UNIVERSITY OF JYVÄSKYLÄ
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FINLAND

RESEARCH REPORTS FROM THE

DEPARTMENT OF BIOLOGY OF PHYSICAL ACTIVITY

NUMBER

10/1976

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by

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This study has been supported with grants from the Finnish Olympic Committee and from the Finnish Research Council for Physical Education and Sports (Ministry of Education).

ISBN 951-677-669-8

URN:ISBN:978-951-39-8731-2
ISBN 978-951-39-8731-2 (PDF)

ABSTRACT

The requirements of 11 different sport events were studied on the basis of fitness profiles calculated from the results of 4 - 6 best athletes in each sport event and on the basis of correlation coefficients between parameters studied and the ranking order in athletes' own sport event. Each sport event seemed to have its own specific requirements and even the pure endurance events, cross-country skiing and long-distance running, differed from each other Inspite of the specific demands the events could be classified into four subgroups. The aerobic endurance events included cross-country skiing, long-distance running and nordic combination. The canoeists, 800m runners and alpine skiers were classified into anaerobic endurance athletes. The third group of events, ice hockey and speed skating, were regarded as speed-endurance events. The skijumpers 100 400m runners jumpers and throwers formed the fourth group of events: power events

Based on the correlation coefficients between various parameters it is suggested that the neuromuscular and anaerobic determinants of physical performance capacity are opposite characteristics of aerobic performance capacity both at whole body level and at muscle tissue level.

INTRODUCTION

In order to achieve new records and victories in international competitions there is an ever-increasing demand for more effective and especially for more specialized training. However, in most instances the development of such specialized training programs still rests on the trial and error type of approach rather than on the knowledge of physiological and kinesiological characteristics of each special sport event. Our approach to obtain such information is to make detailed studies on elite athletes in various sport events in order to see how these athletes differ from relatively untrained subjects and to characterize the major physiological differences between athletes competing in different sport events.

MATERIAL AND METHODS

Altogether 89 athletes and 38 reference subjects were employed in the study. The athletes represented the following sport events: cross-country skiing (17 male and 5 females), nordic combination (5 males), skijumping (9 males), alpine skiing (6 males), speed skating (6 males), ice hockey (13 males), canoeing (8 males), power events (6 males, 100-400m running 3, throwing 1, jumping 1, decathlon 1), long-distance (8 males) and 800m (6 males) running. The physical characteristics and the performance characteristics of these athletes have been described in previous reports (Komi et al. 1976, Rusko et al. 1976).

Only the best athletes were included in the calculations of the fitness profiles. These athletes were four male and five female cross-country skiers, four nordic combination skiers, four skijumpers, six alpine skiers, six speed skaters, six ice hockey players, four canoeists, six power athletes, four long-distance runners and six 800m runners. These athletes were among the best of Finnish athletes in their own particular sport event. Almost all of them had belonged to the Finnish national teams and most of them had been successful in international competitions.

The reference subjects were divided into three groups. The male reference subjects (23) were policemen, students and members of the university staff and most of them had exercised regularly according to their own fitness programs. The male physical education students (8) had trained and competed without any special success in their own sport specialities. The female reference subjects (7) were three physical education students, two physiotherapists, one dentist and one clerical worker and all of them had trained regularly according to their own fitness programs.

The anthropometric variables were height, weight, fat-free weight, percentage and total amount of body fat estimated from skinfolds. The variables of neuromuscular and anaerobic performance capacity were vertical velocity (V_v) and muscular power (MP) during running up the stairs, total (TLF) and relative (RLF) maximal isometric force of extensor muscles of both legs and blood lactate concentration after maximal treadmill running test. The variables of aerobic performance capacity were maximal oxygen uptake (max$\dot{V}_{O_2}$) and maximal heart rate during maximal treadmill running test, percentage of slow twitch fibers (%ST fibers) and succinate dehydrogenase (SDH) activity in m. vastus lateralis (VL). The relative power index (RPI, speed/endurance) was also calculated for all subjects.

In addition, max$\dot{V}_{O_2}$ and maximal heart rate during and blood lactate after maximal arm ergometer work, ratio between arm and leg max$\dot{V}_{O_2}$ and maximal isometric arm force were determined for male and female cross-country skiers, nordic combination skiers and most of the reference subjects. Furthermore lactate dehydrogenase (LDH) activity in m. VL of male and female cross-country skiers, nordic combination skiers, alpine skiers and skijumpers was assayed.

Max$\dot{V}_{O_2}$ during treadmill running and arm ergometer work was determined according to the principles described by Åstrand and Rodahl (1970) and the methods have been presented previously (Rusko et al. 1976). Oxygen uptake was measured using Douglas bags, Scholander gas analysis, wet and dry gas meters and corrected for STPD.

A muscle biopsy was taken from m. VL according to Bergström (1962). In order to classify the 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). Part of the muscle sample was weighed, homogenized and used for SDH activity (Pennington 1961), LDH activity (Kornberg 1955) and protein (Lowry et al. 1951) determination. SDH activity was expressed as nM substrate reduced x mg^{-1} muscle protein x min^{-1} at 37°C and LDH activity as µM NADH oxidized x mg^{-1} protein x min^{-1} at 22°C.

The running velocity of the subjects was measured using the method of Margaria et al. (1966). The subjects ran up the stairs at maximal speed two steps at a time. The running velocity was recorded electronically and the vertical component of the speed in m x sec^{-1} (V_v) and kg x m x sec^{-1} (MP) was calculated. RPI was obtained by dividing the estimated theoretical oxygen cost of running by the measured maximal oxygen uptake (Margaria et al. 1966).

The isometric forces of extensor muscles of both legs and the right elbow were measured in standard positions using special dynamometers (Komi 1973 a, b). The angles of the knees and the elbow were 107 and 94 degrees, respectively. The relative leg force was calculated 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 maximal arm ergometer work. The reagents and instructions of Biochemica Boehringer were used.

Heart rate was registered every minute during the work tests using a one-channel ECG-apparatus.

The performance level in actual sport events was scored as follows. The ranking lists of the Finnish Ski Association during winters 1973, 1974 and 1975 were used to place the male and female cross-country skiers, the nordic combination skiers, alpine skiers and skijumpers in order of superiority. The 800m runners and long-distance runners were ranked according to their best 800m, 3000m, 5000m, 10000m and marathon running times during 1973, 1974 and 1975 using international rating tables for the comparison of the different distances and seasons. The ranking of canoeists and speed skaters was easy because their order was almost the same in all competitions they participated. The ice hockey players were ranked into two groups: those who had belonged to the Finnish national team during seasons

1973-74 and 1974-75 and the other players who all belonged to the best Finnish club team during the season 1974-75.

