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Secular trends in aerobic fitness performance in a cohort of Norwegian adolescents

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The purpose of the present study was to compare 3000 m running test results between 1969 and 2009 in a cohort of Norwegian high school pupils. Between 1969 and 2009, a total of 4981 (2827 boys) 3000 m running tests were collected from two Norwegian senior high schools. One-way ANOVA with Tukey's *post hoc* test was used to analyze the differences in the running times between the different decades. The running times have increased by 10% and 6% from the 1980s to the 2000s for boys and girls, respectively. The distribution showed a decline in aerobic fitness performance for all deciles. The largest negative change in difference was found for pupils with the poorest aerobic fitness level in both boys and girls. The cohort of 16- to 18-year-old boys and girls in the decade 2000–2009 had a poorer aerobic fitness performance in the 3000 m running test compared with earlier decades. The decline in running performance was greater for boys than girls, and the gap between the most and the least fit is becoming considerably larger.

Aerobic fitness performance (later used only aerobic fitness) is an important target in preventing obesity in adolescents (Tomkinson & Olds, 2007b). It is also strongly related to reduced cardiovascular risk (Wedderkopp et al., 2003) and a pronounced health status marker at any age (Ortega et al., 2008). There is a paucity of data regarding earlier generations' aerobic fitness, and few studies of secular trends in this area have been published. To identify the secular changes during the most recent decades, we are forced to base our conclusions on minor studies that alone have limited value. To our knowledge, there are only two published studies investigating changes in aerobic fitness in Norwegian subjects. Fredriksen et al. (1998) concluded that the mean aerobic fitness in a group of 8- to 16-year-old Norwegian boys and girls showed only small differences compared with similar studies in Scandinavia from 1952, 1973 and 1980, although the results were more dispersed in the study from 1998 compared with the earlier studies. Dyrstad et al. (2005) found that aerobic fitness in 18-year-old Norwegian men had decreased by 8% from 1980 to 2002.

Three other Nordic studies reporting secular trends in adolescent aerobic fitness were found.

In a Danish study, maximal oxygen uptake (VO_{2max}) from three population studies, aged 15–19 years, from 1983, 1997 and 2003, was compared. No difference was found between the three cohorts (Andersen et al., 2010). A Swedish study reported a 3–4% decrease in aerobic fitness, as measured by a modified Cooper test between 1974 and 1995, for 16-year-old boys and girls (Westerstahl et al., 2003), and a Finnish study (Huotari et al., 2010) found that performance in 2000/1500 m running by 13- to 18-year-old boys and girls decreased by 6–10% between 1976 and 2001. Tomkinson and Olds (2007b) studied the global change in aerobic running test performance in boys and girls, aged 6–19 years. The results revealed a decline in the running performance of 0.36% per annum between 1958 and 2003. This change was not consistent over time, with improvements from the late 1950s until about 1970, and declines of increasing magnitude every decade thereafter.

As very little information is available on the secular trends in aerobic fitness of adolescents from Norway, the aim of this study was to investigate secular trends in aerobic fitness based on test results from the last 30 years in 3000 m running in a cohort of Norwegian adolescents.

Materials and methods

Participants

A total of 4981 pupils (2827 boys), age 16–18 years, in their first, second and third years from two high schools in the city of Stavanger, Norway, were included in the study. Of the included

Table 1. Numbers of included and dropouts for boys and girls with percent of dropouts for each decade

	Year				Total
	1969–1979	1980–1989	1990–1999	2000–2009	
Boys					
Included, *N*	261	1029	526	1011	2827
Dropout, *N* (%)	42 (16)	91 (9)	109 (21)	201 (20)	443 (16)
Girls					
Included, *N*		654	576	924	2155
Dropout, *N* (%)		152 (23)	129 (22)	251 (27)	532 (25)
Total included per decade (*N*)	261	1683	1102	1935	4981

subjects, 4006 pupils (2384 boys) completed the running test (Tables 1 and 2). The tests were conducted between 1969 and 2009 for boys and between 1983 and 2009 for girls. Pupils were classified into three study line groups according to their educational course emphasis: (1) general theoretical studies, (2) pupil athletes in general theoretical studies and (3) vocational school programs. The admission grade for pupils admitted to these two schools is, according to the regional admission office, representative for the pupils in the Stavanger region. The Regional Committee for Medical Research Ethics and Norwegian Social Science Data Service approved the study.

