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Maximum Aerobic Power and Body Composition During the Puberty Growth Period: Similarities and Differences Between Children of Two European Countries

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Abstract. This report gives results of a longitudinal study of two cohorts of school children in Norway and West-Germany. The rate of growth in body size and composition is identical for the two samples, but different for the two sexes, and follows closely the trend of growth which has been found for North-Europeans in general.

Despite of this similarity in growth of anatomical variables the Norwegian children appeared to be superior in their maximum aerobic power at all comparable ages and in both sexes. The differences between means in maximal oxygen uptake varies somewhat with age and sex and are in the range of 5–10%.

It is suggested that the mean differences between Norwegian and German children in their exercise and cardio-vascular fitness are brought about by a more physically active behavioural pattern of living in Norway.

Key words: Exercise – Fitness – Body composition – Growth – Longitudinal study

Introduction

One aspect of the rapid changes in the way of living today is the decreased need for physical exertion which is a threat to maintenance of a good level of health in general, as well as a risk in relation to cardio-vascular health (Thorén et al. 1973). Although the alteration in human behaviour in the direction of a more sedentary living pattern etc. affects all age groups, and is operative almost through the whole life-span, the effect in the formative years of childhood and adolescence is of particular importance. The needs for research into the problems of the interaction between physical activity, performance and health during growth are generally recognized and has been recommended by an expert group set up at the initiative of the World Health Organization (WHO Technical Report 1977).

The effect of various types and intensities of physical activity programs upon bodily structures and functions has been experimentally studied (Åstrand et al. 1963). However, in order to describe and understand how and to what extent the complexity of all the environmental and behavioural conditions interacts and shapes the body, its function and health, an epidemiological approach becomes necessary. Population studies aimed at describing differences and similarities in the growth of body size, composition and performance in response to real life pressures and conditions have been performed as a German-Czechoslovakian-Norwegian undertaking coordinated by the WHO in all three countries, and some methodological evaluations and results have been published (Andersen et al. 1971, 1974, 1978). This paper describes the results of longitudinal studies on school children living in two rural communities in Norway and West-Germany.

In addition to the object of establishing reference data with regard to maximum aerobic power and cardiovascular function during growth, the study was also set up to determine to what extent the developmental process shows similar or different patterns in Norway and West-Germany.

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Table 1. Body size and composition of Norwegian children

Age, years		*n*	Stature, cm	T.B.M., kg	L.B.M., kg	Body fat, %
Boys	8.4	29	130.8± 4.47	27.4±3.92	22.0±2.44	19±3.6
	9.4	29	136.6± 4.80	31.0±4.52	25.3±3.11	19±3.7
	10.4	31	141.2± 5.00	33.9±5.03	26.8±2.94	20±4.2
	11.4	29	145.8± 5.68	36.8±6.58	29.1±3.65	19±4.4
	12.3	30	150.4± 6.00	40.3±6.90	32.2±4.26	19±3.9
	13.3	29	157.2± 7.32	44.1±7.52	35.8±5.03	18±4.5
	14.5	27	164.4± 7.38	50.0±7.87	41.9±5.62	16±4.0
	15.3	28	171.1± 6.70	56.2±7.55	45.8±5.01	17±4.7
Girls	8.2	33	130.1± 4.52	26.7±3.46	20.5±2.17	23±2.9
	9.3	33	136.1± 5.05	30.8±4.09	23.8±2.64	23±3.0
	10.3	34	141.3± 5.52	34.4±4.56	25.8±2.88	24±3.5
	11.2	34	145.5± 10.31	38.1±6.45	28.5±3.75	24±3.5
	12.2	34	152.5± 6.54	42.7±7.16	32.0±4.42	24±3.5
	13.3	33	158.6± 6.22	48.6±8.25	37.6±4.89	22±4.6
	14.2	32	162.5± 5.60	53.4±8.23	39.7±4.30	25±4.9
	15.2	33	164.9± 5.63	56.6±7.83	40.2±4.45	29±5.7

(Mean ± SD; T.B.M. = Total body mass; L.B.M. = Lean body mass)

Table 2. Body size and composition of German children

Age, years		*n*	Stature, cm	T.B.M., kg	L.B.M., kg	Body fat, %
Boys	12.7	28	152.7± 8.92	40.9± 6.08	32.5±4.55	20±2.8
	13.7	27	159.7± 10.20	46.2± 7.62	37.5±6.27	19±3.6
	14.7	26	168.2± 9.53	54.2± 8.14	44.3±6.97	18±3.5
	15.8	27	172.9± 10.17	58.8± 8.80	48.3±7.69	18±3.7
	16.7	27	176.1± 9.39	62.8± 9.55	52.2±8.07	17±4.2
	17.8	26	177.5± 8.26	65.6± 8.75	56.9±7.56	13±2.4
Girls	12.7	27	157.1± 7.11	46.9± 8.33	34.4±4.74	26±4.2
	13.7	24	161.9± 7.08	51.4± 9.14	39.6±5.15	22±5.1
	14.7	22	164.2± 6.41	55.2± 9.85	40.0±4.78	27±5.5
	15.7	23	165.3± 5.67	57.6± 9.88	41.3±4.68	28±5.6
	16.7	18	166.5± 4.97	59.8± 11.50	43.2±4.84	27±6.6
	17.8	19	166.7± 4.63	59.5± 10.38	45.9±4.78	22±5.7

(Mean ± SD; T.B.M. = Total body mass; L.B.M. = Lean body mass)

Material and Methods

1. Study Design

Two cohorts of children living in similar rural settings in Norway and West-Germany were selected for annual testing. The project started in 1969 in Norway as a cross-sectional study of the total school-children population in the community in Lom. This community was selected because the size of the population was small enough to allow for physiological measurement of the total number of school-children by the resources available, as each age class numbered about 70 children. Furthermore the socio-economic and living conditions differed only slightly between the families, the nutritional status was good, and few people migrated. The people made a living from small farming and tourism: some were engaged in various types of community services. The industrial activity in the community was limited to some small workshops.

