

Umeå University Medical Dissertations, New Series No. 1309

Gender and Physiology in Ice Hockey

- A multidimensional study

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Umeå 2009

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ISSN: 0346-6612 ISBN: 978-91-7264-893-7

Cover: illustration by J. Wigren, photo published in A. Forberg: "Kvinnor och idrott"
1988

E-version available at <http://umu.diva-portal.org/>

Printed in Sweden by Print & Media, Umeå University, Umeå, Sweden 2009

*Dedicated to my wonderful family – Henrik and Petra.
You keep my world in the right perspective!*

“To explain the cultural at the level of the biological encourages the exaggeration and approval of analyses based on distinctions between men and women, and masks the complex relationship between the biological and the cultural”

J Hargreaves, *Sporting Females. Critical Issues in the History and Sociology of Women's Sports*. Routledge, London, 1994. Page 7

“From a physiologist’s perspective, ice hockey is a complex and challenging sport consisting of a variety of skills involving both gross and fine body coordination. These skills are performed with varying amounts of muscle mass and at varying muscle lengths, velocities, and power outputs. Moreover, these skills must be performed repetitively for an extended period at high intensity in a confined area under hostile circumstances and frequently under adverse environmental conditions. Astoundingly, all of this is accomplished with the player elevated from the ice and balanced on a contact area of no more than 3 in.² (19.4 cm²)”

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Green, H.J, Physiologic Challenges Induced by Participation in Ice Hockey – Implications for Training.

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Abstract

Background That men are prioritised over women has been called the “gender regime in sport”, and has in part been explained by the gender difference in performance. However, gender differences in physical performance between women and men can be debated to depend on how comparisons are made and on the fact that there are many different confounders that may influence the results. Even if attempts are made to overcome this and the groups of women and men are stated to be matched, there are still often differences in training experience in years, or differences in training load. Women tend to have less experience in ice hockey in relation to age and differences in training conditions have also been reported. The aim of this thesis was to investigate how female and male ice hockey players position themselves in their sport and to visualise the interactions between society and biology that may affect performance.

Theoretical approach and methods Harding’s three perspectives (Symbolic, Structural and Individual) were applied on information from team administration as well as on results from questionnaires, semi-structured interviews, and tests of puck velocity, anthropometrics, body composition, isokinetic muscle strength, ergospirometry and on-ice tests from female and male ice hockey players.

Results Vast differences in structural conditions were found, for example in hockey history and in the financial situation within the teams and both women and men were aware of the gender differences in structural conditions. However these differences were not even considered when comparisons of the ice hockey performance of women and men were made. Nine out of ten female players increased puck velocity when a more flexible stick and a lighter puck were used thus indicating that poorly adjusted equipment may affect performance. Male ice hockey players were taller, heavier and stronger, had more lean body mass and a higher aerobic capacity compared to the women in absolute values as well as in relation to body weight. However, the differences diminished or disappeared when the values were expressed in relation to lean body mass. Men had higher expectations on their situation as athletes and the interviewed women described men’s ice hockey as superior to theirs and consequently male ice hockey players deserved better conditions.

Conclusions The views of women and men may affect structural conditions in sport which in turn may affect possibilities in sport for the individual. Gender differences in conditions thus risk confirming the traditional views of femininity and masculinity. However, by moving outside the normal gender boundaries individuals may change the traditional views of femininity and masculinity.

Sammanfattning

Bakgrund Att män har bättre förutsättningar än kvinnor i idrott har kallats för idrottens genusregim och den har till viss del ursäktats av skillnad i prestation mellan könen. Skillnaden i fysisk prestation mellan män och kvinnor varierar dock beroende på hur jämförelserna är gjorda och pga. att det finns många faktorer som kan påverka resultatet. Även om försök görs att matcha män och kvinnor så kvarstår ofta skillnader i träningserfarenhet och antal år man tränat liksom träningsbelastning mellan grupperna. Målet med denna avhandling är därför att undersöka hur kvinnliga och manliga ishockeyspelare positionerar sig själva i sin idrott och att påvisa hur samband mellan samhälle och biologi kan påverka prestation.

Teoretisk ansats Hardings tre nivåer (symboliskt, strukturellt och individuellt perspektiv) har använts för att studera information från klubbarna, frågeformulär, semistrukturerade intervjuer och mätning av puckhastighet, skridskosnabbhet, antropometri, kroppssammansättning, styrka och aerob kapacitet hos dam- och herrhockeyspelare.

Resultat Stora skillnader fanns i strukturella förutsättningar, såsom hockey historia och ekonomiska förutsättningar mellan lagen och att både kvinnor och män var medvetna om dessa skillnader. Däremot använde de inte dessa strukturella skillnader vid jämförelser mellan dam- och herrhockey. Nio av tio kvinnor förbättrade puckhastigheten vid slagskott när en mjukare klubba och lättare puck användes, vilket indikerar att prestation kan påverkas av dåligt anpassad utrustning. Männerna hade mer hockeyerfarenhet, hockeydebut vid en lägre ålder och var längre, tyngre, starkare, hade högre andel fettfri kroppsvikt och hade en lägre aerob kapacitet jämfört med kvinnorna både i absoluta tal och uttryckt i relation till kroppsvikt. Dessa skillnader försvagades eller försvann när värdena uttrycktes i relation till fettfri kroppsvikt. Männerna hade högre förväntningar på sin situation inom idrotten och de intervjuade kvinnorna beskrev herrhockeyn som bättre än damhockey och att män därför förtjänade bättre förutsättningar inom idrotten. Hos kvinnorna var skridskosnabbhet relaterad till flera av laborietesterna, men detta samband saknades för männen.

Slutsats Synen på kvinnan och mannen kan påverka de strukturella förutsättningarna inom idrotten vilket i sin tur kan påverka individens möjligheter inom idrotten. Skillnader i förutsättningar inom idrotten mellan kvinnor och män riskerar därför att förstärka synen på kvinnan och mannen. Genom att gå utanför de vanliga gränserna för kvinnligt och manligt kan innebörden av dessa begrepp nyanseras.

Preface

This thesis is based on the following papers, referred to in the text by the following Roman numerals:

- I. Gilenstam K, Hammarström A, Henriksson-Larsén K.
Gendered Expectations and Structural Conditions in Ice Hockey.
Submitted for publication
- II. Gilenstam K, Karp S, Henriksson-Larsén K.
Gender in Ice Hockey – Women in a Male Territory.
Scand J Med Sci Sports 2008 18(2):235-49
- III. Gilenstam K, Henriksson-Larsén K, Thorsen K. Influence of Stick
*Stiffness and Puck Weight on Puck Velocity During Slap Shots in
Women’s Ice Hockey.*
Sports Eng 2009 11:103-107
- IV. Gilenstam K, Thorsen K, Henriksson-Larsén K. Physiological
*Correlates of Skating Performance in Women’s and Men’s Ice
Hockey.*
Submitted for publication

Abbreviations

1 RM	1 repetition maximum, the load you can lift only once
BW	Body Weight
CSA	Cross Sectional Area
DXA	Dual Energy X-ray Absorptiometry
FFM	Fat Free Mass (equivalent to LBM)
IIHF	International Ice Hockey Federation
LBM	Lean Body Mass (equivalent to FFM)
NHL	National Hockey League
OBLA	Onset of Blood Lactate
RER 1	Respiratory Exchange Ratio =1
SIHA	Swedish Ice Hockey Association
Type I-fibre	Muscle fibre with high aerobic capacity, Slow Twitch
Type II-fibre	Muscle fibre with high glycolytic capacity, Fast Twitch
VO _{2peak}	Peak oxygen uptake
VO _{2max}	Maximal aerobic uptake

Introduction

I got the chance to switch from an interested spectator to a player on the ice when I was 24 years old. As an adult woman, I was intrigued by the atmosphere in the arena – it was clear that it belonged to men. The women's team had the responsibility for the cafeteria when the men's team played games, however, the women did not get anything in return for this. I found this strange, and I could not understand why my team accepted this deal.

It was difficult to find hockey equipment in the sports shop, especially regarding the ice hockey stick. I was too tall for the youth sticks, but the sticks for adult players were too stiff for me.

As a physical therapist interested in physiology I sometimes questioned the way we performed our hockey practice. Why did we not perform strength training, should not women have even more use of this kind of practice compared to men in ice hockey?

When I got the opportunity to start a PhD, I was asked to present my research plans. I wanted to do a series of physiological tests to investigate how women should practice to increase ice hockey performance. I also wanted to investigate the effect of stick stiffness on slap shot performance. When I told my supervisors about my research plans, Karin told me that I had to consider the gender aspect as well.

At the time, I had no knowledge of gender, but after a brief introduction to the topic I could see that she had a point. To learn about gender is the toughest job I have ever done and I must admit that there have been times when I have wished that I could take off my gender glasses! However, from my current point of view, this thesis would not be as interesting without the gender aspect.

In this thesis gender and physiology are introduced to the readers in order to put ice hockey into a context relevant for the understanding of this thesis. As a consequence these topics are not extensively reviewed, but introduced to the readers. It is my hope that this thesis may broaden the horizons to the readers of the constant interactions between the individual and its environment.

History of Sports

Development of Ice Hockey

Ice hockey developed in Canada in the middle of the 19th century. English soldiers have been described to have started the development of ice hockey by bringing the sport bandy to Canada ⁽⁵⁴⁾. The first amateur ice hockey association was formed in Canada in 1885 and the first professional league (NHA) started in 1910 ⁽⁵⁴⁾. The first women's game was played in Canada in 1891 and in the beginning of the twentieth century women's ice hockey was a popular sport in some areas of Canada. However, the popularity decreased and the sport became dormant for many years. Canadian women played their first national championship in 1982 ⁽¹²³⁾. According to the homepage, there are 85 308 women ice hockey players, constituting 14.6% of the licensed ice hockey players in Canada ⁽⁴⁸⁾.