Collection of data

All test results from 1969 to 2007 were collected by two physical education teachers, while data from 2008 to 2009 were collected by seven physical education teachers. Tests from classes having other physical educational teachers are not included due to the fact that these data were not preserved. The testing procedure was well established at both schools, and the pupils in both schools have been tested at least once a year since the 1960s.

In school A, the pupils ran 3050 m around a lake. In school B, pupils ran three laps around a smaller lake, totaling 2943 m. For comparing 3050 m running times with 2943 m times, running times were adjusted to a 3000 m time by dividing running time by running distance and multiplying by 3000. The surface of both courses is firm cinder ground and the difference between the highest and the lowest points is <3 m for both courses. The surfaces of the cinder paths around the two lakes have been the same from 1969 to 2010.

All tests were carried out in either August, September, or October. Pupils who did not take part in the test or did not finish the test were registered as dropouts.

In order to characterize the physical fitness of the dropouts, we analyzed the physical education grade for 37 randomly selected dropouts in 2008 and 2009.

Statistics and data processing

All data from school A and data from 2008 and 2009 from school B were controlled and corrected for possible data entry errors. A random selection of 424 tests from the years 1969, 1974, 1981 and 1990 from school B was also controlled for data entry errors. Five errors, corresponding to 1.1%, were found and corrected. To avoid the influence of extreme outliers, the maximal test time was set to 30 min. One test result from 2008 was excluded due to this limit.

Minutes and seconds were first recalculated to minutes during the statistics, and then recalculated to minutes and seconds in the text and tables. As there was no statistical difference in the running time between pupils in first year of high school (age: 15–16 years) compared with the second (age: 16–17 years) and third years of high school (age: 17–18 years), the test results from the different years from both schools were merged. To analyze the secular trends between decades, test results from 1969–1979, 1980–1989, 1990–1999 and 2000–2009 were merged and compared. The annual change in aerobic performance between the 1980s and 2000s was calculated by dividing the mean difference in running time between the decades by 20.

To adjust for the increased dropout rate for girls between the 1990s and 2000s (5% or 47 persons), we used the grade in physical education for the randomly selected dropouts in 2008/2009 to estimate the dropouts' running times. Dropouts with no grade in physical education or a grade below average were given a running time corresponding to the poorest decile. Dropouts with an average grade were given the mean running time, while dropouts with a grade above average were given a running time corresponding to the best decile.

One-way ANOVA with Tukey's *post hoc* test was used to analyze the differences in running times from the different decades. Results are presented as mean (standard deviation). A P-value <0.05 was regarded as statistically significant.

Table 2. Mean running time in minutes and seconds for 3000 m for boys and girls with 95% confidence interval (CI) for the last decades

Year	*N*	Running time (min:s)	95% CI (min:s)	
			Lower bound	Upper bound
Boys				
1969–1979	219	12:43	12:29	12:56
1980–1989	938	12:28	12:22	12:34
1990–1999	417	12:32	12:22	12:42
2000–2009	810	13:42*	13:32	13:52
Total	2384	12:55	12:50	13:00
Girls				
1980–1989	502	16:05	15:52	16:17
1990–1999	447	16:04	15:50	16:16
2000–2009	673	17:02*	16:50	17:14
Total	1622	16:28	16:21	16:35

*Different from the other decades ($P<0.001$).

Results

The 3000 m running time increased by 10% and 6% from the 1980s to the 2000s for boys and girls,

respectively (Table 2). The effect size in the same time period was -0.60 and -0.38 (Cohen's *d*) for boys and girls, respectively.

The yearly average running time with a polynomial trend line is shown in Fig. 1. Figures 2 and 3 shows the secular trend in running time for the 3000 m in deciles for boys and girls during the last three decades. The difference between the slowest and the fastest group of pupils increased from 1980s to 2000s. For boys, the running time for the fastest decile increased from 10:19 to 10:43 (min:s) or 3.9% from 1980s to 2000s ($P<0.001$), while the running time for the slowest decile increased from 16:05 to 18:57 (min:s) or 17.8% during the same period of time ($P<0.001$). For girls, the running time for the fastest decile increased from 12:28 to 13:10 (min:s) or 5.6% ($P<0.001$) from 1980s to 2000s, and the running time for the slowest decile increased from 20:57 to 22:30 (min:s) or 7.4% ($P<0.001$).

