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ABSTRACT

The determinants of aerobic and anaerobic performance capacity of 58 junior athletes were studied. The main parameters studied were maximal oxygen uptake ($\text{max}\dot{V}_{O_2}$) in leg and arm work, the percentage of slow-twitch muscle fibers (%ST fibers) and succinate dehydrogenase activity (SDH) in m. vastus lateralis (VL), m. gastrocnemius c.l. (GL) and m. deltoideus (D), vertical velocity (V_v) and muscular power (MP) during running up the stairs, total (TLF) and relative (RLF) isometric force of extensor muscles of both legs, blood lactate after maximal leg and arm work and relative power index (RPI).

The junior endurance athletes, cross-country skiers and long-distance runners, had highest $\text{max}\dot{V}_{O_2}$ of 75 $\text{mlxkg}^{-1}\text{xmin}^{-1}$. The female cross-country skiers had 10% lower $\text{max}\dot{V}_{O_2}$ than male skiers. In arm work $\text{max}\dot{V}_{O_2}$ of the male and female junior skiers was 77% and 74% as compared with $\text{max}\dot{V}_{O_2}$ in leg work, respectively. The junior long-distance runners had the highest oxidative capacity both in m. VL and m. GL according to the mean values of %ST fibers and SDH activity. The junior short-distance runners performed best in the running velocity test (1.47 mxsec^{-1}) and they also had the highest blood lactate (11.8 mM) after maximal leg work. The junior skijumpers had significantly higher TLF and RLF than the other junior athletes.

The age of the male junior athletes was found to correlate significantly with $\text{max}\dot{V}_{O_2}$ ($r = .39$), %ST fibers ($r = .25$), SDH activity ($r = -.29$) and RPI ($r = .28$). When the effect of age of the male juniors was kept constant by using the partial correlation methods $\text{max}\dot{V}_{O_2}$ was found to correlate significantly with RLF ($r = -.37$) and RLF with RPI ($r = .33$).

INTRODUCTION

The performance capacity of athletes has been investigated rather intensively during the last ten years and the test results show that athletes have become more and more fit. At the same time the athletes of the future, boys and girls, have begun systematic progressive training earlier in their adolescence or even in childhood. However, studies on the performance capacity of male and female junior athletes and especially on the effects of training have been few. In addition, only some of the junior athletes studied could be regarded as successful competitors in their own sport events (e.g. Robinson 1939, Åstrand 1952, Åstrand et al. 1963, Knuttgen 1967, Daniels and Oldridge 1970, 1971, Eriksson 1972). The purpose of this investigation was to describe the aerobic and anaerobic performance capacity of junior athletes undergoing intensive training and to study the relationships between age and the selected performance characteristics.

MATERIAL AND METHODS

The subjects were 58 junior athletes who represented the following sport events: cross-country skiing (7 females and 31 males), skijumping (3 males, one of them also successful nordic combination skier) and running (22 males). The runners were divided into long-distance (1500 m - 10000 m) and short-distance (100 m - 800 m) runners according to the distances of their races. All of the female skiers and skijumpers and about 2/3 of the male skiers and runners had belonged to the national junior training groups and national teams. Great individual differences were observed in the quantity and quality of training. For instance,

Table 1. Physical characteristics of the junior athletes (mean and SD)

Group	n	Age yrs	Height cm	Weight kg	FFW kg	Fat %
Cross-country skiing, males	31	18.7 1.8	177.3 5.0	66.6 6.4	59.9 4.6	10.2 1.9
Long-distance running, males	10	18.8 1.9	177.8 6.1	63.0 6.4	57.2 5.3	9.3 1.7
Short-distance running, males	12	18.0 1.9	177.3 6.3	65.0 6.2	58.0 5.8	10.4 1.8
Skijumping, males	3	17.9 1.9	175.0 5.2	67.5 2.5	59.1 3.3	10.7 1.5
Cross-country skiing, females	7	18.3 1.4	165.2 7.2	56.9 8.6	44.6 5.4	21.8 2.2

the annual training distance of the junior endurance athletes ranged from 1000 km to 7000 km of running and/or skiing and the training frequency from 4 to 10 times per week (seasonal differences included). The juniors were tested between the autumn of 1973 and the spring of 1975. The anthropometric variables (Table 1) were height, weight, fat-free-weight (FFW) calculated as a mean of skeletal and skinfold estimations (von Döbeln 1959, Durnin and Rahaman 1967) and the percentage and total amount of body fat (Durnin and Rahaman 1967).

The variables of aerobic performance capacity were maximal oxygen uptake or maximal aerobic power (max$\dot{V}_{O_2}$) during treadmill running and maximal arm ergometer work, the percentage of slow twitch muscle fibers (%ST fibers) and succinate dehydrogenase (SDH) activity in vastus lateralis (VL), gastrocnemius c.l. (GL) and deltoid (D) muscles.

The variables of anaerobic capacity were vertical velocity (V_v) and muscular power (MP) during running up the stairs, total (TLF) and relative (RLF) isometric force of extensor muscles of both legs, heart rate during and blood lactate concentration after maximal treadmill running and arm ergometer work and relative power index (RPI). The methods have been described previously (Komi et al. 1976 a, Rusko et al. 1976).

MAx$\dot{V}_{O_2}$ during treadmill running and maximal arm work was determined according to the principles described by Åstrand and Rodahl (1971). After ten minutes' warming-up and a short rest the work load was increased by 1^o (treadmill) or 150 kpmxmin^{-1} (ergometer) every second minute until exhaustion occurred. Oxygen uptake was measured using Douglas bags, Scholander gas analysis and calibrated dry gas meters and corrected for STPD. Muscle biopsies were taken with the needle biopsy technique (Bergström 1962). For classification of muscle fibers into slow twitch and fast twitch types (Gollnick et al. 1972) myosin ATPase staining was used according to Padykula and Herman (1955). Part of the muscle sample was weighed, homogenized and used for SDH activity (Pennington 1961) and protein (Lowry et al. 1951) determinations. SDH activity was expressed as nM substrate reduced x mg^{-1} muscle protein xmin^{-1} at 37^oC.

