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Prediction of Performance in Vasaloppet through Long Lasting Ski-Ergometer and Rollerski Tests in Cross-Country Skiers

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Abstract

The main purpose was to investigate if long lasting cross-country (c-c) test procedures could predict performance time in 'Vasaloppet' and secondly the effect of a 16 weeks training period on a 90 min double poling performance test. 24 moderate trained c-c skiers participated in the study and completed Vasaloppet. All skiers carried out pre and post training tests in a 90 minutes ski-ergometer double poling test and a 120 minutes rollerski field test on a closed paved circuit. 19 skiers provided detailed training logs that could sufficiently establish their training preparation for Vasaloppet. Racing time in Vasaloppet correlated negatively with average work output (W/kg) at the pre ski-ergometer test (Figure 3A) (n = 24; r = -0.79; P < 0.001), i.e. c-c ski performance was positively associated with ergometer performance. Likewise, a similar correlation was obtained after the 16 week training period between average post-test work output in the ski-ergometer and performance in Vasaloppet (n = 24; r = -0.76; P < 0.001). The distance improved significantly from 18.0 ± 0.6 to 19.2 ± 0.7 km/h from pre to post in the ski-ergometer tests. Pre-field-test time performance on rollerskies as measured by average lap time for the 3 km circuit also correlated significantly to performance in Vasaloppet (n = 23; r = 0.78; P < 0.001). In addition, the rollerski post-field-test also showed good agreement with Vasaloppet performance, but a number of individual cancellations appeared and performance time was only measured in 11 skiers. (r = 0.82; P < 0.001). There was no change in body weight, BMI and lean arm mass but borderline increase in lean leg mass (P < 0.067), a significant increase in trunk and total lean body mass (P < 0.05) and a reduction of total body fat percentage (P < 0.05). Long lasting ski-ergometer and Rollerski field tests correlate strongly with performance in Vasaloppet and therefore might be useful test tools for recreational skiers who wish to participate in long lasting c-c competitions.

Keywords: Cross-country ski training, Upper body, Exercise intensity, Field test, Body composition blood lactate

Key Points

- A long lasting (90 minutes) upper-body ski-ergometer test was significantly associated with performance in Vasaloppet pre (r = -0.79) and post (r = -0.76) three months training period
- The distance in ski-ergometer tests improved significantly from 18.0 ± 0.6 to 19.2 ± 0.7 km/h from pre to post after three months training
- A long lasting (120 minutes) Rollerski test was significantly associated with racing time in Vasaloppet pre (r = 0.78) and post (r = 0.82) three months training period
- The total body fat percentage was significantly reduced, while trunk and total lean body mass increased significantly (P < 0.05).

Introduction

For decades cross country (c-c) skiing has been practiced on both a recreational and competitive level [1,2]. One of the world's largest skiing events normally takes place the first Sunday in March where about 16.000 skiers participate in the historic classical c-c ski competition – Vasaloppet. This race is the largest sport event in Sweden and is a 90 km classical c-c skiing race (Figure 1A), where the skiers range from top athletes to recreational skiers (i.e. beginners). C-c skiing is a complex sport implying the use of different techniques depending on the terrain, and the skier's aerobic and technical capacity are essential determinants for skiing performance [3]. Over the last few decades the double poling (DP) technique has become more and more important in c-c races [1]. DP is performed with symmetrical and synchronous movements of the poles, involving primarily trunk flexion while the legs' involvement is smaller as compared to DP with kick (DK) and especially diagonal stride (DS) [4]. Overall DS is used mainly on moderate to steep uphill slopes, DP is used on horizontal tracks (the preferred technique at high speeds), and DK is mainly used for skiing on low to moderate slopes, where the resistance forces are relatively low. In Vasaloppet the terrain is mostly flat terrain (Figure 1A), but it is uncertain how much recreational skiers use the three different skiing techniques during the race, Certainly Vasaloppet favors DP as the main technique in more well trained recreational skiers.

