Physiological- and Socio-Cultural Conditions for Performance in Women’s Ice Hockey

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“Hockey is where we live. Life is just a place where we spend time between games.”
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Abstract

Background: The ice hockey community is founded on masculine norms and values, and the hockey rink is often described as “the home of men’s ice hockey”. Despite a growing popularity, women’s ice hockey has low priority in comparison to the men’s game. On top of that, the women’s game does not allow body checking, which makes it deviant from what some see as “the real game of ice hockey”. The checking prohibition causes physiological requirements to differ from the men’s game, and since women are underrepresented in ice hockey research, not much is known regarding the physiological- and socio-cultural conditions of women’s ice hockey. There are many available studies that are conducted on male ice hockey players, but where the results are not generalizable to female players. The overall aim of this doctoral thesis is to investigate physiological- and socio-cultural conditions important for performance in women’s ice hockey.

Methods: This thesis is unique in terms of the interdisciplinary approach between physiology and gender science, and the inclusion of studies based on both qualitative and quantitative research methods. Qualitative thematic interviews with ice hockey coaches from Sweden, Canada, and the United States were used to explore socio-cultural conditions in relation to performance and sport development (Paper I). Relative age effect (RAE) in relation to maturity status was examined through anthropometric measurements and a player questionnaire (Paper II). Physiological field- and laboratory assessments were used to investigate physiological conditions and performance in female competitive ice hockey players from Sweden (Paper III-IV), and players from Canada (Paper IV).

Results: The findings from Paper I suggest that coaches need to maintain a holistic approach to coaching to be able to coordinate and optimize the effects based on available conditions. Socio-cultural conditions, such as structural and financial support, are mentioned as important to support opportunities in women’s ice hockey. Furthermore, the results (Paper I) show that female players in Canada and the United States have superior opportunities compared to female players in Sweden. These advantages are mainly attributed to the support provided by the North American education systems. The findings from Paper II suggest that the relative age effect (RAEs) in women’s hockey are also influenced by socio-cultural conditions. Significant RAE (p<.05) was found for Swedish players born in the third quartile (Q3) and for Canadian player born in the second quartile (Q2). Players born in the fourth quartile (Q4) are significantly (p<.05) underrepresented in both countries. Players tend to be average or late maturers, but no differences can be found by country or position.
The findings from Paper III show that field-based assessments are comparable to laboratory assessments with the purpose of predicting skating performance. The Prediction models accounted for 13.6 % to 42 % (laboratory-based models) and 24.4 to 66.3 % (field-based models) of the variance in skating time. Regardless of assessment method, uni-lateral assessments are superior to bi-lateral assessments. The results support the use of field-based assessments in Paper IV. The findings from Paper IV show various physiological profiles for female Swedish and Canadian players. Swedish players had less body fat (p=.007), more lean mass (p=.005), and greater aerobic fitness measured with the 20-meter shuttle run beep test (p=.001). Canadian players had greater maximal isometric leg strength (p=.026), exhibit a greater running acceleration (p=.001), performed better in single leg standing long jumps (right leg p=.002, left leg p=.030), and showed better anaerobic endurance (p=.029) on-ice. No significant differences can be found between forwards and defenders.

**Conclusion:** The findings of this study show that physiological- and socio-cultural conditions should both be considered in relation to performance in women’s ice hockey. For example, the various physiological profiles are probably an effect of the different socio-cultural conditions in Sweden and Canada. The Canadian profile may be better adapted to performance in ice hockey, but further research is needed to establish a relationship. Since women’s ice hockey often has somewhat limited resources, this knowledge may help optimize the effect of the available resources, and thus improve performance. Improved performance may have a positive long-term effect on the symbolic view of women’s ice hockey. Women can probably further optimize their physical performance in relation to their current conditions. But for permanent changes to occur, power structures in sport must also change. Women themselves have limited opportunities to affect the dominating gender norms and values in ice hockey.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 RM</td>
<td>One Repetition Maximum</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>CIS</td>
<td>Canadian Interuniversity Sport</td>
</tr>
<tr>
<td>CL:S</td>
<td>95% Confidence Intervals</td>
</tr>
<tr>
<td>CMJ</td>
<td>Counter Movement jump</td>
</tr>
<tr>
<td>CWHL</td>
<td>Canadian Women’s Hockey League</td>
</tr>
<tr>
<td>DXA</td>
<td>Dual X-ray Absorptiometry</td>
</tr>
<tr>
<td>IIHF</td>
<td>International Ice Hockey Federation</td>
</tr>
<tr>
<td>MIH</td>
<td>Men’s Ice Hockey</td>
</tr>
<tr>
<td>MRSS</td>
<td>Modified Repeat Skate Sprint</td>
</tr>
<tr>
<td>NCAA</td>
<td>American National College Athletic Association</td>
</tr>
<tr>
<td>NHL</td>
<td>The National Hockey League</td>
</tr>
<tr>
<td>NWHL</td>
<td>National Women’s Hockey League</td>
</tr>
<tr>
<td>ORs</td>
<td>Odds Ratios</td>
</tr>
<tr>
<td>RAE</td>
<td>Relative Age Effect</td>
</tr>
<tr>
<td>SDHL</td>
<td>Swedish Women’s Hockey League</td>
</tr>
<tr>
<td>SHL</td>
<td>Swedish Hockey League</td>
</tr>
<tr>
<td>SJ</td>
<td>Squat Jump</td>
</tr>
<tr>
<td>SSC</td>
<td>Stretch Shortening Cycle</td>
</tr>
<tr>
<td>VO2</td>
<td>Oxygen Uptake</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>VO2MAX</td>
<td>Maximum Oxygen Uptake</td>
</tr>
<tr>
<td>VO2PEAK</td>
<td>Maximum Measured Oxygen Uptake</td>
</tr>
<tr>
<td>WIH</td>
<td>Women’s Ice Hockey</td>
</tr>
</tbody>
</table>
## Definition of terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditions</strong></td>
<td>Conditions is a central notion in this thesis and refers to both physiological and socio-cultural conditions, since they are both considered to have impact on ice hockey performance.</td>
</tr>
<tr>
<td><strong>Socio-cultural conditions</strong></td>
<td>Socio-cultural conditions refers to social and cultural conditions that can be related to ice hockey performance, such as financial support and training opportunities.</td>
</tr>
<tr>
<td><strong>Physiological conditions</strong></td>
<td>Physiological conditions refers to the physiological functions of the body that can be related to ice hockey performance, such as strength, power, aerobic and anaerobic capacity.</td>
</tr>
<tr>
<td><strong>Skating performance</strong></td>
<td>Skating performance refers to the overall concept of skating skill, including repeated sprint ability, long crossover cornering ability, and skating transitions (forward-to-backward pivoting). Skating performance is considered an important skill to succeed as an ice hockey player.</td>
</tr>
<tr>
<td><strong>Interdisciplinary studies</strong></td>
<td>Refers to research that draws from two or more disciplines. To be able to investigate both physiological and socio-cultural conditions in women’s ice hockey, this thesis includes the combination physiology of gender science.</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Power refers to the amount of work performed per unit of time. Power is often considered a decisive physiological characteristic in sports.</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>Strength refers to the ability of a muscle or muscle group to exert force to overcome the most resistance in one effort.</td>
</tr>
<tr>
<td><strong>Aerobic capacity</strong></td>
<td>Aerobic capacity refers to the maximum rate at which one can utilize oxygen during physical activity. Aerobic capacity is determined by a combination of age and fitness status.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Anaerobic capacity</td>
<td>Anaerobic capacity refers to the energy output capacity of anaerobic glycolysis. The anaerobic capacity accounts for the main part of the energy production during maximal intensity efforts.</td>
</tr>
<tr>
<td>Sex</td>
<td>Sex refers to the biological characteristics of the two sexes, females and males. Females and males are differentiated by the presence of absence of a y chromosome, sex hormones, and reproductive ability.</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender refers to social or cultural constructions of female or male characteristics as feminine or masculine.</td>
</tr>
<tr>
<td>Gender order</td>
<td>Gender order refers to the structure of gender relations in a given society at a given time. The gender order is affected by culture and represents patterns of power relations between masculinities and femininities.</td>
</tr>
<tr>
<td>Gender regime</td>
<td>Gender regime refers to the structure of gender relations within in a given setting, such as school, or in this case the ice hockey community. The gender regime is affected by the present gender order, and by norms and traditions within the particular setting.</td>
</tr>
</tbody>
</table>
Enkel sammanfattning på svenska

**Bakgrund:** Ishockeysamhället är grundat på maskulina normer och värderingar, och hockeyrinken beskrivs ofta som "herrishockeyns hem". Trots en växande popularitet är damishockey lågt prioriterad i jämförelse med herrishockey. Tacklingar är inte tillåtna i damishockey, vilket gör att den skiljer sig från herrishockey som ofta benämns som "riktig ishockey". Tacklingsförbudet innebär att de fysiologiska kraven förändras gentemot om tacklingar skulle vara tillåtna, och det medför att studier gjorda på herrishockey inte är generaliserbara till damishockey. Eftersom kvinnor är underrepresenterade i ishockeyforskning så saknas det kunskap om de fysiologiska såväl som sociokulturella förutsättningarna inom damishockey. Det övergripande syftet med denna doktorsavhandling är att undersöka fysiologiska och sociokulturella förhållanden som är viktiga för prestation i damishockey.