The running velocity of the subjects was recorded electronically when the subjects ran up the stairs at maximal speed two steps at a time (Margaria et al. 1966). The vertical component of the speed in mxsec^{-1} (vertical velocity) and kg x mxsec^{-1} (muscular power) was calculated. The relative power index was obtained by dividing the estimated theoretical oxygen cost of the running by the measured maximal oxygen uptake (Margaria et al. 1966).

The maximal isometric force of the extensor muscles of both legs was measured according to Komi (1973) using a special dynamometer. The angle of the knees was 107 degrees. The relative leg force was obtained by dividing the total leg force by body weight.

Blood lactate concentration was measured from two capillary blood samples taken from a fingertip about 3 and 5 minutes after maximal treadmill running and arm ergometer work and the highest values were selected to represent the maximal blood lactate concentration. The reagents and instructions of Biochemica Boehringer were used.

Heart rate was registered with Mingograf 14-ECG throughout the treadmill running and arm ergometer work at the end of each minute and at exhaustion. The heart rates were calculated from ten heart beats and the highest values were recorded as maximal heart rates. The mean values of 1-4 tests during the investigation period have been used to minimize the effects of seasonal variations and the error of the methods.

RESULTS

The mean ages of the subjects were 17.9 to 18.8 years. The anthropometric differences between the junior athlete groups were small except for the female junior skiers who were smallest in size and who had highest fat depots (Table 1).

The male junior cross-country skiers had the highest max$\dot{V}_{O_2}$ of 4.99 $lxmin^{-1}$ (Table 2). When max$\dot{V}_{O_2}$ was calculated per kilogram body weight the male junior skiers and long-distance runners had equally high values of about 75 $mlxkg^{-1}xmin^{-1}$. The junior short-distance runners had significantly smaller

Table 2. Aerobic performance capacity of junior athletes (mean and SD)

Group	Sample site	Maximal oxygen uptake (STPD) $l \times min^{-1}$	$ml \times kg^{-1} \times min^{-1}$	$ml \times kg^{-1} FFW \times min^{-1}$	%ST fibers m. VL m. D	m. GL	SDH activity m. VL m. D	m. GL	Max heart rate
Cross-country skiing, males	leg	4.99	74.6	84.0	57.7	68.7[x]	26.4	22.7	197
n = 31		0.54	6.6	8.4	9.8	16.3	9.5	5.3	8
	arm	3.81	57.3		71.0[x]		16.5[x]		190
		0.66	7.8		23.2		6.2		8
Long-distance running, males	leg	4.71	75.0	81.8	65.7	73.6	31.0	46.2	208
n = 10		0.38	4.6	6.3	7.7	13.0	9.6	11.9	8
Short-distance running, males	leg	4.53	69.7	78.0	50.5	49.2	27.7	35.5	202
n = 12		0.47	4.2	5.2	11.5	11.1	9.4	10.5	13
Skijumping, males	leg	3.92	58.5	66.1	52.3		26.7		198
n = 3		0.72	8.8	8.7	7.4		11.0		11
Cross-country skiing, females	leg	3.80	67.2	84.7	63.4	73.0	21.9	24.5	197
n = 7		0.47	3.8	4.3	4.6	8.1	7.5	7.9	10
	arm	2.83	49.5		74.2		17.7		183
		0.48	4.2		10.0		9.6		13

[x] n = 17 intead of 31

max$\dot{V}_{O_2}$ in $ml \times kg^{-1} \times min^{-1}$ than junior long-distance runners or male skiers. The female junior skiers had 24% lower max$\dot{V}_{O_2}$ than male junior skiers. This difference was reduced to 10% when values in $ml \times kg^{-1} \times min^{-1}$ were compared and to zero when max$\dot{V}_{O_2}$ was expressed in relation to fat-free body weight. The maximal aerobic power of the female and male junior skiers in arm work was 74% and 77% as compared with max$\dot{V}_{O_2}$ in treadmill running.

The junior long-distance runners had the highest oxidative capacity both in m. VL and in m. GL according to the mean values of SDH activity and %ST fiber distribution (Table 2). The female junior skiers had almost the same %ST fiber distributions in their muscles as junior long-distance runners but their SDH activities were significantly lower. The junior short-distance runners and skijumpers had about 50% ST fibers in their muscles.

The mean maximal heart rate ranged from 197 to 208 beats$\times$min^{-1} and standard deviations from 8 to 13 beats$\times$min^{-1}. During treadmill running the mean maximal heart rates of male and female junior skiers were 197 beats$\times$min^{-1} but in arm work the male juniors attained significantly higher mean value than the female junior cross-country skiers.

The junior short-distance runners performed best in the running velocity test: their vertical velocity was 1.47 m$\times$sec^{-1} and muscular power 95.6 kgm$\times$sec^{-1} (Table 3). Excluding the nordic combination skier the vertical velocity of the junior skijumpers was 1.44 m$\times$sec^{-1}. The vertical velocity of the female junior skiers was 17% less than V_v of the male junior skiers. The vertical velocity and muscular power of the junior long-distance runners were significantly less than the respective mean values of the junior short-distance runners.