An upper body c-c ski-ergometer for DP was constructed 25 years ago [5] and subsequently ski specific ergometers have been used in the analysis of the torso capacity [6,7]. While studies have shown a strong correlation between upper body strength and performance in a c-c skiing track [8-11] few studies have investigated the relationship

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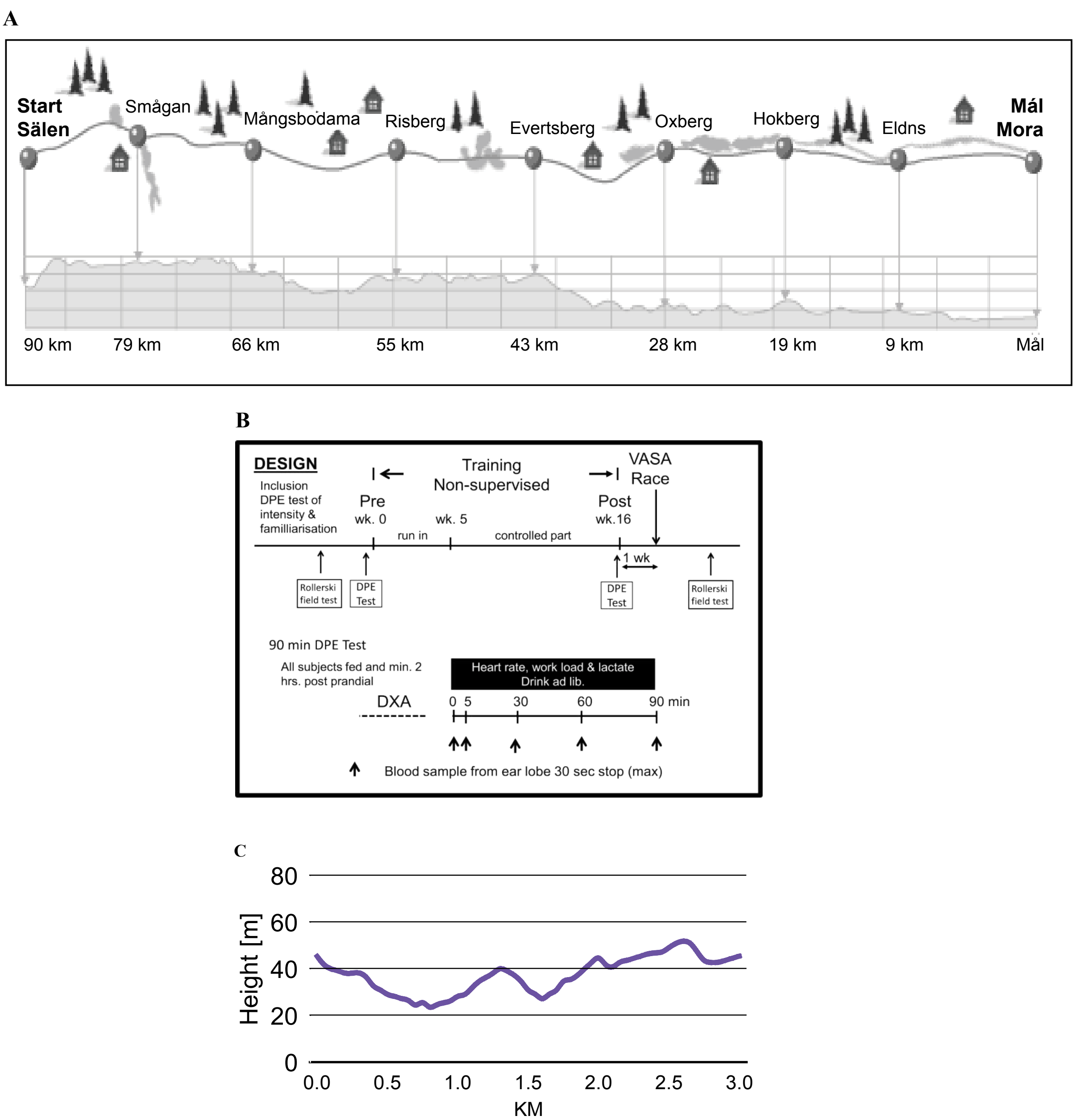

Figure 1: (A) Race and elevation profile of the 91 km ski race Vasaloppet. The dots indicate start and finish and the 7 stations with food and water located evenly over the race course. Vasaloppet takes place on the first Sunday in March every year (www.vasaloppet.se). (B) Schematic design of research project. (C) Circuit elevation profile of the rollerski field test.