**Metod:** Denna avhandling är unik när det gäller det tvärvetenskapliga tillvägagångssätt mellan fysiologi och genus, samt att den inkluderar studier gjorda med både kvalitativa och kvantitativa metoder. Kvalitativa tematiska intervjuer med ishockeytränare från Sverige, Kanada och USA användes för att utforska sociokulturella förhållanden i förhållande till prestation och idrottsutveckling (Studie I). Relativ ålderseffekt (RAE) i förhållande till mognadsstatus undersökes genom antropometriska mätningar och en spelarenkät (Studie II). Fysiologiska fält- och laboratorietester användes för att undersöka fysiologiska förhållanden och prestation hos kvinnliga ishockeyspelare från Sverige (Studie III-IV) samt Kanada (Studie IV).

**Resultat:** Resultaten från Studie I visar att tränare måste försöka ha ett helhetsperspektiv för att kunna samordna resurser och optimera effekterna av dessa utifrån sina förutsättningar. Sociokulturella förhållanden, såsom strukturellt och ekonomiskt stöd, nämns som viktiga faktorer för att skapa utvecklingsmöjligheter inom damishockey. Dessutom visar resultaten (Studie I) att kvinnliga ishockeyspelare i Kanada och USA har överlägsna förutsättningar jämfört med kvinnliga ishockeyspelare i Sverige. Dessa fördelar uppkommer främst på grund av det ekonomiska och strukturella stöd som de nordamerikanska utbildningssystemen bidrar med. Resultaten från Studie II föreslår att även relativ ålderseffekt (RAE) i damishockey påverkas av sociokulturella förhållanden. Signifikant RAE (p <.05) hittades för svenska spelare födda i tredje kvartilen (Q3) och för kanadensiska spelare födda i andra kvartilen (Q2). Spelare födda i fjärde kvartilen (Q4) är signifikant (p <0,05) underreprenterade i båda länderna. Mognadsstatusen på spelarna uppmättes till medel eller sen utifrån tid för första menstruation, men inga skillnader hittades mellan länderna eller mellan positioner.
Resultaten från Studie III visar att fälttester är jämförbara med laboratorietester när syftet är att prediktera skridskoåkningsförmåga. Prediktionsmodellerna förklarade 13.6 % to 42 % (laboratoriebaserade modeller) och 24.4 % to 66.3 % (fältbaserade modeller) av variansen i åktid. Oavsett bedömningsmetod visar sig unilateralala tester överlägsna bilateralala tester att prediktera skridskoåkningsförmåga. Resultaten stöder valet av fälttester i Studie IV. Resultaten från Studie IV visar att de svenska och kanadensiska spelarna hade olika fysiologiska profiler. De svenska spelare hade mindre kroppsfett (p = .007), mer fettfri massa (p = .005) och högre aerob kapacitet mätt genom beepertest (p = <.001). De kanadensiska spelare hade högre maximal isometrisk benstyrka (p = .026), bättre löpaceceleration (p = <.001), bättre hoppkapacitet i stående längdhopp på ett ben (höger ben p = .002, vänster ben p = .030) och högre anaerob uthållighet (p = 0,29) på MRSS. Inga signifikanta skillnader hittades mellan forwards och backar.

**Slutsats:** Resultaten från denna avhandling visar att såväl fysiologiska som sociokulturella förhållanden bör beaktas i förhållande till prestation i damishockey. Till exempel är de olika fysiologiska profilerna troligen en effekt av de olika sociokulturella förhållandena i Sverige och Kanada. Den kanadensiska profilen kan vara bättre anpassad till prestation i ishockey men ytterligare forskning behövs för att fastställa om det finns ett verkligt samband. Eftersom damishockeyn ofta har begränsade resurser kan den här kunskapen bidra till att damlag kan nyttja sina resurser på ett mer effektivt sätt och därmed förbättra sin prestation. En förbättrad prestation skulle kunna ha en positiv effekt på damishockeyns symboliska värde, men för att permanenta förändringar ska uppstå måste maktkulturerna i sporten också förändras. Kvinnorna själva har begränsade möjligheter att påverka den dominerande könsnormen i ishockey.
List of Original Papers

This doctoral thesis is based on the following original papers. Their roman number will be used as reference in the thesis.

**Paper I**  
Henriksson T, Gilenstam K, Fjellman-Wiklund A. Running a team is like laying a puzzle – Elite coaches’ experiences of women’s ice hockey – *In manuscript*

**Paper II**  

**Paper III**  

**Paper IV**  
Henriksson T, Vescovi JD, Geithner CA, Fjellman-Wiklund A, Gilenstam K. Performance profiling of female ice hockey players by country and position – *In manuscript*

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Paper III is published in an open access journal, which permits free download.
Authors Contribution

Paper I  
TH, KG and AFW designed the study. TH performed the data collection. TH and AFW compiled the data and performed the qualitative analysis. TH wrote the first draft of the manuscript. TH and AFW contributed to the revision of the manuscript. KG provided editorial advice for the manuscript.

Paper II  
CG, KG, TH and AFW designed the study. TH, KG and CG performed the data collection. CG and CM compiled the data and performed the statistical analysis. CG wrote the first draft of the manuscript. CG, KG, CM, AFW and TH contributed to the revision of the manuscript.

Paper III  
TH, KG and AFW designed the study. TH and KG performed the data collection. TH compiled the data and performed statistical analysis. TH wrote the first draft of the manuscript. TH, JV, KG and AFW contributed to the revision of the manuscript.

Paper IV  
TH, KG and AFW designed the study. TH, KO and JV performed the data collection. TH compiled the data and performed the statistical analysis. TH wrote the first draft of the manuscript. TH, JV, CG, KG and AFW contributed to the revision of the manuscript.
Introduction / Background

Development of Women’s Ice Hockey

Women’s ice hockey is described as a rather “young” sport. It is considered young because it is relatively undeveloped, but it has actually been around for nearly as long as men’s ice hockey. According to the Ontario Women’s Hockey Association (2004), the first documented game was held in 1891 in Barrie, Ontario, Canada. Supposedly the first female club team, called “the Love-Me-Littles”, was formed at Queens University in Kingston the same year. Another important event in the development of women’s ice hockey occurred in 1967, when the first Dominion Ladies Hockey Tournament was held in Ontario (Ontario Women’s Hockey Association, 2004). The first official Swedish national championship was played in 1987 (SIF, 2017) , and in 1990, the first ”official” Women’s World Championship sanctioned by the International Ice Hockey Federation (IIHF, 2017b) was held in Ottawa, Canada. However, at the same time the IIHF prohibited intentional body checking in women’s ice hockey (Weaving & Roberts, 2012). The large variation regarding skill and age among female ice hockey players at that time was used as an argument for the change in order to reduce the risk of injuries (Weaving & Roberts, 2012). On the contrary, Theberge (2012) argued that this decision rather was based on preconceived notions of women’s frailty, due to the belief that women are not physically capable of managing full body contact in the same way as men. Women’s ice hockey reached another milestone in 1998 with its first appearance in the Winter Olympic Games in Nagano. In the year 2015, the first all-professional women’s hockey league, the National Women’s Hockey League (NWHL) was developed in Canada and in the United States. All the players in the NWHL receive a salary, something that is unique in the history of women’s ice hockey.

Opportunities for women to play ice hockey have been - and are still, limited (Mccrone, 1991; Theberge, 1995; Weaving & Roberts, 2012). They have faced hardship and contradictions for entering a male dominated sport (Etue & Williams, 1996). Nevertheless, opportunities for female ice hockey players have improved during the last years (Ransdell, Murray, & Gao, 2013). Globally, the development of women’s ice hockey has reached different stages. Based on their history and international results (Table 1-2), one can observe that the North American countries are leading the development in women’s ice hockey. Canada or the United States have won all the international championships, including both the World Championships and the Olympics, held so far (IIHF, 2017b).
Table 1: Standings from previous IIHF women’s world championships. The IIHF Women’s World Championship is not played during Olympic seasons.

