PHYSIOLOGICAL CORRELATES OF SKATING PERFORMANCE IN WOMEN'S AND MEN'S ICE HOCKEY

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ABSTRACT

The purpose of the current investigation was to identify relationships between physiological off-ice tests and on-ice performance in female and male ice hockey players on a comparable competitive level. Eleven female, 24±3.0 years and ten male ice hockey players, 23±2.4 years were tested for background variables: Height, body weight (BW), ice hockey history as well as lean body mass (LBM) and peak torque (PT) of the thigh muscles, VO_{2peak} and aerobic performance (OBLA, RER1) during an incremental bicycle ergometer test. Four different on-ice tests were used to measure ice skating performance. For women, skating time was positively correlated ($p < 0.05$) to BW and negatively correlated to LBM%, PT/BW, OBLA, RER 1, and VO_{2peak} (ml $O_2 \cdot kg^{-1}$ $BW^{-1} \cdot min^{-1}$) in the Speed test. Acceleration test was positively correlated to BW and negatively correlated to OBLA and RER 1. For men, correlation analysis revealed only one significant correlation where skating time was positively correlated to VO_{2peak} (l $O_2 \cdot min^{-1}$) in the Acceleration test. The male group had significantly higher physiological test values in all variables (absolute and relative to BW), but not in relation to LBM. Selected off-ice tests predict skating performance for women but not for men. The group of women was significantly smaller and had a lower physiological performance than the group of men and were slower in the on-ice performance tests. However, gender differences in off-ice variables were reduced or disappeared when values were related to LBM, indicating a similar capacity of producing strength and aerobic power in female and male hockey players. Skating performance in female hockey players may be improved by increasing thigh muscle strength, oxygen uptake and relative muscle mass.

Key words: Body composition, exercise test, muscle strength, gender

INTRODUCTION

In sport a number of different laboratory and field tests have been used to evaluate the physical abilities of athletes in order to determine individual strengths and weaknesses to serve as a base for planning a training program, or to assess the effect of training programs (37, 44). Anthropometrics, body composition, flexibility and strength are usually measured with easily available and simple test tools (caliper, bench press repetitions, vertical jump tests etc.). Aerobic and anaerobic capacities are also often measured by field tests that are considered to reflect aerobic- and anaerobic performance such as the 20-m shuttle run test and sprint tests respectively (44).

Ice hockey is described as a physically demanding sport, where bouts of high intensity are interspersed with periods of rest, requiring the use of both anaerobic and aerobic energy systems (11, 20, 49).

Off-ice physiological fitness in ice hockey has been studied previously (9-11, 16, 18, 21, 22, 25, 33, 39, 40) and in some investigations, off-ice tests have been used to predict on-ice skating performance (8, 16, 33).

On-ice tests have been used to assess physical fitness as well (6, 15, 18, 22, 31). Depending on the structure of the test, on-ice tests for ice hockey players may measure skill as well as physiologic fitness (40). A test involving predominantly forward skating is considered better for measurement of fitness whereas a more complex test has been reported to result in greater performance differences between players of different skill levels (40). On-ice performance in male players has been found to be correlated to playing level, which was suggested to be a result of player selection (16). In ice hockey it has been recommended to use laboratory tests with more sophisticated equipment to measure aerobic and anaerobic capacities, such as the ergometer cycle test and Wingate cycle test (11). However it has recently been shown that off-ice VO_{2max} values and Lactate thresholds are not adequate predictors of on-ice $VO_{2\,max}$ and Lactate thresholds in young male ice hockey players (14).

Women’s ice hockey is a substantially smaller sport compared to the male version of the game. A few milestones in the history of women’s hockey was the first world championship for women in 1990 and the inclusion in the Olympic programme in 1998 (51) and the number of women ice hockey players are growing. The body of physiological research on women’s ice hockey is small, but recent research has studied the physiological profiles of women’s ice hockey players, both off- and on-ice (7, 8, 18). The relationship between off- and on-ice performance has also been studied in women’s synchronized figure skating (5).

The most important predictors for skating speed for both women and men have been found to be jump tests (4, 8, 16, 33) and off-ice sprint tests (4, 8, 16). Isokinetic muscle strength has also been found to be correlated to skating speed for men (33).

When test results are compared between different groups of athletes it may be important to include more variables into the comparison before similarities or differences in physiological performance are interpreted. Body weight and body composition are important factors to consider, especially in weight bearing sports (54). In ice hockey added weight has been shown to reduce skating speed (38) and Farlinger et al. suggest that weight has to be accounted for when physiological tests are used to predict skating speed (16).

If comparisons are made between women and men, one might thus have to consider possible differences in body size, body composition and player experience. In general adult women have a higher percentage of body fat compared to adult men (17), primarily due to hormonal factors (52). Therefore, women have a lower power-to-total-weight ratio since power output is related to lean body mass (50).