between performance in a DP poling ergometer in the laboratory and DP performance in c-c skiing. One study found a strong correlation between DP performance on snow and a 6-min ski-ergometer DP performance test, both where performance was expressed in absolute (W) and relative (W/kg) ($r = 0.86$, $P < 0.05$ and $r = 0.89$, $P < 0.05$, respectively) [12]. The current state of art comparing c-c ski performance on snow and laboratory tests can be summarized as a preferred use of short lasting test procedures, i.e. many studies have examined the relationship between shorter ski-ergometer tests, treadmill running and shorter c-c (simulated) races up to approximately 10 km [7,8,11-17]. There is a lack of studies that investigate the association between longer lasting DP tests in a ski-ergometer or long lasting rollerski field test and long-distance skiing performance in competition and particularly for recreational skiers. Moreover there is a lack of studies that investigate the effect of training in the upper body ski-ergometer for recreational/moderate trained skiers. Therefore, the main aim of the present study was, to investigate the agreement between a 90 minutes ski-ergometer DP test and a 120 minutes rollerski field test and performance in Vasaloppet. In addition a secondary aim was to investigate the effect of 16 weeks ski training on performance in a 90 minutes DP test and a classic rollerski field test.

Methods

Study design, skiers and training

The skiers were recruited among members of the skiing clubs and/or from an internet based interest group that provides information about c-c and rollerskiing possibilities in the greater Copenhagen area. In total 31 potential skiers volunteered to participate in the study and out of these 24 (average age 40 ± 2 years) had an entry ticket to Vasaloppet and was included in the study. Three were classified as c-c ski beginners, but were experienced with longer lasting endurance exercise events (e.g. marathon or ironman triathlon). C-c ski experience varied among the remaining 21 skiers, but all were experienced skiers and had completed long-distance (> 50 km) c-c races several times (personal communication). The skiers were informed about the project at a meeting and provided signed consent to participate in the research project. The project was approved by the Regional Ethics Committee of the Capital Region (Protocol: H-2-2009-145).

The skiers were tested before and after a 16 week training period leading up to participation in Vasaloppet (Figure 1B). During all test procedures the skiers were non-fasted. The skiers were informed that the testing included a performance test at their highest exercise capacity and they were instructed to abstain from or minimize training on the preceding day.

During the 16 weeks all skiers reported their training data to the research group using an electronic c-c specific detailed training diary that was used in our prior studies [5]. Initially all the skiers were supervised about description of exercise and assessment of intensity and instructed how to determine HRmax in the ski ergometer and during running [18]. The actual training was performed individually. The training was categorized into three exercise intensities of HRmax: 55-75%, 75-85% and 85-100%. The relative exercise workload was calculated according to the Karvonen formula [19]. With an online communication network group (igroups.dk) questions relating to training and determination of exercise intensity could be answered and instructions given on a daily basis. The initial 5 weeks of the training period was used as a run in period allowing the skiers to adapt to the training protocol and the last 11 weeks were evaluated as the primary training period. Access to training in the DP ski-ergometer was available to all skiers during the training period, but due to unexpected good c-c skiing conditions throughout the project period the participants were able to perform more training on snow and less in the ski-ergometer

Laboratory tests

The laboratory tests were performed in the afternoon or early evening. After arrival the subjects rested for 10 minutes in the sitting position, a venous blood sample was obtained from a cubital vein and whole body DXA scanning was performed (Prodigy, GE Healthcare, Chalfont St. Giles, UK). Blood hematocrit, hemoglobin, glucose and lactate were immediately analyzed on an automated analyzer (ABL 800 flex; Radiometer, Copenhagen). Blood glycosylated hemoglobin (HbA1c) was analyzed on a Bayer DCA 2000+ (Bayer Healthcare, Elkhart, IN, USA) using a latex immune agglutination inhibition method.

Lastly, a 90 minutes all-out ski-ergometer endurance test was completed (ThoraxTrainer ELITE, attached with Dansprint computer, Hvidovre, Denmark) to assess DP performance under very controlled conditions. Ski poles (Exel, E-sports group oy, Espoo, Finland) were provided for individual size and the same pair of poles was used pre and post. Sitting heart rate (HR) (Polar Electronics, Kempele, Finland) and blood lactate (earlobe) was measured after 10 minutes prior testing (Lactate Scout, EKF Diagnostic). After 5, 30, 60 and 90 minutes in the ergometer test skiers were stopped shortly (30 sec) in order to sample blood for measurement of lactate. Heart rate was measured throughout the 90 minutes test. All skiers informed they had tried a DP ski-ergometer, but were familiarized with the ergometer during a continuous 30 minutes DP test simulating a c-c skiing competition in the week preceding testing in order to get a feeling for a longer lasting test procedure.

