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SEASONAL AND ANNUAL CHANGES IN PHYSICAL PERFORMANCE CAPACITY OF ELITE ATHLETES

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ABSTRACT

Seasonal and annual changes in physical performance characteristics of 10 female and 28 male cross-country skiers, 5 male nordic combination skiers and 7 male skijumpers were studied. Following parameters were investigated on most of the athletes: maximal oxygen uptake (max$\dot{V}_{O_2}$) in leg and arm work, vertical running velocity (V_v), total isometric leg force (TLF), percentage of slow twitch muscle fibers (%ST fibers) and succinate dehydrogenase activity (SDH) in m. vastus lateralis. The measurements were made between the spring of 1973 and winter of 1976. The yearly measurement times were spring (the beginning of the basic training period), autumn (a change from the basic training period to special training period of each event) and winter (competitive season).

The max$\dot{V}_{O_2}$ of the cross-country skier groups increased by 4.7 - 9.9 % from spring to winter and by 3.1 - 4.6 % annually. In arm work max$\dot{V}_{O_2}$ of the same subjects increased by 5.6 - 13.8 % from spring to winter and by 4.2 - 5.9 % annually. The nordic combination skiers increased annually their max$\dot{V}_{O_2}$ in leg by 1.7 % and in arm work by 5.7 %. The SDH activity of the male and female skiers increased by 32.7 % and 40.3 % from spring to winter and the annual increases were 29.8 % and 16.2 %, respectively. The nordic combination skiers increased their SDH activity by 42.5 % annually. The TLF of the nordic combination skiers and skijumpers increased annually by 24.8 % and 29.1 % and the annual increases in V_v were 16.1 % and 8.3 %, respectively. Annual increases in max$\dot{V}_{O_2}$, SDH activity, V_v and TLF were not related to the initial level in each parameter. The %ST fibers of no groups changed during the investigation period. Instead, the annual increases in max$\dot{V}_{O_2}$ were positively related to %ST fibers.

INTRODUCTION

Several investigations have described the effects of different training programs on the fitness and performance of relatively untrained subjects, such as children, young adults and middle-aged persons. In most cases considerable improvement in fitness variables has been observed and the effects of the different training programs have been compared. The application of these results to the training of athletes has met with serious suspicion by coaches because the athletes differ from the "normal" subjects with regard to their level of fitness and intensity and amount of training. The athletes should also continuously improve their fitness and performance. The purpose of this approach was to describe the seasonal and annual changes in physical performance characteristics of Finnish junior and senior athletes during their normal course of training.

MATERIAL AND METHODS

The subjects were 50 adult and junior athletes of international or national caliber. The anaerobic and aerobic performance characteristics of these and some other athletes have been described previously (Komi et al. 1976 a; Rusko et al. 1976 a, b). The athletes represented the following sport events: cross-country skiing (10 females and 28 males), nordic combination (5 males) and skijumping (7 males). The male cross-country skiers were divided into two subgroups of 10 adult and 18 junior skiers. Because of small numbers of repeated test results it was considered difficult to divide the other athletic groups into subgroups although 5 female skiers, 3 skijumpers and one nordic combination skier were junior athletes at the beginning of the investigation period (Table 1). All of the athletes were among the best Finnish athletes in their

Table 1. The physical characteristics of the subjects (mean and standard deviation).

	n	Age yrs	Height cm	Weight kg	FFW[x] kg	Fat[xx] %
Cross-country skiing,						
male adults	10	25.1 2.4	173.3 5.1	68.8 6.1	59.7 5.5	11.1 1.8
male juniors	18	19.1 1.9	174.5 5.1	68.0 4.3	60.4 3.8	10.9 2.0
females	10	21.2 4.2	165.3 6.7	59.3 6.6	46.6 4.2	21.9 2.9
Nordic combination,						
males	5	22.9 2.1	176.2 5.4	70.4 5.7	62.0 5.0	11.2 1.4
Skijumping,						
males	7	21.3 3.2	173.3 5.5	67.7 9.0	58.8 5.7	12.5 2.4

[x] Calculated as a mean of skinfold (Durnin and Rahaman 1967) and anthropometric (von Döbeln 1959) measurements.

[xx] According to Durnin and Rahaman (1967).

own sport events and most of them were members of the national training groups of the Finnish Ski Association. The athletes had trained under the leadership of experienced coaches for at least two years and had followed detailed training programs. Some of them had trained for nearly ten years. Thirty of the athletes had been members of the national teams in European Junior Championships, World Championships or the Olympic Games between 1972-1976. The measurements of this study were made between the spring of 1973 and the winter of 1976. The yearly measurement times were in the spring during May-June, in the autumn during September-October and in the winter during January-February-March. These times correspond to the beginning of the basic training period (spring),

Table 2. Number of subjects studied at various dates (S = spring, A = autumn, W = winter).

	total	1973		1974			1975			1976
	n	S	A	W	S	A	W	S	A	W
Cross-country skiing,										
male adults	10	6	3	5	-	4	1	4	6	2
male juniors	18	1	8	1	-	7	-	13	11	2
females	10	6	5	5	-	6	-	3	4	-
Nordic combination,										
males	5	5	3	-	3	2	-	3	1	-
Skijumping,										
males	7	7	3	-	7	6	-	-	-	-

a change from basic training period to special training period of each event (autumn) and to the competitive season (winter). Thus altogether 9 test occasions were organized; each athlete visited the laboratory and was tested from 2 to 6 times (Table 2).

The anthropometric variables (Table 1) were height, weight, percentage (fat, %) and total (fat, kg) amount of body fat from subscapular, triceps, biceps and suprailiac skinfolds (Durnin and Rahaman 1967) and fat-free body weight (FFW) calculated as a mean of skinfold measurements (Durnin and Rahaman 1967) and skeletal measurements (radio ulnar and femurcondylar widths and body height; von Döbeln 1959).

