Cardiorespiratory fitness and body mass index values in nine-year-old rural Norwegian children

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Abbreviations:

VO_{2peak}	Peak oxygen uptake
BMI	Body mass index
PI	Ponderal Index
DXA	Dual X-ray absorptiometry
SPSS	Statistical Package for the Social Sciences
SD	Standard deviation
RER	Respiratory exchange ratio
HR_{peak}	Maximal heart rate
SV	Stroke volume
MIN	Minutes
KG	Kilograms
CM	Centimetres

Abstract

Aim: To describe cardiorespiratory fitness and body mass index (BMI) values in a representative population of nine-year-old Norwegian children in two rural communities and compare present values with previous findings. *Methods:* Two hundred and fifty nine 9-year-old children were invited, and 256 participated in this study. Maximal oxygen uptake was directly measured during a continuous progressive treadmill protocol. Body mass and height were also measured. *Results:* The mean±SD relative maximal oxygen uptake was 52.8±6.5 for boys and 46.9±7.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for girls. Eight percent of the boys and 16.8% of the girls were classified as overweight, and 1.6% of the boys and 6.9% of the girls as obese. Mean age, body mass, height and ponderal index were not significantly different between sexes. Girls had a higher BMI than boys (p=0.05).

Conclusion: Compared to earlier Norwegian studies, children's body mass index values seem to have increased substantially. This increase is most pronounced in girls. When assessing these differences using the ponderal index, this increase is less marked. Comparing maximal oxygen uptake data with that in earlier Nordic studies, there is no evidence that fitness has declined among nine-year olds. However, the limitations of the few earlier studies make reliable comparisons difficult.

Key words: BMI, children, fitness, VO_{2peak}, overweight

Introduction

Cardiorespiratory fitness is established as an independent risk factor for clustering of cardiovascular disease risk factors in children [1], and there is a growing concern over an apparent decline in children's cardiorespiratory fitness [2]. However, few studies of population-representative samples include *directly* measured maximal oxygen uptake (VO_{2peak}) measures. Therefore, it may be argued that the existing research literature does not permit confident conclusions to be drawn regarding secular trends in children's cardiorespiratory fitness. It is well documented that childhood overweight and obesity are both increasing rapidly throughout the world [3]. Furthermore, since 1975 mandatory body mass and height measurements have been discontinued in Norwegian schools. Therefore, few data exists on children's body mass and height status since then. However, a recent study in Bergen, Norway, indicates an increase in children's weight-for-height over the last three decades [4]. Due to their public health importance [5], trends in children's body mass and height need to be closely monitored.

It is important to establish accurate baseline data on children's fitness and fatness levels. To do so, population-representative samples are required. This paper's aim, therefore, is to describe cardiorespiratory fitness and body mass index (BMI) values in a population-representative sample of nine-year-old healthy Norwegian children in two rural communities. In addition, the paper compares present values with previous findings.

Methods

All fourth graders (9.3±0.3 years, *n=259*) in two consecutive years (born 1995 and 1996) in two rural elementary schools in Sogn og Fjordane County, western Norway, were invited to participate in a two-year intervention study, including 60 minutes of physical activity each school day. The communities, Sogndal (population 6,836) [6], and Førde (11,327), are 105 kilometres apart. All VO_{2peak} tests were performed at the Human Physiology Laboratory, Sogn and Fjordane University College, in Sogndal. The children from Førde also had their body mass and height measured there. For the Sogndal group, body mass and height were measured at their school. The study was approved by the Regional Committees for Medical Research Ethics and the Norwegian Data Inspectorate. Written, informed consent was obtained from the children's parents or guardians. Participation was voluntary and a child could withdraw from the study at any time, without giving reasons. Data were collected in September–October in both 2004 and 2005.

BMI

The same nurse carried out all body mass and height measurements. Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Seca 770, SECA GmbH, Hamburg, Germany) with children wearing light indoor clothing, for which an allowance of 0.2 kg was subtracted from results. Height, without stretch, was measured to the nearest 0.1 cm, with children standing shoeless facing forward. BMI ($kg \cdot m^{-2}$) was analyzed using the cut-points published by Cole et al. [5]. Their table includes cut off points for every 0.5 year of age and these values differ substantially from those for adults. For nine-year olds the cut off points for overweight are 19.1 (both sexes) and 22.8 for obesity (both sexes). Ponderal Index (PI, $kg \cdot m^{-3}$) was also analysed.