Energy output was recorded in watts/kg and distance. The average speed was calculated by dividing the distance reached between two blood lactate samples with the time. Prior to testing the ski-ergometer was calibrated using a dynamometer controlling that each pole developed a force (constant) corresponding to approximately 2 kg, each time the cord was fully stretched. This standardizes the output of the ergometer and gives an adequate return (both feeling and effort) of the poles, when they are moved back for the next DP arm stroke [20]. Throughout the whole test the skiers were verbally encouraged by the scientific staff, but blinded for information regarding test performance. *Ad libitum* diluted sports drink (water including glucose, 5% Vitargo, Kalmar, Sweden) was provided throughout the test. All skiers used the 30 second breaks to drink, where blood was collected for lactate measurement. The resistance in the ski-ergometer was set to one (very easy workload) out of ten (heavy load), i.e. the easiest poling work load was used during both pre and post tests for all skiers.

Rollerski field test

A 2-hour rollerski field test was conducted on a closed paved circuit (length 3 km) in a forest terrain with small hills to simulate c-c skiing performance (Figure 1C). The place was chosen with the purpose to avoid traffic problems and the influence of the wind on performance. All subjects were provided with rollerskies (Swenor Fibre Glass, Sport import A/S, Sarpsborg, Norway) with identical wheels type (no 2). After pre-test the rollerskies were cleaned and kept dark, dry and untouched and the same pair of Rollerski was used pre and post. Only classical c-c techniques were allowed and the objective was to complete as many laps as possible over 2 hours. All skiers started at the same time (as one group) and the number of laps and mean lap time was calculated. At both tests the course was swept and cleaned for leaves and branches before testing. On both occasions minor parts of the tracks were wet but the asphalt clean. Weather conditions: No wind on both tests because the circuit was located in a forest; Temperature, 9 and 6 degrees on pre and post-test-days, respectively. The similar sports drink was available at the starting/finishing line throughout the 120 minutes and each skier determined their own fluid intake during the test. Unfortunately, it was not possible to perform the post training field test before Vasaloppet, as intentionally planned, due to snow and icy conditions on the circuit and the test had to be rescheduled to seven days after Vasaloppet.

Vasaloppet

Skiers were identified by unique starting numbers and race time was registered at finish and at each of the 7 food and drinking stations located through the race (Figure 1C). Skiers were placed in starting-groups based on earlier race results and performance in races approved by the organizing committee of Vasaloppet. Due to the starting conditions in Vasaloppet we decided only to use the performance data (speed km/h) from the second fluid station (Mångsbodarna) about 24 km after the start and until the finish in Mora (Figure 1A). The race includes a mass start of app. 16.000 skiers and performance in the first part of race is dependent of starting position. This is further accentuated by an approximately 2 km long and steep climb 1 km after the start where variation in skiing performance also depends on starting position.

Statistical analysis

Data are presented as mean ± SEM unless otherwise indicated. The data were tested for normal distribution using the Shapiro-Wilk test and for equal variance by a computation applying the Spearman Rank correlation test. In the present study data were normally distributed and had similar variance. Correlations between the independent variables and the outcome of Vasaloppet were calculated using the Pearson's product-moment correlation coefficient. The pre- and post-test results in the ski-ergometer and the DXA scanning results were compared using a paired t-test. A two-way ANOVA with repeated measures was used to evaluate the effect of training. A value of $p < 0.05$ was accepted as statistically significant and Sigma Plot (version 11.0, 2008 SYSTAT Software, Inc., Germany) was used.

Results

Prediction of performance in Vasaloppet

Racing time in Vasaloppet (from Mångsbodarna (2nd station) to the finish) correlated negatively with average work output (W/kg) at the pre ski-ergometer test (Figure 2A) ($n = 24$; $r = -0.79$; $P < 0.001$), i.e. c-c ski performance was positively associated with ergometer performance. Likewise, a similar correlation was obtained after the 16 week training period between average post-test work output in the ski-ergometer and performance in Vasaloppet ($n = 24$; $r = -0.76$; $P < 0.001$).