**IIHF World Championships Women**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Gold</th>
<th>Silver</th>
<th>Bronze</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Ottawa, CAN</td>
</tr>
<tr>
<td>1992</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Tampere, FIN</td>
</tr>
<tr>
<td>1994</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Lake Placid, USA</td>
</tr>
<tr>
<td>1997</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Kitchener, CAN</td>
</tr>
<tr>
<td>1999</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Espoo, FIN</td>
</tr>
<tr>
<td>2000</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Mississauga, CAN</td>
</tr>
<tr>
<td>2001</td>
<td>Canada</td>
<td>USA</td>
<td>Russia</td>
<td>Minneapolis, USA</td>
</tr>
<tr>
<td>2003</td>
<td>Cancelled due to outbreak of SARS disease in China.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Halifax, CAN</td>
</tr>
<tr>
<td>2005</td>
<td>USA</td>
<td>Canada</td>
<td>Sweden</td>
<td>Linköping, Norrköping, SWE</td>
</tr>
<tr>
<td>2007</td>
<td>Canada</td>
<td>USA</td>
<td>Sweden</td>
<td>Winnipeg, Selkirk, CAN</td>
</tr>
<tr>
<td>2008</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Harbin, CHN</td>
</tr>
<tr>
<td>2009</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Hämeenlinna, FIN</td>
</tr>
<tr>
<td>2011</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Zurich, Winterthur, SUI</td>
</tr>
<tr>
<td>2012</td>
<td>Canada</td>
<td>USA</td>
<td>Switzerland</td>
<td>Burlington, USA</td>
</tr>
<tr>
<td>2013</td>
<td>USA</td>
<td>Canada</td>
<td>Russia</td>
<td>Ottawa, CAN</td>
</tr>
<tr>
<td>2015</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Malmo, SWE</td>
</tr>
<tr>
<td>2016</td>
<td>USA</td>
<td>Canada</td>
<td>Russia</td>
<td>Kamloops, CAN</td>
</tr>
<tr>
<td>2017</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Plymouth, USA</td>
</tr>
</tbody>
</table>

Table 2: Standings from previous Olympic ice hockey tournaments.

**Olympic Ice Hockey Tournaments Women**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Gold</th>
<th>Silver</th>
<th>Bronze</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>USA</td>
<td>Canada</td>
<td>Finland</td>
<td>Nagano</td>
</tr>
<tr>
<td>2002</td>
<td>Canada</td>
<td>USA</td>
<td>Sweden</td>
<td>Salt Lake City</td>
</tr>
<tr>
<td>2006</td>
<td>Canada</td>
<td>USA</td>
<td>Sweden</td>
<td>Turin</td>
</tr>
<tr>
<td>2010</td>
<td>Canada</td>
<td>USA</td>
<td>Finland</td>
<td>Vancouver</td>
</tr>
<tr>
<td>2014</td>
<td>Canada</td>
<td>USA</td>
<td>Switzerland</td>
<td>Sochi</td>
</tr>
</tbody>
</table>

Despite improved opportunities, sports participation for women is still limited, and women have a hardship when competing for attention and resources (Gilenstam, Karp, & Henriksson-Larsen, 2008; Theberge, 1997; Weaving & Roberts, 2012). However, the research is limited and the conditions for female ice hockey players have primarily been investigated in Canada and in the United States (Etue & Williams, 1996; Theberge, 2000; Weaving & Roberts, 2012). Only one study has investigated the conditions for female ice hockey players outside North America (Gilenstam et al, 2008). These studies indicate that women’s ice hockey has a low priority in comparison to men’s ice hockey, regardless of which
country they belong to. However, additional research is needed to further explore conditions in women’s ice hockey. Exploring the conditions in women’s ice hockey from an international perspective may hopefully provide assistance to sport development and potentially enhanced performance, in women’s ice hockey.

**Ice Hockey Performance**

Ice hockey performance is central in this thesis and thus this concept needs to be defined. The concept of ice hockey performance is complex; every situation is unique and one variable can rarely explain the overall performance (Atkinson, 2003; Roczniok et al, 2015). For example, the evaluation of a player’s performance is to a large extent based on subjective assessments. Depending on the subjective perception regarding the capacity of a particular player, expectations will differ. Furthermore, the skill of the opponents will also contribute to making each situation unique. Thus, difficulties arise when attempting to establish relevant criteria for performance in team sports such as ice hockey (Jones & Wilson, 2009). Still, in order to do meaningful research, previous studies have used various quantifiable sub-capacities that have been considered relevant to ice hockey performance (Table 3). Skating performance is the most frequently used sub-capacity, although only three studies (Bracko & George, 2001; Geithner, Lee, & Bracko, 2006; Gilenstam, Thorsen, & Henriksson-Larsen, 2011) have included women. This highlights the need to further investigate the skating performance in women’s hockey.


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<th>Performance measures</th>
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<td><strong>Skating performance</strong></td>
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<td>Allisse, Sercia, Comtois, and Leone (2017)</td>
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<td><strong>Potential for playing in the NHL</strong></td>
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Performance is not only a product based on physiology, a passive unfolding of biological traits. Physiological qualities must also be understood as an interplay
of cultural construction of gender and biology (Fausto-Sterling, 2003). Accordingly, ice hockey performance has been described as a combination of technical skill, physiological qualities, and socio-cultural conditions, such as training opportunities and financial support (Cox, Miles, Verde, & Rhodes, 1995; Gilenstam et al, 2008; Montgomery, 2000). Mental ability has also been described as an important factor in ice hockey (Montgomery, 2000), but has not been included in this thesis. In order to understand the conditions that support ice hockey performance, the physiological qualities must be explored in relation to the socio-cultural conditions. The issue will initially be addressed from a physiological perspective and a gender perspective, and then discussed in relation to each other.

Women’s Ice Hockey from a Physiological Perspective

Almost all research on ice hockey has been performed on men, with a few exceptions (Geithner et al, 2006; Gilenstam et al, 2011; Ransdell et al, 2013). The rules of the women’s game don’t allow body checking, which means that the physical requirements differ from the men's game. In spite of these differences, physiological requirement profiles are still based on men’s ice hockey (Weaving & Roberts, 2012). Further physiological research is needed to acquire an accurate physiological requirement analysis for women. This paragraph will attempt to summarize the physiological research in ice hockey both from a female and a male perspective.

The Character of the Game

The character of the ice hockey game has been studied exclusively from a male perspective. The game is characterized by its intermittent nature, comprised by a combination of repeated high-intensity sprints followed by low-intensity efforts, separated by periods of recovery (Biasca, Simmen, Bartolozzi, & Trentz, 1995; Noonan, 2010). Time-motion analysis has shown an average shift to last 60-90 seconds of continuous play (Houston & Green, 1976; Montgomery, 2000; Noonan, 2010). An ice hockey game is 3x20 minutes of effective playing time, separated by two 18- minute breaks (sometimes 15 minutes for adolescents and juniors). Field players usually have a 1:4 work to rest ratio (Nightingale, 2014), however, variation exists depending on role, position, and level of play (Farlinger et al, 2007; Vescovi, Murray, & Vanheest, 2006). Two studies have investigated positional characteristics in female players (Geithner et al, 2006; Ransdell et al, 2013). The study by Geithner et al. (2006) displayed significant differences between positions, where forwards (F) were described as leaner with greater anaerobic power and aerobic capacity than defenders (D) and goalies (G). D were described as more robust, which means taller than F and G, and heavier than F. Physiological requirements were described to be position-specific, according to various movement patterns (Geithner et al. 2006). D generally covered a
relatively small surface compared to F, and were exposed to more physical contact. F generally performed a greater amount of work, which required greater versatility. G were exposed to completely different requirements because of their position, specific equipment, and particular movement pattern. In contrast, the study by Ransdell et al. (2013) found no physiological differences based on player position. In comparison, previous research on men has shown D to be taller, heavier (Montgomery, 1988), with more fat-free mass compared to players in other positions (Vescovi, Murray, & Vanheest, 2006). Another study reported no differences between F and D, while F and D were found to be heavier than G (Agre et al, 1988). Consequently, research regarding positional differences in ice hockey is not consistent, and this finding applies to both the female and the male perspectives.