The fitness profiles were calculated as follows. The mean values ($\pm$ one standard deviation) of the 4 - 6 best athletes in each sport event were compared to the corresponding mean values ($\pm$ one standard deviation) of the reference subjects of the same sex. The mean values of the reference subjects were taken to represent the zero line in each performance characteristics.

RESULTS

There were no similar fitness profiles as calculated from the results of the best athletes in each sport event (Figure 1-5, see also the numerical values in Appendix 1). The differences in fitness profiles were most prominent between endurance and power athletes.

The best cross-country skiers and long-distance runners differed from the male reference subjects by having smaller fat depots and higher max$\dot{V}_{O_2}$ in leg work. The cross-country skiers tended to have slightly higher max$\dot{V}_{O_2}$-values than long-distance runners. With respect to the %ST fibers and SDH activity in m. VL the best long-distance runners had higher values than the best cross-country skiers who also had higher mean values as compared with the reference subjects. In both groups the RPI was smaller than the mean value of the reference subjects. In arm work the male cross-country skiers had 30-60% higher max$\dot{V}_{O_2}$ than the reference subjects. (Figure 1)

The profile of the best nordic combination skiers agreed fairly well with the profiles of the above mentioned endurance athlete groups. The nordic combination skiers had slightly higher fat depots, smaller max$\dot{V}_{O_2}$ both in leg and arm work, lower %ST fibers and lower SDH activity in m. VL than the best male cross-country skiers and long-distance runners. (Figure 2).

With respect to the amount of body fat, max$\dot{V}_{O_2}$ in leg and arm work and %ST fibers in m. VL the female cross-country skiers differed less from the female reference group than the male skiers from the male reference group. On the contrary, the SDH activity in m. VL of

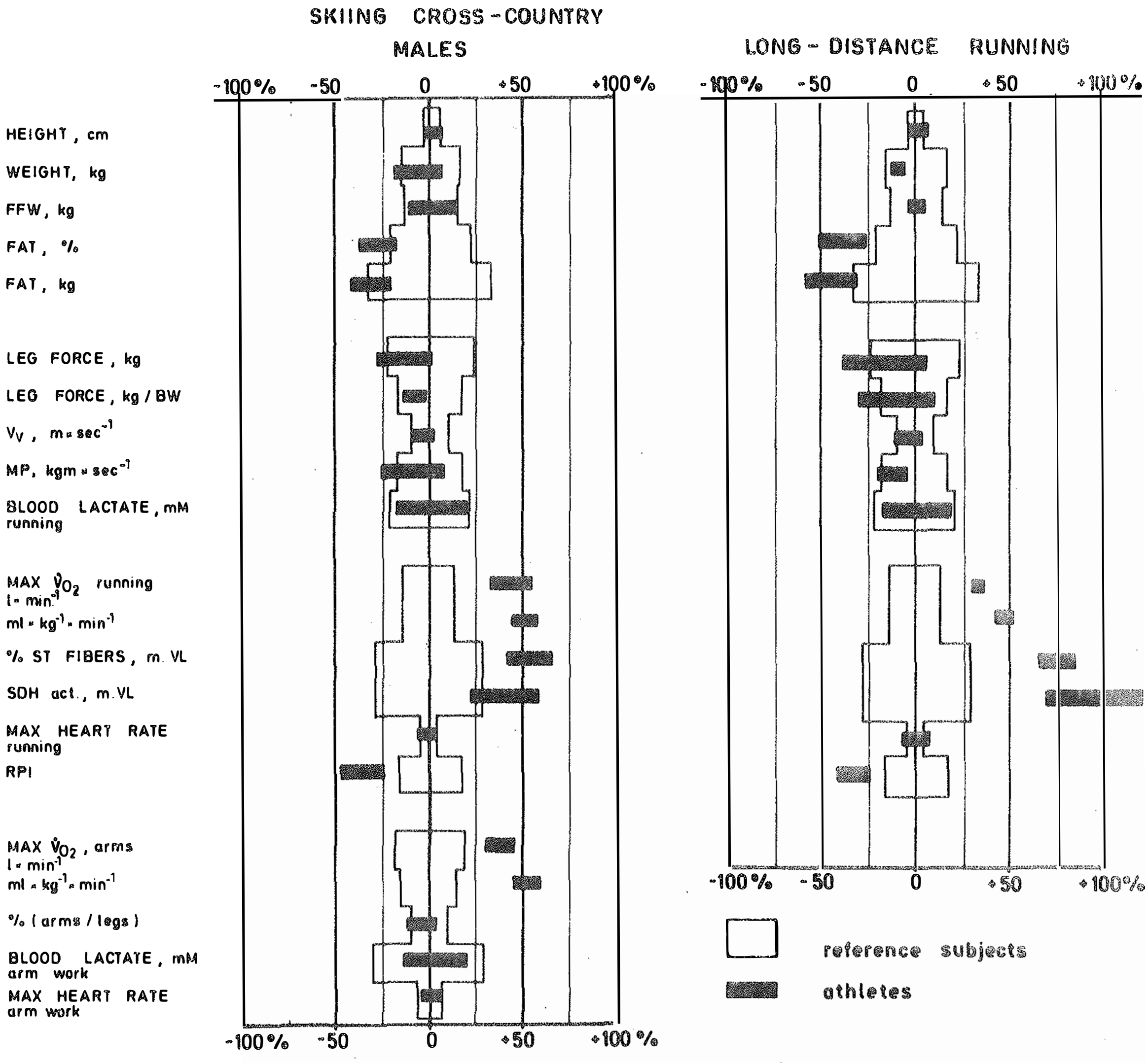

Figure 1. Fitness profiles of the best male cross-country skiers and long-distance runners. The mean values of the athletes ($\pm$ 1 SD) have been compared to the mean values ($\pm$ 1 SD) of the reference subjects in each parameters. Abbreviations are explained on page 2.

the female skiers differed much more than that of the male cross-country skiers from the values of their reference subjects. (Figure 2).

The best ice hockey players were characterized by high leg forces, vertical velocity and muscular power (Figure 3). They also had high maximal oxygen uptake and SDH activity in m. VL as compared with the male reference subjects.