Pre-field-test time performance as measured by average lap time for the 3 km rollerski circuit also correlated significantly to performance in Vasaloppet ($n = 23$; $r = 0.78$; $P < 0.001$) (Figure 2B). Exclusion of the three c-c skiing beginners, participating in the study, lead to a higher correlation coefficient ($n = 20$; $r = 0.84$; $P < 0.001$). In addition, the rollerski post-field-test also showed good agreement with Vasaloppet performance, but due to the need for rescheduling of

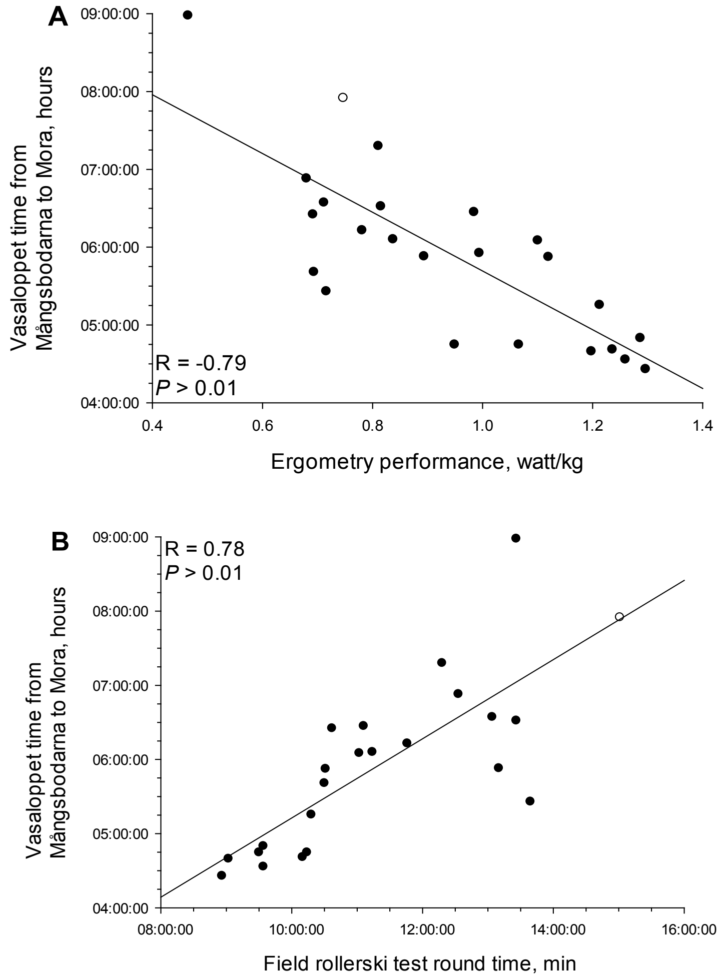

Figure 2: Pearson correlation of (A) average work output during a 90 min all out ski-ergometer pre-test and performance time from Mångsbodarna to the finish line in Vasaloppet and (B) the mean lap time during a 120 min rollerski field pre-test and performance time from Mångsbodarna to the finish in Vasaloppet.

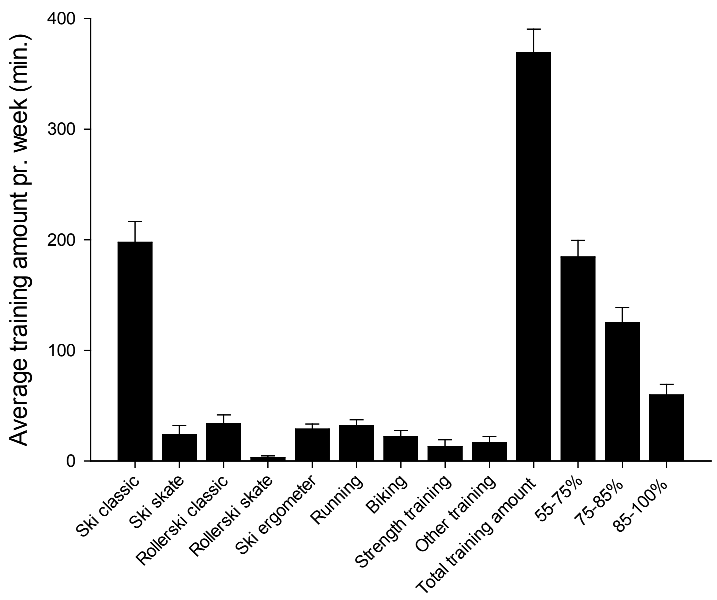

Figure 3: Average weekly time spent in different training forms and the training intensity divided into low [55-75% HRmax], moderate [75-85% HRmax], and high [85-100% HRmax] intensity during the last 11 weeks before Vasaloppet

the post rollerski field test (after Vasaloppet) a number of individual cancellations appeared and performance time was only measured in 11 skiers. ($r = 0.82$; $P < 0.001$). The prediction of performance was not influenced by the 16 weeks training period.