The small farms were scattered around a community center, where there was a main school which was attended by all older school-children: those living at the periphery were transported to and from the school by buses. The youngest children attended some local schools in the periphery. The youngest age-class of children—which aged about 8 years at the first test in 1969—was retested the subsequent nine years by annual measurements which took place in September/October each year.

The longitudinal study of the German school-children started in 1974 with measurements of a total age class of school-children who at that time were about 12 years old, to match in age the children being investigated in Norway. The community of Fredeburg was selected because its population was similar to that in Lom with regard to size, socio-economic and living conditions. Although the geography of Fredeburg resembled that at Lom, there were characteristic climatic differences due to the fact that Lom is situated 2000 km north of Fredeburg which makes for differences in the length of the various seasons. The facilities and possibilities for sport and outdoor recreational activities did not differ greatly between the two different communities. The winter at Fredeburg was short compared to Lom but gave the children ample opportunities for skiing and other winter sports.

2. Subjects

Tables 1 and 2 list the number and physical characteristics of the children tested each year. There are some variations in the number of children from year to year due to sickness and to some minor migration of children. Some of the German girls aged 16 and 17 years refused to take part in the programme. The overall compliance was considered very good in this study.

3. Methods

A German-Czechoslovakian-Norwegian research team was organized under the auspices of the World Health Organization and performed throughout the whole project period the annual testing programme by establishing field laboratories in the respective communities (Andersen et al. 1971, 1974, 1978). The anthropometric measurements followed closely the criteria for the IBP-methods (Weiner and Lourie 1969). The skinfolds were measured using a Harpenden skinfold caliper (Tanner and Whitehouse 1955) in Norway and a Holtain caliper in Germany. These two calipers give similar readings (Rehs et al. 1975). Fat percent was calculated according to Pařizková (1977) and Rehs et al. (1978). The physiological test programme included bicycle ergometrics with measurements of maximal oxygen uptake, according to previous given instructions (Andersen et al. 1971). Ordinary statistics for describing variations were employed by calculation of means and standard deviations. The shape of the distribution was evaluated on basis of the calculations of skewness: a skewness index between −1 and +1 was taken as indicating normal distribution. Statistical significance between means were tested by Student's *t*-test.

Results

1. Growth in Body Size

The statistics for stature and total body mass are given separately for boys and girls in Tables 1 and 2. Except for a few ages, the data for stature as well as for total body mass (body weight) were found to be normally distributed. The growth curves were closely similar for the two countries and no significant differences in height exist at any comparable age. The total body mass also increases in close linear fashion to age during the age span from 8 to 14 years. The girls are slightly heavier at each age than the boys during the span from 11 to 14 years, then the boys become heavier than the girls. The sex difference in weight before age 14 are brought about by the girls greater fatness, as apparent from the calculation of lean body mass (L.B.M.). The Norwegians and Germans are similar in growth of body weight, and there are no significant differences at any age.

Table 3. Annual increment in body size of Norwegian children

Age, years		n	Stature, cm	T.B.M., kg	L.B.M., kg
Boys	8–9	29	5.8± 0.89	3.6± 1.05[a]	3.3± 0.73
	9–10	29	4.8± 0.78	3.2± 1.08	1.7± 0.46
	10–11	28	4.8± 0.77	3.0± 1.77	2.6± 1.11
	11–12	28	4.4± 1.30	3.5± 1.33	2.8± 1.09
	12–13	29	6.9± 2.00	4.2± 1.80	3.9± 1.68
	13–14	27	6.8± 1.96	5.4± 1.50	5.7± 2.03
	14–15	25	6.6± 2.37	6.4± 1.89	4.6± 1.86
Girls	8–9	33	5.9± 1.03	4.2± 2.06[a]	3.2± 1.29[a]
	9–10	33	5.5± 1.06	3.7± 1.65	2.3± 0.91
	10–11	34	5.5± 1.62	3.7± 2.60[a]	2.8± 1.71
	11–12	34	5.5± 1.26	4.6± 1.72	3.5± 1.41
	12–13	33	6.6± 2.34	5.9± 2.13	5.6± 1.73
	13–14	32	3.6± 2.24	4.6± 2.86	2.0± 1.66
	14–15	32	2.3± 1.59	3.1± 2.61	0.5± 1.84[a]

(Mean ± SD; T.B.M. = Total body mass; L.B.M. = Lean body mass)