**Physiological Requirements**

Research on female ice hockey players is limited, but there are some studies that have tried to characterize the physiological profile of female hockey players, however, they differ by competitive level (Geithner et al, 2006; Ransdell & Murray, 2011; Ransdell et al, 2013). The study by Geithner et al. (2006) included female Canadian college hockey players -“college players”. The study by Ransdell & Murray (2011) investigated elite players invited to the try-outs for the 2010 United States national team -“elite players”. The study by Ransdell et al. (2013) included 204 female players (under-18 as well as senior players) from different countries who attended a development camp held by the International Ice Hockey Federation (IIHF) -“international players”. When physiological characteristics were compared between the studies, obvious differences were found. The elite players were heavier than the college players (5.9%) as well as the international players (12.2%). The elite players performed better on vertical jumps than the college players (16.7%) as well as the international players (6.5%). The elite players performed better in long jump than the international players (8.7%). The elite players performed better in pull-ups than the international players (275.9%). Finally, the college players (64.2%) and the international players (16.8%) had more body fat than the elite players. These results indicate that general fitness differs depending on the competitive level. The elite players were among the best in the world, and were also the physiologically strongest group, compared to the international and the college groups. This is further supported by Ransdell et al. (2013), who showed that participants from the best national teams were stronger, had more lean mass, and less body fat, than their less successful counterparts. The results from the study also indicated similar differences between junior and senior players. The senior players had significantly more body mass, performed significantly better in vertical jump, 4-jump, long jumps, pull-ups, and had a significantly greater Vo²max, than the junior players.
**Metabolic demands**

The metabolic demands in ice hockey has also been characterized mainly from research on men. The repeated high-intensity efforts make great demands on the metabolic systems for energy production and lactate clearance. Studies on men have tried to map the metabolic requirements of the game, by using heart rate data (Green et al., 1976; Spiering, Wilson, Judelson, & Rundell, 2003), and lactate measurements (Noonan, 2010). The average player is active approximately 16 minutes during a game (Cox et al., 1995), with an average heart rate (HR) between 85 to 90% of maximum HR, which indicates a considerate stress on the oxidative system (Green et al., 1976). Accordingly, a study by Spiering et al. (2003) reported that working HRs were well above 90% of maximum during a significant part of a game. A study by Noonan (2010) reported intra-game blood-lactate values between 4.4 to 13.7 mmol/l during a shift, which indicates a considerate stress on the anaerobic glycolytic system. A study by Durocher (2010) found that ice hockey players did not reach equally high lactate values and maximal aerobic capacity during off-ice assessments compared to on-ice assessments. Their results suggest that players would benefit from being tested in a sport-specific manner, preferably on-ice in their natural environment (Durocher et al., 2010; Runner et al., 2015).

Including only male players in studies limits the generalizability to women’s ice hockey (Krause et al., 2012). Only two studies have compared performance between female and male ice hockey players (Durocher, Jensen, Arredondo, Leetun, & Carter, 2008; Gilenstam et al., 2011). Durocher et al. (2008) found that female ice hockey players had a lower maximal aerobic capacity, but a higher ventilatory threshold (VT) than male players. VT refers to the point during exercise where pulmonary ventilation increases at a faster rate compared to the increase of oxygen consumption. The authors speculate that the differences in VT may be a mechanism to compensate for the female player’s lower aerobic capacity. Previous research on men has suggested that maximal aerobic capacity is important to ice hockey players in order to recover between high-intensity shift and to support repeated sprint ability (Cox et al., 1995; Peterson et al., 2015a; Stanula, Rocznik, Męczczyk, Pietraszewski, & Zajac, 2014). Aerobic capacity has been studied previously and a range of values have been presented: Cox et al. (1995) reported average values of 60 mL · kg⁻¹ · min⁻¹ in male players that participated in the National Hockey League (NHL) whereas Agre (1988) reported lower values (53.4 ± 0.8 mL · kg⁻¹ · min⁻¹) in male players on a similar competitive level. Vescovi et al. (2006) reported comparable values (57.1 ± 5.4 mL · kg⁻¹ · min⁻¹) in male players attending the draft combine, which represents a lower competitive level than the previous studies. Based on the aforementioned studies, a high maximal aerobic capacity was seemingly important, but the requirements did not necessarily increase by the level of play. In contrast, a study by Carey et al. (2007) questioned the need for a high maximal aerobic capacity in
female ice hockey players in order to recover between high-intensity shifts. The study presents an explanation to support their results based on previous research: a minimal level of aerobic capacity may be required to support recovery of the anaerobic systems (primarily the creatine phosphate system) (Hoffman, 1997). The high-intensity character of the game, and the rapid motion pattern, makes great demands on the anaerobic energy metabolism (Vescovi, Murray, & Vanheest, 2006). Accordingly, a study by Roczniok et al. (2016) showed that the ability to repeatedly produce high amount of energy through anaerobic metabolism is a determinant to success in men’s ice hockey. There is limited research available regarding the anaerobic requirements in women’s ice hockey.

**Muscular demands**

The fast-paced game demands high-speed movements and first-rate coordination. Players are supposed to withstand collisions, accelerate and change direction at high speed, which requires a high anaerobic energy production as well as significant maximal strength (Naimo et al., 2015). The upper body should assist in force production during checking and shooting, and force reduction when absorbing the speed at quick directional changes, or when absorbing the force in a tackle (Vescovi, Murray, & Vanheest, 2006). Despite the checking prohibition, these general requirements are valid in the women’s game as well. A study on men by Peyer et al. (2011) found that maximal strength in the legs, back and chest correlated significantly with game performance. Accordingly, Kutac & Sigmund (2015) suggest that increased body mass and lower % body fat (which indicate a greater relative lean mass) are necessary for male players in order to be able to meet the physiological requirement of high-level ice hockey. This statement is supported by Nightingale (2014) who suggests that male ice hockey players require high levels of overall strength and power. A study by Gilenstam et al. (2011) compared female and male ice hockey players, found that the male players were, e.g. 7.7% taller, 10.4% heavier, and had 147.0% more lean body mass than the female players. However, when strength and Vo$_2$peak were related to lean body mass, no significant differences were found. The result suggests that women and men should not be compared unconditionally. Therefore, a physiological requirement analysis based on research on women is necessary to accurately map the physiological requirements in women’s ice hockey.

Studies investigating muscular demands in skating have exclusively been performed on men. Several studies have found skating ability to be important in ice hockey (Fortier, Turcotte, & Pearsall, 2014; Montgomery, 2000; Pearsall, Turcotte, & Murphy, 2000). Corresponding skating technique is important to support in-game situations such as competition for possession, positioning for shooting, passing or receiving the puck, and attending strategic tasks in the game (Upjohn, Turcotte, Pearsall, & Loh, 2008). Bracko & George (2001) reported the
two-feet glide to be the most common activity in skating. However, a study by Pearsall et al. (2000) indicates that even when both skates are in contact with the surface, weight will be distributed so that one leg will be subjected to greater forces. The authors claim that the main part of the time (~80%) will be spent absorbing and producing force in single-leg support phase. Furthermore, the authors suggest that the quadriceps and gluteus (maximus and medius) are the major contributing muscles in skating. Hamstrings seem to contribute indirectly by stabilizing the knee during the sliding phase of a stride. Accordingly, a study by Bracko (2004) found that high relative strength in quadriceps and hamstrings distinguishes a strong skater. Accordingly, a study by Buckeridge et al. (2015) argues that knee extension is important for force production in steady-state strides, and also suggests that a greater range of motion in the hip (especially during abduction movement) would assist a more extensive stride length. In addition, postural stability and mobility support greater lateral movements, which contribute to a greater stride length. A greater stride was shown to distinguish high-level skaters to weaker skaters (Buckeridge et al, 2015; Fortier et al, 2014). Furthermore, the plantar-flexion muscles have been found to affect force application in the acceleration phase (Buckeridge et al, 2015). These data indicate that off-ice assessments should include measurements of force production in the quadriceps, gluteus, hamstring, and plantar-flexion muscles to adequately assess skating ability (Fortier et al, 2014). In addition, assessments that evaluate stability and mobility in the knee joint and hip, would give coaches important information regarding players’ skating ability. The use of uni-lateral and/or bi-lateral assessments should also be considered. However, most of the research is performed on men, which means that we do not know if the data is generalizable to women’s ice hockey.

Assessment of Physiological Qualities
From a physiological perspective, performance will manifest itself differently according to the specific requirements of the sport. Technical, physiological, and morphological requirements will vary depending on the specific character of the sport, the position of a player, or the specific role of a player. To enable accurate evaluation of performance, and/or sub-capacities that support performance, it is necessary to develop assessment tools that are valid and reliable. Nightingale (2013) suggest that the current assessment methods and protocols frequently used in ice hockey research, display limited credibility, and equivocal transferability in performance measures. Thus, research recommends more specific assessment methods that take the physiological requirements, specific equipment, and sport-specific motion patterns into consideration (Allisse et al, 2017; Nightingale et al, 2013). Accordingly, Allisse et al. (2017) emphasize the importance of using proper assessment (e.g. methods and protocols). It would be particularly beneficial to teams or clubs with limited resources, in order to help
them prescribe suitable training programs to improve on-ice performance. As women’s teams often have limited financial resources (Gilenstam et al, 2008; Weaving & Roberts, 2012), consideration must be taken to costs, competence- and time requirements when selecting appropriate assessment methods (Nightingale, 2014). Thus, an evaluation of existing assessment (e.g. methods and protocols) are necessary in order to be able to target resources and choose relevant measures.