Table 3. Anaerobic performance characteristics of the junior athletes (mean and SD)

Group	n	Vertical velocity m$\times$sec^{-1}	Muscular power kg$\times$m$\times$sec^{-1}	Isometric leg force kg	Isometric leg force kg/BW	Blood lactate mM$\times$l^{-1} legs	Blood lactate mM$\times$l^{-1} arms	Relative power index
Cross-country skiing, males	31	1.40 0.09	93.5 8.3	274 77	4.13 0.95	10.5 2.0	10.2 2.5	2.15 0.27
Long-distance running, males	10	1.35 0.09	85.1 9.7	229 50	3.63 0.74	10.1 2.0	-	2.04 0.22
Short-distance running, males	12	1.47 0.08	95.6 12.6	246 45	3.80 0.79	11.8 2.6	-	2.38 0.21
Skijumping, males	3	1.33 0.22	89.6 13.7	396 37	5.88 0.65	9.1 0.4	-	2.63 0.63
Cross-country skiing, females	7	1.17 0.17	67.7 15.5	198 50	3.46 0.60	10.5 1.6	8.3 2.0	1.97 0.36

The junior skijumpers and short-distance runners had a significantly higher relative power index than the other junior groups. The total and relative isometric leg forces of the junior skijumpers were significantly higher than the mean values of any other group. The male junior skiers ranked next and they had 28%, 16% and 3% higher leg force than female juniors when the force was expressed in total force, in relation to body weight and in relation to fat free body weight, respectively.

The junior short-distance runners had the highest blood lactate concentration of 11.8 mM after the maximal treadmill running but only the mean value of the junior skijumpers was significantly smaller. The male and female junior skiers had equal blood lactate concentrations (10.5 mM) after treadmill running but in maximal arm work the male juniors attained a significantly higher mean value.

The results of the junior athletes were compared to the corresponding values of adult reference subjects and 4-6 best adult athletes in each sport event by means of the fitness profiles (Arstila and Rusko 1976). The percentage differences between the mean values of athlete groups and reference subjects (± one standard deviation) are described in Appendices 1-3.

In general the configurations of the fitness profiles of the junior athletes were similar as compared to the best adult athletes. The deviations from the mean values of the reference subjects were smaller and variations among the juniors greater. The most prominent differences as compared to the best adult athletes were in TLF, RLF, V_v, blood lactate and SDH activity of the junior skijumpers, in blood lactate and max$\dot{V}_{O_2}$ ($l x min^{-1}$) of the junior short-distance runners, and in max$\dot{V}_{O_2}$, %ST fibers and SDH activity of the junior long-distance runners and cross-country skiers.

The age and body weight of the male juniors were found to correlate significantly with maximal aerobic power and total isometric leg force. When the latter two variables were expressed in relation to body weight only max$\dot{V}_{O_2}$ was found to correlate significantly with age ($r = .39$, $p < .01$). Within the group of male junior skiers this correlation was also significant ($r = .69$, $p < .001$). Small significant correlations were found between age and %ST fibers in m. VL ($r = .25$, $p < .05$), between age and SDH activity in m. VL ($r = -.29$, $p < .05$) and between age and the relative power index ($r = .28$, $p < .05$) of the male junior athletes.

When the effect of age of the male juniors was kept constant by using the partial correlation method, two significant correlations were observed between the variables: $r = -.37$ ($p < .05$) between max$\dot{V}_{O_2}$ and relative leg force and $r = .33$ ($p < .05$) between RPI and relative leg force. Among male junior skiers the same partial correlations were also significant, $r = -.44$ ($p < .01$) and $r = .51$ ($p < .01$) respectively. In addition, the correlation between vertical velocity and isometric leg force among the male junior skiers remained significant ($r = .57$, $p < .001$).

DISCUSSION

The junior athletes of the present study were chosen by national sport associations and recommended to the tests by the Finnish Olympic Committee. Thus the athletes were thought to represent the best Finnish juniors in their own sport events. However, according to the information from the coaches the variation in the quantity and quality of training was found to be wide, which may reflect the variable need of training to achieve good performances in each sport event, but which also was found to be reflected in the performance level of the junior athletes. Those who trained least were mainly considered less successful in their sport competitions and those who trained most and intensively were also members of the National Teams and some of them medalists in European Junior Championships (some male and female cross-country skiers). However, the representativeness of the junior athlete groups as best national juniors was considered good except, perhaps, the short-distance runners who, on the average, trained less than the other groups. Only three skijumpers were studied and one of them was also a successful nordic combination skier.

Previous studies on various groups of junior athletes have shown that the mean values of maximal aerobic power range from 45 to 60 $mlxkg^{-1}xmin^{-1}$ for female juniors (e.g. Robinson and Harmon 1941, Åstrand et al. 1963, Cumming 1967, Sprynarova and Parizkova 1969, Maksud et al. 1970, Brown et al. 1972, Kamon and Pandolf 1972, Drinkwater 1973, Novak 1973, Hermansen 1973, Holmer 1974) and from 57 to 75 $mlxkg^{-1}xmin^{-1}$ for male juniors (Robinson and Harmon 1941, Ribisl and Kachadorian 1969, Daniels and Oldridge 1970 and 1971, Kamon and Pandolf 1972, Shephard et al. 1974, Holmer 1974). In some of these investigations the performance level of the junior athletes is comparable to that of our subjects which is also seen in the high mean values of max$\dot{V}_{O_2}$ (Åstrand et al. 1963, Cumming 1967, Daniels and Oldridge 1970). The male adult cross-country skiers (Rusko et al. 1976) had significantly higher max$\dot{V}_{O_2}$ in leg work and %ST fibers in m. VL than the junior skiers. The adult long-distance runners had significantly higher %ST fibers and SDH activity in m. VL and the adult skijumpers significantly lower leg force than their junior counterparts, respectively (Komi et al. 1976 a). With respect to the main parameters the female junior cross-country skiers and junior short-distance runners did not differ significantly from their adult competitors.

In the present study only the variables related to endurance correlated significantly with age when the effect of body size was kept constant. The low and insignificant correlations between age and force-velocity might be explained by the selection of the subjects: most of them could be regarded as endurance athletes.