The men's game was introduced to Europe and the first European ice hockey game was played in 1902 (England). An international ice hockey organisation was formed in 1908 (Ligue Internationale de Hockey sur Glace, (LIHG), later named International Ice Hockey Federation, IIHF) and the first European Championships for men took place in 1910 ⁽⁵²⁾. The first world championship for women was played in 1990 and women's ice hockey was included in the Olympic programme in 1998 ⁽¹²³⁾.

Sweden became a member of IIHF in 1920 (as a part of the Swedish Football Association). The Swedish Ice Hockey Association (SIHA) was formed in 1922 and first national championship for men was played the same year ^(54, 115). The first official game between two women's teams in Sweden was in 1969 and the first national championship for women was played in 1987. According to the homepage, there are 3 612 women's ice hockey players in Sweden, constituting 6% of the licensed ice hockey players in Sweden ⁽¹¹⁵⁾.

Development of Sports and Sports for Women

From a historical perspective it is evident that sports are influenced by society⁽⁷²⁾. Modern sports were developed in parallel with the industrialisation process (in Sweden, this process started in the middle of the 19th century). When the 24-hour-day was divided into working hours and rest, spare time was created⁽¹⁰⁷⁾. This opened the possibility for sports participation for men. The changes in society affected women differently and without the help from the extended family working class women were responsible for household labour and childcare beside the work in the factory, with little or no spare time. In contrast to the factual situation among the industry workers, the ideals in society were influenced by bourgeoisie values where the men were the sole breadwinners (production) whereas the women gave birth to, and took care of the children (reproduction)⁽⁴³⁾. According to these ideals, the “nature of woman” became a frail, weak woman, physically inferior to men, victim of their own biology, where the reproductive functions were directly linked to the functions of the body and mind^(43, 72, 107). The fact that boys were raised by their frail and feminine mothers was seen as problematic, and could be counteracted by sport, where boys were transformed to men⁽¹⁰⁷⁾. Seen in this perspective, women in sports must have been a contradiction in terms.

The Women’s movement, the new public health campaign and the fact that women gained the opportunity to the labour market and to pursuit formal education led to yet another change in the view of women, where a healthy and strong woman was the new ideal. This happened during the later part of the 19-th century in Sweden⁽¹⁰⁷⁾. Gentle forms of physical activity were considered to improve women’s health and ability to bear children, whereas physical exhaustion could lead to loss of femininity and fertility⁽¹⁰⁷⁾. Women were allowed into certain sports, carefully guided by “medical science”^(43, 72, 107). By following the expertise, women did not challenge the cultural structures and could perform sports without risking their femininity⁽⁴³⁾. Over time women have managed to increase the number of sports and physical activities available for them, although change has been slow⁽⁴³⁾. This process has been a struggle especially in sports traditionally associated with masculinity, such as physical contact sports and team sports^(34, 43, 47, 103, 124, 125).

Women in “Men’s Sports”

Previous research about women in sports (predominantly from the Anglo-Saxon countries) has found that women have difficulties to get access to sport and have less opportunities and financial resources compared to men ^(43, 81, 90). This situation, where men are prioritised over women, has been called the “gender regime in sport” ⁽⁸¹⁾. The situation in women’s soccer in Europe is described to depend on the level of “integration” into the men’s soccer, and the facilities and financial situation are routinely worse for women ⁽¹⁰³⁾. However, as sports are organized in different ways in different countries, it is sometimes difficult to compare the results, and the results may vary, as shown by the work of Scraton, Fasting, Phister and Bunuel (Scraton et al., 1999).

The women’s struggle to get access to the world of ice hockey in North America has been described and analysed previously ^(31, 120, 122, 123), where women clearly have less resources and opportunities compared to men. Pelak (2002) has examined the sexist structures in an American university in the development of a women’s team and Theberge has made several interesting gender studies of women in North American ice hockey ⁽¹²⁰⁻¹²⁴⁾. Women’s ice hockey in Europe has been included in two previous gender studies; four female ice hockey players were included in a study of aggressive emotions in women’s ball games in Denmark (Thing, 2001), and women’s ice hockey was included in an analysis of gender in sports in Sweden (Redelius, 1999).

Barriers and Constraints in Sports

The most research about barriers and constraints to physical activity has been performed in North America and Great Britain. When it comes to the general aspect of gender division in labour and leisure time, results from Sweden are similar to those in the U.S. where there is a “leisure gap” between genders where women in general have less spare time and where the spare time is divided into shorter periods than for men ^(104, 114). This could be a disadvantage for women participating in team sports since it is necessary to have longer periods of leisure time in order to be active in organised sport activities ⁽¹⁰⁴⁾. A study from Sweden has revealed that the women considered their spare time to belong to the family and that time for physical activity was conditional of family arrangements such as child care ⁽¹²⁹⁾. This gendered “leisure gap”, might be obvious to women and

could affect the expectations the women have on their surroundings in terms of the conditions associated to their ability to perform team sports.

The differences in the way sport is organised may affect opportunities and barriers for women in sports⁽¹⁰³⁾. In both North America and Great Britain sports for young people are based on a school system in contrast to Sweden and other Nordic countries, where sport is based on a club system⁽³²⁾. Due to this difference in sports organisation it is difficult to make direct comparisons between different countries; at least these differences should be kept in mind when comparisons are made. However, in general the gendered structures in sport tend to give women's sport the "back seat" regardless of where the study is performed.

Physiology in Sports

Development of Sports Physiology

In the introduction of a textbook ⁽¹³¹⁾, the history of exercise physiology is sketched where the important scientists who started the broad research area that exists today are named. Exercise physiology developed quite late in the world of science, during the later part of the 19th century. The laboratory associated with the University of Copenhagen (established 1909) and the Harvard Fatigue Laboratory (founded 1927) performed many classical physiological tests, and the scientists educated in these laboratories later started their own research groups, expanding the world of exercise physiology ⁽¹³¹⁾.

Confounders in Comparisons between Women and Men

Subject Selection

When the physiological performance has been compared between women and men, different subject selection has been used.

The most basic form of gender comparisons is between “women and men in good health” or “college students” and has been used to study aerobic capacity, anaerobic capacity and power as well as strength ^(22, 75, 105). Another popular group of subjects is the group of “untrained” or “non-athletes”. The definition of this group varies between studies, from “sedentary or mildly active, but never involved in regular exercise programs” or “non athletes” to “not involved in regular exercise programs in the last 6 months”. The untrained subject groups have been used to study differences between women and men regarding muscle strength and/or muscle CSA ^(8, 9, 17, 55, 76) or aerobic capacity ^(22, 24).

Another subject selection that often has been used in gender comparisons are physical education students, as they have similar amount of physical activity classes in school. This subject group has been used to measure differences between women and men in: muscle strength, muscle fibre areas and muscle CSA ^(101, 102), aerobic capacity ⁽¹³³⁾ and anaerobic performance ⁽⁹²⁾. Sometimes the level of physical activity has been estimated by a physical activity index as well ^(28, 29).

Gender differences have also been studied in “trained” women and men. Usually the studies have used subjects within a specific sport such as swimming^(8, 9) speed skating^(56, 57), distance running⁽²³⁾, ice hockey⁽¹²⁾, and in strength training⁽¹⁷⁾. Sometimes the level of physical activity is stated to be matched between the groups⁽⁸³⁾. However, “similarly trained” women and men may have similar physical activity level, but not the same training experience in years^(12, 108), or have difference in training load (swimmers 7.34 km for women vs. 9.72 km for men)^(8, 9).

Body Size and Composition

The average adult woman is shorter (0.13m) and lighter (14-18 kg total weight) than the average man⁽¹³¹⁾. Differences in body size affect the results in most physiological tests when results are given in absolute values. This methodological problem has been discussed previously when comparisons are made between young and adult groups or between groups of women and men. Different solutions have been suggested, where the test values are related to body weight (BW), lean body mass (LBM) or in relation to body surface area⁽¹³⁴⁾.

Body composition can be measured by hydrostatic weighing or by DXA scanning^(60, 80). Another commonly used method to estimate the amount of body fat in ice hockey is skinfold measurement^(12, 13, 51, 86, 94). The average woman has a lower muscle mass (18-22 kg) but a higher fat mass (3-6 kg) compared to the average man, resulting in a higher percentage of fat mass in relation to body weight⁽¹³¹⁾.

Muscle Strength, Muscle CSA and Muscle Fibres

Strength training was not prescribed for women until the 1970s, as women were not considered capable of gaining strength due to their low levels of testosterone^(62, 131). Most research about gender differences in muscle fibres, muscle CSA and strength was performed in the 1980s and scientists still refer to these studies as a measure of the true differences between the sexes, as can be seen in textbooks about exercise physiology^(35, 131, 134).

Muscle strength can be measured in a number of different ways where the 1RM (the weight you can lift once but not twice)^(8, 83) as well as isokinetic strength^(17, 45) are the two most often used methods.

Although there is a great range in strength within the groups of women and men as well as a large overlap between the two groups⁽⁵⁰⁾, gender differences in *absolute strength* are well documented^(3, 95, 99, 102). The differences in strength are more pronounced in the upper extremities, where women have about half the strength of men compared to about two-thirds in the lower body^(45, 134). The differences between upper and lower body strength may in part be explained by a difference in the distribution of lean body mass, where women tend to have a greater part of the fat free mass in the lower part of the body^(45, 53).

Strength can be expressed in relation to body weight, lean body weight (LBM) or muscle CSA⁽⁵⁰⁾, in an effort to be able to compare groups of different body constitution. When strength is related to BW, differences are smaller compared to the absolute values, but significant differences still remain between women and men in the upper extremities^(17, 87). Contradicting results are found when strength in the lower extremities is related to body weight, where studies have found that significant differences still remain⁽¹⁹⁾ or where differences disappear⁽¹⁷⁾. Strength in the lower extremity has also been shown to be similar between the sexes if the values are expressed in relation to FFM⁽⁴⁵⁾, whereas differences usually remains in the upper extremity^(17, 45). A factor that might be involved is a difference in regional distribution of FFM, where women tend to have a smaller part of FFM in the upper extremities⁽⁵³⁾. This might lead to an overestimation of muscle strength in relation to total FFM in the lower extremities as well as an underestimation of muscle strength in the upper extremities compared to men⁽¹³¹⁾.