[a] Skewness index >+1 or <−1

Table 4. Annual increment in body size of German children

Age, years		*n*	Stature, cm	T.B.M., kg	L.B.M., kg
Boys	12–13	27	7.0± 2.77	5.3± 2.53	4.9± 2.23
	13–14	26	7.7± 1.62	7.3± 2.55	6.2± 2.35
	14–15	26	5.9± 2.18	5.6± 2.24	5.0± 1.99
	15–16	27	3.1± 2.08	4.1± 3.39	3.9± 2.64[a]
	16–17	26	1.9± 2.08[a]	3.0± 3.32[a]	4.9± 3.44[a]
Girls	12–13	24	4.5± 2.20	4.6± 3.32	5.2± 2.11
	13–14	22	2.8± 1.77[a]	4.1± 2.39	0.5± 1.55
	14–15	22	1.4± 1.61[a]	2.3± 3.71	1.4± 1.84
	15–16	18	0.4± 1.17[a]	1.6± 2.56	1.2± 1.97
	16–17	17	0.5± 0.74[a]	0.2± 2.55	3.0± 1.45

(Mean ± SD; T.B.M.= Total body mass; L.B.M.= Lean body mass)
[a] Skewness index > + 1 or < − 1

2. Body Composition

The data for lean body mass (L.B.M.) and percentage of body fat were found based on skewness and curtosis indices to be normally distributed except for a few ages. The growth curves for boys and girls with regard to L.B.M. are closely linear up to age 14 years, and up to that age no significant sex differences appeared. At the age of 14 years a sex separation took place: from then on L.B.M. of boys becomes greater. The growth curves for Norwegian and German children were almost identical.

The annual variation in percentage of body fat showed, that the averages for girls were higher at each age than for the boys, and these differences were statistically significant throughout all years of growth. The variation from year to year for percentage of body fat were somewhat different in the two sexes. The girls had an almost constant body fat percentage until age 14, with exception of a possible drop at the age of 13 years which was observed in the Norwegian as well as in the German girls. However, after age 14 years an increase in percentage of body fat was seen; this reached a peak at about the age of 15/16 years and then dropped again.

The boys exhibited a somewhat different body fat curve during growth. The percentage of body fat remained constant up to an age of 12 years, then a significant decrease took place. It is thus clear that the boys' greater body weight after the age of 13/14 years depends on both a greater increase in L.B.M. and a relatively smaller content of body fat as compared to the girls. It was readily seen that only small and insignificant differences exist between German and Norwegian children with regard to growth in percentage of body fat.

3. The Rate of Growth

The annual increment in body size was calculated (Tables 3 and 4). The peak values are reached at age 12 years for the girls and one to two years later for the boys. At an age of 16 years the growth in body size was almost finished for the girls, while the boys at this age are still growing. There are some differences in the rate of growth when Norwegian and German children are compared, but these are statistically insignificant.

4. Body Shape

The geometry of the human body is extremely complex and is difficult to measure, but the height/weight relationship gives a crude picture of body shape. There appear to be no sex differences in the crude measure of body shape in the youngest children. At an average height of about 140 cm (corresponding to a chronological age of 11 years) a sex separation took place. This age corresponds to the beginning of puberty in girls. However, when means of lean body mass are considered, it was readily seen that the sex differences disappear. The greater body weight of girls after the age of 11 years is thus attributed to a greater deposition of body fat.

5. The Energy Requirement for Bicycling at Submaximal Work Rates

The oxygen uptake is a measure of the energy requirement, and statistical data giving means, standard deviations and shape of distribution have been calculated for the two subsequent periods with bicycling at submaximal rates. The calculation revealed some unsystematic and mostly statistically insignificant variation with age and sex, but the Norwegian and German

Table 5. Oxygen uptake ($l \cdot min^{-1}$ STPD) relation to submaximal work (mean figures)

Work output watt	Norwegian		German	
	Boys	Girls	Boys	Girls
50	0.90	0.82	0.78	0.88
75	1.25	1.26	1.18	1.23
100	1.61	1.62	1.58	1.63
125	1.96	1.97	1.99	2.02
150	2.32	2.35	2.39	2.40

children were almost identical with regard to efficiency in pedalling a bicycle.

The means for oxygen uptake at various levels of submaximal work are listed in Table 5. No sex or national differences were found. The variation coefficients around these means ranged from 13.5 to 18%, the "all over" mean figure being about 16%.

6. The Maximal Oxygen Uptake

a) Distribution at Each Age. Mean values and standard deviations for each age class are listed separately for

Table 6. Maximal figures—Norwegian children

Age, years		Work load, W	$\dot{V}_{O_2}$-max, $l \cdot min^{-1}$	$\dot{V}_{O_2}$-max/ T.B.M., $ml \cdot min^{-1} \cdot kg^{-1}$	$\dot{V}_{O_2}$-max/ L.B.M., $ml \cdot min^{-1} \cdot kg^{-1}$	n
Boys	8	87	1.44± 0.19	52.7± 3.93	65± 4.5	28
	9	107	1.59± 0.24	51.4± 5.23	64± 6.3	29
	10	135	2.03± 0.30	60.0± 6.48	76± 7.6	31
	11	158	2.07± 0.30	56.9± 6.14	71± 6.3	29
	12	190	2.31± 0.34	58.0± 7.95	72± 8.6	30
	13	220	2.70± 0.51	61.4± 6.73	75± 7.3	29
	14	265	2.82± 0.41	56.6± 4.96	67± 5.8	27
	15	295	3.14± 0.38	56.0± 4.44	68± 5.1	27
Girls	8	74	1.25± 0.20	47.4± 7.01	61± 8.3	33
	9	90	1.48± 0.19	48.5± 6.60	63± 8.5	33
	10	112	1.79± 0.23	52.4± 6.36	70± 8.3	34
	11	142	1.88± 0.22	50.1± 5.92	66± 6.2	34
	12	178	2.26± 0.32	53.6± 6.83	71± 8.0	34
	13	191	2.48± 0.46	51.8± 9.16	66± 10.3	33
	14	227	2.35± 0.26	44.7± 6.64	60± 6.8	32
	15	209	2.44± 0.30	43.6± 5.97	61± 7.1	30