Cardiorespiratory fitness

VO_{2peak} was measured with a MetaMax I analyzer (Cortex Biophysics GmbH, Leipzig, Germany) using their MetaSoft 1.11.05 software without curve smoothing. The MetaMax uses a mixing chamber, and ventilation is measured with a triple-V sensor on the expired air. The analyzer was fully calibrated according to the manufacturer's guidelines each test day. Additionally, the barometric pressure in the analyzer was calibrated against values from the local weather station. Between each test, calibration of volume and a two-point gas calibration were performed, as well as a measurement of ambient air.

The child and parents/guardians were asked if the child had any disease or condition that could be an obstacle to cardiorespiratory fitness testing. In case of doubt a doctor was consulted. The child and parents/guardians were also informed of test procedures before testing. All children were instructed not to eat for two hours prior to testing, and to engage in normal activity the day before the test and on the test day. Before testing, a Polar heart rate (HR) monitor (Polar OY, Kempele, Finland) was fitted to the chest by an elastic strap. The monitor registered HR throughout testing. Subjects mounted a treadmill (PPM 55, Woodway GmbH, Germany), and began walking slowly (1-2 $km \cdot h^{-1}$). As a subject's technique improved, speed was increased and safety procedures on how to stop the test by jumping off the treadmill or pushing the stop button were rehearsed. A face mask (Hans Rudolph Inc, Shawanee, USA) was put on, controlled for air tightness and connected to an oxygen analyser. Testing started with five minutes walking at 5 $km \cdot h^{-1}$ at an inclination of 5.3%, followed by two minutes jogging at 7 $km \cdot h^{-1}$. Depending on how subject were doing, speed was either maintained or increased by 1 $km \cdot h^{-1}$ every minute, until a maximum speed of 10 $km \cdot h^{-1}$. Thereafter, workload was increased through inclination, which was raised by 1.5% each minute until exhaustion. VO_2 was measured at 10-second intervals, and VO_{2peak} was defined as the mean of the six highest successive measurements. All tests were carried out by the same two test leaders. One monitored safety and urged subjects on, trying to ensure they gave maximum effort. The second controlled measurements and treadmill speed, collaborating with the other on when and how much to increase load. Subject's parents/guardians were encouraged to observe testing. The primary consideration for an acceptable test was that the subjects demonstrate signs of intense effort and clear symptoms of fatigue. Test leaders discussed several subjective criteria after each test; hyperpnoea, unsteady running pattern, and verbal and body language clearly indicating that the child wanted to stop testing, despite repeated strong oral encouragement. Additionally, the objective criteria of respiratory exchange ratio (RER) (≥1.0) and peak heart rate (HR_{peak}) (≥ 200 $beats \cdot min^{-1}$) were taken into consideration. The MetaMax 1 system used in this study was validated against the Douglas Bag technique [7], regarded as the gold standard. The validation showed a systematic overestimation by the MetaMax. This trend was confirmed in later validation tests (data not shown). Hence, the data presented are adjusted hereafter. The VO_{2peak} is presented in absolute values ($l \cdot min^{-1}$), relative values ($ml \cdot kg^{-1} \cdot min^{-1}$) and scaled as a function of body mass$^{0.67}$ as suggested by Åstrand et al, 2003 [8].

Statistics

Data were analysed using SPSS version 15.0 (SPSS Inc, Chicago, Illinois), and tested for normality (Sharpiro-Wilk). Results are presented as mean±SD or percentiles. For table 1, differences between group means were tested with General Linear Model using sex and geographical place as fixed factors. For table 2, differences between group means were tested with T-tests. Significance level was set to $p<0.05$.

Results

A total of 259 children were invited to participate, corresponding to all children born in 1995 and 1996 attending the two schools involved. Three children had a chronic disease; all others were apparently healthy and able to participate. Twelve children were unable or unwilling to travel to the research centre, but their body mass and height data were collected. Of the 242 cardiorespiratory fitness tests, 17 were rejected because of either sickness or injury on test day (n=1), poor compliance (n=4) or equipment failure (n=12). In total, body mass and height data were collected for all 256 children, and 227 children (87.6%) successfully completed VO_{2peak} testing. Of those that successfully completed the VO_{2peak} testing, 90.3% of the children reached a RER ≥1.0 and/or HR_{peak} ≥200. Only six children had a *combination* of RER < 1.0 and HR_{peak} ≤200. These six, however, clearly exerted maximum effort based on subjective criteria.