Training amount, intensities and effects

A total of 19 subjects out of the 24 skiers provided a detailed training log that could sufficiently establish their training preparation for Vasaloppet, and the average training amount during the last 11 weeks were chosen as most important (minutes pr. week; Average and SD) and presented in figure 3.

Anthropometric data on height, BMI, total body fat (%), total lean body mass (kg) and lean and fat mass for trunk, legs and arms are presented in table 1. There was no change in body weight, BMI and lean arm mass and increased borderline lean leg mass ($P < 0.067$) and significant increase in total lean body mass ($P < 0.05$) and lean mass of the trunk ($P < 0.05$). Total body fat ($P < 0.05$), arm fat percentage ($P < 0.05$), leg fat percentage ($P < 0.05$), trunk fat percentage ($P < 0.05$) significantly decreased. No changes took place in rest, sitting rest or maximum heart rate from pre to post (Table 1).

Test variables during the 90 minutes test in ski-ergometer before and after 16 weeks training period are presented in table 2. The distance improved significantly from 18.0 ± 0.6 to 19.2 ± 0.7 km/h. No significant change took place in fluid intake (ml) from pre to post (874 ± 44 vs. 922 ± 49). The average speed and relative intensity (% of max HR) during the first 5 minutes was significantly higher in post vs. the pre-test and also compared to the last 85 minutes in both pre- and post-tests. Furthermore, the average speed in the post-test during the first ½ hour was higher than the last 60 minutes ($P < 0.05$); (Table 2). The relative intensity during the last 30 minutes in in both pre- and post-tests were significantly higher than the preceding 60 minutes - apart from the first 5 minutes. The rest blood lactate level in the post-test was higher compared to the pre-test (1.4 vs. 1.1 mmol/l; $P < 0.05$) while no difference was found in lactate levels during the 90 minutes test measured after 5, 30, 60 and 90 minutes (NS).

Table 1: Anthropometric characteristics in all participants (n = 24) and in participants (n = 19) before and after training prior to participating in Vasaloppet.

Antropometric variables	All (n = 24)	Pre (n = 19)	Post (n = 19)
Age, years Body weight, kg	40 ± 2 77.1 ± 1.4	41 ± 2 76.9 ± 1.5	41 ± 2 76.8 ± 1.6
Height, cm	181 ± 1	181 ± 2	181 ± 20
Body mass index, kg/m²	23.4 ± 0.2	23.3 ± 0.3	23.3 ± 0.3
Total body fat, %	14.2 ± 1.2	14.0 ± 1.2	12.3 ± 1.1 *
Total Lean body mass, kg	64.4 ± 1.4	64.5 ± 1.4	65.4 ± 1.5 *
Arm fat, %	10.0 ± 1.3	9.5 ± 1.1	8.2 ± 0.9 *
Arm lean mass, kg	7.7 ± 0.2	7.8 ± 0.2	7.8 ± 0.2
Leg fat, %	14.5 ± 1.2	14.0 ± 1.2	12.7 ± 1.4 *
Leg lean mass, kg	21.8 ± 0.6	21.9 ± 0.5	22.2 ± 0.5 (†)
Trunk fat, %	15.6 ± 1.0	15.6 ± 1.2	13.4 ± 1.0 *
Trunk lean mass, kg	30.8 ± 0.7	30.8 ± 0.7	31.4 ± 0.7 *
Training variables			
Resting heart rate, beats/min	Na	44 ± 2	44 ± 1
Max. heart rate, beats/min	Na	180 ± 3	180 ± 4
Heart rate sitting, beats/min	Na	60 ± 2	61 ± 3

Data are Mean ± SEM. *: ($P < 0.05$) Pre vs. Post; †: ($P < 0.067$) Pre vs. Post

Table 2: Test variables during a 90 min ski-ergometer test before and after training prior to participating in Vasaloppet.