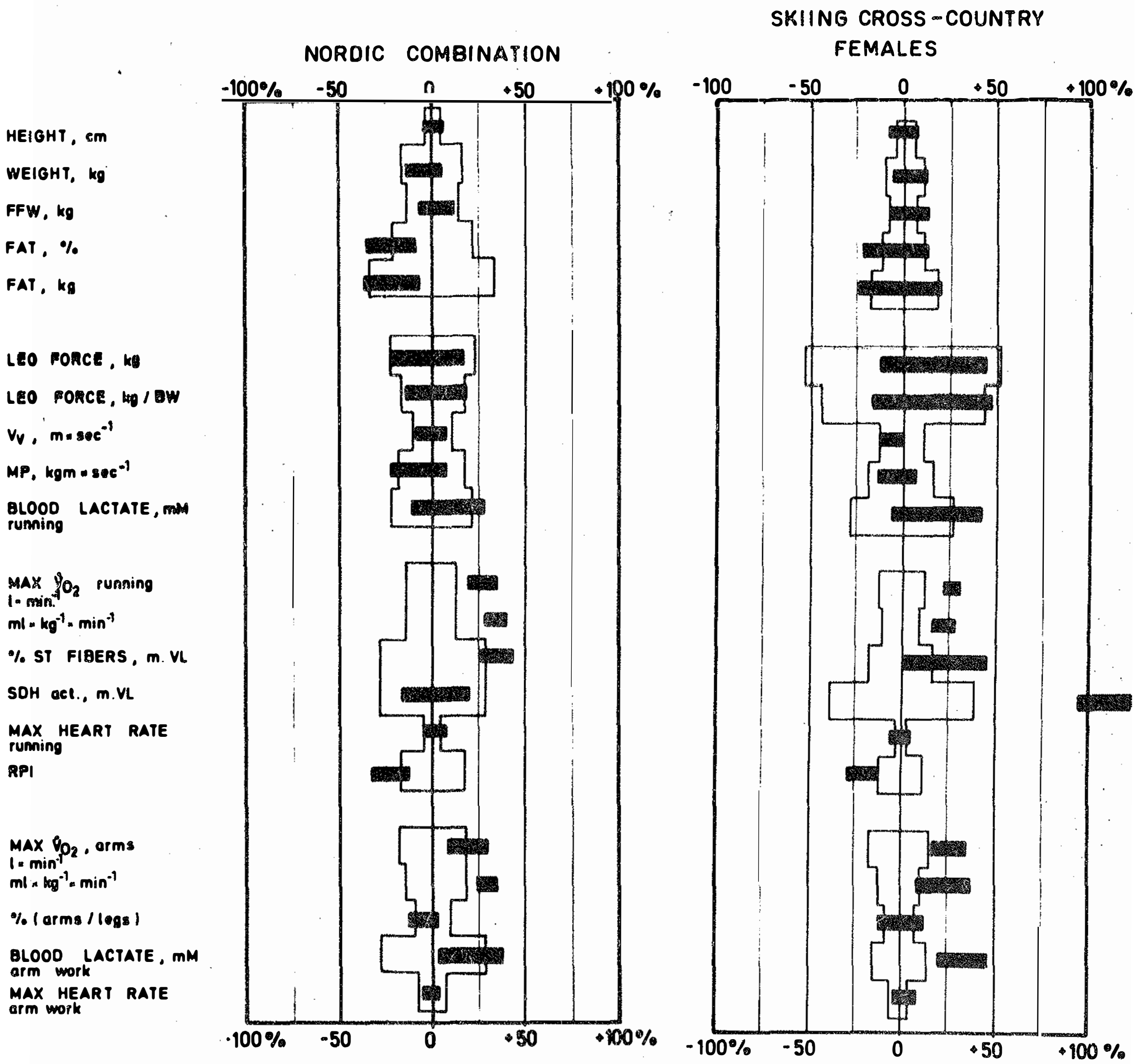

Figure 2. Fitness profiles of the best nordic combination skiers and the best female skiers. For explanations see figure 1.

The best speed skaters differed from the reference subjects by having higher vertical velocity and muscular power as well as higher maximal oxygen uptake and %ST fibers in m. VL (Figure 3). Their body fat, blood lactate and relative power index were slightly lower than those of the reference subjects.

The best canoeists differed from the reference subjects in several characteristics. Their height, weight, fat-free weight, leg forces, muscular power and blood lactate values as well as %ST fibers and relative power index differentiated them from the reference