Muscle CSA can be measured by computer tomography^(83, 102) or by an ultrasonic device⁽⁵⁵⁾. Muscle CSA can also be estimated from an anthropometric formula where limb circumference is corrected for subcutaneous fat from skinfold measurements^(8, 9, 17). One explanation for differences in absolute strength between women and men is the difference in muscle CSA⁽¹⁰²⁾. The estimated number of muscle fibres is about the same for women and men, and the larger muscle CSA in men may be explained by difference in size of the individual muscle fibres^(8, 101). However maximal tension per muscle CSA has been reported to be similar for women and men^(8, 17, 50, 55, 83, 102).

Considering fibre typing, similarly trained or untrained women and men appear to have the same muscle fibre type proportion⁽¹¹⁰⁾ and the number of fibres appears to be unaffected by gender or physical activity level^(101, 102)

. However, the results are inconclusive since it has also been shown that in comparison with untrained women, both untrained men and male body builders have a higher number of muscle fibres ⁽⁹⁹⁾.

The relative area of the muscle fibre types appears to vary with gender, as well as with type of physical activity ^(99, 101, 102). In untrained subjects, women have their largest relative muscle fibre area in type I compared with type IIA for men ⁽¹¹⁰⁾.

Anaerobic Capacity and Power

Contradicting results exist regarding aerobic capacity and power between women and men. A methodological problem is that even though most research has used the Wingate test, different amount of breaking force is applied in different studies, limiting the possibility to make direct comparisons ⁽⁸⁵⁾. Difference in results between studies might also be influenced by subject selection regarding levels of physical activity.

Women and men with similar physical activity level and in physically active students ^(75, 126) have been suggested to have *similar* anaerobic capacity and power when the values were expressed per LBM. However, in similar groups of subjects significant *differences* have also been found even when the results were expressed in relation to LBM ^(78, 79, 92). Other studies have found anaerobic capacity and power of both women and men to be directly related to the type II fibre area in the muscles ⁽³⁰⁾, where women have been found to have smaller muscle fibre CSA, especially regarding type II areas ^(44, 62).

A 4-week sprint training session has been found to reduce gender differences in relative type II fibre area as well as anaerobic performance in physically active students ⁽⁷⁰⁾. This might indicate that women in general might perform high intensity physical activities to a lesser extent than men, which could influence the relative type II fibre areas as well as anaerobic performance.

Another factor that has been suggested to differ between women and men is that the aerobic contribution in an anaerobic 30-second sprint test (Wingate) has been found to be 25% in women and 20% in men ⁽⁴⁶⁾. This result can be understood in relation to the higher relative type I area in women ⁽¹¹⁰⁾.

Aerobic Capacity

Different methods can be used for measurements of aerobic capacity. The Douglas bag method is considered the golden standard where the exhaled air is collected in bags during testing, for measurement of gas contents afterwards. It is a well tested and reliable method that has been used since 1911, both in laboratory settings as well as in sport specific environments ^(73, 134). Limitation of the method is that it only allows average values of the gas contents for the time period that the specific bag was used, and that the method is generally considered cumbersome to use ^(73, 134). Modern metabolic gas analysis systems provide more data and among them there are portable systems that are easy to use even in sport-specific environment ⁽⁶⁵⁾. Many of these systems produce valid and reliable data ⁽⁷³⁾.

“It is well known that physical working capacity is less for females than for males and for children as compared with adults”⁽¹³³⁾. This is the first sentence in the introduction of the famous dissertation by Åstrand in 1952. Physical performance was measured in relation to age and sex, where the adult subjects were physical education students with similar activity levels. Åstrand stated that previous research often had made comparisons between well trained men and untrained women, resulting in less reliable results ⁽¹³³⁾. This methodological error has been repeated many times since then.

Åstrand found a 29% difference in aerobic capacity between women and men in absolute values ⁽¹³³⁾ and the differences were reduced to a 17% difference when the aerobic capacity was related to body weight. Åstrand argued that this kind of comparison should preferably be related to muscle mass due to the differences in fat mass between the sexes ⁽¹³³⁾.

Aerobic capacity has been found to be similar, when the oxygen uptake is related to LBM in similarly trained women and men ⁽¹⁰⁸⁾. Another factor that affects aerobic capacity is the lower haemoglobin (Hb) concentration in women, which affects VO_{2max} to a small, but significant degree ⁽²²⁾.

Physiology in Ice Hockey

Ice hockey has been described as a physically demanding sport of intermittent character, involving repeated bouts of high intensity interspaced with rest ^(15, 21, 85). Games consist of three 20-minute periods of active play interspaced with two 15-minute intermissions between each period and the game extend for 150 to 170 minutes ⁽⁸⁵⁾. The high intensity activity on-ice involves bursts of maximal skating with sudden changes in speed and direction, as well as shooting and checking activities ⁽⁸⁵⁾. It has been reported that 69% of the metabolism is derived from anaerobic glycolysis ⁽¹⁵⁾ and that a high aerobic capacity is required for a quick recovery ^(15, 39).

A physically well trained ice hockey player should thus have a high anaerobic power and capacity for good sprint performance, a high aerobic endurance capacity for fast recovery coupled with high muscle strength, power and endurance ⁽¹⁵⁾.

Physiological Tests of Ice Hockey Players Off-Ice

Consequently, aerobic capacity, anaerobic capacity and power and muscle strength are usually tested in ice hockey players. There is no consensus for the assessment of the physiological profile of hockey players and off-ice tests commonly used are general tests easy to perform with little equipment, such as jump and sprint tests, e.g. Leger's 20m shuttle run and body composition estimated by skinfold measurements ^(6, 12, 13, 37). Other commonly used tests that require more sophisticated equipment that has been frequently used is measurement of aerobic capacity and anaerobic power and capacity. Cycle ergometer and treadmill protocols have been used to measure aerobic capacity ⁽⁴⁰⁾ whereas anaerobic capacity and power have been measured by Wingate test (different test setups exist) ^(21, 85). A few of these studies have included women ^(12, 13, 37), but only one of the studies has been performed on adult players ⁽³⁷⁾.

Physiological Tests of Ice Hockey Players On-Ice

On-ice tests can be used to test both aerobic and anaerobic capacity as well as anaerobic power ⁽²¹⁾. Aerobic capacity has been tested with on-ice (40-lap skate test, 8-minute skate test ^(21, 85) and now there is a skating multistage aerobic test available as well ⁽⁶⁹⁾. The Reed Repeat Sprint Skate

(RSS) is often used for tests of anaerobic power and capacity^(5, 21, 85, 127). Aerobic capacity on-ice has only been tested once in adult women and men⁽²⁵⁾ whereas anaerobic capacity and power have been assessed for both youth and adult players in women's hockey with the shorter version of the RSS (MRSS)^(11, 37) or by using the Speed test in youth female players⁽¹²⁾.

Correlates between Off-Ice and On-Ice Performance

Correlates between off-ice tests and on-ice performance have been performed previously on ice hockey players of different age-groups, skill levels and genders, where jump height and off-ice sprint time correlated with on-ice performance^(6, 13, 33, 40, 41, 74). Only one of these studies has involved female players, and these players were young (8-16 years). The reported correlations are moderate at best, with correlation coefficients of $r = -0.25$ for squat jump to $r = 0.5$ for 40-yard sprint⁽⁶⁾.

In one previous study isokinetic testing of muscle strength of the thigh was used in combination with jump tests⁽⁷⁴⁾. In this study, isokinetic strength measurements and vertical jump both predicted skating performance, but where two values from the isokinetic strength test predicted skating performance to a higher extent than the vertical jump.

Gender in Physiology

Most exercise recommendations have been based on studies with all-male subjects⁽¹¹⁸⁾. In some research areas, the subject's gender is considered so obvious that it is not even mentioned. This has been the case frequently in ice hockey, even in quite recent publications^(6, 40, 74).

When research is performed with both women and men as subjects, we tend to focus only on mean values when we compare the *differences* between the average woman and man. Research of women and men could as well consider the fact that the differences between individuals of the same sex may be greater than the differences between the average woman and man and that there may be considerable overlaps between the groups of women and men^(50, 128). Another factor that may contribute to the idea of gender differences is that the confounding factors previously mentioned seldom are taken into consideration (see above and below).

Differences in Physical Activity

In the industrialised world, women tend to be less physically active⁽¹⁶⁾, and participate to a lesser extent in competitive sports⁽¹¹⁷⁾ and in high intensity activities^(16, 119). However, it seems as if the general trends of physical activity are both dependent of age and gender^(16, 119). This general difference in physical activity may be of more or less importance, depending on the aim of the research. In research where biological differences are studied between women and men, it is important to try to control for physical activity level. When this factor is not investigated, it is impossible to separate biological differences from behavioural ones⁽²³⁾, or perhaps more correctly phrased, it is difficult to reduce the effect of social sport bias.

A few previous studies have attempted to use groups of women and men with similar levels of physical activity^(23, 108, 109). However, they were unable to match the groups for training experience as well. In ice hockey two studies have compared women and men in ice hockey of the same age groups^(12, 25). In the youth hockey players, the women had significantly less hockey experience, however the amount of hockey training was not assessed within the groups⁽¹²⁾. In the college players, the women and men had similar off-ice training loads and number of games per year, but the amount of practice on ice was not described, and not their hockey experience⁽²⁵⁾. As skill level has been found to be correlated to skating

speed⁽³³⁾ it may be important to consider experience within sport when comparisons are made between groups.

Body Size and Composition

The impact of body composition and size is also present when the results are compared between young and adult subjects. However, these comparisons are not used as frequently as the comparisons between women and men.

The energy cost of running has been reported to be related to body weight^(7, 14, 18). As fat mass may be considered metabolically inert, at least in the context of evaluating aerobic capacity, but can constitute a large proportion of the body weight, it may be important to exclude fatty tissue when evaluating the oxygen-transporting capacity⁽¹³⁴⁾. This is important especially when comparisons are made between groups or individuals with different body composition. As women have a higher amount of sex-specific essential fat, they have a higher oxygen consumption per unit of Fat Free Mass, and a lower VO₂max in relation to body mass⁽²³⁾. The higher fat percentage in women has been found to explain 48% of the differences in running performance between women and men⁽¹⁰⁸⁾.