(Mean and SD)

Table 7. Maximal figures—German children

Age, years		Work load, W	$\dot{V}_{O_2}$-max, $l \cdot min^{-1}$	$\dot{V}_{O_2}$-max/ T.B.M., $ml \cdot min^{-1} \cdot kg^{-1}$	$\dot{V}_{O_2}$-max/ L.B.M., $ml \cdot min^{-1} \cdot kg^{-1}$	n
Boys	12	186	2.33± 0.32	57.4± 7.12	72± 7.7	28
	13	245	2.50± 0.46	54.1± 5.63	67± 5.6	27
	14	305	2.83± 0.49	52.1± 4.23	64± 3.6	26
	15	330	3.05± 0.54	51.8± 3.56	63± 3.8	27
	16	353	3.00± 0.34	47.1± 3.63	57± 5.0	23
	17	322	3.11± 0.48	47.5± 4.44	55± 5.5	26
Girls	12	174	2.19± 0.30	47.9± 7.44	64± 7.5	24
	13	214	2.20± 0.22	43.8± 6.57	56± 5.9	24
	14	206	2.26± 0.26	41.8± 6.34	57± 5.8	22
	15	198	2.18± 0.29	39.1± 6.77	54± 6.5	22
	16	211	1.97± 0.31	33.4± 4.87	46± 6.0	17
	17	196	2.06± 0.33	35.0± 5.10	45± 5.6	19

(Mean and SD)

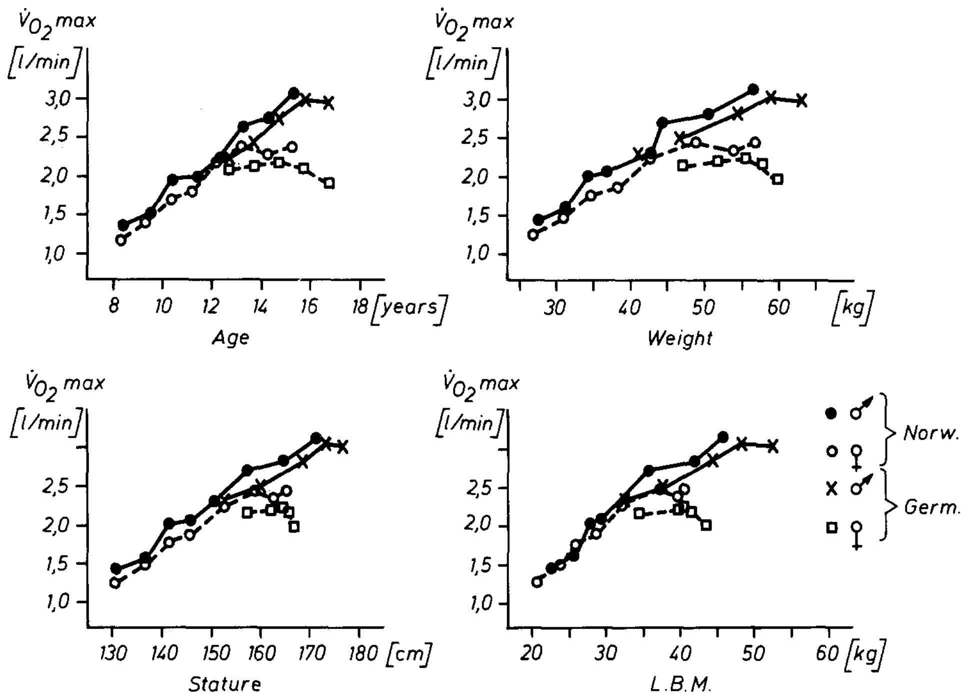

Fig. 1. Maximal oxygen uptake related to age and indices of body size. The diagram is constructed on the basis of mean values

Table 8. Mean heart rates at an oxygen uptake of 1.0 and 1.5 l · min^{-1}

Age, years	Heart rate at					
	1.0 l O_2 · min^{-1}		1.5 l O_2 · min^{-1}		1.5 l O_2 · min^{-1}	
	Norwegian boys	Norwegian girls	Norwegian boys	German boys	Norwegian girls	German girls
8	165	185	—	—	—	—
9	157	172	196	—	—	—
10	145	161	183	—	204	—
11	142	155	177	—	196	—
12	132	145	165	167	175	182
13	127	142	153	162	168	183
14	112	133	141	138	168	173
15	107	134	136	133	166	173
16	—	—	—	136	—	174
17	—	—	—	128	—	170

girls and boys in Tables 6 and 7. The coefficient of variation ranged between 10 and 18% when absolute values (l/min) are considered, the "overall" figure being 14.3% for boys and 13.3% for girls in Norway. Similar figures for the Germans were 14.8% and 13.0% respectively. The variation coefficient differed somewhat between the age classes, but in an unsystematic manner. The differences between Norwegian and German children are insignificant, but the variation coefficient is significant greater in boys than in girls.