Between those completing and not completing VO_{2peak} testing there was no statistical difference in body mass and height. As we *also* had high participation and completion rates, this sample could be considered to be population-representative for nine-year-old children in the two communities where testing was performed. Furthermore, except for relative (p=0.047) and scaled VO_{2peak} (p=0.015) for boys, there were no significant differences in any of the variables between the two rural communities. Hence, their data were combined for descriptive purposes.

Descriptive characteristics of subjects (mean±SD) are presented in Table 1. Mean age, body mass, height and PI were not significantly different between sexes. Girls had a slightly higher mean BMI (p=0.05) than boys. Boys had significantly higher VO_{2peak} ($p<0.001$) than girls, regardless of how it was expressed. In absolute terms the difference was 10.1% (1.68±0.20 vs 1.51±0.21 $l \cdot min^{-1}$). When expressed relative to body mass there was an 11.2% difference (52.8±6.5 vs 46.9±7.2 $ml \cdot kg^{-1} \cdot min^{-1}$). When allometrically scaled, the difference was 11.1% (165.0±15.9 vs 146.7±17.7 $ml \cdot kg^{-0.67} \cdot min^{-1}$). The mean±SD VO_{2peak} relative to body mass in this study was 52.8±6.5 for boys and 46.9±7.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for girls. We defined VO_{2peak} as the mean of the six highest 10-second successive measurements. When we examined the mean of the three highest 10-second successive measurements, we found a 1.6 % higher VO_{2peak} (boys 53.6±6.5, girls 47.7±7.3). The results of the single highest peak measurement (from one 10-second period), showed a 2.9 % higher VO_{2peak} (boys 54.3±6.6, girls 48.3±7.4).

Eight percent of the boys and 16.8% of girls had BMI scores that classified them as overweight, and 1.6% of boys and 6.9% of girls were obese. Of the 20 children with highest BMI (>21.5 $kg \cdot m^{-2}$), 15 were girls. Table 2 shows children with normal BMI versus overweight and obese children grouped together. The latter group had significantly higher values ($p<0.05$) in all variables, except height for boys (p=0.23). To give a better understanding of the data spread, Table 3 shows the distribution of the variables in percentiles. There was a substantial variance in the distribution within both sexes in all variables, and in all variables girls had a greater difference between the 90th and 10th percentiles compared to boys. The biggest percentage difference between the 90th and 10th percentiles for boys and girls was in body mass, 33.6 and 40.3% respectively. The difference between the 90th and 10th percentiles was significantly less ($p<0.05$) when expressing VO_{2peak} to body mass as scaled ($ml \cdot kg^{-0.67} \cdot min^{-1}$) compared to relative ($ml \cdot kg^{-1} \cdot min^{-1}$), 21.3 and 29.1% respectively for boys. For girls, it was 25.5 and 32.1%, respectively.

Table 1. Participant descriptive characteristics

	Boys				Girls				P for sex	P for group
	Sogndal		Førde		Sogndal		Førde			
	n	Mean±SD	n	Mean±SD	n	Mean±SD	n	Mean±SD		
Age (years)	63	9.2±0.3	62	9.2±0.3	62	9.2±0.3	69	9.3±0.3	0.103	0.880
Body mass (kg)	63	32.2±5.2	62	32.2±5.4	62	32.9±7.7	69	33.1±7.7	0.368	0.540
Height (cm)	63	137.8±5.5	62	137.5±5.4	62	136.7±6.5	69	136.6±6.1	0.281	0.418
Body mass index ($kg \cdot m^{-2}$)	63	16.9±2.1	62	16.9±2.3	62	17.5±2.9	69	17.6±3.3	0.116	0.840
Ponderal index ($kg \cdot m^{-3}$)	63	12.3±1.5	62	12.3±1.5	62	12.8±1.9	69	12.9±2.4	0.054	0.984
HR_{peak} ($beats \cdot min^{-1}$)	60	202.5±6.4	51	203.7±7.3	53	206.1±6.7	59	204.9±8.2	0.014	0.996
VO_{2peak} ($l \cdot min^{-1}$)	60	1.65±0.21	51	1.72±0.19	57	1.49±0.21	59	1.52±0.21	0.000	0.115
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	60	51.7±6.7	51	54.1±6.0	57	46.1±7.3	59	47.6±7.3	0.000	0.026
VO_{2peak} ($ml \cdot kg^{-0.67} \cdot min^{-1}$)	60	161.7±16.5	51	169.0±14.4	57	144.7±17.5	59	148.7±17.9	0.000	0.011
Running time (min)	60	11.21±1.36	51	11.80±1.38	56	10.38±1.43	58	10.45±1.08	0.000	0.062