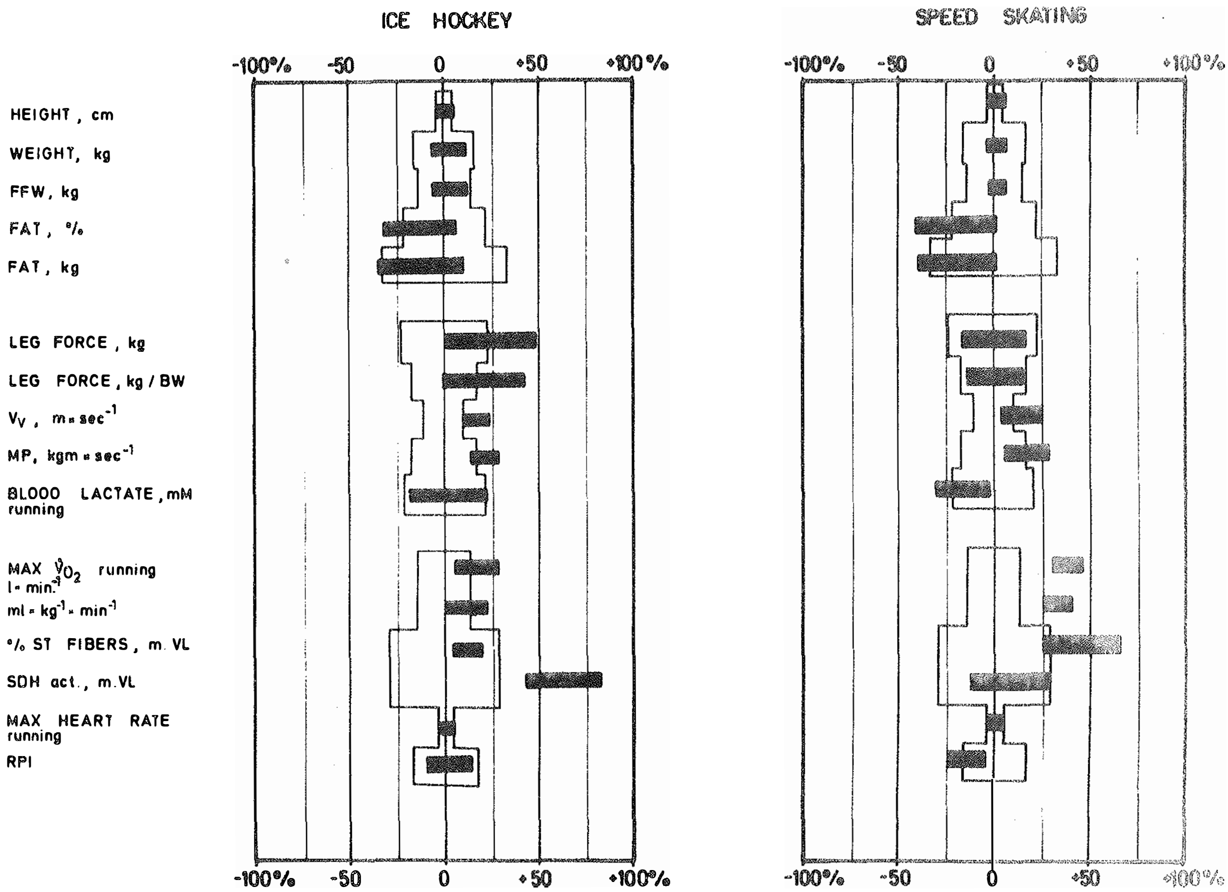

Figure 3. Fitness profiles of the best ice hockey players and the best speed skaters. For explanations see Figure 1.

subjects. Furthermore their maximal oxygen uptake exceeded the corresponding values of the reference group both in leg work and especially in arm work. (Figure 4).

The 800m runners had higher blood lactate concentration, maximal oxygen uptake and SDH activity in m. VL than the reference subjects. They also tended to have lower RPI, percentage and total amount of fat as well as higher vertical velocity and maximal heart rate than the reference subjects. (Figure 4).

The alpine skiers differed from the reference subjects mainly

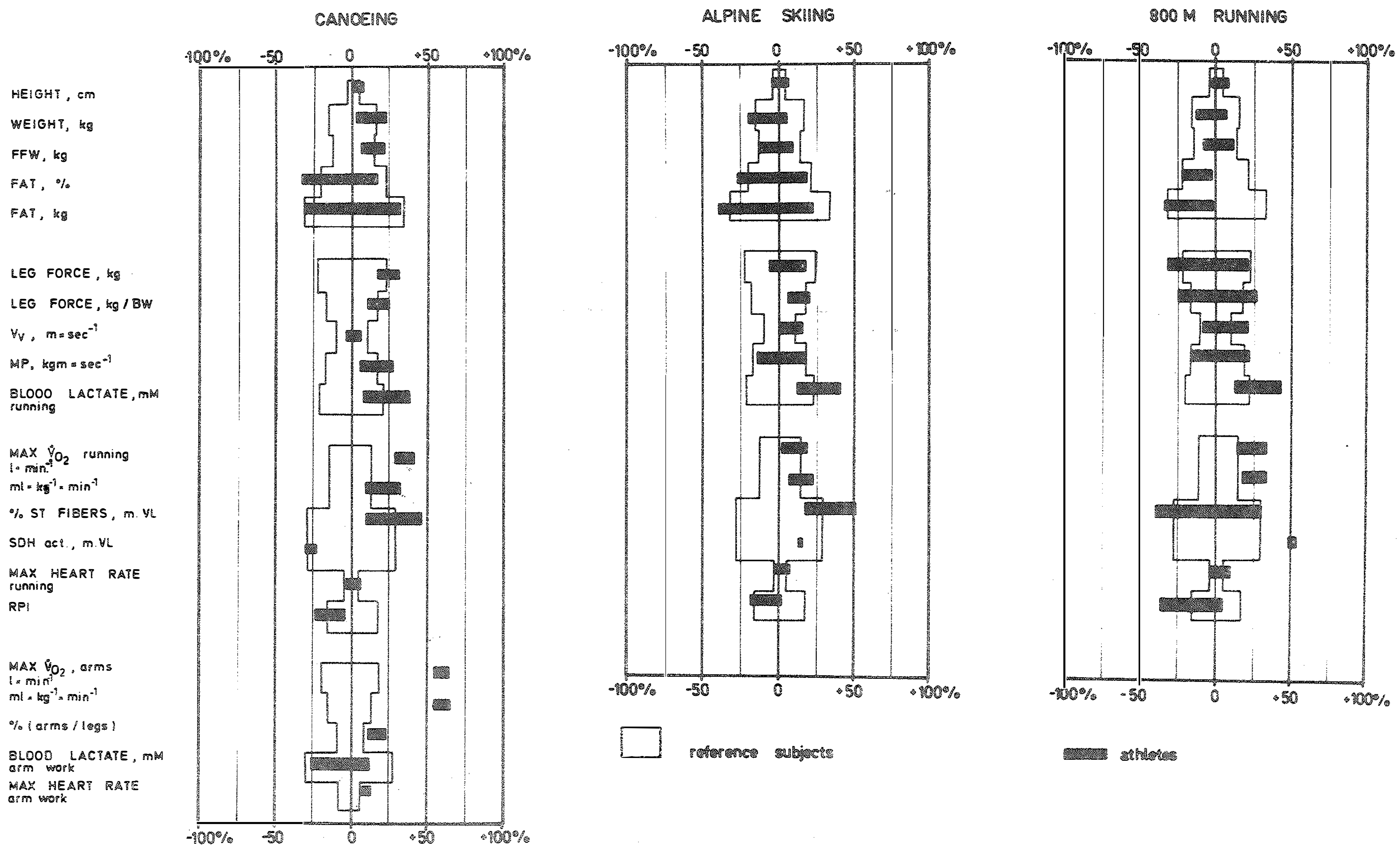

Figure 4. Fitness profiles of the best canoeists, 800m runners and alpine skiers. For explanations see Figure 1.