Only one previous study has compared off- and on-ice performance between women and men. This study found that young (10-15 years) female and male hockey players had similar off-ice performance (except for a higher fat% in the women), but that the male players outperformed the female players' on-ice. Difference in on-ice performance was attributed to more playing experience (7). When interviewed, women players considered themselves second class hockey players due to poorer on-ice performance (19). However, their comparisons were solely based on their perception of on-ice performance, even though other important factors for performance were mentioned in the interviews (i.e. playing experience, practice conditions etc.). To our knowledge no previous study has compared adult women and men ice hockey players regarding off-ice or on-ice performance.

Even though field tests provide useful information, laboratory testing allows more detailed investigations of strength, anaerobic and aerobic performance and body composition in relation to skating performance. In order to enable more detailed investigation of the different physiological variables laboratory testing was chosen instead of simple field tests.

The present study wants to address the existing lack of comparative studies between adult women and men ice hockey players concerning the relationship between the on-ice and off-ice performance in relation to body weight and body composition. The purpose of this study was thus to identify physiological variables that predict skating performance for women and men respectively on a comparable competitive level in relation to anthropometry and ice hockey history.

METHODS

Experimental Approach to the Problem

In order to examine how background variables (anthropometrics and ice hockey history) and physiological fitness (strength and aerobic capacity) were associated with skating performance (skating time), ice hockey players from a women's team as well as from a men's team were evaluated on various off- and on-ice tests. The study was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki of the World Medical Association. The protocol was approved by the Ethics Committee of the Medical Faculty of Umeå University, Sweden

The off-ice tests measured isokinetic peak torque of the thigh muscles, aerobic (and anaerobic) performance and body composition. The on-ice tests measured skating time in four different skating tests previously used to test skating performance on ice hockey players (6, 22). Similarities and differences in test results between the group of women and men were also analysed.

Subjects

One women's ice hockey team and one men's ice hockey team participated in this study. The women's ice hockey team was considered one of the best teams in the region and the men's team played in the second highest division in Sweden. Volunteering players in the selected teams that were 18 years or older were included. Goaltenders were excluded due to the unique physiological demands of goaltending. All participants received an information sheet explaining the nature of the study. The participants were instructed to prepare for the test day as for a hockey game, with no alcohol or tough physical exercise the day prior to testing or at the test day. The tests were performed in day-time at the end of the season. The off-ice tests and on-ice tests were performed on different test days within a period of 6 weeks (with the exception of three male subjects that performed the on-ice tests three months after the off-ice tests, due to technical problems) and on the off-ice test day the body composition and isokinetic strength tests were performed prior to the ergometer incremental test, as it was considered the most physically demanding test. The variables used in the analysis are the variables that are most often presented in scientific research in order to enable comparisons. Background variables were derived from a questionnaire.

Testing Protocols and Procedures

Off-ice tests

Anthropometrics

Height was measured to the nearest centimetre with a Harpenden Stadiometer (Holtain Limited, Crymych, United Kingdom) and body weight was measured to the nearest kilogram with standard digital scale (Avery Berkel model HL 120, Avery Weigh-Tronix Inc, Fairmont, Minnesota, USA) wearing light clothing.

Body composition

Body composition of the whole body was measured using Dual energy X-ray Absorptiometry (DXA, Lunar DPX-IQ software version 4.7, Lunar Co, Wi, USA,). The method is considered to be a valid and reliable method for measurement of bone and soft-tissue composition (35). Soft tissue can be divided into fat mass and fat-free mass, the latter also known as lean body mass (LBM) and in our laboratory the coefficient of variation (CV) for LBM has been reported to be 0.9% in total body scans (42). The Lunar DPX-IQ was calibrated every test day using a standardised phantom. Values of LBM were used in the current study.

Isokinetic muscle strength testing

Gravity corrected isokinetic muscle strength of the knee flexors and extensors were measured with a Biodex isokinetic dynamometer (Biodex System 3, rev. 3.30 02/14/2003 Biodex Co, New York, USA). After five minutes of cycling on an ergometer bicycle, the subjects were seated in the Biodex with their arms crossed in front of their chests, their thighs supported, with a 70° hip angle, the lever attached just above the ankle, a support for their lower back, a fixation girdle around the pelvis and two diagonal straps across the chest. The dynamometer's axis of rotation was aligned with the knee joint and the angular movement was 100°.