b) Growth Curves. The means and standard deviations for each age are listed in Tables 6 and 7. Growth curves considering the absolute values for $\dot{V}_{O_2}$-max expressed in liters per min have been constructed and are shown in Fig. 1. The Norwegian boys increased their $\dot{V}_{O_2}$-max almost in linear relation to age between 8 and 15 years. The Norwegian girls, however, are linear in their $\dot{V}_{O_2}$-max growth from age 8 to age 13, when it levels off and remains almost constant up to the age of 15 years. The German boys increase their $\dot{V}_{O_2}$-max linearly with age from 12 to about 16 years,

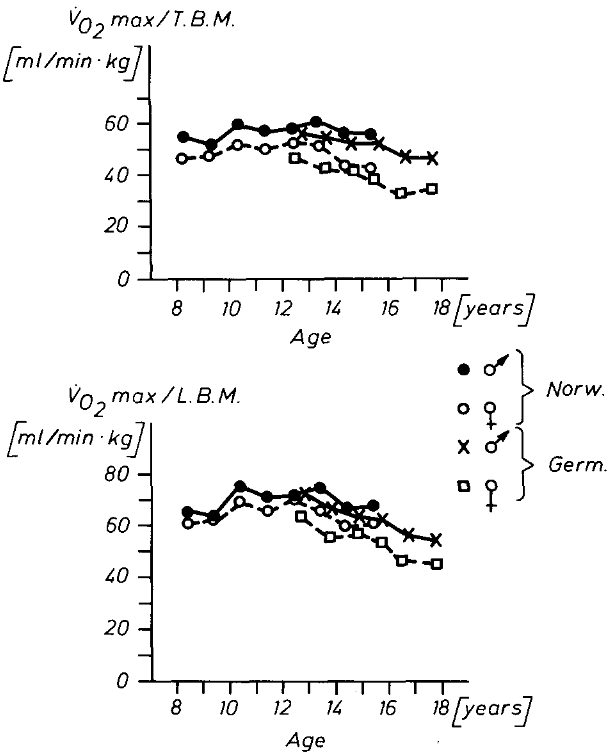

Fig. 2. Maximal oxygen uptake on the basis of total and lean body mass related to age. The figure gives mean values

some irregularities from year to year in the Norwegian children, but for the boys there is a tendency to increase from age 8 until age 13, after which a definite decrease took place. The growth curves for the Norwegian girls exhibit a similar trend, but a peak value was reached at age 12—that is to say one year before the boys—then a decrease took place, at a greater rate than for the boys.

The German children were measured annually from the age of 12, and it is quite obvious that from that age onward they decrease their $\dot{V}_{O_2}$-max expressed on the basis of total body mass. Also, for the Germans the rate of decrease with age is greater in girls than in boys.

Expressing the $\dot{V}_{O_2}$-max on basis of L.B.M. brings about similar growth curves as those when $\dot{V}_{O_2}$-max was expressed on the basis of total body mass, with one possible exception that the Norwegian boys and girls reached the peak value at about 10 years of age when the boys became almost constant until age 13 and the girls until age 12.

c) $\dot{V}_{O_2}$-max in Relation to Body Size. The means of $\dot{V}_{O_2}$-max have been plotted against means of indices of body size to demonstrate the relationships (Fig. 1). A close linear relationship between growth in the $\dot{V}_{O_2}$-

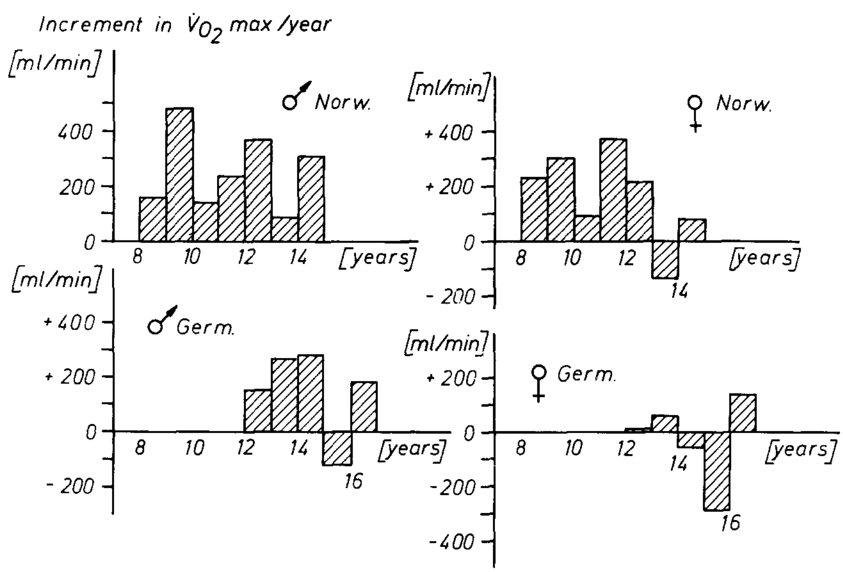

Fig. 3. The rate of growth in maximal oxygen uptake. Figure is based on mean values

then it levels off and there is no significant difference comparing age 17 with age 16. The German girls, however, seem to have reached their peak value at close to 13 years; there is some variation in the values thereafter, but these are insignificant.