Vertical running velocity of the subjects was measured according to the method of Margaria et al. (1966). The subject ran up the stairs two steps at a time at maximal speed. The running velocity was recorded using photocells and an electric timer when a steady speed was attained. The recorded speed was converted to vertical velocity (V_v, m x sec^{-1}) and muscular power (MP, kg x m x sec^{-1}). The relative power index (RPI) was calculated by dividing the estimated theoretical oxygen cost of running by the measured maximal oxygen uptake (Margaria et al. 1966).

Total leg force (TLF) of extensor muscles of both legs was measured isometrically (knee angle 107 degrees) using a special dynamometer (Komi 1973). The relative leg force (RLF) was calculated by dividing the total leg force by body weight.

Maximal oxygen uptake (max$\dot{V}O_2$) during treadmill running and arm ergometer work was determined according to the principles outlined by Åstrand and Rodahl (1970) and presented previously by Rusko et al. (1976). After ten minutes' warming up and a short rest the actual test was started. The treadmill speed and the initial ergometer load were selected according to the fitness of the subjects so that they were exhausted in after about 10 minutes. The treadmill inclination was increased by 1° and ergometer load by 150 kpm x min^{-1} every second minute until exhaustion occurred. Oxygen uptake was measured using Douglas bags, Scholander gas analysis, calibrated dry gas meter and corrected for STPD (Consolazio et al. 1963). Heart rates were measured from the electrocardiogram taken during work. Blood lactate was measured from two capillary blood samples taken from a fingertip 3 and 5 minutes after maximal arm and leg work. The reagents and instructions of Biochemica Boehringer were used.

The percentage of slow twitch muscle fibers (%ST fibers) and succinate dehydrogenase (SDH) activity were assayed in muscle biopsies taken with the needle biopsy technique (Bergström 1962) from vastus lateralis muscle (m. VL).

For classification of muscle fibers into slow twitch and fast twitch types myosin ATPase staining was used according to Padykula and Herman (1955) and Gollnick et al. (1972). The %ST fibers was calculated from the numbers of slow and fast twitch fibers and usually 200-300 fibers were counted. Part of the muscle sample was weighed and 2 % homogenate was prepared in 1 M Tris-HCl buffer (pH 7.5) 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 x min^{-1} at 37°C.

RESULTS

The mean values and standard deviations for the main parameters before and after one or two years of training are seen in Tables 3 and 4. These changes have also been described using the fitness profiles (Arstila and Rusko 1976) in Appendices 1-5.

Table 3. Means and standard deviations of fat percentage, vertical velocity (V_v), relative leg force (RLF), maximal oxygen uptake (max$\dot{V}O_2$), %ST fibers and SDH activity in m. VL before and after one year of training.

Groups	n		Fat % $\bar{x}$	s	V_v m x sec^{-1} $\bar{x}$	s	RLF kg/BW $\bar{x}$	s	Max$\dot{V}O_2$ ml x kg^{-1} x min^{-1} legs $\bar{x}$	s	arms $\bar{x}$	s	%ST fibers $\bar{x}$	s	SDH act. nMxmg^{-1}xmin^{-1} $\bar{x}$	s
Cross-country skiing, male adults	4-6	before	10.5	1.0	1.29	0.13	4.23	0.68	81.5	6.3	60.5	4.8	73.7	5.4	28.4	3.8
		after	9.4^x	1.0	1.35	0.11	4.40	0.57	84.8	7.0	64.1	4.3	71.0	6.4	36.3^x	8.7
Cross-country skiing, females	4-6	before	20.1	2.4	1.27	0.07	3.70	1.31	70.2	2.7	56.0	3.8	59.0	7.4	19.7	5.0
		after	19.7	2.4	1.29	0.05	4.05	0.90	68.9	5.1	55.3	5.8	63.4	11.5	22.9	5.4
Cross-country skiing, male juniors	6-9	before	11.5	2.3	1.32	0.08	3.62	0.54	78.3	3.6	59.8	5.5	63.8	9.0	19.7	6.1
		after	10.4^x	2.6	1.41^x	0.05	4.31^x	0.39	80.9	4.8	59.8	4.5	60.3	9.7	26.6^o	5.4
Nordic combination, males	5	before	12.2	1.5	1.32	0.08	3.73	0.41	72.3	2.4	48.1	3.5	68.5	7.1	18.6	1.3
		after	11.2	1.2	1.41^x	0.05	4.35^x	0.62	72.8	1.7	49.7	4.5	66.9	6.0	26.5^o	4.9
Skijumping, males	6-7	before	13.3	3.2	1.45	0.12	3.86	0.49	65.1	3.9			56.8	10.6		
		after	12.2	2.9	1.57^o	0.07	4.83^o	0.84	62.1	4.0			56.5	4.2		

^{x} Significant change, p .05 ^{o} Significant change, p .01

Table 4. Means and standard deviations of the main parameters (see Table 3) before and after two years of training.

Groups	n		Fat %		V_v m x sec^{-1}		RLF kg/BW		$MaxV_{O_2}$ ml x kg^{-1} x min^{-1} legs		arms		%ST fibers		SDH act. nM x mg^{-1} x min^{-1}	
			$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Cross-country	3-6	before	11.8	0.9	1.26	0.11	3.92	0.63	83.3	4.8	59.2	3.2	77.0	5.2	25.7	9.7
skiing, male adults		after	9.1^{o}	1.0	1.36	0.13	4.23	0.53	86.7^{x}	4.3	64.8^{x}	4.7	71.7	9.3	41.9^{x}	6.3
Cross-country	3	before	20.9	2.3	1.17	0.05	3.81	1.27	67.0	2.9	48.2	9.6				
skiing, females		after	16.8^{x}	1.4	1.21	0.09	4.45	1.04	74.2	3.3	55.4	8.3				
Cross-country	3	before	12.1	2.3	1.37	0.06	3.60	0.70	77.2	1.5	59.7	7.7				
skiing, male juniors		after	11.5	2.4	1.46	0.06	4.35	0.39	81.4	4.4	63.2	4.1				
Nordic combination,	3-4	before	11.8	2.1	1.21	0.13	3.55	0.46	73.7	3.6	48.8	2.7				
males		after	10.7	1.7	1.61^{o}	0.08	5.42^{x}	1.13	73.0	1.4	53.3	5.1				