The positive correlation between age and max$\dot{V}_{O_2}$ in $ml \times kg^{-1} \times min^{-1}$ suggests that the older juniors have higher max$\dot{V}_{O_2}$ than younger ones and that maximal aerobic power of the junior athletes develops faster than their weight increases. The previous studies on the effects of endurance training of adolescents and young adults have shown smaller or greater improvements in max$\dot{V}_{O_2}$ (for ref. see Åstrand and Rodahl 1970 and Pollock 1973) and in some cases the increases in max$\dot{V}_{O_2}$ have been matched by the increases in weight during growth (Daniels and Oldridge 1971). The differences between various results are mainly due to differences in training and pretraining level of max$\dot{V}_{O_2}$ and possibly due to the age of the subjects (e.g. Åstrand and Rodahl 1970, Karlsson et al. 1972, Pollock 1973). All of the subjects studied in the present study have been in regular training at least for two years and most of them even longer. As an example of the quantity of the training it can be mentioned that half of the junior cross-country skiers train now more than their adult counterparts for the Olympic Games in Sapporo 1972. Thus it was not surprising to found that the best junior endurance athletes had equally high max$\dot{V}_{O_2}$ as the presentday adult athletes.

The differences in max$\dot{V}_{O_2}$ between male and female junior skiers were insignificant when the differences in body size and composition were taken into account. This is in agreement with the earlier suggestions that max$\dot{V}_{O_2}$ is dependent on the muscle mass involved and that the differences between male and female subjects depend on the differences in body size, body composition and hemoglobin values of the blood (e.g. von Döbeln 1956, Hermansen 1973).

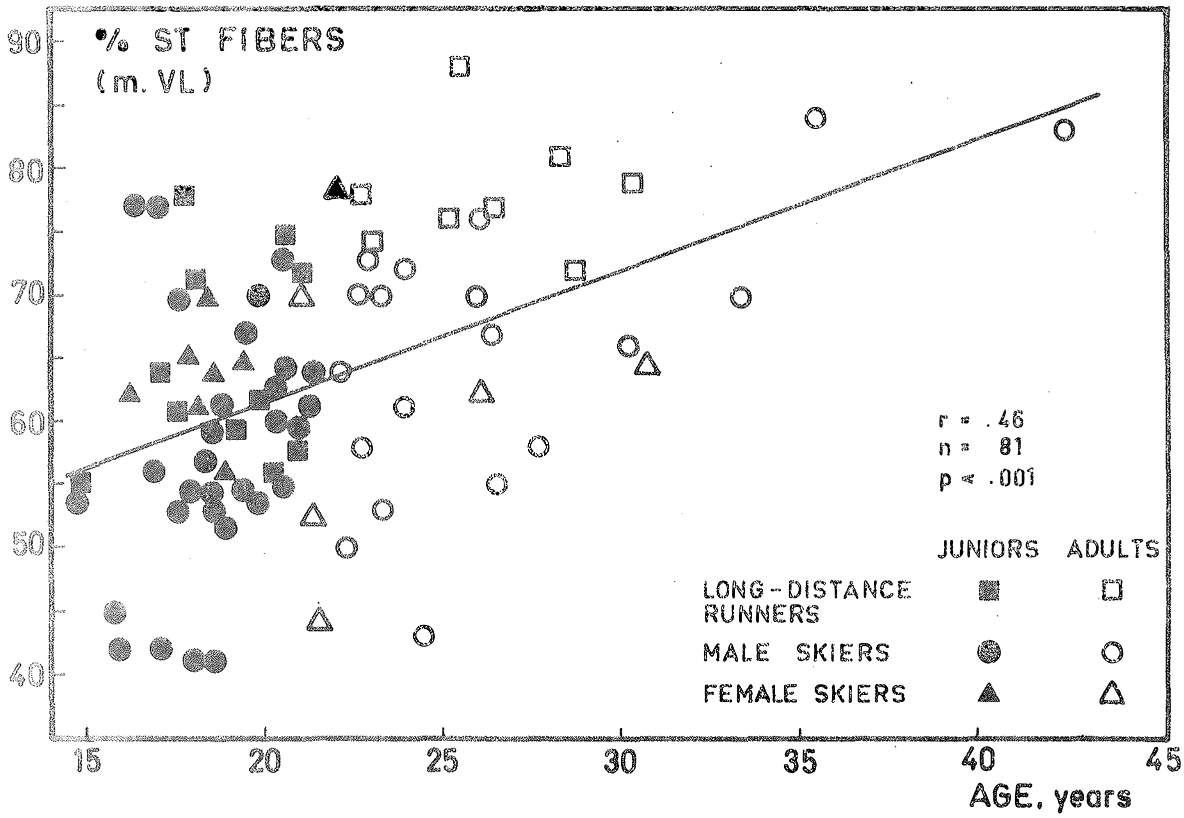


Figure 6. The relationship between age and %ST fibers in m. VL of junior and adult endurance athletes (results from the present study and from Rusko et al. 1976).

The %ST fiber distribution was found to correlate with age, too. This relationship has been demonstrated further in Figure 6 and 7, where the %ST fibers of all studied junior or adult (Rusko et al. 1976) endurance athletes (cross-country skiers and long-distance runners) and short performance athletes (running 800 m or shorter distances, skijumpers, jumpers, throwers) have been plotted against age. In endurance athletes the correlation between age and %ST fibers was .46 ($p < .001$). All 25-30 year old endurance athletes had more than 54% and over 30 year old endurance athletes more than 63% ST fibers in m. VL. Among short performance athletes the correlation between age and %ST fibers was -.39 ($p < .05$) and only a few athletes had less than 30% ST fibers in m. VL. These results might indicate that training changes the fiber distribution and/or some kind of selection occurs with age. According to Gollnick et al. (1972), Thorstensson and Karlsson (1974)and Thorstensson et al. (1975) training does not seem to change the percentage of ST fibers but the training periods might have been too short to produce structural changes in the muscles. However,