Women’s Ice Hockey from a Gender Perspective

Sex often refers to biological differences between men and women, while gender refers to social or cultural constructions of female or male characteristics as feminine or masculine (Connell, 2003). Femininity and masculinity can be considered as descriptions of gender identities. Masculinity must not be understood as equivalent to being a man, but rather to the position men have in the gender order, and the patterns of behaviour in society in relation to that position. The gender order refers to the structure of gender relations in a society. As feminine and masculine identities can be used by people with female and male bodies, there is great diversity how these identities manifest themselves in different cultures or different contexts (Connell, 2003). The biological understanding of sex will be similar in most cultures, but the gender identities can differ. For example, being a “real” woman may require different behavior and different characteristics in various contexts. Gender may represent differences and dichotomies, but also other patterns, such as hierarchies. Hierarchies can symbolize power structures within a group or between groups (Theberge, 1997). In sport, women are generally considered lower in the hierarchy, and have less power than men. For example, a study (Buysse, 2004) found that women were described as less likely to be depicted as active sport participants than men, but rather women more often portrayed in a passive and sexist way. The author (Buysse, 2004) argued that this treatments, from the media and the sport community undermines and limits female athletes potential in sport.

Theoretical Framework

A multilevel analytical model was applied to enable the exploration of gender at a cultural, structural, and interactionist theoretical level in women’s ice hockey (Messner, 2000). These three theoretical perspectives can be used to understand how culture and different social structures interact to shape the conditions for a performance, a performance seemingly based purely on physiological qualities. The three theoretical perspectives as described by Messner (2000):

- The cultural theoretical perspective is used to analyze how cultural meanings are injected into various societal systems, how culture affects
the perception of sex differences, and how culture impacts the constructions of gendered relations between groups and individuals.

- **Structural theoretical framework** is used to analyze the structural conditions from which gender manifests itself in different institutions through sexual divisions of labor.
- **Interactionist theoretical framework** is used to analyze how groups of people perform or do gender, and how differences between the sexes are reflected in their actions.

**Cultural Theoretical Perspective**

Gender is perpetuated and embedded in the culture of sports (Hoeber, 2007). Masculinity in competitive sports is often associated with physicality and power (Theberge, 1998). In this context, masculinity will be a symbol of power and force, and will define the athletic experience. Hence, the centrality of performance in sport and the excessive preoccupation with measurable physical differences often consolidates from the ideology of masculine supremacy (Theberge, 1998). Traditionally men have gained privileges from contact sports that reward features such as aggressiveness and competition (Scranton, Fasting, Pfister, & Bunnel, 1999; Weaving & Roberts, 2012). Identity and behavior are constantly encouraged and shaped by our culture, which allows gender differences in sports to be shaped and enforced by the gender regime of the sport (Connell, 2003; Harding, 1986). Connell (2003) define gender structures as durable or elaborate patterns of social relationships. Gender structures have often been consolidated through years of reproduction, and for that reason they are also difficult to change. Theberge (1997) mentions ice hockey and American football as two examples that “promote hegemonic masculinity”. For example, ice hockey is described as an arena that celebrates force and toughness (Theberge, 1998). An arena where gender differences are established and amplified. Consequently, men and masculinities experience advantages in terms of financial resources, media attention and public appreciation (Theberge, 1997). And the hegemonic masculine ideal in ice hockey has created restrictions for women and feminine characteristics.

In order to understand the basis of gender differences in ice hockey, one must consider that women and men have different potential, due to socio-biological constructions of gender, and due to inherent biological characteristics (Theberge, 1998). The underlying meaning of these categorizations is equally important as the biological categories of male and female (Connell, 2014). As some sports are considered more feminine or more masculine, gender and gender stereotypes will influence the way performance is assessed (Hardin & Greer, 2009). As long as ice hockey is perceived as a symbol of masculine supremacy, women will probably continue to have a hard time when competing for resources and attention.
The critics consider the prohibition of body checking to be a part of the problem. They claim that this prohibition prevents women’s ice hockey both from being taken seriously, and from being considered a “real” form of ice hockey (Weaving & Roberts, 2012).

**Structural Theoretical Framework**

Ice hockey is a male-dominated sport, founded from, and shaped by masculine norms and values (Theberge, 1997). The ice hockey rink has been called “the home of men’s ice hockey” (Pelak, 2002). The masculine context in ice hockey will automatically devaluate feminine traits (Hargreaves, 1994). Consequently, the women’s game has received less institutional and federational support in terms of, financial support, training opportunities, and public attention (Gilenstam et al, 2008; Theberge, 1997; Weaving & Roberts, 2012). Performance is the benchmark from which gender is compared, as well as a determining factor for the allocation of resources (Gilenstam et al, 2008). The fact that women’s hockey is not rated as high as men’s hockey leads to less resources, which in turn restricts the possibilities for women to optimize their performance. While only a few ice hockey studies have included both male and female players (Durocher et al, 2008; Gilenstam et al, 2011; Janot, Beltz, & Dalleck, 2015), only one study has actually explored and compared the differences between female and male ice hockey players (Gilenstam, 2009). The results showed that the female players received approximately one tenth of the financial resources compared to the male players. They got late-hour practices than the men, and received less attention from the federation. Accordingly, Hoeber (2007) described that female athletes participating in male-dominated sports experienced inequities as normal and natural (Hoeber, 2007). By accepting their position as lower in the hierarchy, the women did not challenge the male-dominant norms, and were thus not considered a threat. By not posing a threat the women may face less resistance, which may result in increased acceptance and accessibility, such as "gaining access to the ice halls and training facilities". However, this strategy probably also contributed to reinforce the image of the women as inferior to men (Gilenstam et al, 2008). An unwitting behavior that seems to originate from the gender regime in ice hockey, regarding what is appropriate and natural for men and women, respectively (Pelak, 2002).

**Interactionist Theoretical Framework**

Indeed, the perception of the athletic ability of one’s own gender group is seemingly adaptive (Hively & El-Alayli, 2014). The authors suggest that performance in a gender group will be negatively affected when compared to a gender group they consider superior in that sense. Gilenstam et al. (Gilenstam et al, 2011) found the female players perceived the male players as superior. Interestingly, Belcher et al. (2003) found similar indications in a group of female
ice hockey players when they were exposed to tasks that they considered masculine coded. Reversely the belief in one’s own ability could possibly impact performance in a positive way (Chalabaev, Sarrazin, & Fontayne, 2009). Consequently, women’s perception of themselves in relation to other groups, may have an impact on their performance. Thus, it is possible that preconceptions regarding female performance in ice hockey will be reflected in the players’ actions. Rather than highlighting gender differences, women’s ice hockey would probably benefit from being evaluated compared to the performance of their own gender group, instead of being compared to the men’s game (Hively & El-Alayli, 2014). Sex differences related to physiological differences in strength, speed, and power, cannot be neglected. However, if men and women are not compared, these biological differences only serve to make the game different, and not necessarily inferior to the men’s game (Weaving & Roberts, 2012).

An Interdisciplinary Research Approach
The rapid development in science has led to the understanding that an interdisciplinary research approach is favorable when challenging complex problems (Aboelela et al, 2007). An interdisciplinary research approach refers to research that combine two or more disciplines (Committee on Facilitating Interdisciplinary Research, 2004). The advantage using an interdisciplinary research is the possibility of gaining a more nuanced understanding to a problem that could not have been reached by using one discipline alone. Accordingly, this doctoral thesis has combined the disciplines of gender science and physiology. Gender relations affect, and are being affected by, our bodies. At the same time, gender relations create the social framework in which bodies act (Connell, 2003). Accordingly, sport performance should be considered a product of the combination of biological and social factors, rather than a product from biological factors alone (Fausto-Sterling, 2003). Thus, to be able to answer the overall purpose, the combination of gender science and physiology enables a more comprehensive investigation of the conditions in women’s ice hockey.
Knowledge Gap in Women’s Ice Hockey

As previously mentioned, research regarding women’s hockey is limited. Socio-cultural conditions in women’s ice hockey have been investigated in different cultural contexts (Gilenstam et al, 2008; Theberge, 2000; Theberge, & Birrell, 1994), but the field lacks international comparisons. Only one study (Ransdell et al, 2013) has investigated physiological characteristics from an international perspective. The study indicated that there were physiological differences between “successful” and “less successful” countries, but did not investigate why these differences had occurred. In addition, no performance assessments were included in the study, which makes it difficult to evaluate what the physiological results mean in relation to ice hockey performance. In order to create a physiological requirement profile for women’s hockey, physiological qualities must be investigated in relation to some kind of performance measure. Consequently, existing assessment methods must be evaluated to ensure accurate comparisons in relation to the physiological requirement profile.
Aim of the Thesis

The overall aim of this doctoral thesis was to investigate physiological- and socio-cultural conditions important for performance in women’s ice hockey.