However, in reality, both women and men need to carry their own weight during weight bearing physical activity and thus, in evaluating the individual's ability to move their body, it is of more relevance to express the maximal oxygen uptake in relation to BW⁽¹³⁴⁾. It is thus important to consider *the aim* of the comparison, in order to know *how to make* the comparisons.

Comparisons Leading to Hierarchy

When athletic performance is compared between women and men, women are approximately 10% slower compared to men in running events⁽¹³⁴⁾. In this comparison, no other factors are considered.

However, it appears that added weight on men has been found to reduce skating and running speed for men^(23, 84) and that level of skill in male hockey players affects skating time for men⁽³³⁾. These results indicate that it may be problematic to make valid comparisons, if the groups under investigation differ from each other regarding body composition and size, physical activity and experience within sport. Still, these kinds of

INTRODUCTION

comparisons have often been performed, where women's performance risk being undervalued due to unreflected comparisons.

Ice hockey is an ideal sport to study the interaction between gender and physiology, as it is a sport that is strongly associated with masculinity and where substantial structural differences exist between women and men ⁽¹²⁰⁾. Factors that, at the start of this thesis, were considered important for sports performance are displayed in Fig.1.

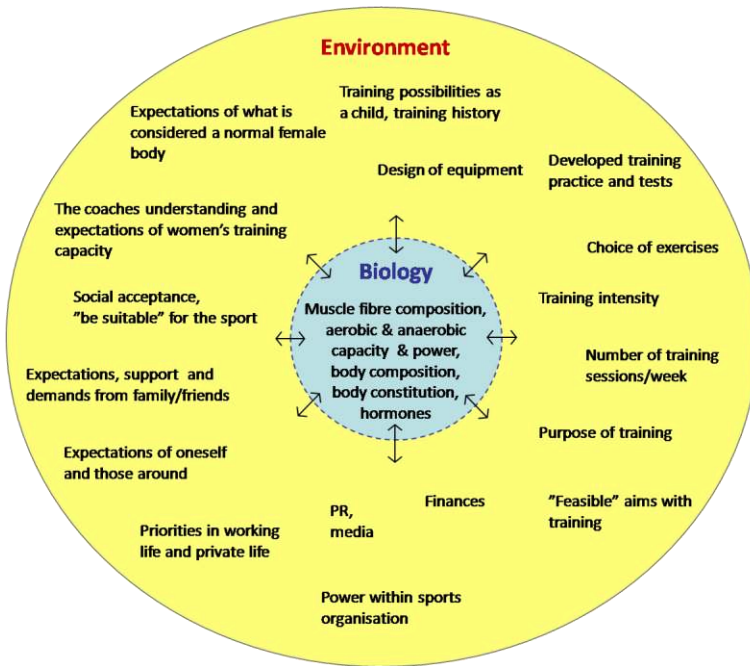


Fig. 1 Factors considered important for performance in women's ice hockey

Theoretical Approach

The method of using different kinds of perspectives, in order to be able to analyse society, has been used previously.

Connell uses four different dimensions of gender ⁽²⁰⁾, that describes the main structures in gender relations in society. Sandra Harding used three perspectives in her critical analysis of science; the symbolic, structural and individual perspectives ⁽⁴²⁾. These perspectives (among others) have been applied to sport science by Kolnes ⁽⁶¹⁾, and her interpretation of these perspectives have been used in this thesis.

The symbolic perspective: (or the cultural perspective, according to Kolnes). The symbolic level represents the set of images and qualities that we associate with a certain object, group of people etc.

The structural perspective: profiles how power and social structures affect the distribution of resources and privileges for both sexes.

The individual perspective explores how socialisation and personal experiences affect how women and men form their identity.

The different levels should not be considered as separate entities, as they constantly interact with each other.

These perspectives made it possible to look at different aspects of the research field in the understanding and analysis of the structures in society and in sports.

Aims of the Thesis

The aim of this thesis was to investigate how women's and men's ice hockey players position themselves in sport and to visualise the interactions between society and biology that affect performance.

The aims of each study in relation to the symbolic, structural and individual perspectives were the following:

- To investigate if expectations of support and hindrance are affected by gender (With focus on the Individual and Structural perspectives)
- To analyse how women's ice hockey players experience their situation within as well as outside their sport (With focus on all three perspectives)
- To investigate if slap shot performance is affected by equipment that is not properly adjusted (With focus on the Structural perspective)
- To determine if skating performance on –ice can be predicted by off-ice testing and anthropometrics, and if so, if the same factors are important for both genders (With focus on the all three perspectives)

In addition to the above, the aim of the thesis was to organise the results from the different studies into a comprehensive model of the interactions between three levels in ice hockey.

Material

Subjects

Studies I, II and IV were performed at the same time, displayed in Fig 2.

The women’s team had 24 players, where 22 players answered the questionnaire (study I). All of the informants in study II (n=8) performed the physiological tests (study IV). All of the subjects included in study IV (n= 11) answered the questionnaire (study I).

The men’s team had 28 players, where 20 players answered the questionnaire (study I). Eight of the players included in study IV (n=10) answered the questionnaire (study I).

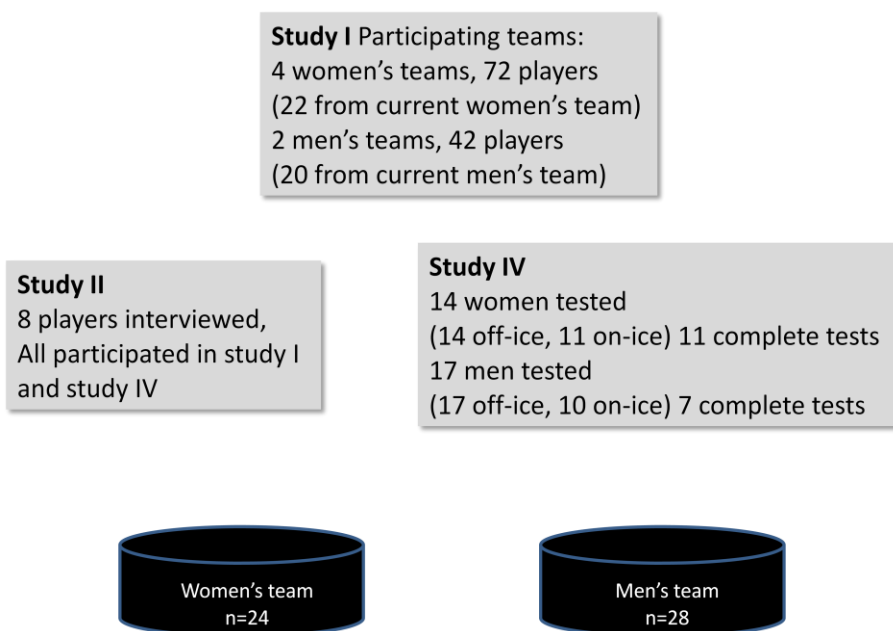


Fig.2 Subject participation in studies I, II and IV

Study III was performed earlier where the current women's team was represented by 5 players. Two of the players from study III were also part of study I, II and IV.

General Inclusion and Exclusion Criteria

Inclusion criteria for studies II-IV was to be member of the two selected teams. Goaltenders and injured players were excluded as well as players under 18 years of age in study IV.

Sticks and Pucks

Two kinds of sticks of different flexibility were chosen with assistance from a stick manufacturer. The stiff stick was chosen as it was in the upper range of stick stiffness that was commonly used by women's players and the flexible stick was the most flexible stick available in adult stick length at that time.

Two kinds of pucks were used, the normal match puck (6 oz, 25.4 mm) and a modified puck where a 3-4mm-layer had been ground away resulting in a lighter (5oz) and thinner puck.

Methods

Sociological Methods

Information about the Teams

Information was gathered retrospectively from the clubs regarding team data (number of practice session/week and number of games in the series) and regarding the team's financial results (the team's revenue and expenditure). Information was gathered by interviews and financial reports. In order to have similar entries for all the involved teams, the information about the team's finances were adjusted and recalculated in order to have comparable results from the involved teams.

Questionnaire

The first author gave a short introduction to the players about the study and was present in case there were questions regarding the questionnaire.

The questionnaire was anonymous and coded only for team membership and sex. As one women's team and one men's team were part of other parts of the thesis, the question regarding age was arranged in five age groups in order to preserve player anonymity. This question was later dichotomised at the age of 18 years into a "Young" and "Adult" age group. The questionnaire consisted of 15 questions about background factors (age, living- and work conditions, ice hockey history, financial support from the club), personal aims in ice hockey, and ability to combine ice hockey with other activities or factors (support and hindrance) in their daily life. The two central questions regarded support and hindrance from their surroundings and were answered from two different points of view, as themselves and from the imagined position as a member of the other sex ("if you had belonged to the other sex").

The questions were measured on a five-graded scale ((1=Very little support, 5=Very strong support) or (1= Very little hindrance, 5= Very strong hindrance) respectively)). The variables were later dichotomised at the 75th percentile in order to create groups of high exposure.

Semi-Structured Interviews

The informants were interviewed individually, according to a semi-structured protocol in a calm environment in an indoor garden. The interview themes were "ice hockey history", "social networks", "life plans and priorities", "me and my sport, ambitions and possibilities". A general theme was to know more about their expectations and if they thought the situation would or should be in any other way, and if they thought the situation would be different if they had belonged to the other sex. Semi-structured interviews ensured that certain themes were covered, but at the same time there was flexibility in the structure of the interviews to discuss other interesting subjects as they emerged in the course of the interviews⁽⁴⁾. At the end of each interview, the interviewer made a summary, and the informant was able to make corrections and add details, a factor which decreased the risk of misinterpretations made in the interview situation.