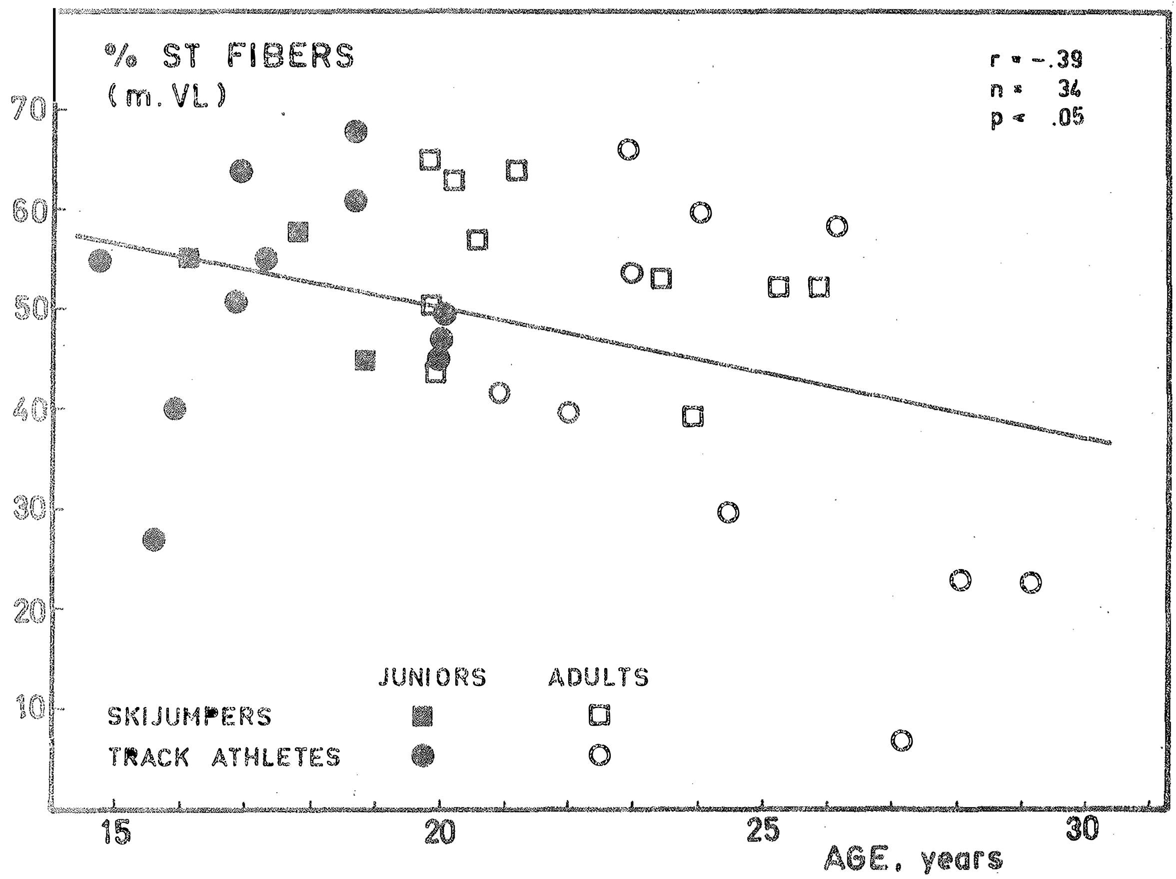


Figure 7. The relationship between age and %ST fibers in m. VL of junior and adult "short-performance" athletes (skijumpers, 100-800m runners, jumpers, throwers, results from Rusko et al. 1976 included).

the possibility that fiber distribution remains unchanged with age and training is supported by Eriksson (1972) and by the fact that fiber distribution seems to be dependent on genetic determinants (Komi et al. 1976 b). Thus the hypothesis that the athletes select such sport events which fit to their natural muscular and cardiovascular endowments seems feasible (Gollnick et al. 1972, 1973, Klissouras 1971, Komi et al. 1976 b). However, during the last few years the intensity or speed in competitions has increased which might put increasingly high requirements also on the use of FT fibers with high oxidative capacity (Dubowich and Brooke 1973, Saltin 1975), in addition to ST fibers.

The correlation between SDH activity in m. VL and age of the male juniors was significantly negative and within the group of female junior skiers this correlation tended to be negative, too. These correlations were mainly due to some of the youngest subjects; for instance, the mean value of the four youngest male skiers (14.7 - 16.3 years) was 37.2 $nMxmg^{-1}xmin^{-1}$ in comparison with the mean value of 26.4 $nMxmg^{-1}xmin^{-1}$ for all male junior skiers. Previously Eriksson (1972) has shown that the 11-16 year old boys have higher SDH activity than untrained men and relatively short six weeks training increased the SDH activity of the 11 year old boys by 30%. Because the SDH activity was not related to age after 17-18 years of age an explanation for the high values of the youngest junior athletes might be related to growth and maturation processes. When the body size and composition of the juniors were compared to corresponding values of the adult athletes it was found that the weights and fat-free weights of the youngest subjects were remarkably small. Thus it seems logical to suggest that the lower SDH activity of the older juniors might be related to the relatively greater increase of the other muscle cell components, such as contractile proteins and/or to increases in connective tissue elements as compared to increases in mitochondria. The high enzyme activity might partly explain the extraordinary ability of young children to constantly move about together with their high maximal aerobic power in relation to body weight.

No significant correlations were found between max$\dot{V}_{O_2}$, %ST fibers and SDH activity although these correlations were highly significant among adult male athletes (Rusko et al. 1976). This is not surprising because all characteristics necessary in sport performance are not yet fully developed in young athletes. It is also evident that the parameters studied measure different characteristics of aerobic performance capacity (Rusko et al. 1976). Max$\dot{V}_{O_2}$ might be best related to cardiovascular function, SDH activity might indicate the mitochondrial capacity of the muscles and %ST fibers the genetic endowment for aerobic work. One possibility to explain the lack of significant correlations in junior athletes could be that in order to compete succesfully it is enough to have only one or some favourable characteristics. For instance, according to Table 4, subject JRa might have selected cross-country skiing because of high natural max$\dot{V}_{O_2}$, subject TP selected it because of high percentage of ST fibers and subject MK because of high (natural) enzyme activity in his muscles. Of these parameters max$\dot{V}_{O_2}$ and SDH activity seem to have adaptive capacity. Also the volume fraction of ST fibers may change through endurance training (Gollnick et al. 1972 and 1973). An explanation might also be the lack of correlation between the variables. As a matter of fact the intragroup correlations between SDH activity and %ST fibers in adult male athlete groups were insignificant (Rusko et al. 1976) which suggests that there might not be great differences between SDH activity of ST or FT fibers. This has also been suggested by Gollnick et al. (1974) and Karlsson et al. (1975).

