor tests in order to determine power (jump and reach), strength endurance (sit ups), speed (20m-Sprint), endurance (800m run), balance (one-leg stand) and flexibility (stand and reach).

Jump and Reach.

The jump and reach test is a common test for measuring explosive leg power. Participants stood sideways next to the wall and reached as high as possible (standing reach height). Subsequently the participants performed a vertical jump to touch the wall with their fingers at the highest possible point. Jumping height was calculated as the difference between the standing reach height and the point marked during the vertical jump – higher jumping height indicates greater power.

Sit ups.

This test examines strength endurance of the core muscles. Starting in fully extended supine position (straight legs) participants lifted their upper body in order to touch their ankles. The number of complete repetitions performed in 15 seconds was recorded – higher values indicated better strength endurance.

20m-Sprint.

The 20m Sprint is a commonly used test to examine linear speed. The participants started in a high-start position with the front toes touching the starting line. Time to cover 20 meters was measured with a stop-watch to the nearest 0.1 second – smaller values indicated better linear speed.

800m Run.

To determine cardiorespiratory endurance participants completed 2 laps on a 400-meter track. Time for completion was

measured with a stop watch in seconds and is reported in minutes – smaller values indicated better endurance capacity.

Single-leg Stand.

Balance was determined by the participant standing barefoot on a 2 cm wide and 10 cm high board with the hands at the waist. Following a signal from the test administrator the participants lifted the second leg from the floor and maintained this position for as long as possible (hands at the waist, one leg off the ground) for a maximum duration of 60 seconds. Time in position were measured with a stop watch – higher values indicate better balance.

Stand and Reach.

This test examines hip flexibility. Participants stood barefoot in a closed stance behind the measurement scale on a gym bench and tried to reach as far as possible down the measurement scale (in cm) while keeping their knees straight. Reaching the toes resulted in a value of 0. A positive value was recorded when participants reached beyond the toes. In case participants could not reach their toes the difference between their finger tips and the toes was recorded with a negative value – higher values indicate better hip flexibility.

Statistical Analysis

Individual data on all test items was available for 2015 and 1987. For the year 1972 only aggregated values for number of pupils as well as means and standard deviations of the individual test items per age level were available. A Chi-square test was used to examine the homogeneity of the age structure of the examined students across the 3 examination times. Means and standard deviations of the results of the individual tests of the 3 collectives of 10 to 14-year-old students in the years 1972, 1987 and 2015 were tabulated. The 95% confidence intervals were calculated and plotted in line diagrams. In order to be able to compare the performance of the three study groups of the years 1972, 1987 and 2015, the weighted arithmetic mean values of the results of the individual tests were calculated across the 5 age groups. The calculation of the standard deviations pooled over the 5 age groups was carried out according to Cohen (1988). The variances were checked for equality by F-test. Mean values across all 5 age groups in the years 1972, 1987 and 2015 were compared by analysis of variance and in case of unequal variances with the Welch test. For post hoc tests, the Tukey Honest Significant Difference Test was performed. The significance level was set to 0.05. Data analysis was carried out using SPSS 24.

Results

A total of 694 male students were measured in 1972. Subsequently, 138 and 222 male students were measured in 1987 and 2015, respectively. Table 1 shows the age distribution of the participants across the 3 time points. Across all measurement times 14% of the participants were 10 years old, 24% were 11 years old, 21% were 12 years old, 22% were 13 years old and 19% were 14 years old. There was no significant difference in age distribution between the 3 measurement times (Chi-square 13.63; df 8; $p=0.092$).

Table 1: Age distribution of participants at the 3 measurement times. Values are number of participants (n); in brackets: row percent (Chi-square: 13.63; degrees of freedom: 8; p-value: 0.092). The higher student count in 1972 is due to a higher number of classes included in the study.