The interview themes were based on previous research in gender and sport and from questions originating from preliminary results from a questionnaire. The questionnaire served as a base for a structured selection of subjects, where the aim was to obtain a selection as wide as possible regarding type of employment, social situation, hockey experience, and age.

The interviews were transcribed verbatim and systematically analysed (Fig. 3) inspired by methods previously described^(58, 63). Raw data quotations representative of the key themes discussed in the interviews were identified and these quotes became the basic units for the analysis, so called lower order themes⁽⁹⁸⁾. A written summary of the interview was made and a copy was sent to the informant to ascertain that no factual errors had occurred in the process. This procedure was repeated with every new interview and a compilation of similarities and differences between the interviews was performed. This procedure of comparisons made it vital to re-examine previous transcripts again and again and made it possible to observe new details in the interviews that had not been noted before. As the number of interviews in the compilation increased, the lower order themes were transformed to more abstract, higher order themes^(27, 71, 82, 113). In general, the process of analysing data corresponds highly to the method described by Ely (1991).

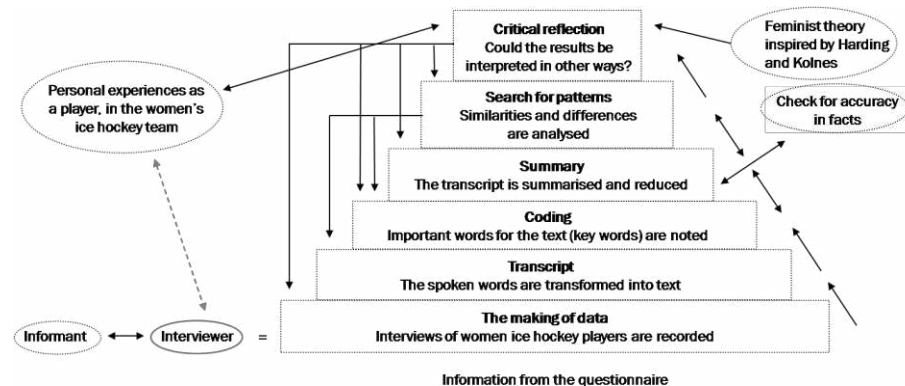


Fig. 3 Analysing process of the interviews

Physiological Measurements – Off-Ice Tests

Puck Speed

The “IVAR Jump and Speed Analyzer” (Spin Test, Tallinn, Estonia), was used to measure the velocity of the puck. Two pairs of infra-red sensors and reflectors were connected to a timer and positioned at a right angle to the path of the puck (Fig. 4). The sensor sends signals every 1/1000 second. The margin of error was 1% at 20 m/s, which corresponds to 0.2 m/s (Spin Test, Tallinn, Estonia). The timer started when the puck passed between the first pair of sensor-and-reflector and stopped when the puck passed the second pair. The first pair was placed as close to the ice surface as possible and measured pucks within the vertical distance of 0.13-0.75 m, and the second pair measured pucks within 0.18-0.80 m above the ice.

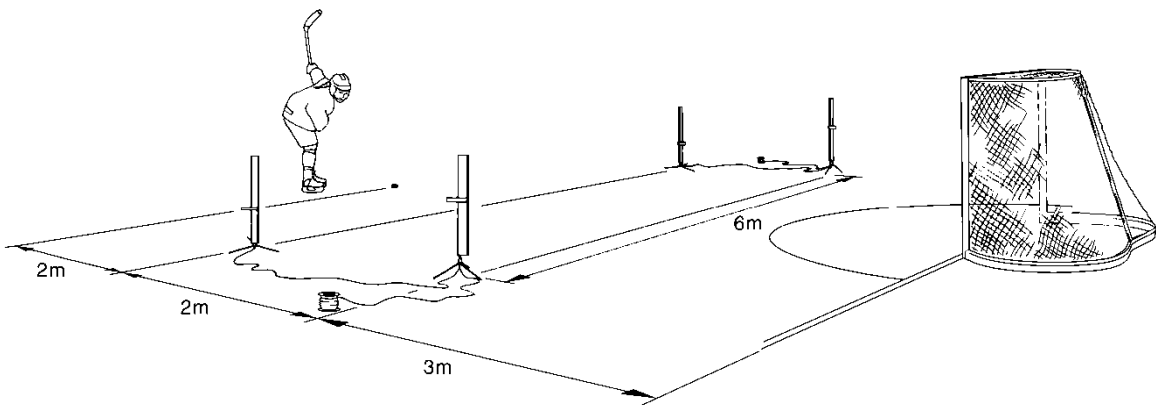


Fig.4 Set-up of puck velocity measurements. Figure from Paper III, Sports Engineering 2009 11:103-207

The players performed five to seven shots with each of the two sticks and pucks. The top three results for each combination of sticks and pucks were included in the results.

Anthropometrics

Body weight was measured to the nearest kilogram while wearing light clothes on a standard digital scale (Avery Berkel model HL 120, Avery Weigh-Tronix Inc, Fairmont, Minnesota, USA). Height was recorded to the nearest centimetre using a wall-mounted Harpenden Stadiometer (Holtain Limited, Crymych, United Kingdom).

Body Composition Measurement

Dual energy X-ray absorptiometry (DXA) is a technique that analyses the photon absorption at two different low radiating energies, which makes it possible to distinguish between bone mineral density, fat mass and lean mass (Fig. 5) with a high precision⁽⁶⁰⁾ and is considered to be a valid and reliable method⁽⁸⁰⁾. Body composition of the whole body was measured using a DXA (Lunar DPX-IQ software version 4.7, Lunar Co, Wi, USA,). In our laboratory the coefficient of variation (CV) for LBM has been reported to be 0.9% in total body scans⁽⁸⁹⁾. The Lunar DPX-IQ was calibrated every test day using a standardised phantom.

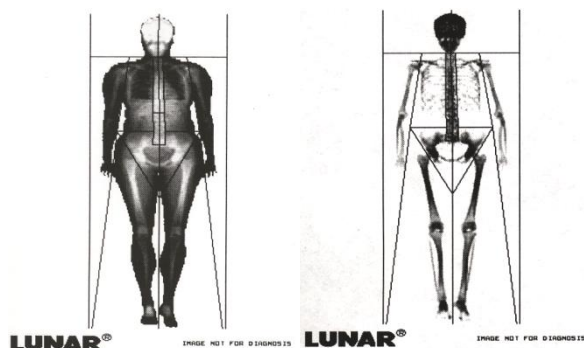


Fig.5 A DXA total body scan measures bone mineral density, fat mass and LBM.

Isokinetic Muscle Testing

Gravitation 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 a general warm-up of 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 (Fig. 6). 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 (knee flexions and extensions) in the dynamometer, the subjects performed five maximal concentric contractions 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 highest peak torque (PT) in each test was noted. The Biodex system 3 has been found to be a valid and reliable instrument in velocities below 300°/sec (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004). The Biodex isokinetic dynamometer was calibrated each week in accordance to the instructions in the manufacturer's manual.



Fig. 6 Isokinetic muscle testing of the thigh muscles with a Biodex dynamometer.
(Photo: Fredrik Eklund)

Cycle Ergometer Incremental Test with Ergospirometry

Aerobic capacity was measured in an incremental test on an electronically braked bicycle (Rodby™, RE 829, Enhörna, Sweden). 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 start (40 W or 50 W) for another 10 minutes as a cool-down. An indwelling catheter was placed in the antecubital vein and blood samples were drawn at rest and 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. 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 ventilation (VE), oxygen uptake (VO₂) and carbon dioxide output (VCO₂). The subject breathed through a mask that was placed over the mouth and nose, and held in place with a cap (Fig.7). The breathing mask was checked for leakage by exhaling against resistance before the test. For every breath a small sample of expired air was drawn into a mixing chamber from which O₂% and CO₂% were measured twice every second. The test procedures and the ventilator- and lactate thresholds have been described elsewhere⁽⁶⁶⁾ and the MetaMax II has been found to be valid and reliable for metabolic gas measurements⁽⁶⁷⁾. The MetaMax II was calibrated every test day for measurements of gas contents and volume⁽⁶⁶⁾.

Respiratory Exchange Ratio 1 (RER 1):

By evaluating how much CO₂ is released compared with the amount O₂ that is consumed, it is possible to determine what kind of fuel that is used, as fat metabolism requires more oxygen compared to metabolism of carbohydrates. RER increases with exercise intensity (when less fat is being oxidized) and when the amount of released CO₂ and consumed O₂ are equal (RER=1), the substrates used for metabolism are solely carbohydrates⁽¹³¹⁾.

Onset of Blood Lactate Accumulation (OBLA):

Approximately the point where the release and/or removal of lactate from the working muscles and the buffering capacity of the blood have been exceeded, and empirically set to a blood lactate level of $4.0 \text{ mMol}\cdot\text{l}^{-1}$ ⁽¹⁰⁶⁾.

Peak Oxygen Uptake ($\text{VO}_{2\text{peak}}$)

The highest oxygen uptake measured during the incremental cycle ergometer test.

Oxygen uptake at a blood lactate concentration of $4\text{mMol}\cdot\text{l}^{-1}$ (OBLA), at a respiratory exchange ratio of 1 (RER 1) and the highest value of oxygen uptake ($\text{VO}_{2\text{peak}}$) was noted.



Fig. 7 Ergospirometry during an incremental cycle ergometer test

Physiological Measurements - On-Ice Tests

Four different tests were performed on ice that have previously been described ⁽¹⁰⁾. The test times were measured with a photo electric timing system (Newtest 300 PowerTimer, Oulu, Finland). The players wore full equipment and carried their stick during the tests. 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 (Fig 8 a-c). The tests were performed twice, and the best trial was noted. All the players received at least two minutes of recovery between the two trials and at least fifteen minutes of recovery time between the different tests when the timers were being repositioned.

Agility

A cornering test (Agility) required the players to complete an S-shaped pattern around the face-off circles (Fig. 8a). The test area spanned over 18.9m (62ft) in width and 22.55 m (74 ft) in length (fig. a). This test has been reported to have a test-retest r value of $r = 0.64$ on adult women ⁽¹⁰⁾ and $r = 0.96$ on 14 to 15 year-old men ⁽⁴¹⁾.