^{x}Significant change, p .05 ^{o}Significant change, p .01

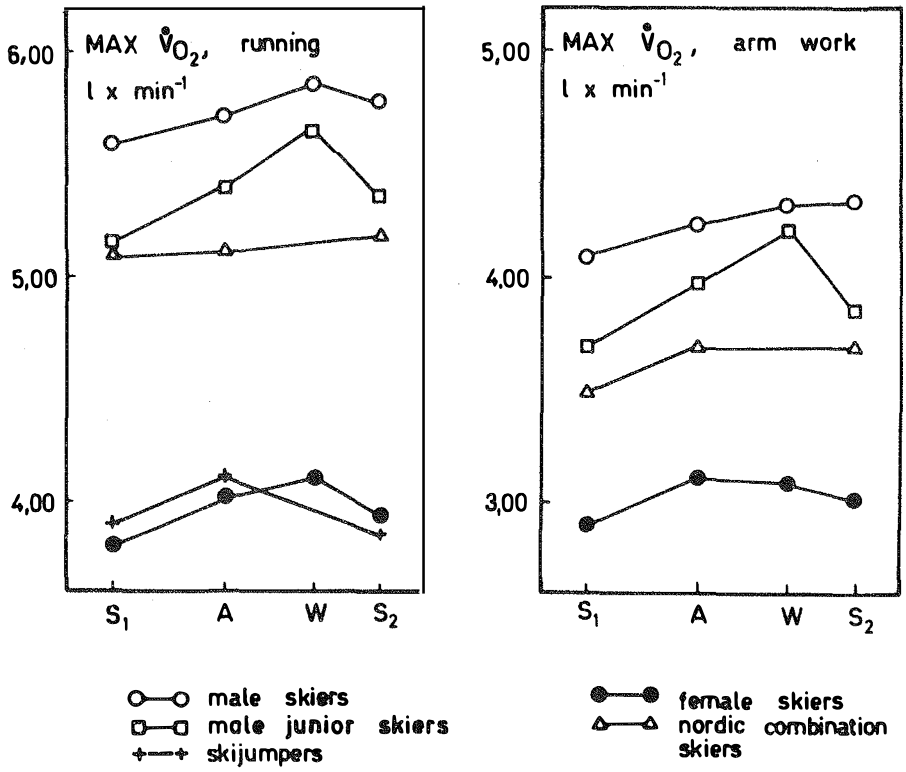
In adult male skiers the following significant changes were observed after one year of training: increase in fat-free weight, maximal oxygen uptake in arm work, SDH activity in m. VL and decrease in the fat percentage of the body. In addition, after two years of training, body weight, maximal oxygen uptake in leg work, max$\dot{V}_{O_2}$ ratio (arms/legs), maximal heart rate in arm and leg work and muscular power had increased and the amount of body fat had decreased significantly. In female skiers the significant changes after one or two years of training were increase in height, body weight and fat-free body weight as well as decrease in the fat percentage and maximal heart rate during arm work. The male junior skiers had significantly higher height, body weight, fat-free weight, maximal oxygen uptake in leg work, SDH activity in m. VL, total and relative leg force, vertical velocity and muscular power after one year of training. After two years of training the same trend continued. The nordic combination skiers had increased significantly their total and relative leg force, vertical velocity, muscular power, relative power index and SDH activity in

m. VL during one year of training, and after two years of training their fat-free weight had increased, too. After one year of training the skijumpers had significantly higher total and relative leg force, vertical velocity, muscular power and relative power index.

To describe the seasonal variations within the different athlete groups the mean changes in the main parameters were calculated for the following time periods: (1) from spring to autumn, (2) from autumn to winter, (3) from spring to winter and (4) from winter to next spring. On the basis of these initial calculations the average curves for each group were formulated (Figures 1 and 2). The maximal aerobic power (Figure 1) of the male adult and female skiers increased between the spring and the competitive season by 4,7 % (0,26 l x min^{-1}) and 6,7 % (0,28 l x min^{-1}), respectively. The male adult skiers increased their max$\dot{V}_{O_2}$ mainly during special training period and female skiers during basic training period. Max$\dot{V}_{O_2}$ of skiers of both sexes decreased slightly between the end of the competitive season and the start of the next basic training period. During two years of investigation the average annual improvements in max$\dot{V}_{O_2}$ were 3.4 % in male adult skiers and 3.1 % in female skiers. These yearly improvements correspond to about 0.18 l x min^{-1} (males) and 0.12 l x min^{-1} (females).

Max$\dot{V}_{O_2}$ of the male junior skiers improved from spring to autumn and even further from autumn to winter and the average change from spring to the competitive winter season was 9.9 % (0.51 l x min^{-1}). The average annual improvement was, on the average, 4.6 % corresponding to 0.24 l x min^{-1}.

Figure 1. Means of maximal oxygen uptake in leg and arm work in spring (S_1), in autumn (A), in winter (W) and in next spring (S_2).