Specific Aims

Paper I  The aim of the study was to explore aspects important for sport development and performance in women’s ice hockey, from a Swedish and a North American perspective.

Paper II  The aims were to examine differences in RAEs by country, and to examine differences in maturity status and body size in women’s ice hockey players by country, position, and birthdate distributions.

Paper III  The purpose of this study was to examine whether field-based and/or laboratory-based assessments are valid tools for predicting key performance characteristics of skating in competitive level women’s ice hockey players.

Paper IV  The purposes of this study were to determine whether physiological qualities and on-ice skating performance differ by country and by position in women’s ice hockey.
Materials and Methods

Study Design
Paper I in this doctoral thesis is an interview study that followed a qualitative study design. Papers II-IV are quantitative studies following a cross-sectional study design. Data was collected pre- and/or post-season during 2011 to 2014 (Figure 1).

![Figure 1: Overall study design. *The national part of the data collection was conducted in 2012. **The international part of the data collected was conducted from 2011 to 2014.](image)

Participants
Eight coaches participated in the interviews (Paper I). Inclusion criteria for the study were that the informants should be active coaches, women or men, working with women’s ice hockey Sweden, Canada, or the United states. Two women and six men were included where four represented Sweden (Riksserien), two represented the Canadian Interuniversity Sport (CIS), and two represented the American National Collegiate Athletic Association (NCAA) division 1. The coaches were chosen as informants because they could be assumed to be aware of the constraints and opportunities for the team. Eighteen coaches were asked to participate and ten coaches declined due to different reasons.
Twenty-three female ice hockey players participated in the skating performance study (Paper III). Inclusion criteria for the study were that the participants should be active players on the highest national level. The players were recruited from a successful Swedish senior level team (Riksserien).

One hundred and nineteen female ice hockey players volunteered to participate in the relative age effect study (Paper II) and the positional profiling study (Paper IV). Inclusion criteria for the study were that the participants should be active players on senior level ice hockey in Sweden or Canada. The players were recruited from senior level teams from Sweden (Riksserien) and Canada (CIS). The participants included in each study are summarized in table (Table 4).

Table 4: Participant characteristics (mean ± SD). Playing experience was not available (NA) for all players in Paper II and IV.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Participants</th>
<th>Avg age (yr)</th>
<th>Experience (yr)</th>
<th>Sex (F/M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Coaches (n=8)</td>
<td>46.0 ± 10.3</td>
<td>20.1 ± 11.3</td>
<td>M/F</td>
</tr>
<tr>
<td>II</td>
<td>Players (n=119)</td>
<td>19.8 ± 2.1</td>
<td>NA</td>
<td>F</td>
</tr>
<tr>
<td>III</td>
<td>Players (n=23)</td>
<td>18.0 ± 2.1</td>
<td>10.6 ± 3.2</td>
<td>F</td>
</tr>
<tr>
<td>IV</td>
<td>Players (n=119)</td>
<td>19.8 ± 2.1</td>
<td>NA</td>
<td>F</td>
</tr>
</tbody>
</table>

Ethics

The Swedish part of the study was approved by the Regional Ethical Review Board in Umeå, Sweden, (Dnr: 2012-22-31M). The international part of the study was approved by the Gonzaga University Institutional Review Board and the Office of Research Ethics, York University, Certificate; 2011-344. The study was carried out in accordance with the principles for research involving human participants expressed in the Declaration of Helsinki (WMA, 2013). Research procedures and potential risks of the study were verbally described and written informed consent was obtained from the participants (and parents when appropriate) prior to volunteering in the study. The participants were briefed about their right to withdraw from the study at any time. No incentives were provided to the participants other than receiving their own test results.

Quantitative Data Collection

The quantitative part of the physiological data collection was performed by using both laboratory- and field-based assessment methods to enable comparison. In addition, performance assessments were conducted on-ice. The specific tests were chosen on account of being recurring elements in performance-based physiological research in ice hockey. All assessments that were part of the international data collection (Paper IV) were conducted during three non-
consecutive days. Laboratory assessments were added to the setup for the national part of the data collection, and for that reason one additional day was needed (Paper III). Inter- and intra-day testing orders were standardized (Table 5).

Table 5: Inter- and intra-day testing order. Days 1-3 were performed during 3 consecutive days, followed by day 4 approximately 1 to 2 weeks later. Days 1-2 were performed off-ice, day 3 on-ice and day 4 in laboratory. At least five minutes of recovery was provided between trials to minimize fatigue. *Dual x-ray absorptiometry. **Modified repeat skate sprint.

<table>
<thead>
<tr>
<th>Field-based assessments</th>
<th>On-ice tests</th>
<th>Laboratory-based assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day1</td>
<td>Day2</td>
<td>Day3</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td>1RM Squat</td>
<td>Agility Cornering S-turn</td>
</tr>
<tr>
<td>10- 20- meter sprint</td>
<td>1RM Bench Press</td>
<td>Cone Agility Skate</td>
</tr>
<tr>
<td>Squat Jump</td>
<td>Isometric Leg Pull</td>
<td>Transition Agility Skate</td>
</tr>
<tr>
<td>Countermovement Jump</td>
<td></td>
<td>MRSS**</td>
</tr>
<tr>
<td>Bosco 30-s Repeated Jump Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing Long Jump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Leg Standing Long Jump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-meter Shuttle Run</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All physical assessments were preceded by a standardized warm-up of approximately ten minutes. The warm-up included two parts: a general warm-up with the main purpose of raising body temperature and a specific warm-up. Exercises, such as jogging, shuffling, sprinting, skating and dynamic mobility, were included in the general warm-up. The specific warm up was intended to target specific structures, and was therefore often performed as low-intensity test trials before each exercise. The test leader (TH) explained the procedure and then the participants performed one to three test trials.

**Field-Based Assessments Day 1** (Paper II-IV)

*Body Mass and Height*

The participants were instructed to wear light clothes (e.g., sports bra or t-shirt, shorts or tights). Body mass was measured to the nearest kilogram using a digital scale (Fitbit Aria, WS-30, Fitbit Inc, San Francisco, CA USA). Height was measured according to previous standards (Kinanthropometry, 2001) with a measuring tape to the nearest 0.5 cm.
**Skinfold Measurements**

Skinfold measurements were conducted using Harpenden calipers CE 0120 (Baty International, Sussex, United Kingdom) according to ACSM guidelines for exercise testing (ACSM, 2014) at the abdominal, chest, midaxillary, subscapular, suprailiac, thigh, and triceps sites. Each site was measured twice, and the mean value was recorded. If the measurements differed by >1 mm, a third measurement was taken and the mean value of the two closest values was recorded. A seven-site-skinfold equation was used to estimate body density (Jackson, Pollock, & Ward, 1980), and then converted into percent body fat by using the Siri equation (Siri, 1961).

**10- and 20 m Sprint**

Timing-gates (Chronojump Co, Barcelona, Spain; version 1.3.9.0) were set up at 0-10- and 20 m. A stationary two-point-support start was used. The participants were allowed a voluntary start and had two trials with at least a two-minute rest in between.

**Squat Jump & Countermovement Jump**

The vertical jumps were performed according to previous standards (Bosco, 1999) using a Chronojump contact platform (ChronoJump Co, Barcelona, Spain; version 1.3.9.0). For the squat jump, the participants were instructed to keep their hands on the hips and to lower their body until they attained 90° in the knee joint. This position should be maintained for at least 2 s before jumping in order to minimize assistance from the stretch shortening cycle (SSC). Similar instructions were given for the countermovement jump, though a fast switch between the concentric and eccentric phase was allowed to benefit from the stretch shortening effect (SSC). Three trials were allowed for the squat jump and countermovement jump respectively, and the best trial was recorded to the nearest 0.1 cm.

**Bosco 30 s Repeated Jump Test**

The 30 s repeated jump test (Bosco, 1999) also used the Chronojump contact platform (ChronoJump Co, Barcelona, Spain; version 1.3.9.0). Similar instructions as for the countermovement jump were given, although the jumps should be performed in a row. Jump height was calculated for each jump and recorded to the nearest 0.1 cm. The decline in jump height (%) during the test was regarded as a measure of anaerobic capacity.

**Standing Long Jump**

The participants were instructed to start with their toes behind the starting line, to perform a countermovement jump and jump as far as possible. Arm swing was allowed. The distance from starting line to the back of the nearest heel was recorded to the nearest 1 cm. Single-leg standing long jump followed the same
procedure. However, due to increased risk of injury, the participants were allowed to land on both feet. Three trials were allowed in each test.

20 m Shuttle Run (Beep test)
Assessments were performed according to the guidelines of Leger et al. (1982). The test consists of a 20-m course paced by audible beeps progressively closer together. The participants ran back-and-fourth until they failed to reach the end line at two consecutive runs. The last completed lap was recorded as their test score. Test-retest reliability for adults is high, 0.95, according to Leger et al. (1988).