Significant differences were found between the three pupil study line groups. Pupil athletes in general theoretical studies had a better mean running time than pupils in general theoretical studies, who again had a better mean running time than pupils in vocational programs (Table 3).

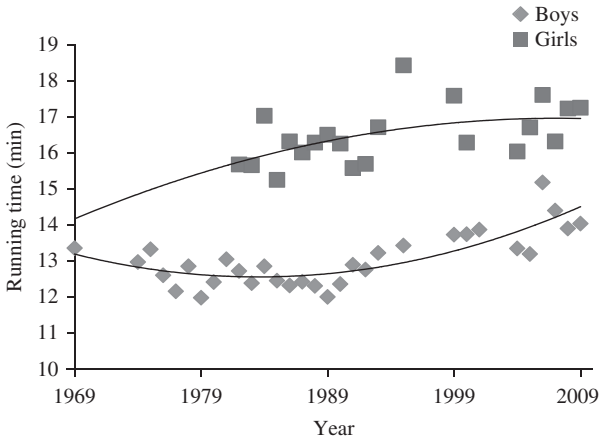

Fig. 1. Yearly average running time for boys and girls with a polynomial trend line.

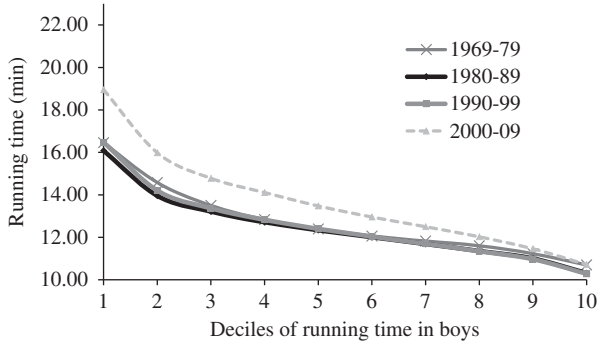

Fig. 2. Mean running time by deciles in boys from the last four decades. All deciles in 2000–2009 have increased their running time compared with 1980–1989 and 1990–1999 ($P<0.001$).

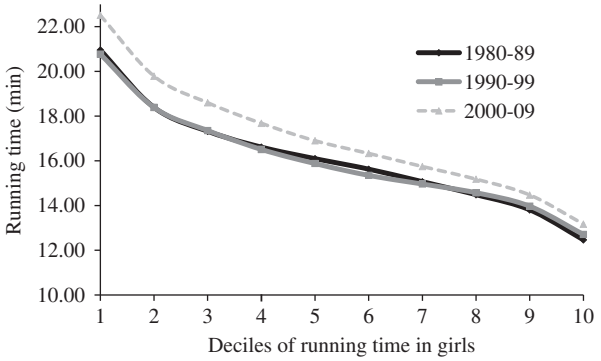

Fig. 3. Mean running time by deciles in girls from the last three decades. All deciles in 2000–2009 have increased their running time compared with 1980–1989 and 1990–1999 ($P<0.001$).

A random test of 37 pupils who did not perform the running test in 2008 and 2009 showed that 59% of these dropouts either did not receive a grade in physical education due to excessive absence or received a grade below the schools' average grade in this subject. More boys than girls completed the running tests, and the percent of dropouts has increased during the last 20 years (Table 1).

Discussion

The main finding of this study was that during the decade of 2000–2009, 16- to 18-year-old boys and girls had a poorer aerobic fitness based on performance in 3000 m running, compared with earlier decades. The distribution showed a decline in performance for all deciles, with the largest change in difference found in pupils with the poorest aerobic fitness. Boys showed a larger decrease in aerobic fitness than girls.

Aerobic fitness

The annual decline in aerobic fitness from the 1980s to the 2000s (last 20 years) was 0.50% for boys and 0.30% for girls. An extensive review from 27 countries found a decline in aerobic test performance between 0.46% and 0.58% for boys, and between 0.38% and 0.49% for girls during the 1980s and 1990s (Tomkinson & Olds, 2007b). Even though the method used to calculate the annual performance decline differs, this shows that the decrease in aerobic fitness in this Norwegian cohort is comparable to the results from other countries.