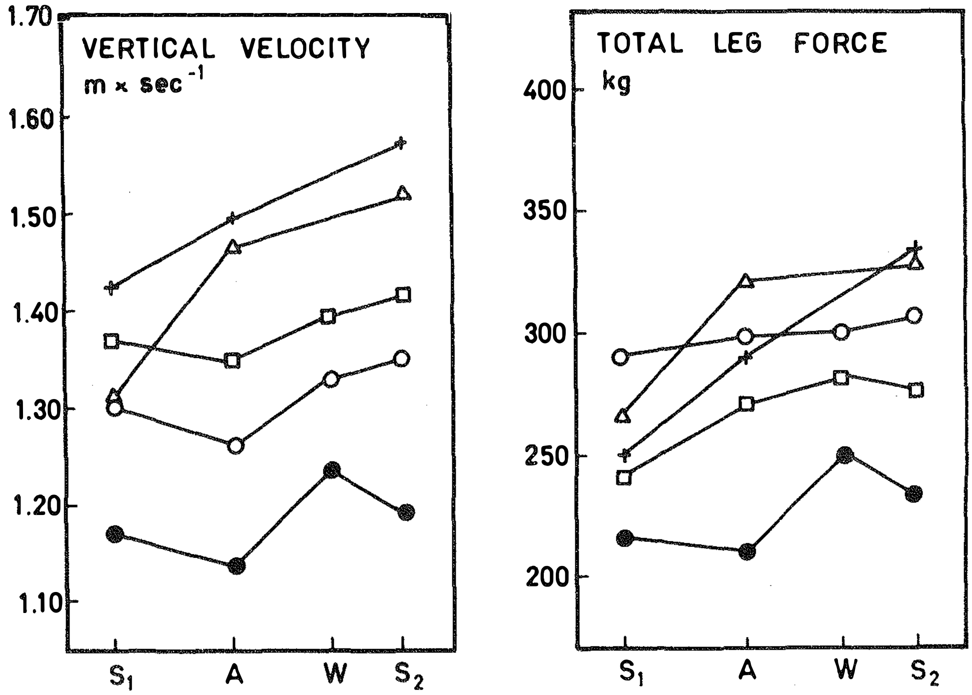
The nordic combination skiers showed only minor seasonal and annual changes in max$\dot{V}_{O_2}$. Their yearly improvement was, on the average, 1.7 % but not noticeable when max$\dot{V}_{O_2}$ is expressed in ml x kg^{-1} x min^{-1}. The annual improvement of male junior skiers decreased also to 2.3 % when the change in body weight was taken into account. Male adult (2.7 %) and female (2.9 %) skiers showed also slightly smaller changes in max$\dot{V}_{O_2}$ as expressed in ml x kg^{-1} x min^{-1}. The max$\dot{V}_{O_2}$ of skijumpers increased by 5-6 % from spring to autumn but the mean annual change was 1-2 % decrease in max$\dot{V}_{O_2}$.

In arm work (Figure 1) the maximal aerobic power of male adult and female skiers increased between spring and the competitive season on the average by 5.6 % and 6.7 %, respectively. These increases occurred during the basic training period. Slight decrease was observed in max$\dot{V}_{O_2}$ of the female skiers primarily between autumn and the competitive season. Thereafter the max$\dot{V}_{O_2}$ in arm work decreased further slightly (females) or improved a little (male adults) and thus the average yearly increases were 5.9 % in male adult and 4.2 % in female skiers. On the other hand, values of the male junior skiers improved between spring and autumn and further from autumn to the competitive winter season by 13.8 % but due to the lowering of the arm work performance immediately after the competitive season their yearly improvement was in the mean 3.9 %. The nordic combination skiers improved their max$\dot{V}_{O_2}$ in arm work by 5.4 % during basic training period and by 5.7 % yearly.

The vertical velocity (Figure 2) of male adult, female and male junior skiers decreased during the basic training period and increased during the special training period. The average changes between spring and the competitive season were improvements of 2.6 % and 7.3 % and 1.9 % in these three groups, respectively. The average yearly improvements in vertical velocity were 4.2 % (male adults), 1.7 % (females) and 4.5 % (male juniors). The nordic combination skiers improved their vertical velocity by 11.9 % from spring to autumn and their average yearly improvement was 16.1 %. The corresponding improvements in skijumpers were 4.8 % and 8.3 %.

The total leg force (Figure 2) of male adult skiers increased between spring and the competitive season by 2.3 %. The female skiers and male junior skiers gained force by 20.5 % and 17.3 %, respectively, during this time. The average yearly increases in total leg force of these groups were 4.9 % (male adult skiers), 9.1 % (female skiers) and 14.9 % (male junior skiers). The nordic combination skiers gained 11.4 % force during the basic training period and their yearly improvement was in the mean 24.8 %. The skijumpers increased their total leg force by 13.1 % from spring to autumn and by 29.1 % in one year.

Figure 2. Means of vertical velocity and total leg force in spring (S_1), autumn (A), winter (W) and next spring (S_2). The symbols are explained in Figure 1.



The relative power index of male adult, female and male junior skiers stayed at the same level during the investigation period. The seasonal changes in RPI were comparable with the changes in vertical velocity except skijumpers, whose RPI did not change from spring to autumn but their mean yearly improvement was 14.1 %.

The %ST fibers in m. VL of male adult and female skiers did not change significantly from the basic training period to the competitive season. The average yearly change in %ST fibers of every group studied was also insignificant. Both male adult and female skiers had higher mean SDH activity in m. VL during the competitive season as compared to the basic training period but only the female skiers increased their SDH activity significantly. The annual increases in SDH activity of male adult, male junior and nordic combination skiers were significant (Tables 3 and 4 and Appendices 1-4).

Two of the male adult skiers were tested six times during the investigation period. On the average, their weight increased and the fat percentage decreased slightly during the two years. These two skiers increased their max$\dot{V}_{O_2}$ by 6.5 % from spring to winter and their average yearly improvement was 1.6 %. Their max$\dot{V}_{O_2}$ decreased from 5.89 l x min^{-1} in the autumn of 1973 to 5.71 l x min^{-1} in the autumn of 1974, but in the autumn of 1975 their max$\dot{V}_{O_2}$ had increased to 6.17 l x min^{-1}. During arm work their max$\dot{V}_{O_2}$ increased by 6.7 % between spring and the competitive season and the average yearly improvement was 10.0 %. No essential changes were observed in %ST fibers but SDH activity increased from 25.4 nM x mg^{-1} prot x min^{-1} in 1973 to 38.9 nM x mg^{-1} prot x min^{-1} in 1975. The corresponding results for one nordic combination skier showed almost no changes in leg max$\dot{V}_{O_2}$. In arm work his max$\dot{V}_{O_2}$ had increased from spring to autumn in 1973 but after that it stayed the same. This nordic combination skier improved his total leg force by 51 % and vertical velocity by 29 % from 1973 to 1975.