Table 4. Maximal oxygen uptake, %ST fibers and SDH activity in arms and legs of some male junior and adult cross-country skiers.

	Subject Age	Sample site	Max$\dot{V}_{O_2}$ ml x kg^{-1} x min^{-1}	%ST fibers	SDH activity nM x mg^{-1} x min^{-1}	Comments on performance
JUNIORS	IP	leg	76.5	70	19.5	European Junior Champion 1975 (15 km)
	19y	arm	61.6			
	RK	leg	81.1	69	34.9	Finnish Champion 1976 (15 km)
	19y	arm	60.[illegible]	88	32.3	National team in the Olympic Games 1976
	MK	leg	78.6	54	39.9	3. in Eur. Junior Championships 1976
	18y	arm	60.9			(15 km)
	JRa	leg	83.6	54	19.5	National junior training group 1973-
	19y	arm	61.0	55	11.9	
	AA	leg	85.2	60	19.5	National junior training group 1973-
	20y	arm	55.9	63		
ADULTS	JRe	leg	88.5	76	33.3	National team in the Olympic Games 1972
	26y	arm	65.5	87	20.0	and 1976 and World Championships 1974
	EN	leg	86.3	72	34.9	National team in World Championships
	24y	arm	60.8	71	25.2	1974
	JL	leg	75.7	70	25.7	National training group 1974
	24y	arm	58.5	74	18.4	
	SK	leg	77.3	43	30.7	National level skier
	25y	arm	56.6			

The lack of correlation between max$\dot{V}_{O_2}$ and %ST fiber distribution might also be due to the fact that juniors in general have not yet achieved such level in their training and performance that fiber distribution would "limit" the development of max$\dot{V}_{O_2}$. Table 4 shows that the best male skiers (JRe, EN) have attained high values in all of the presented variables (see also Appendix 2) related to aerobic performance capacity and that the less successful adult athletes have deficiencies in one or more characteristics. The junior skier RK has high values in all of the three characteristics studied and he has competed quite successfully with Finnish and foreign adult skiers belonging to the Finnish national team in the Olympic Games in Innsbruck 1976.

The fitness characteristics of the athletes are not the only factors necessary for a good performance. Techniques and psychological factors must also be included when the performance capacity of the athlete is concerned. For instance, subject TP had relatively low max$\dot{V}_{O_2}$ and SDH activity but nevertheless he won the European Junior Championship 1975 in cross-country skiing. On the contrary, subject AA had the highest max$\dot{V}_{O_2}$ from all of the studied junior athletes, 85.2 ml$\times$kg$^{-1}\times$min^{-1}, but his best performance is 7th in Finnish championships for juniors in 1973.

REFERENCES

Arstila, A., H. Rusko, Fitness profiles of elite Finnish athletes. Research reports from the Department of Biology of Physical Activity. No 10. University of Jyväskylä 1976

Bergström, J., Muscle electrolytes in man. Scand. J. Clin. Lab. Invest. 1962, suppl. 68

Cumming, G., Current levels of fitness. Canad. Med. Ass. J 1967, 96, 868-877

Brown, H., J. Harrower, M. Deeter, The effects of cross-country running on pre-adolescents girls. Med. Sci. Sports 1972, 4, 1-5

Daniels, J., N. Oldridge, The effects of alternate exposure to altitude and sea level on world-class middle-distance runners. Med. Sci. Sports 1970, 2, 107-112

Daniels, J., N. Oldridge, Changes in oxygen consumption of young boys during growth and running training. Med. Sci. Sports 1971, 3, 161-165

Drinkwater, B., Physiological responses of women to exercise. In: Exercise and sport sciences reviews. Vol. I., Edited by J. Wilmore. Academic Press. New York 1973

Dubowich, V., M. Brooke, Muscle biopsy: A modern approach. W.B. Saunders Company Ltd, London, Philadelphia, Toronto 1973

Durnin, J., M. Rahaman, The assessment of the amount of fat in the human body from measurements of skinfold thickness. Brit. J. Nutr. 1967, 21, 681-689

von Döbeln, W., Maximal oxygen intake, body size and total hemoglobin in normal man. Acta physiol. scand. 1956, 38, 193-199 von Döbeln, W., Anthropometric determination of fat-free body weight. Acta Med. Scand. 1959, 165, 37-41

Eriksson, B., Physical training, oxygen supply and muscle metabolism in 11-13 year old boys. Acta physiol. scand. 1972, suppl. 384

Gollnick, P., R. Armstrong, C. Saubert, K. Piehl, B. Saltin, Enzyme activity and fiber composition in skeletal muscle of untrained and trained men. J. Appl. Physiol. 1972, 33, 312-319

Gollnick, P., R. Armstrong, B. Saltin, C. Saubert, W. Sembrowich, R. Shepherd, Effect of training on enzyme activity and fiber composition of human muscle. J. Appl. Physiol. 1973, 34, 107-111

Gollnick, P., B. Sjödin, J. Karlsson, E. Jansson, B. Saltin, Human soleus muscle: A comparison of fiber composition and enzyme activities with other leg muscles. Pflügers Arch. 1974, 348, 247-255

Hermansen, L., Oxygen transport during exercise in human subjects. Acta physiol. scand. 1973, suppl. 399