Table 2. Children with normal BMI versus children defined as overweight and obese

	Boys					**Girls**				
	Normal BMI		Overweight or obese			Normal BMI		Overweight or obese		
	n	Mean±SD	n	Mean±SD	*p*	n	Mean±SD	n	Mean±SD	*p*
Body Mass (kg)	113	31.1±4.0	12	42.0±5.7	p<0.001	100	30.0±4.2	31	42.9±8.1	p<0.001
Height (cm)	113	137.5±5.4	12	139.4±4.8	0.233	100	136.0±6.2	31	138.7±6.1	0.035
Body Mass Index ($kg \cdot m^{-2}$)	113	16.4±1.5	12	21.6±2.3	p<0.001	100	16.1±1.4	31	22.1±2.8	p<0.001
Ponderal index ($kg \cdot m^{-3}$)	113	11.9±1.1	12	15.5±1.7	p<0.001	100	11.9±1.1	31	16.0±1.8	p<0.001
VO_{2peak} (L min-1)	99	1.66±0.19	12	1.89±0.19	p<0.001	90	1.48±0.20	26	1.61±0.20	0.005
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	99	53.7±6.1	12	45.3±4.3	p<0.001	90	49.3±5.6	26	38.7±6.2	p<0.001
VO_{2peak} (ml $kg^{-0.67}$ min^{-1})	99	166.3±15.9	12	154.8±12.2	p<0.017	90	151.0±15.6	26	131.8±16.2	p<0.001
HR_{peak} ($beats \cdot min^{-1}$)	99	203.1±6.8	12	202.4±7.1	0.733	87	205.7±7.1	25	204.7±8.8	0.555
Running time (min)	99	11.59±1.38	12	10.60±1.26	0.020	88	10.73±1.17	26	9.35±0.92	p<0.001

Table 3. Variables in percentiles

	Percentiles								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Boys									
Body mass (kg)	25.9	28.0	29.2	30.4	31.4	33.0	33.9	35.6	39.0
Height (cm)	130.8	132.5	134.4	136.2	137.5	138.8	141.2	142.8	144.9
Body mass index ($kg \cdot m^{-2}$)	14.5	15.0	15.7	16.1	16.5	17.1	17.6	18.6	19.4
Ponderal index ($kg \cdot m^{-3}$)	10.6	11.0	11.3	11.8	12.1	12.5	12.9	13.4	14.2
VO_{2peak} ($l \cdot min^{-1}$)	1.43	1.53	1.56	1.60	1.67	1.73	1.81	1.87	1.95
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	44.3	47.1	49.7	50.9	52.8	54.3	56.6	58.1	61.1
VO_{2peak} ($ml \cdot kg^{-0.67} \cdot min^{-1}$)	146.7	150.4	155.8	160.6	164.3	169.9	173.5	179.5	186.4
Girls									
Body mass (kg)	25.2	27.0	28.3	29.8	31.4	32.9	35.2	38.2	42.2
Height (cm)	128.9	131.1	133.6	135.0	136.3	138.0	139.5	142.2	145.0
Body mass index ($kg \cdot m^{-2}$)	14.4	15.2	15.6	16.0	16.7	17.3	18.5	19.7	21.8
Ponderal index ($kg \cdot m^{-3}$)	10.7	11.1	11.3	11.7	12.4	12.9	13.5	14.7	15.5
VO_{2peak} ($l \cdot min^{-1}$)	1.25	1.31	1.37	1.43	1.47	1.54	1.62	1.69	1.80
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	37.8	40.6	43.4	45.2	47.8	49.7	51.8	53.1	55.7
VO_{2peak} ($ml \cdot kg^{-0.67} \cdot min^{-1}$)	125.3	132.5	137.2	140.9	147.1	151.4	156.6	162.9	168.1

Table 4. Body mass, height and BMI for boys and girls from Oslo (Bruntland et al., 1980), Bergen (Waaler, 1983) and the present study