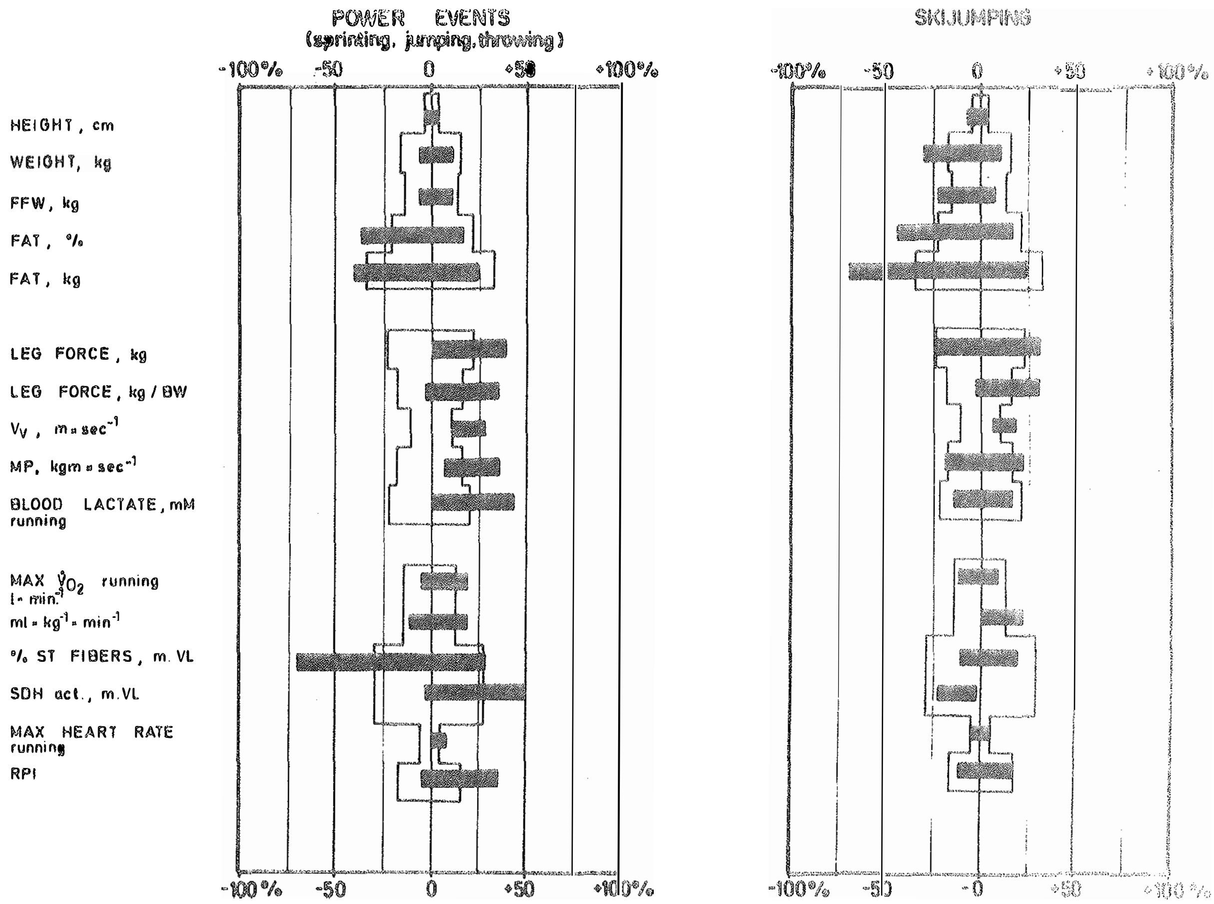

Figure 5. Fitness profiles of the best skijumpers and power athletes. For explanations see Figure 1.

by having higher blood lactate, vertical velocity, maximal oxygen uptake and %ST fibers in m. VL.

The skijumpers differed from the reference subjects most clearly by having higher vertical velocity. They also tended to have higher maximal oxygen uptake and smaller body size than the reference subjects. (Figure 5).

The power athletes had higher vertical velocity, muscular power, leg forces and blood lactate concentration than the reference subjects. Their SDH activity and RPI values were also relatively high. (Figure 5).

The correlation coefficients between ranking orders in the athletes' own sport events and the performance characteristics studied are summarized in Table 1. Power athletes were not included because they represented several sport events and in the case of ice hockey significant differences between national team level players and the other players have been calculated.

The maximal oxygen uptake of the male and female cross-country skiers and the long-distance runners correlated negatively with ranking orders indicating that the best athletes seem to have highest max$\dot{V}_{O_2}$-values. In long-distance running also %ST fibers in m. VL correlated negatively and V_v and RPI positively with ranking order. In nordic combination %ST fibers and SDH activity in m. VL correlated negatively with skiing performance and V_v with jumping performance. In speed skating V_v and MP correlated negatively with ranking order in short distances (500-1500m skating) and max$\dot{V}_{O_2}$-values with long-distance performances (3000-10000m skating). In ice hockey the national team players had significantly lower %ST fibers and SDH activity and they also tended to have higher leg forces and vertical velocity than the other players. In canoeing max$\dot{V}_{O_2}$ of both arms and legs correlated negatively with ranking order in actual canoeing performances. The best 800m runners were characterized by higher max$\dot{V}_{O_2}$ and lower fat percentage than the runners with weaker performances as judged from the correlation coefficients. In alpine skiing the leg forces, V_v and max$\dot{V}_{O_2}$ correlated negatively with ranking order. In skijumpers %ST fibers correlated significantly and V_v, RLF and RPI almost significantly with ranking order.

When calculated from the results of all male subjects two significant correlations were found between variables of aerobic and anaerobic-neuromuscular performance capacity: $r = -.25$ ($p \leq .01$) between max$\dot{V}_{O_2}$ and V_v and $r = -.24$ ($p \leq .05$) between SDH activity in m. VL and RLF. When calculated from the results of the male athletes the following pairs of variables correlated negatively with each other: max$\dot{V}_{O_2}$ - V_v ($r = -.55$, $p \leq .001$), max$\dot{V}_{O_2}$ - RLF ($r = -.26$, $p \leq .05$), max$\dot{V}_{O_2}$ - LDH activity ($r = -.52$, $p \leq .01$), SDH activity - RLF ($r = -.30$, $p \leq .05$) and SDH activity - LDH activity ($r = -.42$, $p \leq .05$). Within different groups of subjects only one significant correlation was

Table 1. The correlations between ranking order in athletes' own sport sport events and the performance characteristics studied. The signs in front of the parameters indicate negative (-) or positive (+) relationship between the variables. In the case of ice hockey the national team level players have been compared with the other players and (+) means that the national team players have higher mean values.