Considering the growth curves for $\dot{V}_{O_2}$-max expressed on basis of total body mass (ml/kg), there are

max and growth in stature took place in boys. Such a linear relationship is not present for the girls above a height of about 160 cm.

For German and Norwegian boys a linear relationship between $\dot{V}_{O_2}$-max and body weight appeared up to a weight of about 55 kg. For the girls a similar linearity seems to exist up to a body mass of about 45 kg.

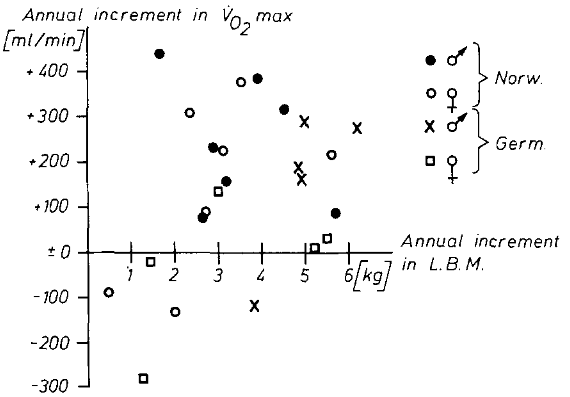

Fig. 4. Annual growth rate in maximal oxygen uptake related to the rate of growth in lean body mass. Figure gives mean values

Table 9. Highest recorded heart rates (beats/min)

Age, years		Norwegians	Germans
Boys	8	198 ± 7.6	
	9	197 ± 7.5	
	10	198 ± 7.5	
	11	199 ± 7.5	
	12	198 ± 8.1	199 ± 6.6
	13	197 ± 7.7	200 ± 6.1
	14	197 ± 7.1	195 ± 5.6
	15	200 ± 6.9	195 ± 5.9
	16		193 ± 5.3
	17		192 ± 4.5
Girls	8	197 ± 8.7	
	9	198 ± 5.0	
	10	200 ± 6.9	
	11	200 ± 5.4	
	12	201 ± 6.0	204 ± 6.7
	13	200 ± 7.0	204 ± 7.7
	14	197 ± 5.4	199 ± 6.8
	15	200 ± 6.0	198 ± 6.4
	16		194 ± 6.8
	17		194 ± 5.6

(Mean and SD)

$\dot{V}_{O_2}$-max appears to be closely and linearly related to lean body mass up to a value of about 45 kg for boys, and up to about 32.5 kg for the girls. The German boys are superior to German girls at all ages in $\dot{V}_{O_2}$-max expressed in absolute values as well as on basis of indices of body size, and the differences between means are statistically significant at each age.

The Norwegian boys also had somewhat better fitness than the girls before puberty—that is to say before age 12—particularly when expressed in relation to total body mass. However, these prepuberty differences seem to be completely related to the girls' greater fatness, because the sex differences disappear when $\dot{V}_{O_2}$-max is related to L.B.M. (Fig. 2). However, after age 12, a definite sex separation takes place, the boys becoming more fit than the girls.

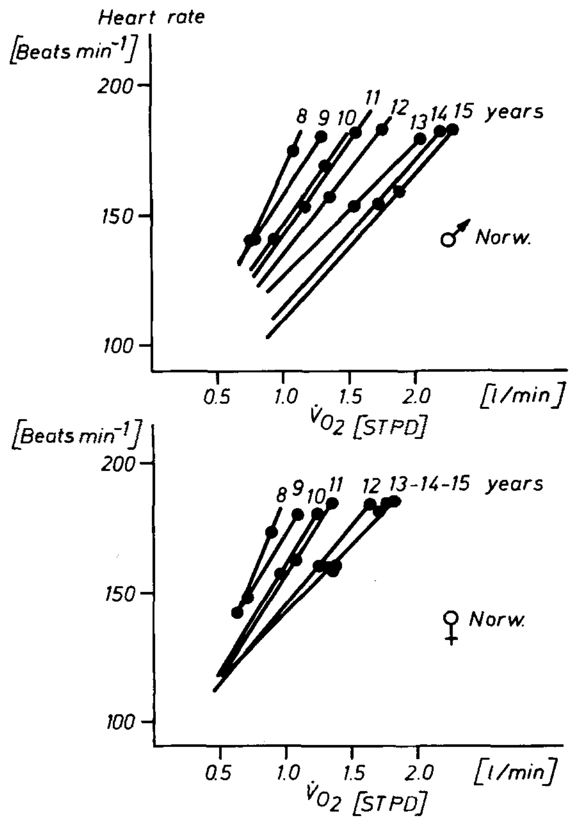

Fig. 5. The linear relationship between heart rate and oxygen uptake at various ages in Norwegian school-children

d) Annual Increment. The annual increment in $\dot{V}_{O_2}$-max was calculated in terms of means, standard deviations and indices of distribution. The mean annual increments are plotted against age in order to visualize the rate of increase (Fig. 3). A variation in the annual increment appeared which was unsystematic to age, sex and where the children were living. This unstability in the rate of increment in performance is also apparent when the means for annual $\dot{V}_{O_2}$-max increment are plotted against means for growth in lean body mass (Fig. 4).

e) Differences Between Norwegian and German Children. A comparison between the Norwegian and German children revealed a superior fitness of the former. Not only are the absolute values at each age significant greater in the Norwegian children by up to 8% in boys and up to 12% in the girls, but also when expressed on the basis of body weight—and in particular on basis of L.B.M.—the Norwegian boys and girls are more fit than the Germans.