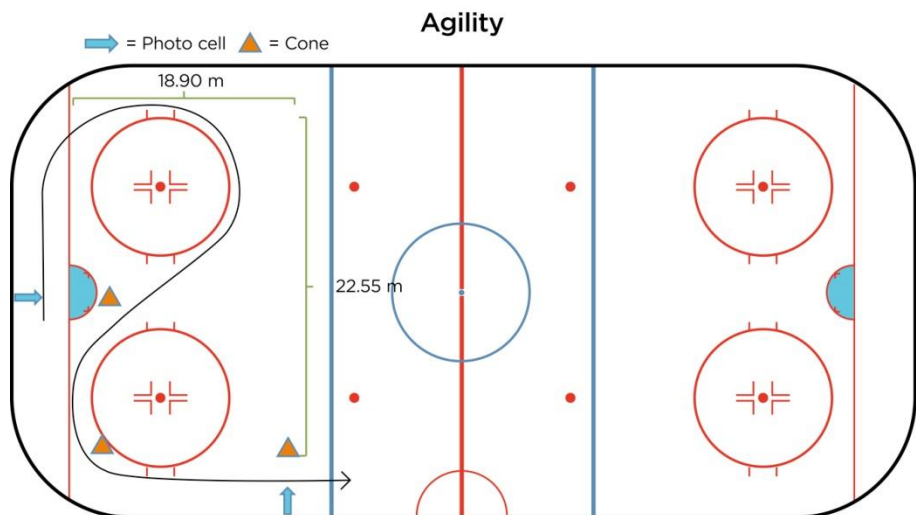


Fig. 8a Agility test

Acceleration and Speed

The “Acceleration test “ (Acceleration) and the “Speed test” (Speed) were measured in one continuous skating bout from a stationary start (Fig. 8b), 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). The acceleration and Speed tests have been reported to have test-retest values of $r = 0.8$ (Acceleration) and $r = 0.76$ (Speed) in adult women⁽¹⁰⁾.

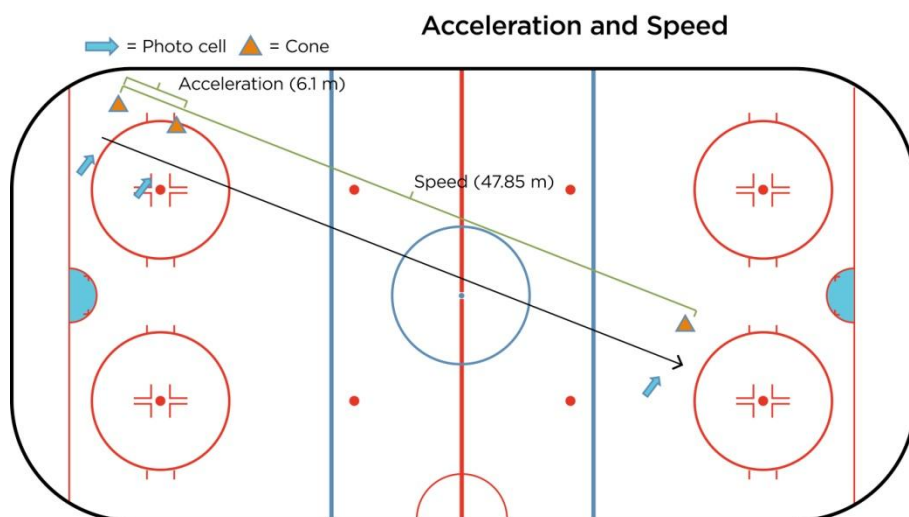


Fig. 8b Two tests in one continuous skate where the first 6.1m is the Acceleration test, and the whole distance of 47.85m is the Speed test

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. 8c).

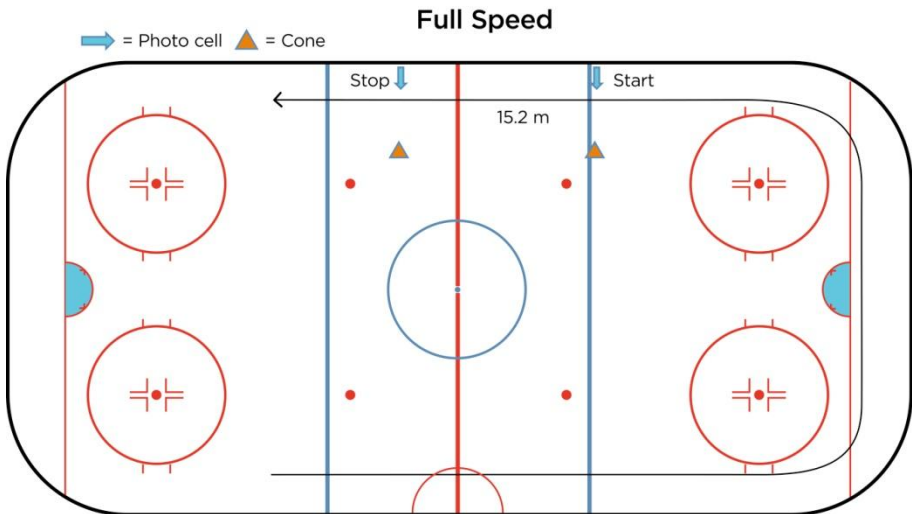


Fig. 8c Full speed test with a flying start

Limitations of the Thesis

At the beginning of the study, it was planned to perform study II and IV on two women’s in two cities where one team of each gender shared the same arena. However, as the men’s team decided to withdraw from the tests with one week’s notice, these tests were only performed with the teams in one city. This limits the possibilities to perform more advanced types of statistical analysis.

This thesis only includes analysis of interviews of women ice hockey players. Hence, the men’s ideas and thoughts are not represented in the same way as the women’s are. However, interviews with the men were performed and may be analysed later on.

Statistical Methods

The SPSS package (version 11.5-17, SPSS Inc., Chicago, IL, USA) was used for all statistical analysis. A p-value of < 0.05 was considered statistically significant. Non parametric tests were used due to the low number of participants.

Differences between groups concerning continuous data were calculated with the Mann-Whitney U-test. Differences between groups concerning data on an ordinal scale were analysed with cross tables and X^2 test (The Fisher's exact test was used if the count was < 5 in 20% of the cells).

Paired comparisons were made with the Wilcoxon's two-related samples test.

A graphical analysis supported the assumption that the results (study III) were normally distributed and a parametric two-way analysis of variance (ANOVA) was used to test for increased velocity between the different combinations of sticks and pucks, where the participants were used as a block factor (study III).

Ethics

Informed consent was given by all participants and the study protocol was approved by the Ethical Committee of the Medical Faculty Umeå University, Sweden.

Results – Summary of Papers

Paper I

Gendered Expectations and Structural Conditions in Ice Hockey

Aim

The aim was to investigate the player's ratings of experiences and expectations of support and hindrance from their surroundings in their daily life.

Subjects and Methods

A women's division one series including matching men's teams were selected for the investigation. Four women's teams and five men's teams were asked to participate and three men's teams declined to participate due to lack of time (n=2) and due to financial difficulties (n=1). The questionnaire was answered by 114 players (72 women and 43 men, see Paper I, Fig.1) and included background factors and two central questions regarding ability to combine ice hockey with other activities or factors (support and hindrance) in their daily life. These two central questions were answered as themselves and from the imagined position as a member of the other sex. Answers were grouped by sex and age (young and adult women and adult men). Results were analysed in relation to financial and organisational information from the involved clubs in order to put the ratings into a structural context. Team data and financial results of the season were gathered retrospectively by interviews and from financial reports.

Results

Adult women and men rated similar levels of support and hindrance, yet both women and men rated higher support and lower hindrance for men compared to women. There was an age difference in the ratings between the young and adult women where the young women rated significantly higher amount of support from their closest ones. The young women rated similar results of support and hindrance from the two perspectives as

RESULTS

themselves and as a member of the other sex, whereas the adult women ratings indicate that they believed that the situation would improve if they had been men (higher ratings of support and lower ratings of hindrance). The men's ratings indicate that they believed that their situation would have worsened if they had been women; however few of the changes in ratings were statistically significant.

The women's teams' median financial revenue corresponded to 11% of the men's teams, where the men's teams had expenditure for financial support for the individual players (personal hockey equipment and financial compensations). The women's teams did not have the corresponding costs (paper I, Table 3) as these factors were financed by the players themselves.

The question regarding whether they were given financial support was answered favourably by 51% of the men compared with 26% of the women. These answers thus diverge from the information from the clubs, results presented in the previous paragraph.

Paper II

Gender in Ice Hockey – Women in a Male Territory

Aim

The aim was to investigate the strategies used by women's ice hockey players in order to be accepted in their sport by conducting and analysing semi structured interviews, where the structural conditions in their sport were described and compared with the situation in men's ice hockey, and where feminine and masculine behaviour in sport was discussed.

Subjects and Methods

Eight players in a women's team in the highest division was asked to participate in the study. Preliminary results from a questionnaire study was used to make a structured selection of subjects in order for the informants to represent different aspects of the team regarding age, playing experience, social and working conditions. The preliminary results also served as a starting point in defining the themes in the interview guide. Semi-structured interviews were performed regarding their life within and outside sport and where a general theme was their expectations in relation to their sport. Another line of discussion was whether they thought their situation in sport would have been different if they had been of the other sex.

Results

The players described structural differences between women's and men's ice hockey, where practice conditions and financial situation are worse for women and where women's ice hockey renders little interest from media, sponsors and audience. The women considered the performance in women's ice hockey to be inferior to men's and this fact explained the structural conditions for women in hockey. The women shared the general views in society of femininity and masculinity, but considered themselves as an exception to the rule.

Paper III

Influence of Stick Stiffness and Puck Weight on Puck Velocity during Slap Shots in Women's Ice Hockey

Aim

To investigate if a modification of stick and puck improves slap shot performance in women's ice hockey

Subjects and Methods

Ten ice hockey players from two women's teams were chosen by their team coaches for their skills in slap shots. Slap shots were performed with two kinds of sticks (stiff and flexible) and two kinds of pucks (normal and light). The players performed five to eight registered shots with the two kinds of sticks and pucks, where the order the sticks and pucks were used was randomly assigned to the players.