Measurement Time	Age Group				
	10 years	11 years	12 years	13 years	14 years
1972	83 (12 %)	155 (22 %)	150 (21 %)	170 (25 %)	136 (20 %)
1987	23 (17%)	42 (31%)	24 (17%)	24 (17%)	25 (18%)
2015	38 (17%)	51 (23%)	48 (22%)	40 (18%)	45 (20%)

Motor competence by age group

Except for the stand and reach test performance increased with increasing age at each measurement time (Table 2). Jumping height increased across all 3 measurement time points with increasing age from 30.6 cm in 10-year-old boys to 43.0 cm in 14-year-old boys. The number of sit ups increased from 9.8 in 10-year-old boys to 10.9 in 14-year-olds, 20m sprint times decreased from 4.2 seconds to 3.8 seconds and 800m running times decreased from 3.9 minutes to 3.2 minutes from 10 years of age to 14 years of age, respectively. Time for the one-leg stand increased from 8.1 seconds in 10-year-olds to 11.7 seconds in 14-year-olds.

Motor competence across time

The main focus of this paper, however, was on change in motor competence in male Tyrolean students from 1972 to 2015 who were recruited at the same schools. Jump and reach performance increased by 12% from 1972 to 2015 ($F=7.58$; total df: 210; $p=0.007$) (Figure 1). Specifically, participants' jumping

Table 2: Performance on motor competence tests at various ages at the 3 measurement times. Values are number of means ± standard deviation.

		Age Group				
		10 years	11 years	12 years	13 years	14 years
1972	Jump and Reach (cm)	28.3±4.81	30.6±5.6	32.9±5.2	35.0±6.1	38.3±6.0
	Sit ups (# in 15 sec)	8.9±1.7	9.4±1.7	10.1±1.9	10.5±2.0	11.1±1.8
	20m Sprint (sec)	4.6±0.3	4.3±0.2	4.2±0.3	4.2±0.3	3.9±0.3
	800m Run (min)	N/A	3.4±0.4	3.3±0.3	3.3±0.4	3.1±0.3
	One-leg Stand (sec)	5.3±3.8	6.3±4.2	7.3±5.9	10.5±9.1	10.4±7.6
	Stand and Reach (cm)	-0.5±5.2	0.7±6.2	0.9±6.6	1.3±7.1	0.4±6.6
1987	Jump and Reach (cm)	30.5±5.9	32.7±6.6	31.1±5.6	37.3±7.7	46.2±8.2
	Sit ups (# in 15 sec)	9.7±3.7	9.8±2.8	11.3±2.6	10.3±3.6	11.7±3.2
	20m Sprint (sec)	4.1±0.3	3.9±0.2	3.9±0.2	3.8±0.5	3.6±0.2
	800m Run (min)	3.7±0.5	3.6±0.4	3.5±0.4	3.6±0.8	3.1±0.4
	One-leg Stand (sec)	8.8±6.0	8.1±4.0	8.8±4.3	11.5±8.4	11.9±6.5
	Stand and Reach (cm)	2.4±5.6	3.0±5.0	1.9±8.7	3.8±5.5	7.1±5.8
2015	Jump and Reach (cm)	33.2±5.8	32.3±4.2	37.4±7.9	39.6±5.9	44.4±7.0
	Sit ups (# in 15 sec)	10.9±1.4	9.8±1.5	10.9±2.2	10.4±1.3	9.7±1.2
	20m Sprint (sec)	3.9±0.3	4.1±0.3	3.9±0.3	3.9±0.2	3.7±0.3
	800m Run (min)	4.1±0.6	4.0±0.5	3.6±0.9	3.8±0.6	3.4±0.4
	One-leg Stand (sec)	10.1±3.9	10.2±4.0	12.1±3.4	13.3±3.2	12.8±3.3
	Stand and Reach (cm)	2.6±5.9	2.3±6.5	0.2±7.2	-3.2±6.3	-0.9±7.9