Holmer, I., Physiology of swimming man. Acta physiol. scand. 1974, suppl. 407

Kamon, E., K. Pandolf, Maximal aerobic power during laddermill climbing, uphill running and cycling. J. Appl. Physiol. 1972, 32, 467-473

Karlsson, J., L. Hermansen, G. Agnevik, B. Saltin, Energikraven vid löpning. Idrottsfysiologi, Rapport nr 4, Trygg, Stockholm, 1972

Karlsson, J., B. Hulten, K. Piehl, B. Sjödin, A. Thorstensson, Suorituskyvyn riippuvuus lihassäietason tekijöistä. Suomen Lääkärilehti-Finlands Läkartidning 1975, 30, suppl. 1A, 5-14

Klissouras, V., Heritability of adaptive variation. J. Appl. Physiol. 1971, 31, 338-344

Padykula, R., E. Herman, The specificity of the histochemical method of adenosine triphosphatase. J. Histochem. Cytochem. 1955, 3, 170-195

Pennington, R., Biochemistry of dystrophic muscle. Mitochondrial succinate-tetrazolium reductase and adenosine triphosphatase. Biochem. J. 1961, 80, 649-654

Pollock, M., The quantification of endurance training programs. In: Exercise and sport sciences reviews. Vol. I. Edited by J. Wilmore. Academic Press, New York 1973

Ribisl, P., W. Kachadorian, Maximal oxygen intake prediction in young and middle-aged males. J. Sports Med. 1969, 9, 17-22

Robinson, S., Experimental studies of physical fitness in relation to age. Arbeitsphysiologie 1938, 10, 251-323

Robinson, S., P. Harmon, The effect of training and of gelatin upon certain factors wich limit muscular work. Amer. J. Physiol. 1941, 133, 161-169

Rusko, H., M. Havu, E. Karvinen, Aerobic performance capacity in athletes. Research reports from the Department of Biology of Physical Activity, No 9. University of Jyväskylä 1976

Saltin, B., Physiological analysis of endurance exercise. Lecture held in Scandinavian Symposium on endurance training, 5. - 7.6.1975, Espoo, Finland

Shepherd, R., G. Godin, R. Campbell, Characteristics of sprint, medium and long-distance swimmers. Europ. J. appl. Physiol. 1974, 32, 99-116

Sprynarova, S., J. Parizkova, Comparison of the functional, circulatory and respiratory capacity in girl gymnasts and swimmers. J. Sports Med. 1969, 9, 165-172

Thorstensson, A., J. Karlsson, The effect of strength training on muscle enzymes related to high energy phosphate metabolism. Acta physiol. scand. 1974, 91, 21A-22A

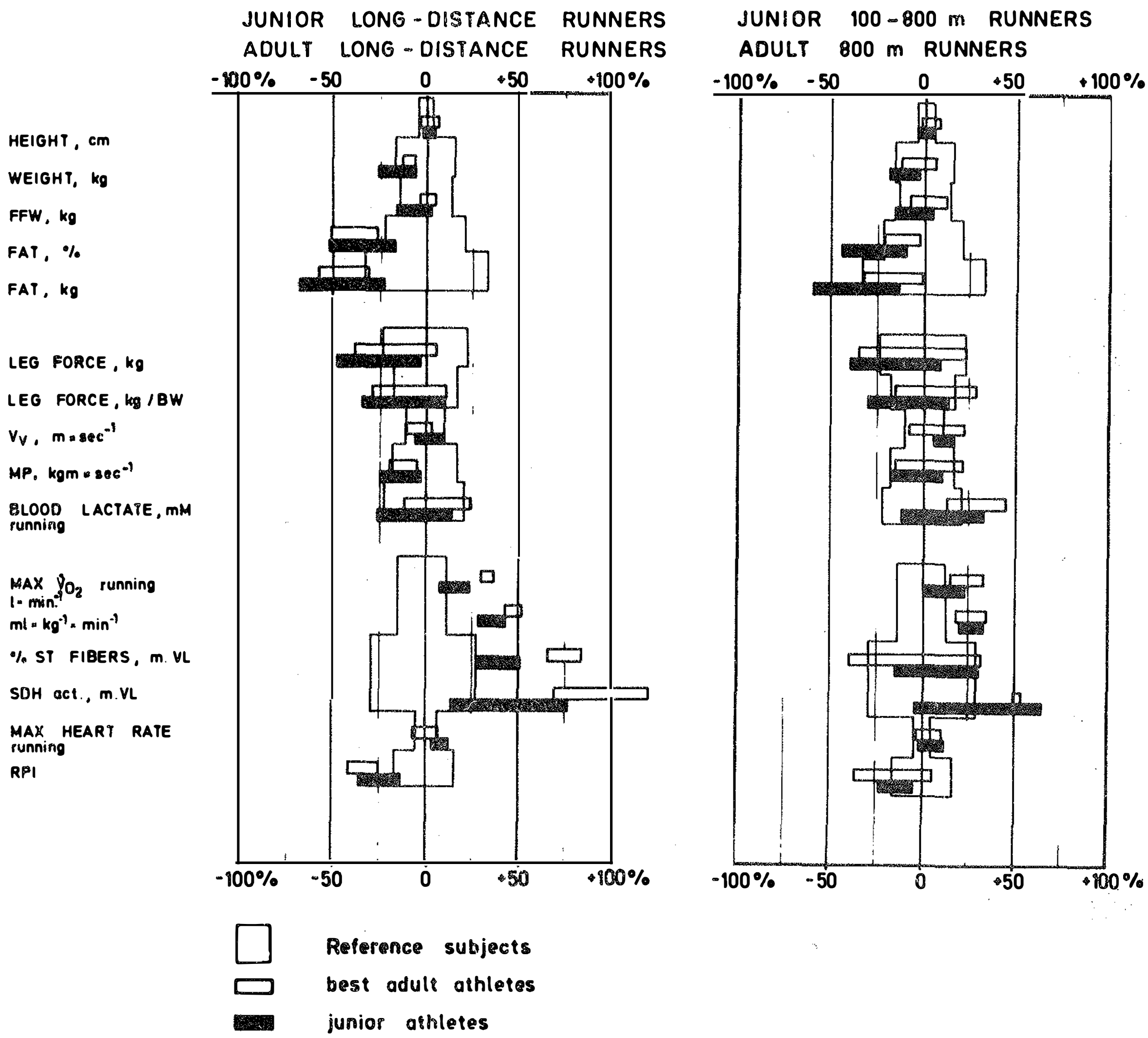
Thorstensson, A., B. Sjödin, J. Karlsson, Enzyme activities and muscle strength after "sprint training" in man. Acta physiol. scand. 1975, 94, 313-318