Two skijumpers were tested four times between spring 1973 and autumn 1974. During this time their max$\dot{V}_{O_2}$ decreased from 3.90 l x min^{-1} to 3.69 l x min^{-1}, their total leg force increased by 37.4 % and their vertical velocity increased by 5.4 %.

The effects of %ST fibers and initial level of each performance variable were studied by dividing each group of athletes into two subgroups on the basis of the following: those whose values were below group average and those whose values were above average. The initial level of maximal oxygen uptake, vertical velocity, total and relative leg force, and SDH activity in m. VL had no significant relationship to the annual increases in each parameter. Instead, those whose %ST fibers in m. VL were above average were able to increase their maximal oxygen uptake annually more ($p < .05$) than those whose %ST fibers were below average in each group (Table 5). When only athletes competing in cross-country skiing were included the tendency was the same.

Table 5. The mean annual changes of max$\dot{V}_{O_2}$ (ml x kg^{-1} x min^{-1}) in leg work for four subgroups of athletes. The athletes were divided into the subgroups on the basis of %ST fibers in m. VL and the initial level of max$\dot{V}_{O_2}$.

Mean annual changes in max$\dot{V}_{O_2}$ (ml x kg^{-1} x min^{-1})		Initial level of max$\dot{V}_{O_2}$: below average	Initial level of max$\dot{V}_{O_2}$: above average	Mean annual change
%ST fibers, m. VL	above average	+1.6 ml 2.0	+1.7 ml 2.7	+1.7 ml 2.3
	below average	+0.2 ml 3.2	-0.9 ml 4.3	-0.3 ml 3.6
Mean annual change		+0.9 ml 2.7	+0.5 ml 3.6	

$t = 1.74$
$n = 29$
$p < .05$

DISCUSSION

The data concerning the effects of physical training have often been drawn from cross-sectional studies by comparing the physiological characteristics of well-trained persons to those of sedentary subjects. However, these studies do not reveal whether the differences between groups depend on constitutional factors or on the effects of the training process. In this study it was possible to follow-up the performance capacity of Finnish elite athletes from spring 1973 to winter 1976. Because of the poor performance of the Finnish athletes in the Olympic Games in Sapporo in 1972 the training of the athletes was intensified in order to compete more succesfully in international competitions. Special emphasis was put on the improvement of max$\dot{V}_{O_2}$ both in arm and leg work, on the increase of total amount of training and on the control of training using tests and training diaries.

It has been proposed that max$\dot{V}_{O_2}$ is an endowed physiological characteristic which cannot be improved by more than about 50 % after which a ceiling of max$\dot{V}_{O_2}$ is achieved no matter how much one trains or how intensively one trains (Klissouras 1971; Åstrand and Rodahl 1970; Saltin and Åstrand 1967; Ekblom 1969). In this study no definite ceiling of max$\dot{V}_{O_2}$ was observed in the values of the best skiers. This is possibly due to the intensified training of the athletes studied, which might have been reflected also in the tendency to attain higher maximal heart rates in the maximal treadmill running test after two years of training. All male adult skiers were able to increase their max$\dot{V}_{O_2}$ but three female skiers and one male junior skier demonstrated a slight decrease in their max$\dot{V}_{O_2}$. In the female skiers this was evidently due to a lack of hard competitions in the winter of 1975 between the World Championships in Falun 1974 and the Olympic Games in Seefeld in 1976, and only a few of them were studied during the 1975-1976 training season. The lack of hard competition was reflected also in max$\dot{V}_{O_2}$ of male adult and nordic combination skiers. According to the training diaries and information from the coaches the athletes had trained quantitatively more for winter 1975 but the intensity of training might have decreased during this time.

The increase in max$\dot{V}_{O_2}$ was not related significantly to the initial level of max$\dot{V}_{O_2}$ but a tendency was observed in that those having a low max$\dot{V}_{O_2}$ were able to increase their max$\dot{V}_{O_2}$ more. On the other hand, the muscle fiber composition was positively related to the changes in max$\dot{V}_{O_2}$ showing that athletes with high %ST fibers have not only higher max$\dot{V}_{O_2}$ (Rusko et al. 1976) but also higher annual increases in max$\dot{V}_{O_2}$ as compared to the other athletes. However, it is believed that the initial level of max$\dot{V}_{O_2}$ and muscle fiber composition have smaller effect on the improvement of max$\dot{V}_{O_2}$ as compared to training as such, which thus would be the most important factor for having a high max$\dot{V}_{O_2}$.

Prolonged work capacity or the ability to work long times near the max$\dot{V}_{O_2}$ is needed, in addition to high max$\dot{V}_{O_2}$, in the cross-country skiing competitions. This prolonged work capacity might include high local endurance capacity in the working muscles, availability of substrates in the muscles and blood and proper regulation of various functions of the body. In this study the prolonged work capacity was estimated indirectly by determining the %ST fibers and SDH activity in m. VL. It has been observed previously (Gollnick et al. 1972; Rusko et al. 1976 a) that the elite endurance athletes have a high %ST fibers in their muscles and that this characteristic remains unchanged after shorter periods of endurance (Gollnick et al. 1973) or sprint and strength training (Thorstensson et al. 1974 and 1975). In this study no significant changes were observed in muscle fiber composition of endurance athletes or of skijumpers. Because this variable seems to be determined solely by hereditary factors (Komi et al. 1976 b) it is concluded that the top level athletes are products of genetic selection at least in endurance sport events. However, a few of the successfull cross-country skiers had relatively low %ST fibers in their muscles. These athletes were characterized by very small fast twitch fibers and very large slow twitch fibers resulting in a higher volume fraction of ST fibers than expected from the numbers of FT and ST fibers.