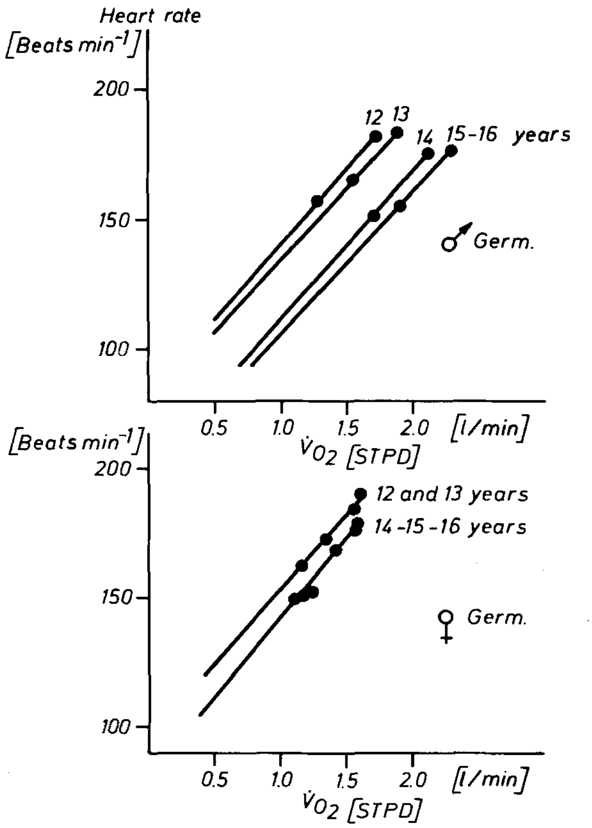

Fig. 6. The linear relationship between heart rate and oxygen uptake at various ages in German school-children

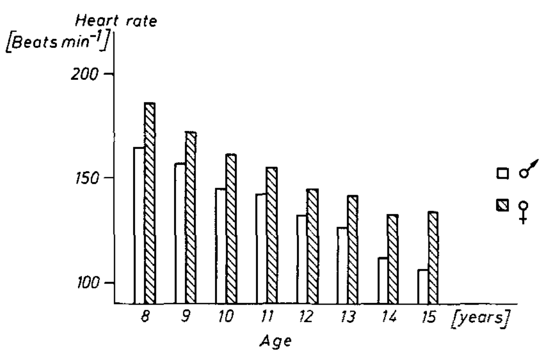

Fig. 7. Average heart rate at an oxygen uptake of 1 l · min^{-1}. The figure demonstrates sex differences and the effect of age in Norwegian children

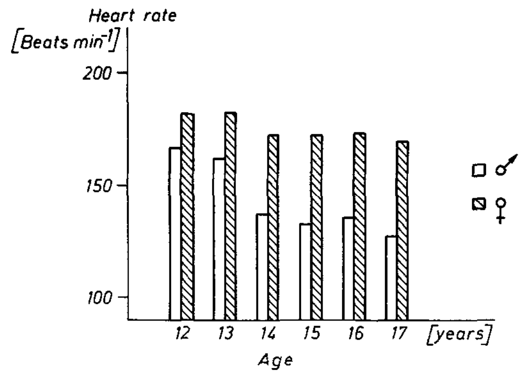

Fig. 8. Average heart rate at an oxygen uptake of 1.5 l · min^{-1}. The figure demonstrates sex differences and the effect of age in German children

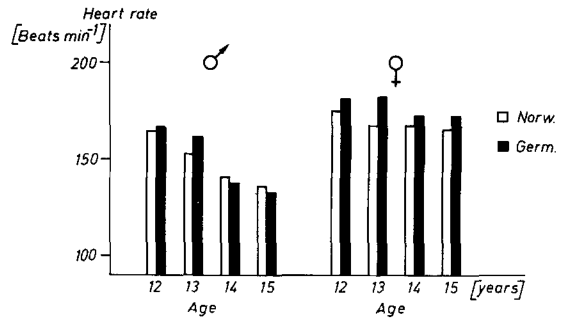

Fig. 9. Average heart rate at an oxygen uptake of 1.5 l · min^{-1}. The figure demonstrates a difference between Norwegian and German children

7. Heart Rate Responses to Exercise

a) Submaximal Work. Averages have been calculated for oxygen uptakes of 1.0 and 1.5 l · min^{-1}, and are listed separately for boys and girls and for the two cohorts of children in Table 8. The variation coefficient around the mean varies somewhat between ages and sexes, but in an unsystematic way. The overall variation coefficient is about 5.5%. The effects of age and sex on heart rate at a given level of oxygen uptake during performance of submaximal work are shown separately for children in Norway and Germany in Figs. 5 and 6.

The Norwegian children are compared at an oxygen uptake of 1.0 l · min^{-1}. The heart rate at an oxygen uptake of 1.0 l · min^{-1} in the Norwegian children at all ages are on average higher in girls compared to boys, and there is a steady decline with age, except for girls at age 14 and 15 years when the average values are similar (Fig. 7).