Following some test-specific warm-up repetitions in the dynamometer, the subjects performed five maximal concentric contractions (knee extension and flexion) at the angular velocity of 90°/second, and ten maximal contractions at the angular velocity of 210°/second. The rest period between changes of velocities was approximately two minutes. The Biodex system 3 has been found to be a valid and reliable instrument in velocities below 300°/sec (13). The Biodex isokinetic dynamometer was calibrated each week in accordance with the instructions in the manufacturer's manual. The highest peak torque (PT) in each test was noted. The mean value of left and right PT for quadriceps and hamstrings were calculated at 90°/sec and 210°/sec, respectively.

Ergometer incremental test

Aerobic performance was measured in an incremental test on an electronically braked bicycle (Rodby™, RE 829, Enhörna, Sweden). Visual feedback from a tachometer was used to keep a steady pace at 60 repetitions per minute (rpm). The work load at the start of the test was 40 Watts (W) for women and 50 W for men and with an increase in the work load every three minutes by 40 W for women and 50 W for men. The test continued until exhaustion (when the subject was unable to maintain the pace of 60 rpm). After this, the subjects pedalled at the work load at the start (40 W or 50 W) for another 10 minutes as a cool-down. During the incremental cycle ergometer test a metabolic gas measurement system

(MetaMax II, CORTEX, Biophysik GmbH, Leipzig, Germany) was used to measure the subject's oxygen uptake (VO_2), carbon dioxide output (VCO_2) and ventilation (VE). An ind-welling catheter was placed in the antecubital vein and blood samples were drawn at rest, after two minutes into every workload and at the end of the test. The blood was analysed for blood lactate in an YSI 1500 Sport L-Lactate analyser (YSI Inc, Yellow Springs, Ohio, USA). Heart rate was monitored with a Polar chest transmitter (Polar Electro, Kempele, Finland) and transmitted to the MetaMax II. The test procedures and the ventilatory- and lactate thresholds have been described elsewhere (28) and the MetaMax II has been found to be valid and reliable for metabolic gas measurements (30). The MetaMax II was calibrated every test day for measurements of gas contents and volume (28). Information used in the current study was oxygen uptake at a blood lactate concentration of 4mMol (OBLA), at a respiratory exchange ratio of 1 (RER 1) and the highest value of oxygen uptake at the end of the test (VO_{2peak}).

On-ice tests

Four of the five tests previously described (6, 22) were performed.

Agility

A cornering test (Agility) required the players to complete an S-shaped pattern around the face-off circles (Fig. 1a). The test area spanned over 18.9m (62ft) in width and 22.55 m (74 ft) in length (Fig. 1a). This test has been reported to have a test-retest *r* value of 0.96 on 14 to 15 year-old men (22) and $r = 0.64$ on adult women (6).

Acceleration and Speed

The "Acceleration test " (Acceleration) and the "Speed test" (Speed) were measured in one continuous skating bout from a stationary start (Fig. 1b), where the first 6.1 m being measured as an acceleration split time (Acceleration), and the entire 47.85 m being measured as the speed time (Speed). These tests have been reported to have test-retest values of $r = 0.8$ for Acceleration and $r = 0.76$ for Speed in adult women (6).

Full Speed

The "Full speed test" (Full Speed) was measured over a distance of 15.2 m after a required build-up of speed from the opposite blue-line (Fig 1c). This test has been reported to have a test-retest *r* value of 0.84 in adult women (6).

The tests were performed in a similar manner as described by Bracko (6). Skating time was measured with a photo electric timing system (Newtest 300 PowerTimer, Oulu, Finland). The centre of the photo cells was 108 cm above the ice-surface. The players wore full equipment and carried their stick during the testing. Prior to the testing, the players performed usual warm-up exercises for approximately 15 minutes.

The ice tests were performed on an international rink in the following order: Agility, Acceleration, Speed and Full speed. The tests were performed twice, and the best trial was recorded. All the players received at least two minutes of recovery between the trials and at least fifteen minutes of recovery time between the different tests when the timers were being repositioned.

Statistical Analysis
Data were analyzed by using SPSS for PC, Statistics 17.0 (SPSS, Inc., Chicago, IL, USA).

Non- parametric Spearman's correlation analysis was calculated to examine bivariate relationships between the off-ice and on-ice test variables. The non-parametric test Mann Whitney was used to test for significant differences between women and men. All results presented as median ± *SD*. For all statistical tests, an alpha level of $p \leq 0.05$ was operationally defined as statistical significance.

RESULTS

Descriptive statistics for background variables are shown in Table 1. The men and the women were similar in age, but the men were significantly taller and heavier than the women and had more hockey playing experience. The women's and the men's teams had similar amount of practice on ice each week, but the men's team had more than three times as many games in their league.

The men had significantly higher values in all physiological variables expressed in absolute values as well as in relation to body weight (Table 2) and all men skated faster than the fastest woman in the four on-ice tests (Table 3). When the physiological off-ice test values were expressed in relation to LBM, differences between the group of women and men diminished or disappeared (Table 5).