Åstrand, P-O., Experimental studies of physical working capacity in relation to sex and age. Munksgaard, Copenhagen 1952

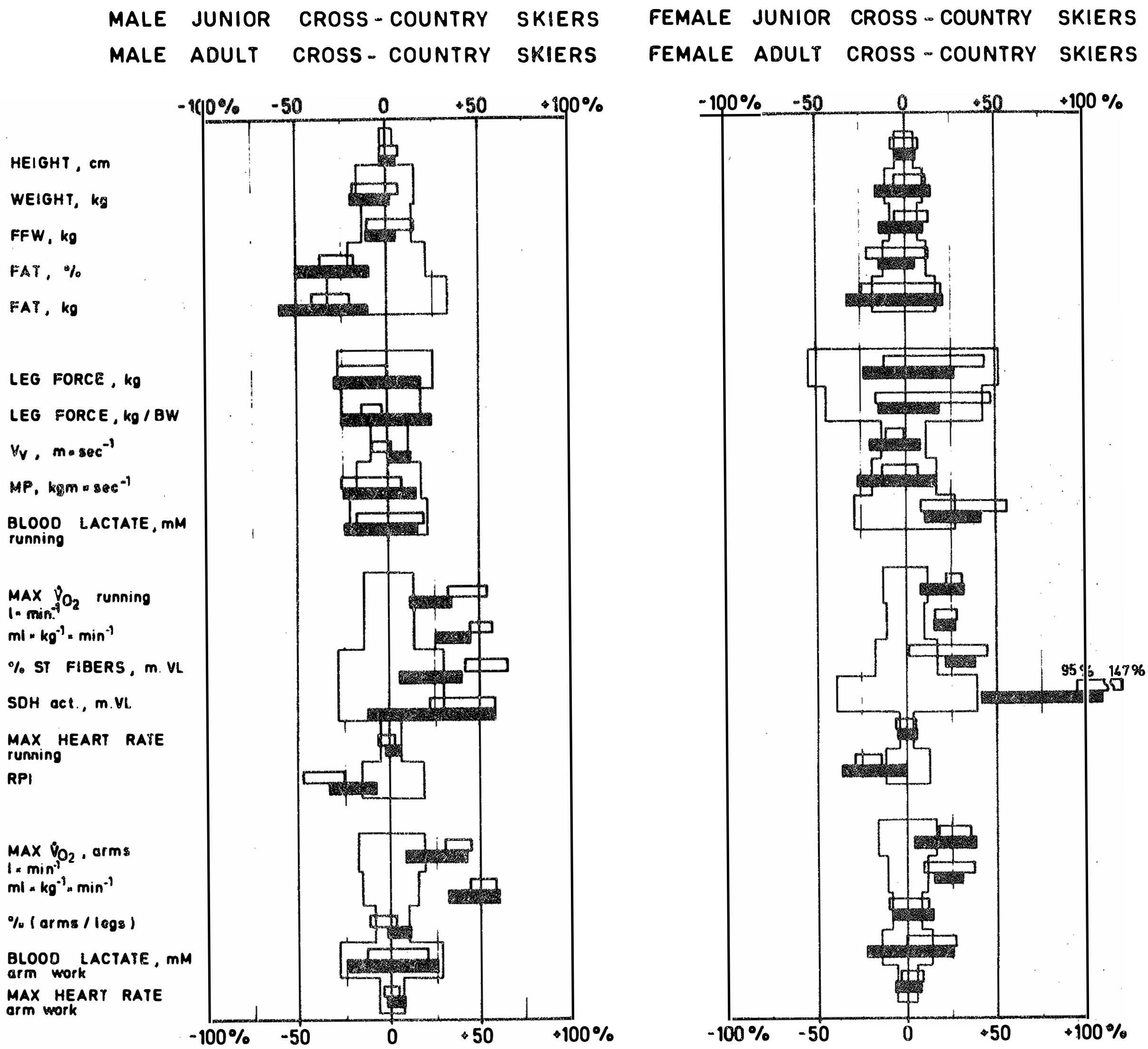
Åstrand, P-O., L. Engström, B. Eriksson, P. Karlberg, I. Nylander, B. Saltin, C. Thoren, Girl swimmers. Acta Paediat. 1963, suppl. 147

Åstrand, P-O., K. Rodahl, Textbook of work physiology. New York, McGraw-Hill 1970

Appendix 1. Fitness profiles of the junior long-distance (left) and short-distance (right) runners as compared to the corresponding fitness profiles of the best adult runners (Arstila and Rusko 1976). The mean values (± 1SD) of the athlete groups were compared to the corresponding mean values (zero line ± 1SD) of the reference subjects. Abbreviations are explained on page 3-4.



Appendix 2. Fitness profiles of the male (left) and female (right) junior cross-country skiers as compared to the corresponding fitness profiles of the best adult cross-country skiers (Arstila and Rusko 1976). For explanations see Appendix 1.



Appendix 3. Fitness profiles of the junior skijumpers as compared to the corresponding fitness profiles of the best adult skijumpers (Arstila and Rusko 1976). For explanations see Appendix 1.