	Pre (n = 19)	Post (n = 19)
Distance, km Fluid intake, ml Mean Speed, km/h	18.0 ± 0.6 874 ± 44	19.2 ± 0.7 * 922 ± 49
0-5 min	13.1 ± 0.5 #	14.2 ± 0.6 *#
5-30 min	12.0 ± 0.5	13.3 ± 0.5 *¥
30-60 min	11.4 ± 0.5	11.6 ± 0.6
60-90 min	11.8 ± 0.6	11.6 ± 0.6
Relative intensity , % HRmax		
0-5 min	68.9 ± 2.6 ‡	77.9 ± 1.4 *#
5-30 min	79.8 ± 2.4	81.6 ± 1.9
30-60 min	81.7 ± 2.1	82.8 ± 1.7
60-90 min	91.5 ± 1.8 $	89.6 ± 1.9 $
Blood lactate, mmol/L		
Rest on chair	1.1 ± 0.1 †	1.4 ± 0.1 †
5 min	4.4 ± 0.4	4.0 ± 0.3
30 min	4.4 ± 0.3	5.1 ± 0.3
60 min	4.3 ± 0.6	3.9 ± 0.4
90 min	5.3 ± 0.8	5.2 ± 0.8

Data are Mean ± SEM. *: ($P < 0.05$) Pre vs. Post; †: ($P < 0.05$) Rest vs. Exercise; ‡ ($P < 0.05$) 0-5 min vs. (5-30 min & 30-60 min & 60-90 min); $:($P < 0.05$) 60-90 min vs. (5-30 min & 30-60 min); #: ($P < 0.05$) 0-5 min vs. (30-60 min & 60-90 min); ¥: ($P < 0.05$) 5-30 min vs. (30-60 min & 60-90 min)

Table 3: Blood glucose, hematocrit, hemoglobin and glycosylated hemoglobin at rest in the fasted condition before and after training period prior to participating in Vasaloppet.

	Pre (n = 19)	Post (n = 19)
Blood glucose, mmol/L	5.3 ± 0.2	5.3 ± 0.2
Hba1c, %	5.41 ± 0.05	5.28 ± 0.05*
Hematocrit, %	47.4 ± 0.6	46.2 ± 0.6*
Hemoglobin, mmol/L	9.6 ± 0.1	9.3 ± 0.1*

Data are Mean ± SEM. *: ($P < 0.05$) Pre vs. Post

Rollerski field test

Due to icy conditions on the paved 3 km circuit the pre-planned date before the post-test had to be rescheduled from a week before to a week after Vasaloppet. A week was chosen to give the skiers a sufficient recovery period after the Vasa race. Only 11 skiers made both the pre- and post-test and the mean (± SD) round performance level improved from 11.04 ± 1.39 to 10.07 ± 1.24 minutes or 8.6%.

Blood analysis

The blood glucose level was unchanged from pre- and post-test (5.3 ± 0.2 vs. 5.3 ± 0.2 mmol/l) while a significant decrease took place in Hba1c %, hematocrit % and hemoglobin (mmol/l) from pre to post (Table 3; $P < 0.05$).

Discussion

The main finding in the present study was a strong correlation between performance in the 90 minutes ski-ergometer test both before and after training and the performance in Vasaloppet in a group of moderately trained recreational c-c skiers. Furthermore, we observed a strong correlation between the 120 minutes Rollerski field pre- and post-tests and the performance in Vasaloppet. In summary, our results show that long lasting ski-ergometer and/or rollerski field test performance protocols can explain between 58-70% of the variation in the performance in a long distance classic style c-c race such as Vasaloppet. In other words 30-42% of the variation in performance in Vasaloppet must be due to other factors e.g. ski wax, ski design/structure and technical skills.

Prediction of performance

Many studies have examined the relationship between shorter ski-ergometer tests, treadmill running and shorter c-c (simulated) races up to approximately 10 km and also found strong correlations [7,8,11-17]. The reason why these test procedures correlate quite well to c-c race performance may be due to the great variation in the terrain in normal c-c races (intermittent work) which requires the ability to generate short but vigorous force during especially uphill skiing in contrast to the downhill parts [11]. In Vasaloppet the course is mainly in flat terrain and does not offer these variations, which emphasizes continuous upper body exercise rather than the ability to make shorter and harder uphill bursts and therefore test procedures of longer durations could be useful for both elite and recreational c-c skiers.