No significant correlations were found between skating performance in the four on-ice tests (including Agility) and background variables (anthropometrics and ice hockey history) except for BW for women. As the Agility test is supposed to test skill and not physiological performance, the Agility test was not tested for correlations to physiological variables, and is not included in Table 4a and 4b.

For the women the Acceleration test and the Speed test both revealed significant positive correlations to BW (r = .639, p = .034 and r =.831, p = .002 respectively) and Speed test had a significant negative correlation to LBM% (r = -.773, p = .005). Both the Acceleration test and the Speed test also showed significant negative correlations to physiological off-ice values expressed in relation to BW in women (Table 4a). Furthermore in women, the Acceleration test had significant negative correlations to OBLA and RER 1 expressed in relation to BW (r =-.690, p = .019 and r =-.658, p = .028 respectively) and the Speed test had significant negative correlations to both strength and aerobic performance expressed in relation to BW. Full speed test had few significant correlations with physiological variables (Table 4a).

For the men correlation analysis revealed only one significant correlation (Table 4b), where skating time in the Acceleration test was positively correlated with VO_{2peak} l O_2 (absolute value) (r= .889, p = .007). No significant correlations were found between skating performance and off-ice test results expressed in relation to LBM (results not shown) neither in women nor men.

DISCUSSION

This study showed four primary findings: 1) Off-ice fitness predicts skating performance for women but not for men; 2) The group of women was significantly different from the group of men in all background variables except for age, which makes it hard to compare the two groups; 3) Gender differences in off-ice variables were reduced or disappeared when values were related to LBM, indicating that the LBM of the group of women and men had (approximately) similar capacity of producing strength and aerobic power; and 4) On-ice performance was significantly different between genders and was not associated with physiological variables related to LBM neither in women nor men.

To our knowledge, this is the first study that has used laboratory equipment to get specific data regarding body composition, isokinetic strength and aerobic performance in ice hockey players and that has compared off- and on-ice tests between female and male players. Laboratory tests provide more information concerning aerobic/anaerobic performance, body composition and muscle strength. I.e athletic performance can be divided into different aerobic and anaerobic thresholds (28), body composition can be divided into bone- fat- and lean body mass in different regions of the body (35) and muscle strength can be measured at different angular velocities or at different joint angles of the movement (53). However since most previous studies on physiology in ice hockey has been performed with simple off-ice tests it is difficult to make direct comparisons to earlier studies as correlations between jump tests and isokinetic muscle strength have been reported to be moderate to low (45). Another factor that limits the possibilities of comparisons is that the time of the season when the tests have been made varies between studies, which could influence the results as physiological fitness to some extent varies during the year. Flexibility and aerobic performance have been shown to be unchanged, but concentric and eccentric peak torques change over the season (26, 39, 43). Furthermore the physiological profile of male ice hockey players has changed over the years and the players today are taller and better physically trained than before (10, 11, 41). This is also true for women in other sports (50), but has not been studied in ice hockey.

Women

Peak Torque

In comparison with other groups of women athletes in comparable test settings, the women in our study seem to have a quite undeveloped quadriceps strength, particularly in relation to BW, where the women in our study were 17% weaker than the women in another team in the same league (47) and 12% weaker than women in volleyball (2). However, hamstrings strength appears to be on a more comparable level in absolute values, but in relation to BW the women in the current study were 8% and 4% weaker than the hockey players and volleyball players respectively (2, 47).

Aerobic capacity

Aerobic capacity in women's ice hockey has mostly been performed by the Leger test off-ice which makes direct comparisons difficult. With this limitation in mind, the results in the current study (Table 4a VO_{2peak} 45 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) are comparable to the predicted test value of 46 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (forwards) and 43 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (defensemen) in Leger's test on University players (18).

On-ice performance

The results in the current study are 6-8% slower compared to Elite players from the Canadian National Hockey Team (6) but on a similar level to the results in a Canadian study of University players (18) (Table 3).

Correlations

Only one previous study has investigated the associations between off-ice tests and on-ice performance in women's ice hockey (8). In that study the players were only 8-16 years old and the off-ice tests were different compared to the current study, limiting the ability to make direct comparisons. Bracko and George found that age, playing experience, body mass and height were predictors of speed and discussed how these four variables were thought to be linked together in this population of growing women. In the current study age, hockey experience and height were not correlated to skating performance, which might be explained by the fact that the subjects were adult. Instead, skating time was correlated to physiological variables related to body weight, and body weight in itself. The Speed test was the on-ice test with the strongest correlations to off-ice test variables and predominantly to aerobic variables. The best predictors for good skating performance in the Speed test were OBLA ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, RER 1 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and VO_{2peak} ml O_2 $kg^{-1} \cdot min^{-1}$. This might seem somewhat confusing, however, these variables have previously been reported to be closely correlated to high intensity performance in cross country skiing as well, in the short steep uphill sections of the skiing course (28). In cross-country skiing RER 1 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ has also been shown to be the best predictor for performance in female athletes over a variety of distances (2,5km to 15 km) (29). It was concluded that lactate produced when working above the OBLA ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and RER 1 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ thresholds has to be "repaid" immediately, which results in a limited time of the work above these thresholds. This time limitation could also affect short bouts of activity (28). However further studies have to be made in order fully understand the relationship between the results of the speed test and OBLA ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, RER ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and VO_{2peak} ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ in the current study (Table 4a).