The SDH activity of the muscles of the endurance athletes was found to increase during the investigation period, but at the end of the study the enzyme activities of the cross-country skiers were still lower than those of long-distance runners (Rusko et al. 1976 a) or bicyclists (unpublished results). During skiing, when large muscle masses are working, the training loads relatively more the central circulation as compared to the local strain of running and bicycling. The SDH activity of the endurance athletes studied did not appear to decrease after the competitive season as proposed by Bergh (1974). This might result from the intensified training during special spring skiing camps in May. On the basis of the information on athletes' training as given by the coaches it is suggested that the level of SDH activity is determined mainly by the total amount of training or by the total amount of work done by the muscles.

Vertical velocity, relative power index and isometric leg force of skijumpers and nordic combination skiers were low at the beginning of the investigation period. This most probably resulted from too much emphasis having been placed on endurance training and too little on speed-force training. Although the intensified speed-force training improved their values, much work remains to be done in the development of speed-force training to the level required for international elite athletes.

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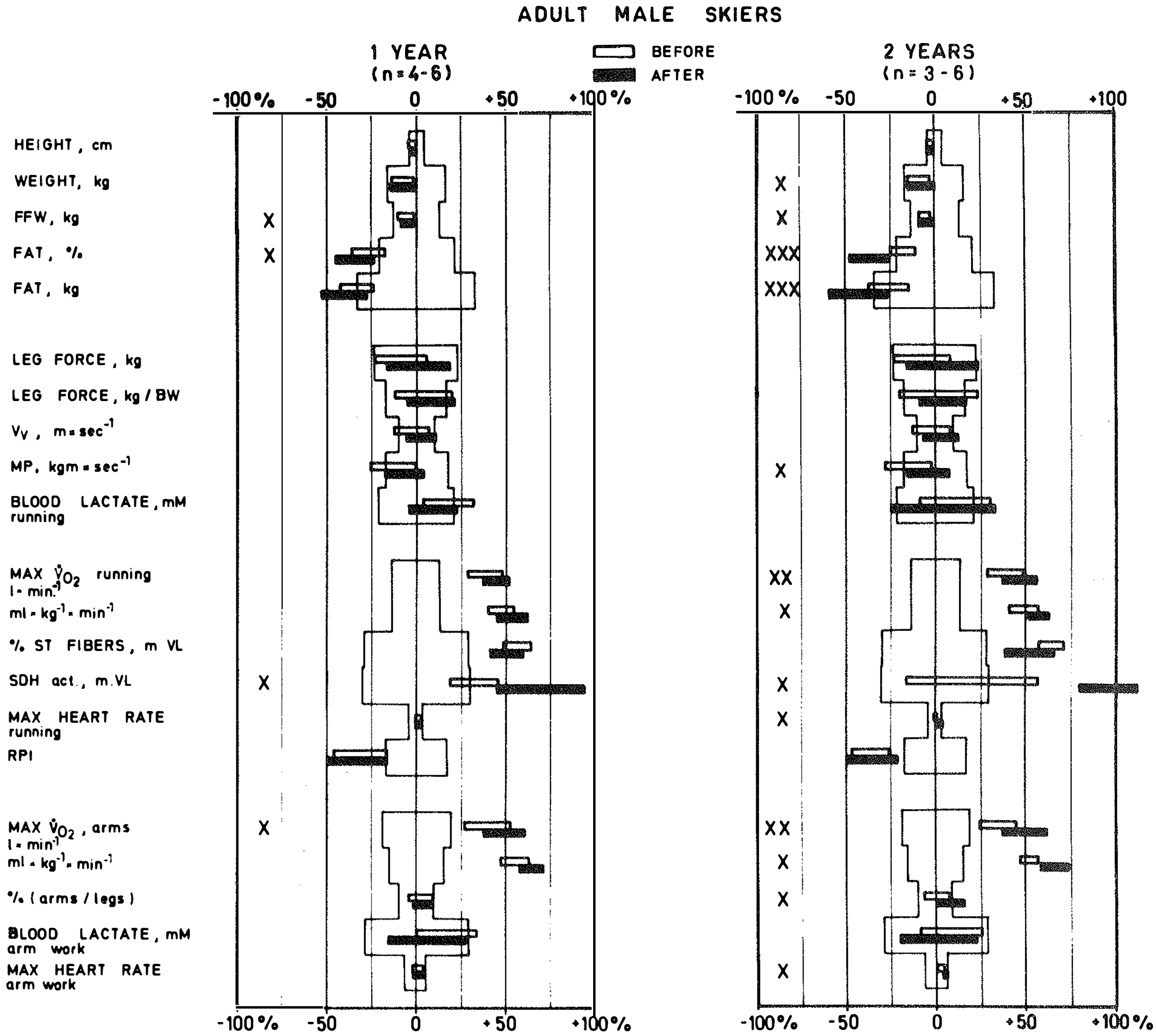
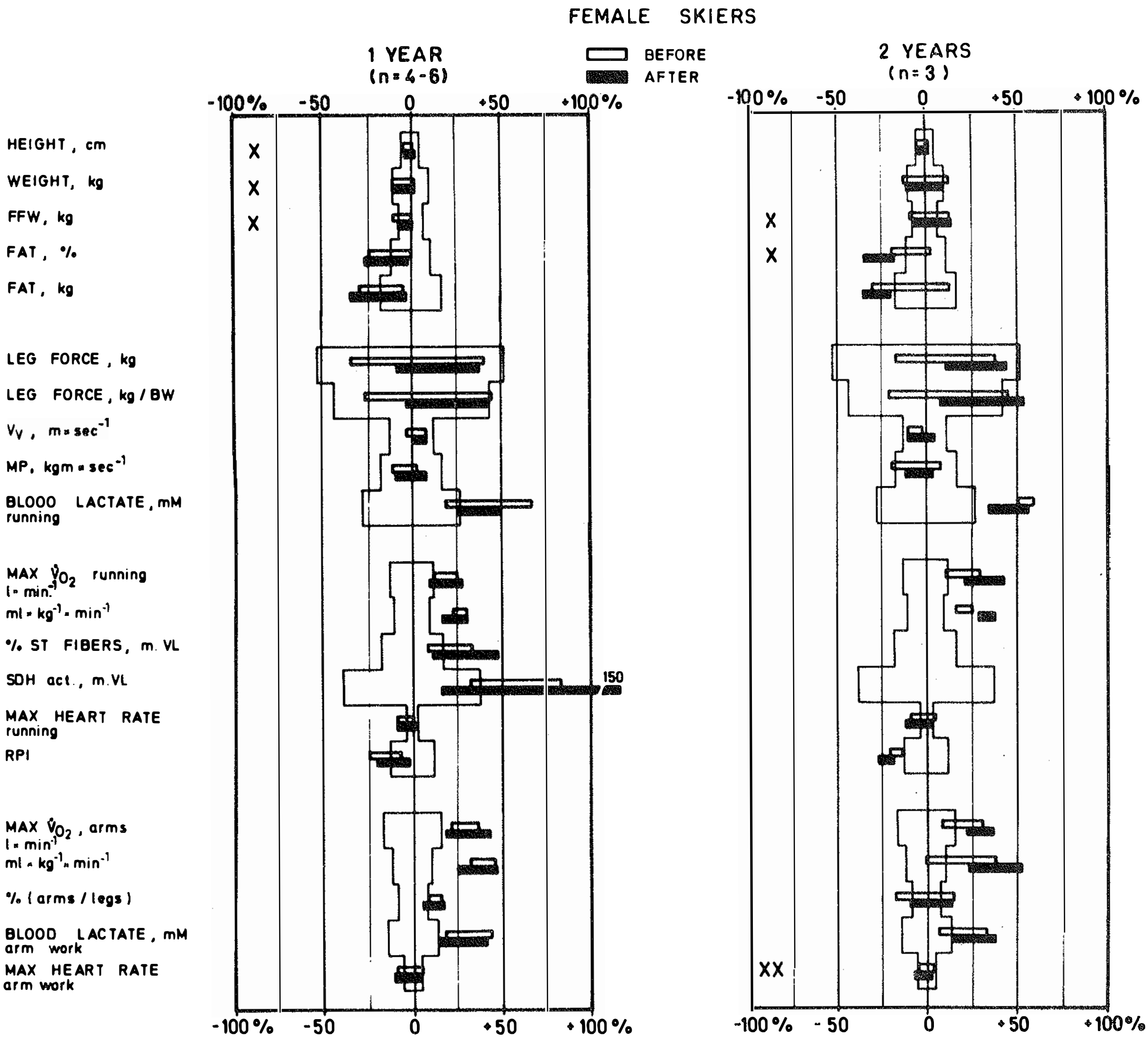
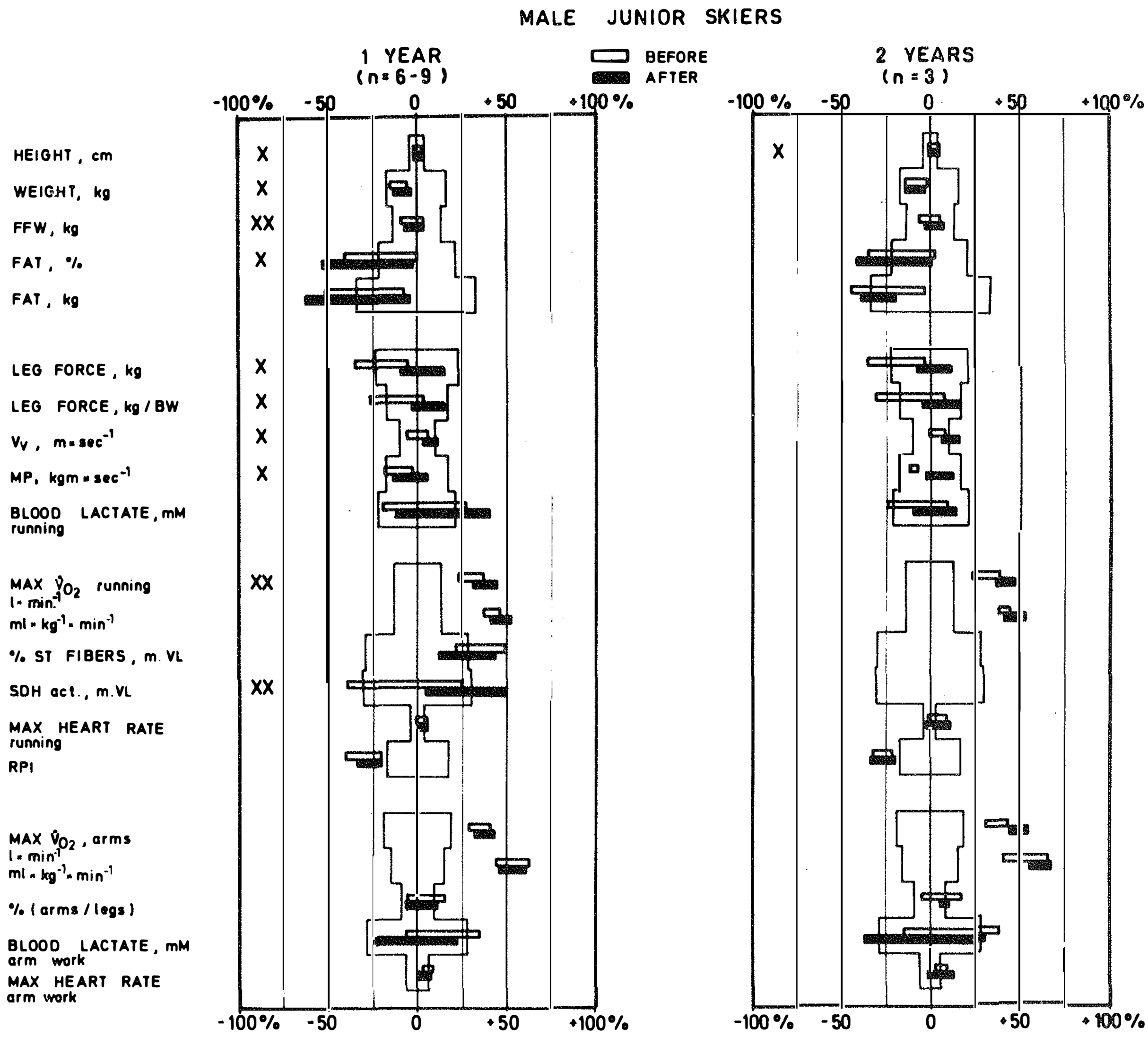
Appendix 1. Fitness profiles of the male adult cross-country skiers before and after one (left) or two (right) years of training. The mean values of the athletes (± 1 SD) have been compared to the mean values (zero line ± 1 SD) of the reference group in each parameter (Arstila and Rusko 1976). The crosses in the profiles denote significant changes (x = p< .05, xx = p<.01, xxx = p<.001). Abbreviations are explained on page 3 to 5.