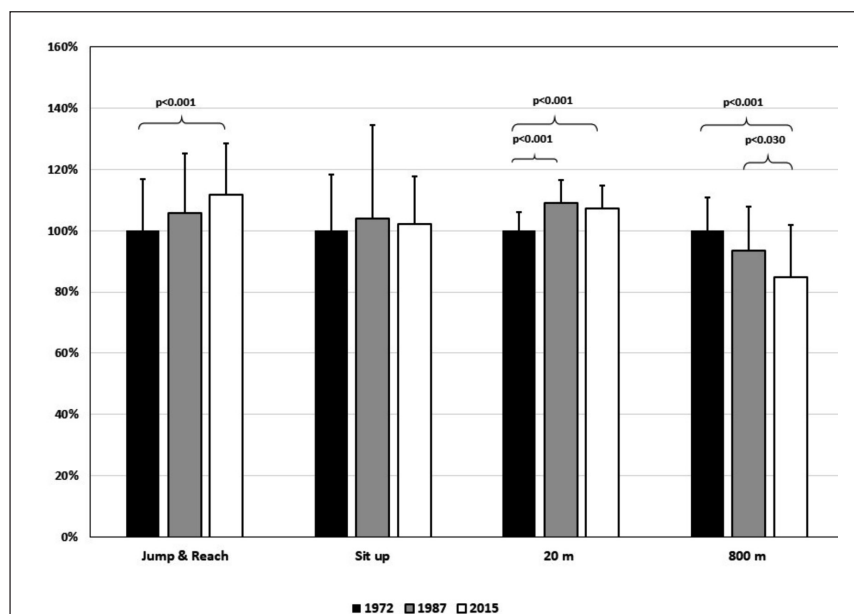


Figure 1: Performance on power, strength endurance, sprint and endurance capacity tests at the 3 measurement times. Values are weighted means with pooled standard deviation. Performance in 1972 at the respective test was used as reference (i.e. 100%)

height was 33.4 ± 5.6 cm in 1972, 35.3 ± 6.8 cm in 1987 and 37.3 ± 6.3 cm in 2015. Sprint performance improved by 8% from the year 1972 to 2015 ($F=22.94$; total df: 205; $p<0.001$). In 1972 the 20m-sprint time was 4.2 ± 0.3 seconds while it was 3.9 ± 0.3 seconds and 3.9 ± 0.4 seconds in the years 1987 and 2015, respectively. An increase in time on the one-leg stand by 3.5 seconds from 1972 to 2015 also indicates an improvement in balance over time ($F=2.40$; total df: 176; $p=0.094$) (Table 2). In 1972 duration of the one-leg stand was 8.2 ± 6.7 seconds, which increased to 9.8 ± 6.0 seconds in 1987 and to 11.7 ± 3.6 seconds in 2015.

Performance on the 800m run, on the other hand, declined by 15% from 1972 to 2015 ($F=20.28$; total df: 203; $p<0.001$). Finishing times for the 800m run increased from 3.3 ± 0.4 minutes in 1972 to 3.5 ± 0.5 minutes in 1987 and 3.8 ± 0.6 minutes in 2015 (Figure 1). Similarly, flexibility as indicated by the stand-and-reach test declined from 1972 to 2015 ($F=3.88$; total df: 207; $p=0.022$). In 1972 and 1987 participants were generally able to reach beyond their toes (0.7 ± 6.5 cm and 3.7 ± 6.2 cm, respectively), while the average value in 2015 shows that participants could not reach their toes (-0.9 ± 6.8) (Table 2).

There were no significant changes in strength endurance as indicated by the number of sit ups completed ($F=0.51$; total df: 206; $p=0.601$) (Figure 1). In 1972 participants completed 10.1 ± 1.8 sit ups, in 1987 participants completed 10.5 ± 3.2 sit ups and in 2015 participants completed 10.3 ± 1.6 .

Discussion

Several studies, including two large-scale meta-analyses, have shown a decline in motor competence among children and adolescents over the last decades (Albon et al., 2010; Bös 2003; Müllerova et al., 2015; Runhaar et al., 2010; Sandercock et al., 2010; Tomkinson et al., 2003). The present study used motor competence data from two cross-sectional studies carried out in male students of similar age in 1972 and 1987. In addition, the same research protocol was used in 2015 to obtain current data on motor competence in male students at the same schools used at the previous time points.

The results provided by Tyrolean male middle school students paints a more diverse development of motor competence in youth over the last 40 years. The present study indicates an improvement in muscular power and speed as well as balance while there was a decline in endurance and flexibility. Limited change over time was observed in muscular endurance of the core muscles. As such no clear secular trend in overall motor competence could be observed. In addition, it was shown that motor competence generally increases with age in 10- to 14-year old boys, except for flexibility.