Men

Peak Torque

Few studies are available that have studied athletes at the same angular velocities as in the current study. However, one study of ice hockey players has studied PT in quadriceps at 90°/sec and their results (233 Nm) (26) correspond to the results in the current study. A study of male soccer players presents PT of 266 Nm and 134 Nm for quadriceps at an angular velocity of 60 ^{o}/sec and 180^{o}/sec respectively (45). As isokinetic muscle strength decreases with increased angular velocity (53), these results seem in line with the present study (Table2), at least for the lower contraction speed. A study of male elite gymnasts presents PT of 182 Nm and 87 Nm for quadriceps and hamstrings respectively at an angular velocity of 60 ^{o}/sec (46). These results are considerably lower compared to the results in the current study, however when difference in body weight is considered (85 kg in our study compared to 67 kg in the gymnasts), this result becomes more reasonable. However, as PT usually is described in absolute values (Nm), and not in relation to BW, it may be difficult to compare results between sports.

Aerobic capacity

Aerobic capacity in men's hockey has been studied using different kinds of tests. The most common methods are by cycle ergometer or treadmill tests and these tests have been reported to produce similar results (40). It appears that the men in the current study (Table 2) had a relative aerobic capacity (VO_{2peak} 56 ml · kg^{-1} · min^{-1}) comparable to previous findings. A study of the players in the NHL entry draft (graded cycle ergometer test) reported an aerobic capacity of 58.1 and 56.7 ml · kg^{-1} · min^{-1} for forwards and defensive players respectively (9), and a study from collegiate athletic ice hockey (graded treadmill test) reported an aerobic capacity of 59 ml · kg^{-1} · min^{-1} (21).

On-ice performance

To our knowledge, few of the previously published studies investigating skating performance have presented skating times in the tests used in the current study with male adult subjects. However, several studies have investigated Bantam players (14-16 years). The adult players in the current study (Table 3) are 22% faster in Agility (7), and 19% faster in the Full speed (22) compared with Bantam players. One study prior to the current one has used the Agility test on adult male subjects, however in that study there was a wide range of playing levels and the players were between 15 and 22 years old (16) and the results in the current study are 11% faster. Considering that the adult men in the current study were taller, heavier and with more hockey experience compared to players in the other studies comparisons are difficult to make.

Correlations

Previous studies of the associations between off-ice and on-ice tests on adult men have shown significant correlations between isokinetic muscle strength and skating speed (33), and that a good performance in off-ice sprint tests predicts skating speed (4, 16). Considering this, it is somewhat surprising that only one of the selected physiological values predicted skating time for the men in the current study (Table 4b). The reasons why these associations were not found in the current study are not known, however there are a few factors that might have contributed to the results. The men as a group were more homogenous, with low SDs when the test results are related to BW. Only seven men completed the cycle ergometer test, compared with ten players in the rest of the test. It is reasonable to assume that the combination of a homogenous group of men and a small sample might have made it more difficult to find strong associations in the group of men compared to the group of women.

Comparisons between women and men

In sports physiology it is quite common to compare women and men, for example in aerobic- or anaerobic capacity (15, 24, 32, 34, 48) or strength (1, 3, 23, 27, 36). In the current study, even though they were competing on a comparable level, the groups of women and men were significantly different from each other in all aspects regarding background variables (except for age), where the men had more ice hockey experience and were taller and heavier than the women.

The off-ice tests revealed that the physiological capacity was significantly different between women and men when absolute values or values in relation to body weight were used. Considering that most absolute values are associated to body size, this was expected. Absolute values of strength and oxygen uptake are dependent on both body size and level of physical conditioning (52). In sports physiology aerobic capacity is often described in relation to body weight (ml O_2 $kg^{1} \cdot min^{-1}$). This value is relevant as the athlete usually carries her/his own weight and this parameter is thus of importance in the evaluation of performance in sport (54). A difference in physiological values related to BW in the current study was also expected due to the significant differences in percentage of LBM between the groups (Table 2).