Field-Based Assessments Day 2 (Paper III-IV)

Back Squat
One Repetition Maximum (1RM) back squat was performed according to Fleck and Kramer (2004). For a successful attempt, from a standing position, the bar should be lowered until the hamstrings/thighs were parallel to the floor. The test leader gave a verbal sign when the participant reached sufficient depth. The warm-up consisted of three light sets, eight to twelve repetitions, on an estimated load of 50 % and 75 % of 1RM. Participants were instructed to reach 1RM within five sets including warm-up to avoid fatigue. The maximal successful attempt was recorded as their result. At least a two-minute recovery was mandatory between each maximal attempt at all 1RM assessments.

Bench Press
For a successful attempt, from a supine position lying on a bench with both feet on the floor, the bar should be lowered until in contact with the chest, at the same time keeping feet, shoulders, and buttocks to the surface (Fleck & Kramer, 2004). No bouncing at the chest was allowed. The warm-up followed the same procedure as the back squat. The participants were instructed to reach 1RM within five sets including the warm-up to avoid fatigue. The maximal successful attempt was recorded as their result.

Isometric Leg Pull
Isometric strength was measured by the use of a dynamometer (Vetek AB, Vaddo, Sweden; VZ101BH 500 kg). From a standing position, the participants were slightly bent at the hip while maintaining a neutral back, arms completely stretched, and both hands with a firm grip on the bar. The dynamometer was adjusted with the bar between the patella and tuberositas tibiae. The participants were instructed to pull as hard as they could for 5 s, without making any jerky movement. Two trials were allowed and the maximum achieved force was recorded to the nearest 0.1 kg.
On-Ice Assessments Day 3 (Paper III-IV)

On-ice assessments included different elements of skating without puck or opponents: long crossover cornering ability, short turn ability, skating transitions, forward-to-backward pivoting, and repeated sprints. All participants were tested wearing full equipment, stick included. Three to five minutes of recovery between each trial were mandatory to avoid fatigue. Two trials were allowed for all tests, and direction was reversed for the second trial. The exception was the modified repeat sprint skate (MRSS), which was allowed only one trial because of the heavy strain. Two test leaders held one handheld timer each, by which the average from the two measurements was recorded to the nearest 0.01 s.

Agility Cornering S-Turn
The assessment followed the procedure described by Gilenstam et al. (2011). However, the distance between the goal lines was reduced to 17.7 meters to fit the measurements of the European as well as the North American rinks. The starting line was situated behind the goal. The participants started following a verbal signal, skated an s-shaped pattern outside the face-off circles, which ended at the nearest blue line (Figure 2).

Figure 2: On-ice assessments and measurements. Agility Cornering S-Turn.
**Cone Agility Skate**
The assessment followed the procedure described by Behm et al. (2005). The participants started on the blue line following a verbal signal, then skated around three pylons placed on the blue line and on the center red line, and finished back over the blue line (Figure 3).

![Figure 3: On-ice assessments and measurements. Cone Agility Skate.](image)

**Transition Agility Skate**
The assessment followed the procedure described by the National Skills Standards and Testing Program published by Hockey Canada (1999). The participants started on the line at the bottom of the circle following a verbal signal, then skated a butterfly-shaped pattern, which ended at the goal line at the far end of the circle (Figure 4).

![Figure 4: On-ice assessments and measurements. Transition Agility Skate.](image)
Modified Repeat Skate Sprint (MRSS)
The assessment followed the procedure described by Bracko & George (2001). The participants skated from one end line to the other (53.0 m), and then returned to the initial blue line (35.4 m). Four 88.4 m repetitions were performed on a 30-s clock. The next repetition was initiated every 30 s, after which the participants got the remaining time for recovery (Figure 5).

![Figure 5: On-ice assessments and measurements. Modified repeat sprint skate (MRSS).](image)

Laboratory-Based Assessments Day 4 (Paper III)

Body Composition
A total body scan (Lunar iDXA, GE Medical Systems Lunar, WI, USA; Encore version 14.10.022) was used to assess body composition. The Lunar iDXA is considered a valid and a reliable method for measuring body composition (Ackland et al, 2012).

Maximal Aerobic Capacity
Direct gas analysis was used to assess aerobic fitness. A Jaeger Oxycon Pro System version 5.3 (Viasys Healthcare, Conshohocken, PA, USA) was used to measure expired respiratory gases. Values were calculated over 20 s. Blood lactate was taken through a venous catheter and analyzed using a YSI 2300 STAT PLUS (Yellow Springs International, Yellow Springs, Oh 45387 USA). The test started at 40 W with 40 W increments every three minutes and followed a modified ramp protocol using a Monark 839E cycle ergometer. Blood lactate was taken during the last 30 s of each stage. When 4 mmol/l of blood lactate was reached, the intensity was increased by 20 W every 20 s to volitional fatigue. The participants were instructed to maintain a cadence between 70-80 rpm during
the test. The maximum measured oxygen uptake (Vo$_2^{\text{peak}}$) was recorded as mL·kg$^{-1}$·min$^{-1}$.

*Isokinetic Strength*

A Biodex system 4 (Biodex Co, New York, USA) was used to assess isokinetic strength in the knee joint. The assessment followed the procedure of Gildenstam et al. (2011). A standardized warm-up preceded the test. The warm-up consisted of five minutes of low-intensity cycling (40 W and 60 rpm) including a short progressive 4-5 s- sprint following each minute. Some test-specific warm-up repetitions were also performed in the Biodex, prior to each test. Peak torque/kg body mass in the knee flexor and knee extensors were assessed by performing five maximal concentric contractions at 90 °/s, and 10 maximal concentric contractions at 210 °/s. The maximum torque (N·M) and total work (J) for knee flexors and extensors at each velocity was recorded as their results. Total work has been suggested as a valid measure of anaerobic work capacity (Bosquet et al, 2016).

*Qualitative data collection*

The qualitative part of the data collection was conducted through thematic individual interviews (Kvale & Brinkmann, 2009; Lincoln & Guba, 1985). This method has been suggested to be appropriate when investigating areas with many unknown factors (Kvale & Brinkmann, 2009). The method is sensitive for detecting variations in a qualitative material (Graneheim & Lundman, 2010). The interviews followed a thematic interview guide including six various question areas (Table 6). Each question area addressed extensive areas regarding women’s ice hockey, where the coaches were allowed to reflect and speak freely based on their experiences. Follow-up questions were used continuously during the interview whenever the interviewer found it necessary. Follow-up question have been suggested as a proper way for the interviewer to immerse in the stories (Peek & Fothergill, 2009). Each interview was preceded by an informal conversation to help the informant feel more relaxed (Rapley, 2004). The interviews took between 50-80 minutes and were digitally recorded. The recordings were transcribed by a professional transcriptionist.
Table 6: Thematic interview guide

<table>
<thead>
<tr>
<th>Question Areas</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Educational level and experiences of hockey</strong></td>
<td>The first area was designed to provide insight regarding the coaches’ sport specific education, background, as well as their experiences from the sport.</td>
</tr>
<tr>
<td><strong>Coaching philosophy</strong></td>
<td>This second area was designed to help us gain insight about the coaches: motives for coaching, coaching style as well as their understanding of the athletes (determining and prioritizing demands and expectations).</td>
</tr>
<tr>
<td><strong>Public and governmental support</strong></td>
<td>The third area was designed to gain an understanding regarding support for female ice hockey players, such as training opportunities, financial support, media attention, and support from the society.</td>
</tr>
<tr>
<td><strong>Team dynamics and coaching strategies</strong></td>
<td>The fourth area was designed to investigate team dynamics, such as leadership, short-term and long-term goal settings.</td>
</tr>
<tr>
<td><strong>Valuable features in a good hockey player</strong></td>
<td>The fifth area was designed to investigate the coaches physiological and mental preferences in a player, and their attitudes towards player development. It also aimed to explore their perception regarding constraints and opportunities for player development.</td>
</tr>
<tr>
<td><strong>The future of WIH</strong></td>
<td>The sixth and last area was designed to explore the coaches’ perception regarding the future for women’s ice hockey.</td>
</tr>
</tbody>
</table>

The data was analyzed using qualitative content analysis (Graneheim & Lundman, 2004). *First*, the text was read by the authors to gain an understanding of the contents. *Secondly*, the authors divided the text into selected parts of the text, so called “meaning units”. The meaning units were further shortened into “condensed units”, and then condensed into “codes”. The codes were interpreted on a manifest level and sorted into sub-categories and categories. The data was analyzed for latent meanings and a theme was formed. The theme serves as a reflection of the overall contents and as a link between manifest and latent contents. The manifest contents refer to what the text says, e.g. the obvious components found in the text. The latent contents are referred to as the underlying meaning of a text, e.g. what is said “between the lines” (Graneheim & Lundman, 2004). The transcriptions were analyzed by all authors, and repeatedly triangulated throughout the entire analytical process to ensure a valid and reliable result (Lincoln & Guba, 1985).
Statistical analysis

Statistical calculations were made using SPSS for Mac, Statistics 22.0 (SPSS, Inc, Chicago, IL, USA) (Paper II-IV). Data was normally distributed (Paper II-IV) according to Shapiro-Wilks test p>.05, analysis of Q-Q plots and histograms. In addition, player data was submitted to Kolmogorov-Smirnovs to analyze for normality (Paper II). Descriptive statistics and means (M±SD) were compared between groups, and by half year, and quartile with Manova (Paper II), and by groups and position with two-way Anova (Paper IV). The analyses were adjusted with a Bonferoni correction due to multiple comparisons, in order to avoid Type 1 error (Delorme, 2013). (Paper II), and by Tukey post hoc analysis (Paper IV).