Data from the present study also show that the decline in aerobic fitness for the least fit pupils (decile with the poorest running time) is greater than for the fittest pupils. The decline in aerobic fitness for the

Table 3. Mean running time for 3000 m in minutes and seconds with 95% confidence interval (CI) for boys and girls in the three different lines of study for the last decade (2000–2009)

	N	Running time (min:s)	95% CI (min:s)	
			Lower bound	Upper bound
Boys				
General studies with sport	159	12:00*	11:48	12:12
General studies	593	13:58*	13:47	14:10
Vocational studies	58	15:35*	14:50	16:20
Girls				
General studies with sport	69	14:24*	14:01	14:46
General studies	564	17:11*	16:58	17:23
Vocational studies	40	19:38*	18:39	20:37

*Different from the two other lines of study ($P<0.001$).

least-fit boys was more than three times larger than for the fittest boys. This trend is corroborated by several other studies (Wedderkopp et al., 2004; Albon et al., 2010; Andersen et al., 2010). From the late 1960s to the late 1990s, there was a significant increase in BMI in the upper percentiles, but also a trend toward decreased BMI in the lowest percentiles in Norwegian girls as well as boys (Bjornelv et al., 2007). Low fitness is associated with a low level of physical activity and high BMI (Stratton et al., 2007), and increased BMI can be a reason why the performance shows a greater decline among the least-fit pupils. The aerobic fitness decline for the least aerobically fit pupils is comprehensive and is alarming as physical activity and aerobic fitness are inversely associated with metabolic risk (Brage et al., 2004) and low aerobic exercise capacity is a strong predictor of mortality in adults (Myers et al., 2002; Yusuf et al., 2004). This increasing gap in aerobic fitness among pupils can result in a larger class distinction in physical fitness and health.

Although it is clear that aerobic fitness has declined among the least-fit pupils, there is ongoing debate about whether the same trend is occurring among the most-fit pupils. Some studies have found no change in aerobic fitness in the fittest group (Wedderkopp et al., 2004; Andersen et al., 2010), while others have found a secular decrease (Dollman et al., 1999; Dyrstad et al., 2005; Huotari et al., 2010). The present study found a decline in aerobic fitness in all deciles, included the fittest. This finding is supported by anecdotal evidence from physical education teachers involved in the study. They have experienced that fewer pupils achieve very good running results, i.e. running times better than 11:00 for boys and 13:00 for girls. However, this is their personal, subjective opinion.

Gender differences in aerobic fitness

The effect sizes showed that there were moderate-sized declines for boys and small- to moderate-sized declines for girls. The differences in secular changes between boys and girls were small. However, a larger decline in aerobic fitness for boys than girls was unexpected, and could have several explanations. In the present study, the dropout rate for girls was higher than for boys, and has increased more during the last decade. An important question then is whether the dropout group would have had a significant influence on the test results. The teachers conducting the running test had the opinion that the least-fit pupils were overrepresented in the dropout group. This was confirmed when we studied the score in physical education for 37 of the pupils who did not perform the running test in 2008 and 2009. Only 19% of these pupils received a grade above the mean grade in physical education. An increased dropout rate for girls in the running test between the 1990s and the 2000s (Table 1) could therefore mean that more of the least-fit girls did not perform this test during the last decade. The aerobic fitness for girls in general, and especially for the least-fit decile, may therefore be overestimated. After adjusting for the increased dropout rate for girls, the decline in aerobic fitness among girls from the 1980s to 2000s was 7.8%, which is still significantly lower than the decline of aerobic fitness in boys. Several studies have found a greater decline in aerobic fitness in boys than in girls (Ellingsen, 1998; Wedderkopp et al., 2004; Tomkinson & Olds, 2007a, b; Huotari et al., 2010), but only one study found the opposite to be the case (Moller et al., 2007). A study of Swedish adults has also found that aerobic fitness in men, but not women, was worse in 2000/2001 than in 1990/1991 (Ekblom et al., 2007). What could explain why boys have experienced a greater decline in aerobic fitness than girls during the last decade?