Results

Nine out of ten players improved mean puck velocity when the combination of flexible stick and light puck was used compared with the results with the match puck and stiff stick. Differences in puck speed were 4.1% ($p = 0.037$). However, modification of stick or puck alone did not significantly alter puck velocity.

Paper IV

Physiological Correlates of Skating Performance in Women's and Men's Ice Hockey

Aims

To identify variables that predict skating performance for adult women's and men's ice hockey players on a comparable competitive level in relation to anthropometry, ice hockey history and off-ice physiological tests.

Subjects and Methods

Volunteering adult players from one women's and one men's team on a comparable level performed physiological off-ice and on-ice tests. Goaltenders were excluded due to their unique physiological demands during play.

Results

Background variables displayed that the two groups were similar in age but there were significant differences between women and men in anthropometrics, hockey history and hockey activity.

For women, low body weight, high percentage of LBM, and the off-ice variables leg strength and aerobic capacity related to BW were positively correlated with skating performance whereas only one of the variables was significant for men. Gender comparisons displayed significant differences between women and men in all the off-ice tests when the results were displayed in absolute values or in relation to body weight. However, when the physiological test results were related to LBM, the differences were diminished or disappeared.

Discussion

The results from the different papers will be discussed from the three perspectives.

Symbolic Level

From the symbolic perspective sets of images and qualities associated with certain objects or groups of people are studied. This is what we usually consider the natural way of how things are, we categorise people by their appearance, the way they dress, behave, by gender, class and ethnicity. Each category is associated to a gigantic system of specific qualities/characteristics and other symbols ⁽²⁰⁾.

It can be argued that this is the most important of the three levels as it affects our way of interpreting our surroundings even if we seldom reflect over this process.

The ideas of how women and men “are” affect our way of thinking and our way of interpreting our results. Men are considered to be physically better equipped compared to women regarding muscle strength, aerobic capacity, anaerobic capacity and anaerobic power ⁽⁵⁹⁾. This view of men as “better” than women sometimes makes it unnecessary to explain or investigate “social bias” that might have influenced the results. When the view of men as better was challenged, due to the faster rate of improvement by female runners ⁽¹³⁰⁾, the influence of social factors became more interesting to study ^(18, 109).

Even in physiological research with quantitative methods, the symbolic level might influence the interpretation of the results concerning male and female subjects since it is considered without questioning that the results can be divided into the groups of women and men. Men and women are considered different even if the difference between the average woman and man is smaller than the difference within the groups of women and men ⁽⁵⁰⁾. Since the results are most often discussed and valued in relation to previous research in the area (For further discussion in this area see the structural level).

The majority of the research in physiology has been performed on (young) male subjects. What is important to consider is that the conclusions in these studies sometimes are considered to be true for all humans “in man”

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(77, 88, 91) in a sometimes unreflected manner. The physique and physiology of young men are thus considered to be true to the whole human race, which may become problematic. In physiological research about ice hockey, most studies have been performed on men. As it is a sport predominantly performed by men, the gender of the subjects is sometimes so obvious to the researchers that they omit to describe their gender ^(6, 40, 74).

When the results in this thesis are viewed from the symbolic perspective, it seems as if the general views of femininity and masculinity were shared by the women's hockey players (paper II). This might be a bit surprising, considering that the women themselves have crossed the gender line as they perform a sport categorised as a sport for men. However, the players described themselves as different from other women, and in that aspect, the traditional view of femininity and masculinity remained unchallenged. This is a common strategy which has been described previously for example in soccer ⁽¹⁰³⁾ and in track and field athletics ⁽⁶⁴⁾. As sport in general is considered a male territory, women tend to challenge institutional structures within sports when they start to participate in new sports or demand practice time in sports arenas ⁽⁸¹⁾. The women reduce the challenge of masculinity in sport by accepting the general views of women and men in sport which may lead to better treatment within sport. A similar approach was used when women started to participate in sport, when women followed the recommendations made by the expertise and thus reduced the challenge to structures in society ⁽⁴³⁾.

The women described men as better players, more skilled and more dedicated to their sport compared to women. This hierarchical order appears to be the most important factor in the whole thesis, influencing the other perspectives.

The fact that women ice hockey players are less skilled in passing and shooting ⁽⁶⁸⁾ is in agreement with the symbolic view of women in sport. It might explain, in part, why few studies have investigated the impact of stick stiffness on shooting performance in women as has been done in young men. When the lighter puck was tested in a pilot study to paper III, some of the players reacted strongly against the idea of a special puck in women's ice hockey. The players were not interested in "adjustments" for women; they wanted to be considered "real" ice hockey players and they wanted to use the "real" puck.

Structural Level

From the structural perspective the distribution of power, resources and responsibilities are studied as well as the distribution of different groups of people in sports or in professions. The structural perspective is as important as the symbolic perspective, but is easier to identify and to make comparisons between groups of people in solid results.

The symbolic level is strongly associated with the distribution of women and men in different sports, and professions. In Sweden, many sports and professions are strongly gender divided^(111, 116), and the distribution may be considered to follow the categories from the symbolic perspective, where different sports and professions are considered more suitable for women or men.

It has been found that there are important structural differences in the amount and/or intensity in physical activity between women and men^(16, 104, 114, 119). This is a factor that has often been overlooked in previous research in physiology. As mentioned in the introduction, comparisons between women and men have been made in various ways. However, there is a serious flaw in many of these studies, as factors in the structural level have not been considered.

The amount and quality of spare time has been reported to be lower for women compared to men^(114, 117). When athletes within the same sports are compared there are still structural differences to consider: women may have a lower training experience, even if they have similar practice time per week^(23, 108). The same finding is displayed in paper IV. In conclusion, it is difficult to make comparisons between groups of women and men as the physical activity levels seldom are on a comparable level.

Another structural factor to consider is that the number of active women is lower compared with the men within a sport, which might influence the selection process, practice time per week and performance⁽¹¹²⁾. The improvements in running performance by women were found to be due to positive social changes for women^(18, 109).

It might be argued that in the way we compare the average woman and man we focus on *gender differences*, whereas we tend to disregard the fact that there are considerable variation within each gender⁽⁵⁰⁾ as shown in Fig. 9a. When we find the same variation between women and men, we tend to

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regard them too different to be regarded as one group and do not considered the results to be valid (Fig.9b). We also often forget that there are considerable similarities between the groups of women and men ⁽⁵⁰⁾.

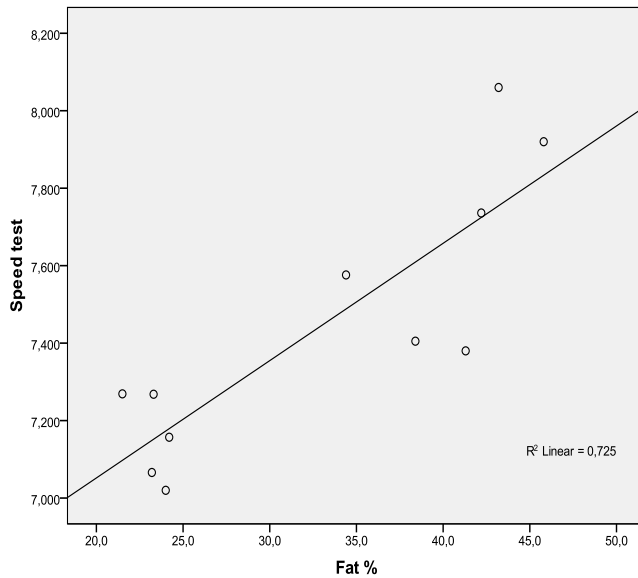


Fig. 9a Two groups of female subjects are displayed in regards to fat %

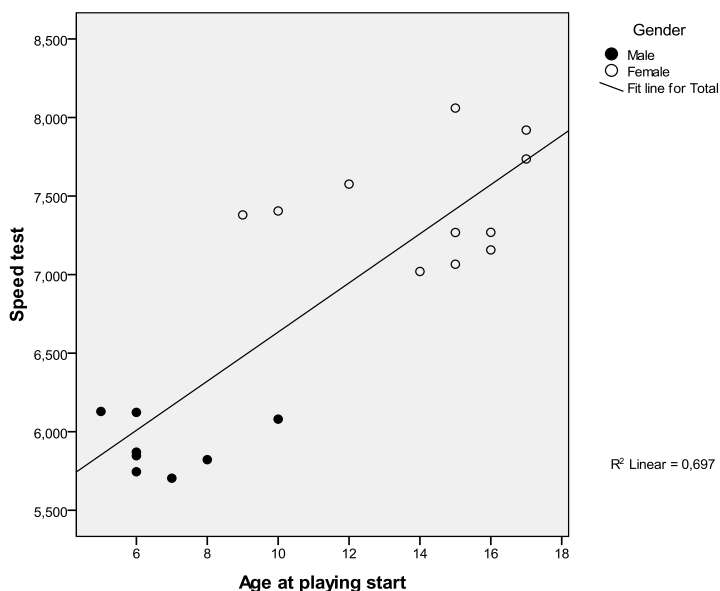


Fig 9b Correlation that was considered to be a comparison between two groups too different from each other to be analysed together.

In the way of displaying the results in mean values, we contribute to the symbolic view of women and men as different from each other⁽⁵⁰⁾. On the other hand, in paper IV we compared the on-ice results between our adult male subjects and 14 to 16-year old males^(12, 41), but this comparison was not regarded to be of great interest since it was considered too obvious and not a novelty. Female subjects are more comparable to 14-16 year-old male than adult male subjects, at least concerning body size. Still comparisons in results between adult females and males are made without considering differences in body composition as well as structural differences which is highly questionable unless the reason is thoroughly stated.