Sport event	Level of significance of the correlation coefficient (or t-value)		
	$p \leq .01$	$p \leq .05$	$.05 < p < .10$
Cross-country skiing, males		(-)Max$\dot{V}_{O_2}$ mlxkg^{-1}xmin^{-1} (+)Max$\dot{V}_{O_2}$ arms/legs	(-)Max$\dot{V}_{O_2}$ lxmin^{-1} (-)%ST fibers (+)RLF (+)RPI
Cross-country skiing, females	(+)FFW	(-)Max$\dot{V}_{O_2}$ mlxkg^{-1}xmin^{-1} (+)LBH	(+)RPI
Long-distance running	(-)Max$\dot{V}_{O_2}$ lxmin^{-1}	(-)%ST fibers (+)V_V (+)RPI	(-)Max$\dot{V}_{O_2}$ mlxkg^{-1}xmin^{-1} (+)SDH
Nordic combination x	(-)%ST fibers (-)SDH	(+)V_V x	(-)Max$\dot{V}_{O_2}$ lxmin^{-1} (-)TLF x
Speed skating xx	(-)Max$\dot{V}_{O_2}$ mlxkg^{-1}xmin^{-1}	(-)Max$\dot{V}_{O_2}$ lxmin^{-1} (-)V_V xx (-)MP xx	(+)RPI (-)SDH (-)TLF xx
Canoeing	(-)Max$\dot{V}_{O_2}$ legs, ml x kg^{-1} x min^{-1}	(-)Max$\dot{V}_{O_2}$ arms, l x min^{-1}	(-)%ST fibers m.VL (-)Max$\dot{V}_{O_2}$ arms, ml x kg^{-1} x min^{-1}
800m running		(-)Max$\dot{V}_{O_2}$ mlxkg^{-1}xmin^{-1} (+)Fat%	(-)Max$\dot{V}_{O_2}$ lxmin^{-1} (+)Fat, kg (-)Blood lactate (+)RPI
Alpine skiing	(-)TLF	(-)RLF (-)Max$\dot{V}_{O_2}$ lxmin^{-1} (-)V_V	(-)Blood lactate (-)RPI
Skijumping	(+)%ST fibers		(-)V_V (-)RLF (-)RPI
Ice hockey	(-)%ST fibers	(-)SDH	(+)TLF (+)RLF (+)V_V

x In nordic combination vertical velocity and leg force were correlated with jumping performance, other parameters with skiing performance.

xx In speed skating vertical velocity, muscular power and leg force were correlated with performance in short distances (500-1500m), other parameters with performance in long distances (3000-10000m).

found: r = -.81 ($p < .01$) between max$\dot{V}_{O_2}$ and V_v of long-distance runners. When examining the performance capacity of the arms it was found that the isometric arm force of male subjects correlated positively with their max$\dot{V}_{O_2}$ in arm work (r = .32, $p < .05$). Within groups no significant correlations were found.

The relative power index ranged from 1.84 for male cross-country skiers to 3.18 for power athletes. This variable correlated negatively with %ST fibers in m. VL when calculated from the results of all male subjects (r = -.49, $p < .001$) or all male athletes (r = -.38, $p < .001$) (see figure 6). This correlation was significantly negative also within groups of male cross-country skiers, long-distance runners and ice hockey players.

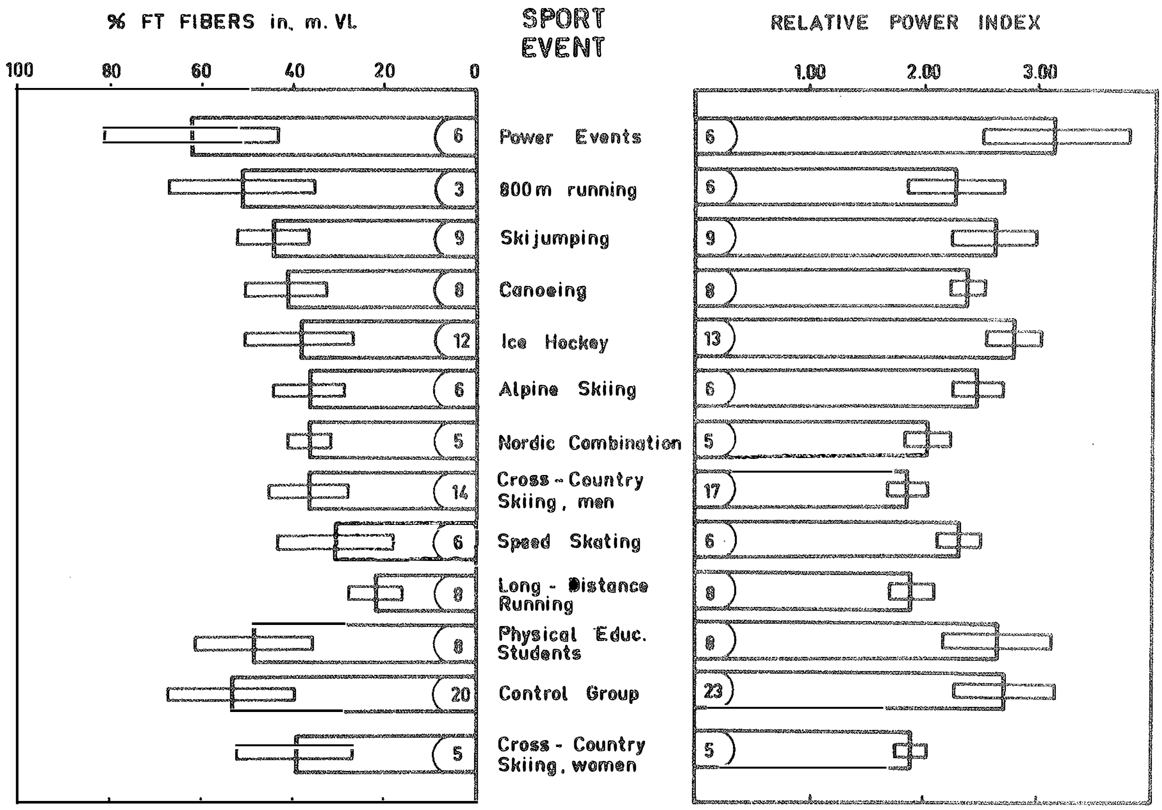

Figure 6. Percent distribution of fast twitch fibers (%FT fibers) in the vastus lateralis muscle (left) and the relative power index (RPI, right) of the different athlete and reference groups (means and standard deviations).

DISCUSSION

Although in recent years there has been considerable increase in research, aimed at the characterization of major physiological factors important in international level athletic competitions, such studies have so far been directed towards few sport events and also only a few physiological parameters have been studied. The overall goal of this project has therefore been to gather data on elite Finnish athletes competing in various sport events and to develop a suitable battery of tests in order to characterize various physiological, metabolic and anthropometrical requirements typical to different sport performances.