Boys	Oslo				Bergen	SIS
Year	**1920**	**1950**	**1970**	**1975**	**1971–74**	**2004/5**
Body mass (kg)	25.3	30.1	29.6	29.5	30.0	32.1±5.2
Height (cm)	126.1	134.5	135.5	135.5	135.4	137.7±5.4
Body mass index (kg·m^{-2})	15.9	16.4	16.2	16.1	16.4	16.9±2.2
Ponderal index (kg·m^{-3})	12.6	12.4	11.9	11.9	12.1	12.3±1.6

Girls	Oslo				Bergen	SIS
Year	**1920**	**1950**	**1970**	**1975**	**1971–74**	**2004/5**
Body mass (kg)	24.6	29.6	29.6	29.2	28.7	33.0±7.7
Height (cm)	125.3	133.3	133.8	135.0	133.9	136.6±6.2
Body mass index (kg·m^{-2})	15.7	16.7	16.5	16.0	16.0	17.6±3.1
Ponderal index (kg·m^{-3})	12.5	12.5	12.4	11.9	12.0	12.9±2.2

Oslo: boys and girls mean age 9 years (range 8.5.0–9.5) (Bruntland et al., 1980). Comment on the Oslo numbers: from 1920 to 1950 *all* school children in Oslo were measured. In 1970 1/3 of the population was measured, and finally, in 1975, a randomly selected 10% of the population was measured. Bruntland et al. (1980) observed a marked increase in body mass, height and BMI from 1920 to 1950 for both sexes. Between 1950 and 1975 the body mass was stable around 30 kg for both sexes, while height increased moderately (more pronounced in girls), resulting in a small decrease in BMI (more pronouncedly in girls). The measurements in Oslo were carried out in September and October. The Oslo children's reported mean age was 9 years. This is explained by the authors in this way; *what we refer to as 9-year-old girls are between 8.5 and 9.5 years old*. **Bergen:** boys (n=351) and girls (332) age 9.0 (8.5.0–9.5) years (Waaler, 1983). **SIS:** The Sogndal Intervention Study. Boys (n=125) age 9.2±0.3 y and girls (n=131) age 9.3±0.3 y. SD or 95 CI is not reported in Bruntland et al. (1980) and Waaler (1983).

Discussion

This paper's aim is to describe cardiorespiratory fitness and BMI values in a population-representative sample of nine-year-old healthy children (*n=256*) in two rural Norwegian communities. In addition, the paper compares present values with previous findings.

There are two main findings. Firstly, compared to earlier Norwegian studies [10–12], children's BMI values seem to have increased substantially, most pronouncedly in girls. When assessing these differences using the PI, this increase is less marked. Secondly, when comparing VO_{2peak} data to that in earlier Norwegian studies [17–19], there is no evidence, at least in this group, of a negative trend in fitness among nine-year olds. However, the limitations of the few earlier studies make reliable comparisons difficult. Study strengths were *direct* measurement of VO_{2peak}, and high participation and completion rates making this a representative population of the nine-year olds in these two rural communities. Moreover, the high mean HR_{peak} (204.3±7.2) suggests that a reliable VO_{2peak} was obtained. There are limitations regarding the generalization of these results, and therefore data from this study may not be representative for the whole country. Also, pubertal status level was not assessed. Especially for girls, this factor cannot be excluded, as some girls tested may have reached puberty.

BMI

BMI is not a direct measurement of body fatness and does not necessarily reflect body composition, but is still widely used as a surrogate for adiposity and as a method to define overweight and obesity among children. Higher BMI during childhood is associated with an increased risk of CVD in adulthood [9]. In this study, 9.6% of boys and 23.7% of girls were defined as overweight or obese. For girls, this number is similar to that reported from a recent study in Oslo, Norway where the body mass and height of 3,453 eight-year-old children were measured [10]. For overweight and obese boys, the value from the Oslo study (20 %) was considerably higher than the value from this study.