The German girls also had higher average heart rates at all ages compared with the boys (Fig. 8). The heart rate declined in boys up to the age of 14, then it remained almost constant. The girls' average heart rate did not change much with age: this corresponds to a similar stability in maximal oxygen uptake.

The Norwegian and German children compared at an oxygen uptake of 1.5 l · min^{-1} are shown in Fig. 9. For girls the average heart rate is lower in the Norwegians at all age. In contrast the Norwegian boys exhibit only a significantly lower heart rate at age 13; in the other years only small and insignificant differences were observed.

b) Maximal Heart Rate. Highest recorded heart rates—named maximal heart rate—are listed separately for boys and girls in the two cohorts of children in Table 9. The maximal heart rate is stable—averaging about 200 beats/min— up to an age of about 15 years. Before that age no sex differences existed, and German and Norwegian children were almost identical with regard to this parameter. Significantly lower values were found in the Germans after the age of 15 years, but there were no sex differences.

Discussion

The growth in body size and composition were quite similar in the two cohorts of children. The means of body size variables at each age were the same, and also the percentage of body fat did not differ. The measured and calculated values for variables of body size and body composition fitted the growth data for Europeans published by Eveleth and Tanner (1976) extremely well. It was therefore concluded that the two cohorts of children were similar in their anatomical growth pattern and that they are representative for growth of Europeans, or at least the Northern Europeans, in general.

Despite this similarity in growth of anatomical variables the Norwegian children appeared to be superior in their maximum aerobic power at all comparable ages and in both sexes. The differences between means in maximal oxygen uptake varies somewhat with age and sex, and are in the range of 5–10%. It was also observed that the Norwegian children were superior in physical performance capacity at age 12, the youngest age which is available for comparison.

There are many factors to consider in order to explain these differences in fitness. As the difference is present in both sexes and at all ages, this points toward a general factor being responsible for these differences. The study in Norway and Germany was undertaken by the same research team, using similar methods and experimental procedures. Frequent calibration of instruments secured high reliability in these field measurements. It is therefore unlikely that the differences have been brought about by methodological variation.

One possible factor to consider is a progressive habituation of the subject to the tests and the investigators. Shephard et al. (1979) tested this possibility, but could not find any evidence that habituation plays any role in the annual fluctuations in exercise fitness during longitudinal studies. It is also considered highly unlikely that habituation has affected the results obtained in this study because the project extended over many years and tests were performed only once a year.

Great care was taken in the sampling of children for this study, and a cluster sampling technique was applied. At the start of the longitudinal investigation all children at one age class in defined communities in rural districts in Norway and Germany were measured. Some—but surprisingly few—children dropped out and in all cases except for the oldest German children the drop out could be explained either because the pupil had moved out of the community or head some sort of acute illness at the time when the tests were performed. Only a few—mostly girls at an age of 17 years—did not want to participate, without giving any specific reason for their withdrawal. Consequently, the differences and similarities observed in this study are not biased by an inadequate sampling technique. It therefore appears likely that some environmental or behavioural factors are of causal significance.

The Norwegian children were measured in early fall (September/October), the Germans in early spring (March). Seasonal variations may therefore be considered. According to several authors (e.g. Lenz 1971) some children increase their stature more during the early months of year than in other seasons. The physiological mechanisms involved in the cyclic variations are unknown.

Shephard et al. (1978) established evidence that season affects the developmental process as much as the rate of growth, and development of exercise fitness exhibited cyclic variations during the course of a year. The authors attributed this to variations in leisure time activities, in other words the usual physical activity varied with the season and this was reflected in exercise fitness.

Many experimental studies have uniformly shown that physical activity in terms of training affects the level of physiological fitness (e.g. Åstrand et al. 1963; Ekblom 1971; Thorén et al. 1973). Active children are in general 5–15% better than untrained children. This is just within the range of difference observed between Norwegian and German children. It is therefore suggested by our still unpublished studies on daily physical activities measured by questionnaires, diaries and cardiocorder techniques, that variations in the level of habitual physical activity are the main cause for the differences in the development of exercise fitness between Norwegian and German children. Whether this is due to generally more active habits of children in Norway throughout the whole year or just reflects seasonal variations in leisure activities remains to be seen.

Inherited constitutional factors are responsible for a great part of the inter-individual differences which exist in homogeneous populations with regard to maximal aerobic power. Except for the anthropometric variables reported in this study—which show no differences at all between the two cohorts of children—no information is available concerning the genetic traits of Norwegian and German children. It is not possible to rule out that a genetic difference is at least partly responsible for the differences in fitness between Norwegian and German children, but this explanation is highly unlikely.

The study revealed that the maximal aerobic power —and the annual increment in this parameter—varied considerably from year to year. The maximum aerobic power is thus not a stable function but is apt to respond quickly to changes in the external and internal environment. This instability of maximal aerobic power has also been observed in other longitudinal studies (Hermansen and Oseid 1971; Pařizková 1977; Bailey et al. 1978). This instability, which is much greater than and nearly independent from the instability in growth of body size (Kobayashi et al. 1978), is of practical significance in as much as it may be utilized in paediatric practice, and in public health in general, to gain insight into effects of changes in environmental and behavioural patterns of children, particularly in relation to their cardio-vascular health so that proper action may be established aiming at promotion of health.

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