In order to analyze the requirements of the sport events results were arranged as profiles, in which the mean values of best athletes practising certain sport events were compared to the corresponding mean values of the reference group of the same sex. The parameters were then arranged into three groups, the first one describing major anthropometrical variables, the second describing some neuromuscular and anaerobic determinants of performance and the third one describing aerobic parameters. The performance characteristics of the arms were also included in those sport events which require extensive use of the arms.

On the basis of the fitness profiles and correlation coefficients between ranking order and parameters studied each sport event seems to have its own specific requirements. Even the pure endurance events, cross-country skiing and long-distance running, seem to differ from each other: the maximal oxygen uptake is a characteristics required especially in cross-country skiing whereas the oxidative capacity of the muscles might be needed in long-distance running more than in cross-country skiing.

When the fitness profiles were analyzed in more detail it was found that the athletes and sport events could be classified into four main groups. The "aerobic endurance" events include cross-country skiing, long-distance running and nordic combination. They are all characterized by high demands for the aerobic performance capacity but by no extra demands for the neuromuscular or anaerobic components of performance capacity. The athletes competing in these sport events seem to have low body weights and fat depots. The female cross-country skiers belong also into this group although their fat depots were almost equal with those of female reference subjects.

The best cross-country skiers and nordic combination skiers all belonged to the Finnish national team during the World Championships in 1974 in Falun, Sweden. The personal records of the four best long-distance runners during the competitive season of 1973-74 varied from 13.48 to 14.11 for 5000m and from 28.52 to 29.07 for 10000m competition. Maximal oxygen uptake seemed to be the best predictor of performance in these aerobic endurance events whereas a high %ST fiber distribution might be a prerequisite for a successful endurance athlete.

The canoeists, 800m runners and alpine skiers might be called "anaerobic endurance" athletes because their blood lactate values were in the mean higher than those of reference subjects. These athletes had also high aerobic performance capacity. Fitness profiles and correlations with ranking order seem to prove that canoeing requires tall muscular men whose aerobic performance capacity is very near the level of the aerobic endurance athletes. Both aerobic and anaerobic determinants of performance capacity predict fairly well the performance in actual sport event. However, measurement of oxygen uptake and oxygen debt during actual canoeing have correlated better (unpublished results) with the ranking order of these same canoeists. The athletes competing in alpine skiing and 800m running have not been very successful in international competitions although they belong to national elite. Therefore their fitness profiles may not reflect the foremost characteristics of international elite athletes. However, the crew of the four best canoeists studied was 7th in München in 1972.

The third group of events, ice hockey and speed skating, might be called "speed-endurance" events because their vertical velocity and muscular power distinguish them from the reference subjects, in addition to some variables of aerobic performance capacity. The best ice hockey players seem to resemble both aerobic endurance athletes and power athletes (below). In addition to fitness, ice hockey requires both technical and tactical skill. Therefore it was not expected that also some of the physiological parameters would differentiate the national team level players from the other players. The best speed skaters belong to national elite but they have not been successful in international competitions. Probably therefore their leg forces and blood lactate might have been relatively low as compared with the reference subjects or the best ice hockey players.

The skijumpers and the power athletes (100-400m runners, jumper, thrower, decathlete) form the fourth group of events: power events. Only vertical velocity distinguished the skijumpers from the reference subjects. This is related to the correlations between ranking order and vertical velocity both in skijumping and nordic combination. The large variations in body size, fat depots and leg forces of the skijumpers suggest that there are also several other (psychological?) factors which might be important in this sport event. Nevertheless, the percent distribution of slow twitch muscle fibers was found to predict significantly the performance in actual skijumping.

In this study a significant negative relationship existed between speed and strength on one hand and aerobic performance capacity on the other hand. This relationship was most pronounced when only male athletes were included in the calculations. This negative relationship appeared both at whole body and at muscle tissue level and it might mainly be due to differences between groups of athletes, in other words, evidently due to differences in training. This negative relationship should be taken into account when planning the training programs for the athletes.

In some sport events both speed and strength as well as endurance are needed. In this study ice hockey, canoeing and speed skating might represent such sport events. Within the group of ice hockey players low nonsignificant positive correlations were found between maximal oxygen uptake and vertical velocity and between maximal oxygen uptake and relative leg force. Previously, we have also found a significant positive correlation between oxygen uptake during and oxygen debt after maximal 1000m canoeing test among the same canoeists studied in the present study (unpublished results).

Recent investigations (Gollnick and Hermansen 1973, Karlsson et al. 1974) seem to indicate that LDH activity is lower in ST fibers that in FT fibers. In this study the endurance athletes had lower LDH activity than skijumpers or alpine skiers and LDH activity was found to correlate negatively both with maximal oxygen uptake and SDH activity in the same muscle. All these results support the hypothesis that LDH activity might decrease as a response to endurance training. Karlsson et al. (1974) have also shown that the LDH isozyme pattern in the skeletal muscle of endurance athletes has changed to the heart type isozyme pattern.

The theoretical basis of the relative power index is not clear and in this study it is rather regarded as an index of speed versus endurance. Anyway, this variable was found to correlate significantly with %ST fibers. Therefore RPI could also be thought to give rough information on the structural qualification of the athletes. Furthermore, it is quite sensitive to training because both of its components change during training and both components have reciprocal characteristics.

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Appendix 1. Means and standard deviations of different variables for the best athletes in each sport event and for the male and female reference subjects. Abbreviations are explained on page 2.

Variable	Cross-country skiing, 4 males		Long-distance running, 4 males		Nordic combination 4 males		Cross-country skiing, 5 females	
Height, cm	176.6	5.8	178.3	4.5	176.2	5.4	163.3	7.8
Weight, kg	70.6	7.4	68.2	1.0	70.4	5.7	59.1	5.2
FFW, kg	62.4	6.9	62.4	1.9	62.0	5.0	47.0	4.8
Fat, %	10.6	0.8	8.6	1.0	11.2	1.4	21.8	3.7
Fat, kg	7.5	0.7	5.9	0.7	7.9	1.5	13.0	2.9
TLF, kg	265	36	256	53	295	54	227	63
RLF, kg/BW	3.75	0.14	3.74	0.72	4.17	0.59	3.90	1.28
V_v, m x sec^{-1}	1.29	0.06	1.28	0.07	1.31	0.09	1.17	0.07
MP, kgm x sec^{-1}	90.8	13.5	87.3	5.1	92.5	12.5	69.3	7.0
Blood lactate, running, mM	10.8	1.9	11.4	1.9	11.8	2.1	11.0	2.6
MaxV_{O_2}, running, l x min^{-1}	5.84	0.50	5.44	0.10	5.12	0.27	4.03	0.15
ml x kg^{-1}x min^{-1}	83.4	4.7	79.8	2.2	72.8	2.5	68.2	3.9
%ST fibers, m. VL	69.5	7.8	82.3	6.0	63.4	4.9	60.0	12.9
SDH act., m. VL	29.7	6.4	41.6	10.0	21.8	3.5	27.7	7.3
Max. heart rate, running	192.5	3.9	197.3	12.7	193.8	7.5	194.8	9.8
RPI	1.73	0.17	1.81	0.12	2.03	0.19	1.90	0.14
MaxV_{O_2}, arm work, l x min^{-1}	4.11	0.33			3.54	0.36	2.93	0.27
ml x kg^{-1}x min^{-1}	59.0	3.8			50.3	2.5	49.8	7.2
% (arms/legs)	0.70	0.05			0.69	0.05	0.73	0.09
Blood lactate, arm work, mM	10.5	1.8			12.2	2.1	9.2	1.2
Max. heart rate, arm work	185.0	5.6			181.2	5.1	187.4	12.0