In this study all men were faster than the fastest woman. This is not surprising, as skating speed is affected by LBM% (38) and the LBM% was lower in the female ice hockey players compared to the male ice hockey players (Table 2). The higher amount of sex specific body fat in women compared to men (12, 17) affects performance in weight-bearing activities as the women have a higher oxygen uptake per unit lean body mass at a specific work load (12). Due to differences in body composition, it has been argued that women and men should not compete in the same event and should not be compared (12). Difference in body composition also affects the comparison of power output when PT is related to body weight, as the power produced by the lean body mass is divided by a weight where the fat mass is included (Table 2). However, when the off-ice values were related to LBM, the physiological differences between women and men diminished or disappeared (Table 5). This was somewhat surprising to us, considering differences in background variables. On the other hand investigations have found that regular ice hockey practice games do not improve physiological performance (22, 49), and it was only the number of games per season that differed between the women's and men's teams (Table 1). Physiological values in relation to LBM showed no significant associations to on-ice performance. This is not surprising considering the fact that during ice skating, the players need to carry their own body weight.

It is thus important to consider the purpose before making comparisons between women and men (or other groups of different body size or body composition) as the way the comparison is made affects the results. If the aim of the study is to deal with more basic physiological questions about sex or gender differences, as in this study, it is also of interest to use physiological values in relation to LBM. By relating the different physiological parameters to LBM all significant differences between the female and male subject diminished or disappeared (Table 5).

Practical implications

When women enter a male-dominated sport, they often adopt the training regimes developed for men. Since there are physiological differences between male and female athletes within a sport, it is important to have a solid knowledge of how these differences affect performance in this specific sport and to take this knowledge in consideration when a training program is planned. The results from the present study show that a well conditioned body (high values of strength and oxygen uptake in relation to body weight) is important for good skating performance in women's ice hockey. In order to develop skating performance in women's ice hockey, the players thus need to increase thigh muscle strength, oxygen uptake and relative muscle mass.

Differences in body composition between women and men result in vast differences on-ice, in spite of similar oxygen uptake and thigh muscle strength when these values were put in relation to lean body mass. This also implicates that there should be differences in training regimes for women and men since women are more dependent on thigh muscle strength in relation to body weight, for skating performance

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TABLE 1. Background variables (anthropometrics and ice hockey history). Values are expressed as median ± *SD*

	Women (n = 11)	Men (n = 10)
Age (years)	24 ± 3.0	23 ± 2.4
Height (m)**	1.68 ± 0.035	1.81 ± 0.053
Weight (kg)*	77 ± 10.7	85 ± 7.8
Ice hockey start (age)**	15 ± 2.7	6 ± 1.6
Ice hockey experience (years)**	8 ± 3.6	15 ± 1.5
According to normal schedule:		
Ice practice (minutes/week)	270	285
Off-ice practice (minutes/week)	0	80
Games in series/year	12+1=13	46+8=54

* Significant difference between women and men, $p \leq 0.05$

** Significant difference between women and men, $p \leq 0.01$

TABLE 2. Physiological values from Off-ice tests, absolute values and relative to body weight. Values are expressed as median ± *SD*.

		Variables	Women (n = 11)	Men (n = 10)
Absolute values	Lunar	LBM (kg)**	44 ±3.2	65 ±4.3
	Biodex 90°	PT 5 q (Nm)**	148 ±19.4	232 ±25.6
		PT 5 h (Nm)**	80 ±9.5	130 ±9.5
	Biodex 210°	PT 10 q (Nm)**	107±12.9	165 ±14
		PT 10 h (Nm)**	66 ±8.5	102 ±7.2
	Cycle ergometer test	OBLA ($l \cdot min^{-1}$)**	2.7 ±0.3	4.1 ±0.3
		RER 1 ($l \cdot min^{-1}$)**	2.6 ±0.5	4.3 ±0.3
		VO_{2peak} ($l \cdot min^{-1}$)**	2.8 ±0.5	4.8 ±0.2
Values relative to body weight	Lunar	LBM%**	61 ±9.0	81 ±5.1
	Biodex 90°	$PT \cdot BW^{-1}$ 5 q**	2.21 ±0.34	2.84 ±0.23
		$PT \cdot BW^{-1}$ 5 h **	1.19 ±0.17	1.61 ±0.13
	Biodex 210°	$PT \cdot BW^{-1}$ 10 q **	1.58 ±0.25	2.03 ±0.17
		$PT \cdot BW^{-1}$ 10 h **	0.94 ±0.14	1.24 ±0.11
	Cycle ergometer test	OBLA ($ml \cdot kg^{-1} \cdot min^{-1}$)**	37 ±6.8	49 ±2.3
		RER 1 ($ml \cdot kg^{-1} \cdot min^{-1}$)**	41 ±8.2	50 ±4.5
		VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)**	45 ±8.7	56 ±4.5

* Significant difference between women and men, $p \leq 0.05$

** Significant difference between women and men, $p \leq 0.01$

TABLE 3 On-ice tests, skating times. Values expressed as median and *SD*.