The percentage of Norwegian adults (Meyer & Tverdal, 2005) and adolescents (Groholt et al., 2008) who are overweight or obese has increased in recent decades. A study exploring changes in the BMI distribution among Norwegian adolescents from 1966/1969 to 1995/1997 found a larger increase in BMI among boys than girls (Bjornelv et al., 2009).

As changes in fatness could account for about 30–60% of the changes in performance on tests of aerobic fitness (Olds et al., 2007), the larger increase in overweight and obesity in boys than girls could be an important reason for the more pronounced performance decline in boys.

Decreased levels of physical activity could contribute to both the increase in overweight and the decrease in aerobic fitness. There is little data on secular trends in physical activity patterns, but a review of a number of smaller studies suggests that young people in the 2000s are less active than young people in previous decades (Dollman et al., 2005). Norwegian 9-year-old boys are more active than girls, but the difference in activity level between genders is reduced for adolescent 15-year-olds (Kolle et al., 2010). More Norwegian boys than girls use TV and computer games (Vaage, 2009). Higher use of computer games in boys than girls is also found in United Kingdom (Biddle et al., 2009). A longitudinal and higher secular increase in leisure-time computer use among US boys than girls has also been reported (Nelson et al., 2006). It is therefore possible that an increasingly sedentary lifestyle with extended use of computer and TV games in general affects boys to a greater extent than girls, resulting in reduced physical activity, more overweight and poorer aerobic performance.

Limitations of the study

Caution should be exercised when interpreting the findings of this study. First, this study was conducted on cohorts of adolescents at only two Norwegian schools. Therefore, the findings may not be considered representative of all Norwegian adolescents. Indeed, a change has occurred in these schools' study programs over the previous decades. One of the schools has developed a sports profile, and the number of included pupils following this study line has increased from 1% of all the included pupils in the 1980s to 12% in the 1990s and 16% in the 2000s. These pupils have better aerobic fitness than the other pupils (Table 3). On the other hand, the other school has, during the 2000s, developed a more vocational profile, recruiting pupils to vocational studies (7% of all included pupils in the 2000s). These pupils have poorer aerobic fitness (Table 3). By excluding the pupils following both the vocational and the sport lines, the difference in aerobic fitness from the 1980s to the 2000s would increase and be 12% and 7% boys and girls, respectively. There has been a change in the ethnic mix in Norway between 1969 and 2009, and it seems that ethnic Norwegians girls are more physically active than girls from ethnic minorities (Sagatun et al., 2008). However, in 2008/2009, the running times and the dropout rate for the few no-ethnic Norwegian pupils in the present study did not differ from the ethnic Norwegian pupils. Second, the number of dropouts has increased during the last decades. The least-fit pupils seem to be overrepresented in the dropout group, meaning that the reported decline in aerobic fitness seems to be underestimated. However, if the proportion of poor performers in the dropout group has not increased over time, our estimates of the secular changes have not been affected. Third, as we found no significant difference in the running tests between 1980s and 1990s, the decline in aerobic fitness seems to have occurred between the 1990s and 2000s. However, it should be noted that we have fewer data from the 1990s compared with the other decades. Finally, even though longer running tests such as the 3000 m run have high validity coefficients to maximal oxygen uptake (Unnithan et al., 1995; Tolfrey et al., 2009), it is recognized that running performance can be affected by factors such as the weather, practise, instructions and the pupils' efforts during the tests. The motivation to perform as well as possible may have changed during the decades, although there is no indication as to why this should be the case. Furthermore, there is no evidence of a systematic time-related bias in these factors.

Perspectives

The present study shows that aerobic fitness has decreased in a cohort of Norwegian pupils during recent decades. The greatest decline in aerobic fitness was found among the least-fit pupils, although a decline in aerobic fitness was also found for the fittest pupils. This confirms that findings in earlier studies in adults, pinpointing a larger gap between the most and least fit, may also be the case for Norwegian adolescents. The reduction in aerobic fitness seems to be larger in boys than in girls, and should be investigated more extensively as it would have consequences when planning target groups for physical activity interventions. As both increased body fatness and decreased aerobic fitness are associated with metabolic risks (Sacheck et al., 2010), it is important to encourage both a healthy body composition and physical fitness in young people.

Key words: physical fitness, running, boys, girls, pupils, change.

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