Appendix 1. (continues) Means and standard deviations of different variables for the best athletes in each sport event and for the male and female reference subjects. Abbreviations are explained on page 2.

Variable	Ice hockey 6 males		Speed skating 6 males		Skijumping 4 males		Power events 6 males	
Height, cm	177,0	3,9	181,4	3,6	172,3	7,4	176,2	4,7
Weight, kg	76,9	5,1	76,5	1,7	67,3	12,5	76,3	6,4
FFW, kg	63,9	4,6	65,7	1,7	57,2	7,3	63,1	5,2
Fat, %	12,6	2,2	11,4	2,3	12,1	3,5	13,0	3,4
Fat, kg	9,7	2,0	8,7	1,7	8,6	3,9	10,1	3,2
TLF, kg	381	82	307	48	314	82	365	70
RLF, kg/BW	4,95	0,97	4,12	0,57	4,65	0,67	4,79	0,80
V_v, m x sec^{-1}	1,56	0,08	1,53	0,14	1,50	0,06	1,57	0,13
MP, kgm x sec^{-1}	119,9	6,6	116,8	12,5	101,2	19,9	119,8	17,2
Blood lactate, running, mM	11,1	2,0	9,0	1,1	10,9	1,5	13,2	2,8
Max$\dot{V}_{O_2}$, running,								
l x min^{-1}	4,75	0,46	5,58	0,37	4,02	0,40	4,33	0,50
ml x kg^{-1}x min^{-1}	62,5	5,7	72,9	4,3	60,7	6,0	57,1	8,4
%ST fibers, m. VL	53,0	3,0	68,8	12,7	49,3	6,4	37,0	18,9
SDH act., m. VL	34,3	6,2	25,1	4,7	19,2	1,6	27,2	8,8
Max. heart rate, running	204,5	3,6	197,2	5,1	202,8	6,6	200,0	6,3
RPI	2,87	0,28	2,36	0,19	2,82	0,35	3,16	0,66

Appendix 1. (continues) Means and standard deviations of different variables for the best athletes in each sport event and for the male and female reference subjects. Abbreviations are explained on page 2.

Variable	Canoeing 4 males		800 m running 6 males		Alpine skiing 6 males	
Height, cm	182,8	3,3	179,5	3,8	176,1	6,0
Weight, kg	82,2	7,4	72,3	4,6	70,1	8,0
FFW, kg	70,0	4,2	62,9	4,5	60,8	5,9
Fat, %	13,0	2,9	12,4	1,4	14,1	3,0
Fat, kg	10,8	3,3	9,0	1,4	10,0	3,0
TLF, kg	377	26	296	84	324	36
RLF" KG/BW	4,77	0,31	4,06	1,06	4,60	0,32
V_v, m x sec^{-1}	1,40	0,05	1,40	0,20	1,43	0,10
MP, kgm x sec^{-1}	115,3	9,4	101,8	19,3	100,5	15,0
Blood lactate, running, mM	11,4	2,6	13,8	2,1	13,6	1,0
$MaxV_{O_2}$, running,						
l x min^{-1}	5,49	0,25	5,04	0,37	4,45	0,35
ml x kg^{-1}x min^{-1}	67,1	6,1	69,8	4,5	63,8	4,5
%ST fibers, m. VL	60,5	9,9	45,3	17,0	63,7	8,3
SDH act., m. VL	15,5	0,5	32,5		24,3	
Max. heart rate, running	196,0	8,1	203,2	11,3	199,0	7,6
RPI	2,37	0,18	2,26	0,44	2,46	0,22
$MaxV_{O_2}$, arm work						
l x min^{-1}	4,75	0,25				
ml x kg^{-1}x min^{-1}	61,9	2,3				
% (arms/legs)	0,86	0,04				
Blood lactate, arm work, mM	9,3	1,8				
Max. heart rate, arm work	192,5	4,1				

Appendix 1. (continues) Means and standard deviations of different variables for the best athletes in each sport event and for the male and female reference subjects. Abbreviations are explained on page 2.

Variable	Reference subjects, 23 males		Reference subjects 7 females	
Height, cm	175,8	7,0	164,4	6,6
Weight, kg	75,0	11,8	57,5	5,5
FFW, kg	61,6	8,4	45,6	3,3
Fat, %	14,4	3,0	22,8	2,4
Fat, kg	10,9	3,6	13,2	2,2
TLF, kg	305	71	195	101
RLF, kg/BW	4,08	0,69	3,39	1,45
V_v, m x sec^{-1}	1,32	0,13	1,24	0,14
MP, kgm x sec^{-1}	98,9	16,7	71,4	12,2
Blood lactate, running, mM	10,8	2,2	8,3	2,1
$MaxV_{O_2}$, running,				
l x min^{-1}	4,06	0,54	3,19	0,36
ml x kg^{-1}x min^{-1}	55,1	7,1	55,6	5,6
%ST fibers, m. VL	47,1	13,1	48,8	8,3
SDH act., m VL	21,4	5,5	12,5	4,7
Max. heart rate, running	193,0	8,1	197,1	4,7
RPI	2,72	0,43	2,40	0,26
$MaxV_{O_2}$, arm work,				
l x min^{-1}	3,00	0,53	2,33	0,38
ml x kg^{-1}x min^{-1}	39,0	5,5	40,4	4,5
% (arms/legs)	0,73	0,06	0,73	0,06
Blood lactate, arm work, mM	12,1	2,8	8,2	1,6
Max heart rate, arm work	184,1	10,2	183,4	9,6