It is important to underline that c-c skiing is a very complex sport where performance can be affected by many different factors. A major factor that influences the relationship between performance in e.g. a ski-ergometer and c-c skiing on snow might be the difference in the skier's technical skills. DP in a ski-ergometer requires less technical skills as compared to coordination during skiing on snow or rollerskiing where both leg and upper-body movement patterns are involved to a higher extent. The distribution of ski techniques during the rollerski test rounds were on average one third easy DP, 300-400 meters DS (10-12%) and about half the distance DP with a kick (Figure 1c). As we do not know how different techniques were used during the Vasalop this must be taken into consideration when comparing with the rollerski test. A more horizontal rollerski track might have been preferred in order to simulate Vasaloppet, but in order to avoid traffic and the very possible influence of wind we preferred the sheltered tracks in the forest.

Training in ski-ergometer

Performance was improved in the ski-ergometer test from 18.0 km (pre) to 19.2 km (post) - a total of 6.7%. This is consistent with the observed improvement in performance (8.6%) observed in our rollerski field test although the number of subjects is smaller. The higher performance level reflect a higher speed during the first 30 minutes of the 90 minutes all out test where the improved trunk and leg lean muscle mass might be the significant factors to the increased performance as no change was found in arm lean muscle mass. The use of specific DP ergometer training is not well elucidated, but Nilsson et al. 2004 showed that 6 weeks of 20-s or 180-s DP interval training, three times a week, significantly increased power output in both a 30-second test and a 6-minutes test, and it also improved work efficiency and decreased blood lactate levels at submaximal levels in a ski-ergometer. However, in the long duration test applied in this study we did not observe decreased lactate levels during the 90 minutes submaximal exercise test.

The hematocrit, hemoglobin and glycosylated hemoglobin concentration were significantly decreased after the training period and these are consistent adaptations after endurance training. Although VO_{2max} was not measured we did not observe a decrease in resting heart rate, which may indicate that there was only a limited cardiovascular effect of the training. However, the above mentioned blood variables does indicate an endurance training effect was present and it is thus tempting to suggest that effect of training may be an improved peripheral adaptation, efficiency and muscle strength. Consistent with this we observed a reduced fat % in arms, legs and trunk and an increased total lean body and trunk mass. The presence of an increased trunk lean mass, unchanged arm lean mass and an improved DP performance is in agreement with a study [10], where upper body muscle mass measured by DXA scan, correlated to c-c performance measured with GPS in different parts of the slope (mainly during uphill skiing).

Strength and limitations

The strength in the present study was the strong correlation found between Vasaloppet performance and long lasting test procedures in ski-ergometer and rollerski field tests which might be useful tools in c-c skier's preparation for very long classic ski races and a guideline for the expected performance time. On the other hand we acknowledge that it might be inconvenient to spend time on long lasting test procedures when shorter tests deliver strong correlations as well, but found that psychological aspects of 90 minutes test in ski-ergometer and/or two hours Rollerski-tests should not be neglected. The ability to keep up pace in these tests simulate psychological factors that might be useful in for instance Vasaloppet.

A major limitation of the present study, is that the study was uncontrolled and not randomized, making it difficult to establish causality in the training parameters. On the other hand the study is by nature very applied and performed in a real-life setting. All skiers registered on their own account and covered own expenses associated with participation in Vasaloppet making a randomization procedure difficult under the settings in the present study. Also we lack detailed information about the use of different techniques during the Vasaloppet, fitness level, volume and intensity before the pre-tests which consequently make it difficult to explain and interpret our results in more details. We have very limited knowledge about the skiers training background before the project took place because many in this group of recreational skiers did not keep training diaries. An interesting question for future research would be how different training techniques would increase performance in long-distance cross country skiing in recreational skiers.

One source of limitation in the present study was the lack of control of the ski preparation among the skiers. Ski glide speed strongly correlates with performance [21,22]. Variability in ski conditions (glide and grip) could influence our findings. On the other hand, the weather conditions (app. -3 - -5 OC, and good snow conditions) in Vasaloppet in 2010 made preparation of skies relatively easy and this probably eliminates some of this variation.

Conclusion and Perspectives

The present study is the first to show a strong relationship between prolonged ski specific ergometer test, rollerski field tests and a very long endurance classic c-c skiing competition like Vasaloppet. The study was performed in a real life setting and the subjects participated in the project because they found it applicable and relevant and could train much like they normally did for the Vasaloppet. Although we found a high correlation between long lasting pre (and post) rollerski field tests and upper body ski-ergometer tests, we acknowledge the value of much shorter lasting test procedures because of similarly reported high correlations and a somewhat less demanding procedure. Future research should apply a more controlled study design and might focus on the impact of high and/or low intensity training before long lasting recreational c-c competitions and the use of the ski-ergometer as a test and training tool.

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