	Women (*n*=11)	Men (*n* = 10)
Agility (sec)**	9.96 ±0.32	8.30 ±0.26
Acceleration (sec)**	1.38 ± 0.10	1.06± 0.12
Speed (sec)**	7.38 ±0.34	5.92 ±0.19
Full speed (sec)**	2.29 ±0.21	1.51 ±0.06

* Significant difference between women and men, $p \leq 0.05$
** Significant difference between women and men, $p \leq 0.01$

TABLE 4a Correlations between skating time and sociological, anthropometric and physiological variables for the group of *women* (n = 11)

Variable type	Variables	Acceleration (sec)	Speed (sec)	Full Speed (sec)
Anthropometric	Height (m)	-.19	-.053	.411
	Weight (kg)	.639*	.831**	.42
Ice hockey history	Ice hockey start (age)	.088	.198	.18
	Ice hockey experience (years)	.177	.244	.024
	Age (years)	.173	.464	.3
Physiological				
- Absolute values	LBM (kg)	-.127	-.045	.336
	PT 5 q	.209	.091	-.045
	PT 5 h	-.082	.236	.491
	PT 10 q	.3	.136	-.1
	PT 10 h	.064	.373	.555
	OBLA l $O_2 \cdot min^1$	-.33	-.142	.43
	RER 1 l $O_2 \cdot min^1$	-.412	-.284	.265
	VO_{2peak} l $O_2 \cdot min^1$	-.233	-.167	.363
- Relative values	LBM%	-.545	-.773 **	-.4
	PT $\cdot$ BW^{-1} 5 q	-.327	-.709 *	-.518
	PT $\cdot$ BW^{-1} 5 h	-.573	-.655*	-.091
	PT $\cdot$ BW^{-1} 10 q	-.255	-.636*	-.609*
	PT $\cdot$ BW^{-1} 10 h	-.427	-.527	-.2
	OBLA ml $O_2 \cdot kg\ BW \cdot min^{-1}$	-.690 *	-.817 **	-.196
	RER 1 ml $O_2 \cdot kg\ BW \cdot min^{-1}$	-.658*	-.890 **	-.269
	VO_{2peak} ml $O_2 \cdot kg\ BW \cdot min^{-1}$	-.572	-.792 **	-.119

* Significant correlation, $p \leq 0.05$
** Significant correlation, $p \leq 0.01$

TABLE 4b Correlations between skating time and sociological, anthropometric and physiological variables for the group of *men* (n = 10, ergometer cycle test n = 7)

Variable type	Variables	Acceleration (sec)	Speed (sec)	Full Speed (sec)
Background variables	Height (m)	-.055	.227	.166
	Weight (kg)	.207	.427	.402
	Age (years)	-.006	-.164	-.067
	Hockey start (age)	-.101	-.406	-.66
	Hockey experience (years)	-.381	-.43	.123
Physiological				
- Absolute values	LBM (kg)	-.079	.139	.127
	PT 5 q	-.115	.03	.042
	PT 5 h	-.164	-.006	.042
	PT 10 q	-.03	.067	-.139
	PT 10 h	-.091	-.115	-.2
	OBLA l O_2·min	.306	.108	-.252
	RER 1 l O_2·min	-.655	.127	-.6
	VO_{2peak} l O_2·min	.889 **	.741	.074
- Relative values	LBM%	-.176	-.042	.176
	PT·BW^{-1} 5 q	-.479	-.479	-.285
	PT·BW^{-1} 5 h	-.055	-.248	-.37
	PT·BW^{-1} 10 q	-.236	-.273	-.248
	PT·BW^{-1} 10 h	-.03	-.274	-.353
	OBLA ml O_2·kg BW^{-1} · min^{-1}	-.371	-.630	-.482
	RER 1 ml O_2·kg BW^{-1} · min^{-1}	.321	-.214	-.714
	VO_{2peak} ml O_2·kg BW^{-1} · min^{-1}	.179	-.143	-.429

* Significant correlation, $p \leq 0.05$
** Significant correlation, $p \leq 0.01$

TABLE 5 Physiological values from Off-ice tests, values relative to LBM. Values are expressed as median and ± *SD*.