Strength and aerobic capacity have been found to be similar in women and men with the similar physical activity level, when the test values were related to LBM^(45, 75, 108). The same results were found in paper IV in spite of differences in hockey history, number of games in the series/year and a difference in haemoglobin contents. This result with similar capacity in women and men is in contrast to the symbolic view of women and men as different, and might be the reason why this finding is not used in the general description of women and men.

When the results in this thesis are viewed from the structural perspective it is evident that the view of men as better athletes was associated with the differences in the distribution of media coverage, sponsor money and conditions in sport and might be seen as a regulator of the level of expectations allowed for women and men ⁽⁸¹⁾. In the interviews (paper II) the women explained that as men's ice hockey is better than women's hockey, men deserve better conditions in sport. This is what Messner ⁽⁸¹⁾ calls the "common sense" in sport, where the unequal conditions in sport between women and men have become incorporated into the institution of sport and is considered the normal situation: – the gender regime in sport ⁽⁸¹⁾. That three men's teams declined participation in the questionnaire study, may be considered a result in itself attributed to a low interest in research about gender differences in ice hockey.

It seems as if factors from the structural level might function as a means to reinforce the symbolic views of women and men. Differences in conditions affect performance, but these differences were not often considered when the performance of women and men were compared (paper II) – increasing the differences in performance and thus reinforcing the view of men as better athletes. The limitation of body checking (a rule) in women's hockey may also serve as a means of reducing the challenge of masculinity in ice hockey ⁽¹²⁰⁾, as women's ice hockey is not as aggressive as the men's version of the game.

Structural differences in women's and men's ice hockey were described, where the women usually started to play hockey at a higher age (paper IV), and with considerable differences in organisation into different leagues (paper II), where vast differences in financial conditions were revealed (paper I), and where the amount of hockey sticks suitable for the average woman was scarce (paper III). In comparison to men, the women were found to have lower expectations from their sport (papers I and II) which might be an indication that they were aware of their position. The results are supported by similar results in a Canadian study, regarding expectations of gender equality ⁽⁴⁹⁾.

Individual Level

From the individual perspective the effect of the interaction of the different levels are studied within different individuals. On the individual level the ideas of femininity and masculinity are internalised within the individual, where the individual's identity is formed within a society by socialisation and personal experiences ⁽⁶¹⁾. In this thesis, this level also includes biology, such as the individuals' physical performance characteristics, anthropometrics and body composition.

“You should invest as much in girls as in boys, I mean with physical training and coaching and everything. You shouldn't pamper girls. I am well aware that female players will never have the same physique as men, because it's not possible. Even if we try to make everything in society equal, that will never happen, but you should get the chance to become as good as you can get”

This quote from one of the informants in paper II illustrates the connections between society and biology. The structural level restricts the possibilities for the individual. These differences in conditions can be applied on both the structural- as the individual level. Differences in financial conditions limit the possibilities for women with shift work from practicing hockey (papers I, II), but not for men to the same extent (paper II). However, women with day-time work were not affected by this specific structural limitation.

The female teams were not organised in a hierarchical system and it was not possible to become a professional player (paper II). As a result the women only played because it was fun. This was a double burden for them; on one hand it made it hard to motivate why hockey should have a high priority in life, but on the other hand, if they prioritised other things, they risked being considered less dedicated athletes and becoming less developed in physical performance.

It is thus important to take the structural conditions into consideration, when the physiological tests are evaluated, as the physiological results of the individual are affected by structural conditions. For example, the individual's performance in sport may be affected by the equipment that is available ⁽⁶⁸⁾. As ice hockey is a sport predominately performed by men, it may be difficult to find hockey equipment, such as sticks of in the proper

length and stiffness. Previous studies of young male ice hockey players have shown an improvement in shooting performance when stick flexibility was increased, especially for smaller and weaker individuals⁽⁹⁶⁾. The average woman is smaller and weaker than the average man, but use sticks designed for men. Poorly adjusted equipment for women has been shown to reduce women's athletic performance⁽⁶⁸⁾, but only one previous peer-reviewed study of shooting performance in ice hockey have used female subjects⁽¹³²⁾. An increase in puck velocity was observed when stick stiffness and puck weight were reduced; thus indicating that shooting performance in women's hockey is reduced due to lack of equipment properly adjusted to the individual player (paper III).

When we perform physiological tests on individuals it is important to keep in mind that there are variations within the groups of women and men but also that there are gendered patterns that might serve as confounders when results are evaluated (see introduction). In comparison between women and men, few studies control for body size⁽¹²⁸⁾. In sports physiology isokinetic strength is usually only described in absolute values^(1, 2, 74, 93, 97, 100), even though body weight has been found to be an important factor⁽¹³⁴⁾. Healthy women should have a higher percentage body fat compared to men⁽³⁶⁾ and body composition have been found to affect skating performance⁽⁸⁴⁾. However this factor is usually not considered when skating performance is evaluated^(12, 25). When performing tests on individuals these factors should be kept in mind, as general comparisons between women and men tend to increase gender differences and confirm the view of women as inferior athletes compared to men.

In paper IV, the men and women were competing on a comparable level but still the groups of women and men were significantly different from each other in all background variables except for age. The men were taller and heavier, with more hockey experience and they had started to play hockey at an earlier age. Usually few of these background variables are discussed when sports performance is compared between women and men^(13, 26, 57, 109). In paper IV all men were faster than the fastest woman, but at the same time all but one man started to play ice hockey at a younger age than all women (fig 9b).

For the interviewed women, men's ice hockey was the norm and women's ice hockey was considered to be of a lower quality, not as fast or interesting to watch (paper II). The women did not include the structural differences into this comparison, only the performance on ice was used, and in that

perspective that their own sport and their own performance were devalued. Boys were considered better than girls. However, some of the women had been involved as coaches for girls' teams in hockey and they had a more nuanced view of the gendered hockey performance (paper II). Their opinion was that girls could be as good as boys if they started to play at a similar age, indicating that the individual's ideas of femininity and masculinity may be influenced by personal experiences.

The structural level is strongly associated with the aims and expectations on the individual level. The women described structural obstacles for their development as players, but still they were quite content with their situation in sport (paper II). The women had adjusted their aims and goals to what was possible to achieve (papers I, II). Few significant differences were found between the groups of women and men in different age groups regarding their experienced support and hindrance for ice hockey participation. Still, both women and men believed that the situation in sport was better for men (paper I). The gender regime in sport might explain why gender inequalities were not considered when these questions were answered. The fact that men are prioritised before women in sport is historically formed and thus considered to be fair ⁽⁸¹⁾. In line with the gender regime in sport, men should thus have higher expectations in sport compared to women. The results in paper II support this theory. Even though the women's teams did not reimburse costs for equipment, or financial compensations 26% of the women answered that they got financial support from their club. In contrast to this, only 51% of the men answered that they got financial support from the club in spite of substantial costs for player equipment and financial compensations (paper I). It is evident that the conditions in women's and men's ice hockey were strikingly different. These structural differences might be explained in part by the commercialisation of men's ice hockey that is a popular sport among spectators and media ⁽³²⁾.

It is important to note that in spite of the existing symbolic views of women as less skilled athletes, and their obstacles in structural conditions, women are still able to play ice hockey. Even though the women in this thesis were not actively trying to change the views in society regarding femininity, these women may still have an impact in the symbolic view of women.

Summary and Conclusions

The view of women and men may affect structural conditions in sport which in turn may affect possibilities in sport for the individual. Gender differences in conditions thus risk confirming the traditional views of femininity and masculinity. However, by moving outside the normal gender boundaries individuals may nuance the traditional views of femininity and masculinity.

- Ratings of experienced support and hindrance were influenced by gendered expectations
- The differences in conditions were not considered when the female subjects explained the gender differences in ice hockey performance
- Shooting performance was improved by adjustment of equipment
- Off-ice fitness predicts on-ice performance for women but not for men. The group of women was significantly different from the group of men in all background variables except for age, which makes it difficult to compare the two groups.
- Gender differences in off-ice variables were reduced or disappeared when values were related to LBM

Acknowledgements

Thanks are due to a lot of people, some of them are named here, but the list could be just as long as the thesis, I am sure. This dissertation would not have been possible to write without the help and support from the individual and structural levels:

- Co-writers and tutors for stimulating discussions
- Karin, for your way of tutoring me. I appreciate the way you have allowed me to be on equal terms with you in our discussions and your quick analytical mind that gives you the ability to be able to be tutor in any topic in research. I miss you, please move back to Umeå!
- Staffan for your calm and wise questions that put me on the right track in the social science. It is amazing how you could coach me into understanding what I needed to do, without actually telling me!
- Kim, for your positive view of life, your understanding of the sport, your thoroughness and for all the time and effort invested in the thesis, especially during the last part of the research project.
- Past and present staff at Sports Medicine Unit, especially Jonte for help with retrieving old references at the library cellar, Erkki, Lennart, Jonas and Totte for helping me conducting the tests, Peter F and Totte for help with pc problems, Peter N for help with SPSS and Anna N for pep-talks about the last months before the dissertation. A special thank you to Lisbeth for conducting the interviews and the fruitful discussions about life, sports, statistics and other important topics
- Involved ice hockey players for your time, blood, sweat, laughs and thoughts that you have invested in this thesis
- Umeå Centre for Gender Studies and the National Graduate School of Gender Studies for providing a home base of knowledge to a foreigner in gender research, a positive environment for cross-sectional gender research for students from all faculties
- Past and present PhD-students in the National Graduate School of Gender Studies, and my seminar group for fruitful discussions
- Swedish National Centre for Research in Sports (CIF) for providing funding for the physiological tests
- Hans Mårtensson for helping me calculate the deformation in sticks with different degrees of stiffness

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- People within the world of ice hockey in Sweden at national, regional and local levels for providing information that I needed and for your patience with me
- My mother and Jamie for proof readings and linguistic support
- Julia and Mia for illustration and layout
- Family and friends for being there for me
- Last but not least, thank you Henrik for always being supportive of me – regardless of what I do. You are a wonderful person, my best friend and the best husband I could find, I love you so much! Petra, our lovely daughter, thank you for understanding that mom had to “go and write the book”. Now you don’t have to ask me anymore how many days there are left before we can play games!

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