A decline in endurance capacity has been shown consistently in various studies (Albon et al., 2010; Bös, 2003; Dyrstad, Berg & Tjelta, 2011; Sandercock et al., 2010; Tomkinson et al., 2003). This may be attributed to the observed decline in general PA in youth as well as increased sedentary choices (Dalene,

Anderssen, Andersen, Steene-Johannessen, Ekelund, Hansen & Kolle, 2018; Dollman, Norton & Norton, 2005; Sigmundova, El Ansri, Sigmund & Frömel, 2011). Along with these behavioral changes there has also been an increase in the prevalence of overweight and obesity (Ahluwalia et al., 2015; Jackson-Leach & Lobstein, 2006; Kelly, Yang, Chen, Reynolds & He, 2008; Moß, Wabitsch, Kromeyer-Hauschild, Reinehr & Kurth, 2007; Reilly, Methven, McDowell, Hacking, Alexander, Stewart & Kelnar, 2003; Pigeot & Walter, 2016; Wang & Lobstein, 2006), which is inversely related with endurance capacity (Graf et al., 2004; Greier & Drenowatz, 2018; Greier, Riechelmann & Burtscher, 2014; Lakoski, Barlow, Farrell, Berry, Morrow & Haskell, 2011; Ruedl, Greier, Kirschner & Kopp, 2016; Starker et al. 2007). This is of particular concern, as low cardiorespiratory fitness and excess body weight are risk factors for various chronic diseases (Dietz, 1998; Hurtig-Wennlöf, Ruiz, Harro, & Sjöström, 2007; Stabelini Neto et al. 2011). Further, excess body weight during youth has been associated with increased risk for chronic disease and premature death in adulthood even in the absence of adult obesity (Dietz, 1998). Along with a decline in endurance several studies have also shown a decline in flexibility (Albrecht et al., 2016; Klein et al. 2004), which is consistent with results of the present study.

Other motor abilities, such as balance and muscular strength, on the other hand, potentially increased during the last several decades. Particularly youth's balance abilities have been shown to increase consistently (Klein et al. 2004; Rethorst 2003). This secular trend may be explained by the emergence of several trend sports such as slackline, inline-skating, skateboarding and mountain biking. Klein et al. (2004) further reported an improvement in 20m sprint performance in a mixed sample of German middle school students compared to previous studies dating back to 1975, which is consistent with results of the present study. Muscular power, measured by the jump and reach test, however, appeared to decline in German youth. A potential explanation may be the use of boys only in the present study, while the German samples consisted of boys and girls. Even though resistance training and plyometrics have become more popular, these exercises may still be more common in boys than in girls.

Some limitations of the present study also should be considered when interpreting the results of this study. Various correlates of motor competence, such as body weight and height, socio-economic background, developmental stage or PA could not be considered as this data was not collected in 1972 and 1987. Although no significant age differences were observed between the 3 collectives measured at the 3 time points ($p=0.092$), differences in age and/or biological maturation may have influenced the results. Generalizability of the results is further limited by the fact that only boys were included in this study. In addition, the sample may not be representative of all Austrian boys as there may be differences in socioeconomic status and living environment in these Tyrolean boys compared to other regions in Austria. The utilization of a similar, standardized and validated test battery to assess motor com-

petence (Fetz & Kornexl, 1970; 1978), on the other hand, is a considerable strength of this study. Additionally, assessments were performed in the same school types and age groups as well as similar geographic regions at each measurement time. The long-time span between measurement times further allows to draw conclusions on secular trends over several generations. It should also be mentioned that there is currently limited data on motor competence in Austrian school children. These results, however, could provide important insights for interventions and strategies targeting motor competence in children and adolescents.

In conclusion, the present study did not show a general decline in motor competence in Tyrolean boys between 10 and 14 years of age. Several other studies did not show negative or diverse trends in motor competence either (Klein et al., 2004; Kretschmer & Giewald, 2001; Roth et al., 2010; Rusch & Irrgang, 2002; Will, Schmidt & Woll, 2016). Rather, secular trends on specific motor skills appeared to differ. Muscular power and speed appear to have improved over the last 40 years while endurance and flexibility declined. Strength endurance appeared to remain stable. In addition to behavioral changes (i.e. increased sedentary pursuits), these changes may also reflect differences in sports participation and trends of leisure-time PA in adolescents.

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Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

All relevant data are within the paper.

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