	Variables	Women (n = 11)	Men (n = 10)
Biodex 90º	PT·tot LBM^{-1} 5 q	3.47 ±0.27	3.56 ±0.25
	PT·tot LBM^{-1} 5 h.*	1.88 ±0.14	2.00 ±0.14
Biodex 210º	PT·tot LBM^{-1} 10 q	2.38 ±0.21	2.57 ±0.13
	PT·tot LBM^{-1} 10 h.	1.52 ±0.16	1.55 ±0.12
Cycle ergometer test	OBLA mlO_2·tot LBM^{-1}·min^{-1}	60 ±4.6	60 ±2.3
	RER 1 ml O_2·tot LBM^{-1}·min^{-1}	60 ±7.7	62 ±4.9
	VO_{2peak} ml·tot LBM^{-1}·min^{-1}	67 ±8.1	72 ±3.7

* Significant difference between women and men, $p \leq 0.05$

** Significant difference between women and men, $p \leq 0.01$

Figure 1a

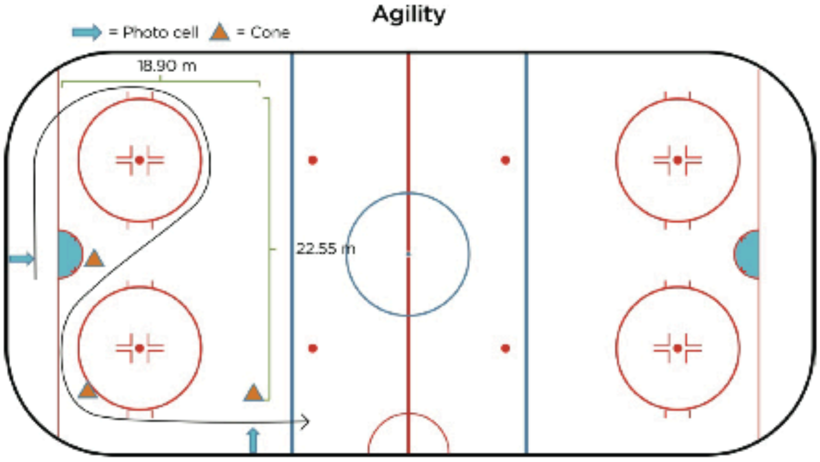

Figure 1b

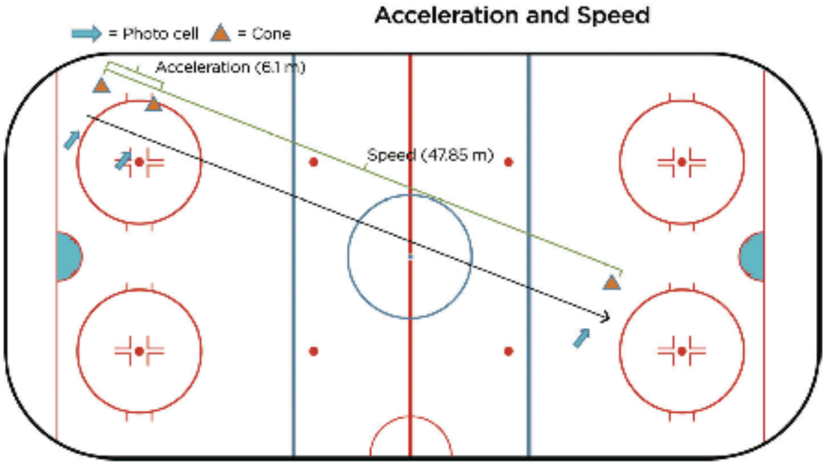

Figure 1c

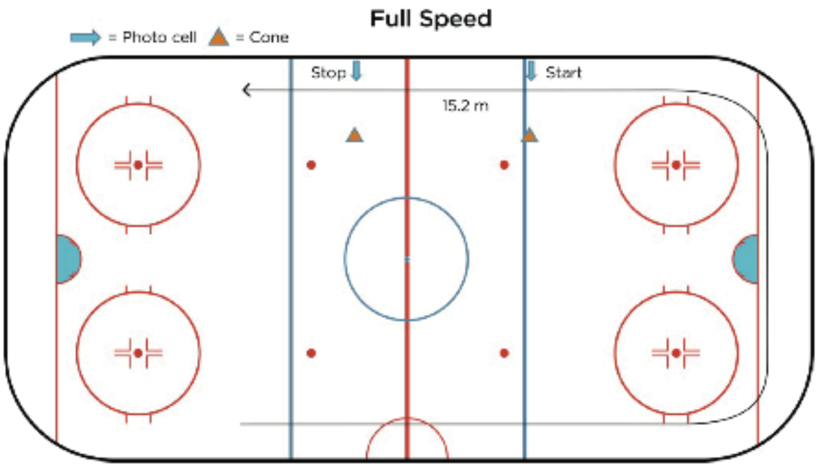

Fig. 1. a) Agility test b) One continuous skate sprint, where the first 6.1m is the Acceleration test and the whole distance (47.85m) is the Speed test c) Full Speed Test 15.2m at full speed, with a flying start.