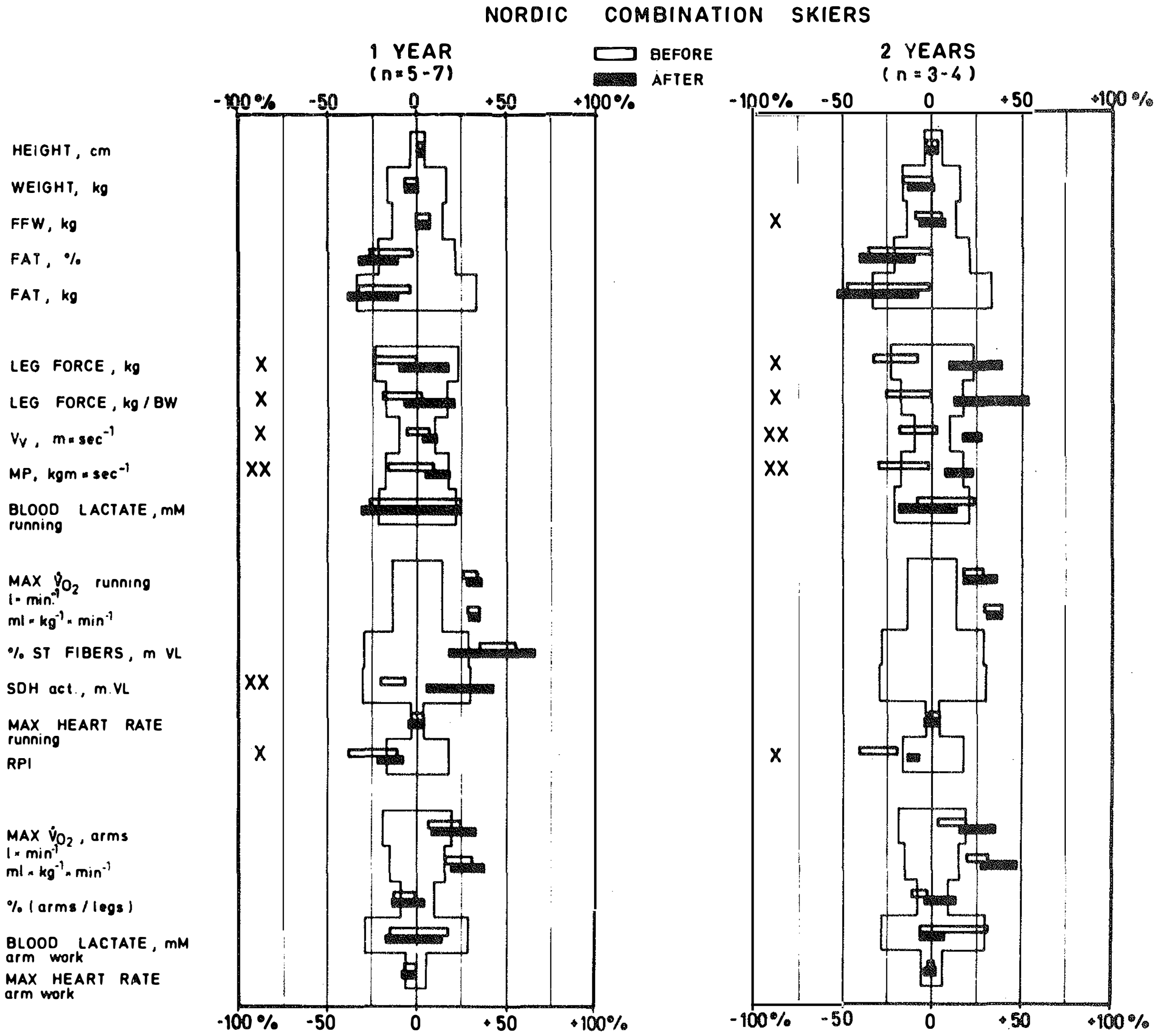
Appendix 2. Fitness profiles of the female cross-country skiers before and after one (left) or two (right) years of training (see also Appendix 1). The crosses in the profiles denote significant changes (x = p<.05, xx = p<.01, xxx = p<.001).



Appendix 3. Fitness profiles of the male junior cross-country skiers before and after one (left) or two (right) years of training (see also Appendix 1). The crosses in the profiles denote significant changes (x = p<.05, xx = p<.01, xxx = p<.001).



Appendix 4. Fitness profiles of the nordic combination skiers before and after one (left) or two (right) years of training (see also Appendix 1). The crosses in the profiles denote significant changes (x = p<.05, xx = p<.01, xxx = p<.001).



Appendix 5. Fitness profiles of the skijumpers before and after one year of training (see also Appendix 1). The crosses in the profiles denote significant changes (x = p<.05, xx = p<.01, xxx = p<.001).