Every fifth year from 1920 to 1975, representative body mass and height values in Oslo children were measured [11] (Table 4). Compared to boys in 1975, boys in this study are 2.6 kg heavier and 2.2 cm taller, resulting in 0.8 $kg \cdot m^{-2}$ higher BMI. Also, the girls have higher values in body mass (2.8 kg), height (1.7 cm) and BMI (1.6 $kg \cdot m^{-2}$), equivalent to a 10% higher BMI. Between 1971 and 1974, 3,068 children in Bergen, were examined for body mass and height, including 351 nine-year-old boys and 332 nine-year-old girls [12] (Table 4). These data are still used as the national reference for Norwegian children, aged 3–17 years. The nine-year olds in Bergen had values similar to those registered in Oslo in 1970 and 1975. When considering these data, one must take into account that the children's mean ages vary slightly. Children in this study had mean ages of 9.2±0.3 (boys) and 9.3±0.3 years (girls), while the Oslo and Bergen children's mean age was set at 9.0 years, including children between the ages of 8.5 and 9.5. For comparison, precise mean age is important because children's bodies change as they grow and they normally gain several kilos yearly at this age. Still, BMI seems to have been a substantially increased over the last 30–35 years.

When considering the *body mass-to-height* indices BMI and PI in analyses of secular trends, one must take into account that BMI is inversely proportional with height squared, while PI is inversely proportional with height cubed. According to Valdez et al. [13] PI could be a more accurate reflection of adiposity in children of varying height. This is supported by Lebiedowska et al. [14] who point out that the use of BMI is justified in adults, because an increase in body dimensions can occur in only two dimensions in adults, whereas growth can occur in three dimensions in children. When applying PI to compare changes in body mass and height in children from this study with those children from 1975 in Oslo, the difference is less pronounced. For girls, BMI increased by 10.0% while PI increased by 8.4%. For boys, BMI increased by 5.0% while PI increased by 3.4%. When assessing secular trends in body mass and height combined, one should therefore consider PI.

Cardiorespiratory fitness

VO_{2peak} is widely recognised as the best single measure of the cardiorespiratory system's functional capacity. The mean±SD VO_{2peak} relative to body mass in this study was 52.8±6.5 for boys and 46.9±7.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for girls. These results agree with findings in the literature. Boys relative VO_{2peak} values using a treadmill at this age are approximately 52 $ml \cdot kg^{-1} \cdot min^{-1}$, with girls' values being slightly lower [15]. When comparing our results with those of earlier Nordic studies, using direct measurements [16–18], the relative VO_{2peak} for nine-year olds seems to have remained relatively stable over time. However, several factors make it problematic to compare VO_{2peak} results of this and past studies. Earlier data, hampered by selection and population bias, often reflects VO_{2peak} in one location in those children who were eager for testing or those chosen to be tested. Also of concern are relatively few subjects in past studies. For example, Åstrand [16] tested only nine boys and no girls in this age group. A selection would usually mean that the least fit dropped out, which could indicate that population values in older studies might be lower. It should be pointed out that Åstrand probably did not intend to present representative data. Fredriksen et al. [19] point out that none of the three earlier studies reported the percentage of the target population that was tested. Fredriksen et al. [19] tested 12 boys (8.9±0.27 y) and 14 girls (8.8±0.45 y) in Oslo. This corresponds to approximately 70% of those asked to perform the test. Compared to our results, Oslo boys had a markedly higher VO_{2peak} (57.6±6.2 $ml \cdot kg^{-1} \cdot min^{-1}$), while girls had approximately same values (47.5±6.2). However, because of the small number of subjects and likely selection bias, it is difficult to assess if there was a change in fitness over time. Furthermore, earlier studies did not report the distribution (e.g. percentiles) of results. This is important because the mean does not show the complete data spread and can mislead when considering secular trends. To our knowledge, the only studies investigating secular trends in nine-year olds fitness, including the distribution of data, are Wedderkopp et al. [20] and Møller et al. [21]. Wedderkopp et al. [20] showed a decrease in nine-year-old Danish boys' fitness from the mid1980s to the late1990s, but no difference was observed for girls. Møller et al. [21] also tested nine-year-old Danish children, from the late1990s to the mid 2000s. They showed a negative trend in girls' fitness and no change in boys' fitness. Both studies showed a polarization, meaning that the difference between children with high and low fitness increased significantly between testing points. We have also chosen to present our data in percentiles (Table 3), allowing for comparison with past and future studies.

In conclusion, the data indicate an increase in Norwegian nine-year olds BMI over the last 35 years. When applying PI to express changes in body mass and height, the difference is less pronounced, but still significant. When assessing secular trends in body mass and height combined, one should consider PI. Compared to earlier Norwegian studies, this study shows no evidence that there is a negative trend in fitness (VO_{2peak}) among nine-year olds. However, this study suggests that one should be careful when comparing VO_{2peak} data with that of earlier studies, due to the limitations of earlier studies.

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