Chi-square was used to investigate the distribution between birthdate quartiles (Q1-Q4) and between half-years (H1-H2). Odds ratios (OR) and confidence intervals (CL) were calculated to reduce risk of Type 1 error (Delorme, 2013), using population data from Sweden and Canada.

Effect size was calculated between groups (Paper II, IV) by comparing mean differences divided by pooled standard deviation. Levels of effects size were classified as small (>0.2), medium (>0.5), and large (>0.8) (Cohen, 1988; Sullivan & Feinn, 2012). In comparison with the p-value, effect size will provide information regarding the size of the effect whereas the p-value will only reveal if an effect exists (Sullivan & Feinn, 2012). Thus, effect size also enables comparison between different studies.

As regression analysis excludes data listwise, Little’s MCAR test for missing values was made (Paper III). The test indicated random patterns of missing values, which allowed data transformation through maximum likelihood estimation. By analyzing all data, the highest probability were identified, and missing values were replaced (Baraldi, 2010).

As data was normally distributed, Pearson’s correlation was applied (Paper III) to assess the relationship between the right and the left leg. Analysis indicated no significant differences between right and left leg values, which allowed exclusion of the right leg values to enable reduction of the number of variables in the analysis.

Multivariate regression analysis was used to calculate prediction models from physiological measurements in order to predict skating performance (Paper III). The best equation from laboratory- and field-based assessments was found by analyzing the data stepwise. The strongest equation (highest adjusted R²) was selected for each assessment.
Results

Paper I

The results (Table 7) from the study revealed a theme: Coaching with a holistic approach, and three categories; a) Individually oriented and humane leadership, b) Insight and understanding of performance requirements, c) Necessary conditions for sports development.

Table 7: The categories and the theme that were formed from the content analysis.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individually oriented and humane leadership</td>
<td>Coaching with a holistic approach</td>
</tr>
<tr>
<td>Insight and understanding of performance requirements</td>
<td></td>
</tr>
<tr>
<td>Necessary conditions for sport development</td>
<td></td>
</tr>
</tbody>
</table>

The theme “Coaching with a holistic approach” described a holistic approach to coaching as a necessity to be able to coordinate available resources. Furthermore, the coaches explained the role of a coach to create opportunities for development, both for their players and for the sport. Three categories were described to support the theme.

The category “Individually oriented and humane leadership” dealt with the way the coaches perceived their players. They explained that sport performance and everyday life was related, and therefore they tried to support their player even outside the sport.

“It’s more about supporting them... obviously, academics in the university setting is really important. So, making sure that we have support mechanisms for them to be successful in school. Stress in school means poor performance in hockey. So, we try to provide all those mechanisms of support, which really... it's not just about athletic performance but it’s about human performance in general.” (North American Interview 3, p.14)
The players were also invited to participate in decision-making, which was believed to increase their investment in the team and in their own development.

In the category “Insight and understanding of performance requirements” the coaches discussed the “ideal player”. The coaches explained the ideal player as physically strong and fit, to have a good and mentally strong character, and above all to be a good skater.

“I mean, the ideal player... it is that work ethic, that attitude, good teammate, they persevere, they will make the sacrifices to reach their goals. That is the ideal scenario, plus they can skate very well.” (North American Interview 2, p.6)

In the category “Necessary conditions for sport performance”, the coaches mentioned time and financial resources as the two most important conditions for the development of women’s ice hockey. They explained that progress takes time, and therefore women’s ice hockey needs time to develop. Furthermore, the coaches emphasized the fact that additional financial resource were necessary.
Paper II

The results from the study showed that the Canadian players exhibited significant RAEs (players born in the second quartile (Q2) from April to June were overrepresented, \( p<0.05 \)), as did Canadian D, and Swedish F. Q3 was overrepresented in the Swedish players, and Q4 was underrepresented in both countries (Figure 6). RAE did not vary by position.

Figure 6: Distribution of birth dates by quartile (Q1-Q4) and half-year (H1-H2) for female ice hockey players by country. Significant RAE's were found for Swedish players (Q3:Q4) and Canadian players (Q2:Q3, Q3:Q4, H1:H2); *\( p < .05 \).

Female births by population in Sweden (Figure 7) and Canada (Figure 8) were relatively evenly distributed across quartiles and half-years. However, the birthdate distribution for the Swedish and Canadian female ice hockey players differed in relation to their respective populations.
Figure 7: Distribution of birth dates by quartile (Q1-Q4) and half-year (H1-H2) for Swedish female ice hockey players in relation to population.

Figure 8: Distribution of birth dates by quartile (Q1-Q4) and half-year (H1-H2) for Canadian female ice hockey players in relation to population.

Maturity status and body size did not vary significantly by country, position, quartile or half-year. The players tended toward average and late maturity status.
Paper III

The results from this study showed that field-based assessments are an adequate substitute for laboratory-based assessments when the purpose is to predict key skating characteristics. The laboratory-based prediction models account for 26.4 % (transition agility), 13.6 % (cone agility), 42 % (agility cornering s-turn), 32.2 % (MRSS) of the variance in skating time on each assessment (Table 8).

Table 8: Model Summary. Lab-based assessments for prediction of on-ice tests

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Transition Agility Skate</td>
<td>.545a</td>
<td>.297</td>
<td>.264</td>
<td>.766</td>
</tr>
<tr>
<td>b) Cone Agility Skate</td>
<td>.418a</td>
<td>.175</td>
<td>.136</td>
<td>.437</td>
</tr>
<tr>
<td>c) Agility Cornering S-Turn</td>
<td>.668a</td>
<td>.446</td>
<td>.420</td>
<td>.216</td>
</tr>
<tr>
<td>d) MRSS</td>
<td>.594a</td>
<td>.353</td>
<td>.322</td>
<td>3.136</td>
</tr>
</tbody>
</table>

a Model Equation: (-.004)Biodex Hamstrings 210° right total work - 14.705
b Model Equation: (-.009)Biodex Quadriceps 90° right peak - 10.804
c Model Equation: (-.009)Biodex Quadriceps 90° right peak TQ - 10.877
d Model Equation: (-0.21)Biodex Hamstrings 90° right peak - 78.115

The field-based prediction models account for 57.1 % (transition agility), 24.4 % (cone agility), 66.3 % (agility cornering s-turn), 54.0 % (MRSS) of the variance in skating time in each assessment. Single-leg standing long jump was the single strongest field-based predictor (Table 9).

Table 9: Model Summary. Field-based assessments for prediction of on-ice tests

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Transition Agility Skate</td>
<td>.769a</td>
<td>.591</td>
<td>.571</td>
<td>.585</td>
</tr>
<tr>
<td>b) Cone Agility Skate</td>
<td>.528a</td>
<td>.278</td>
<td>.244</td>
<td>.409</td>
</tr>
<tr>
<td>c) Agility Cornering S-Turn</td>
<td>.851d</td>
<td>.725</td>
<td>.663</td>
<td>.165</td>
</tr>
<tr>
<td>d) MRSS</td>
<td>.776c</td>
<td>.602</td>
<td>.540</td>
<td>2.585</td>
</tr>
</tbody>
</table>

a Model Equation: (-4.594)Single-leg standing long jump - 19.798
b Model Equation: (-.2558)Bosco test fatigue - 11.36
c Model Equation: (-1.168)Single-leg standing long jump - (0.02) Body mass + (0) Beep test - (0.919) Bosco test fatigue -14.142
d Model Equation: (-12.353)Single leg standing long + (-0.305) Body height + (-0.174) Bench press 1RM - 143.317
Paper IV

The finding from this study showed that physiological profiles differed between Swedish and Canadian players. The Swedish players were characterized as leaner (less body fat and greater lean mass) with greater aerobic endurance (Table 10), while the Canadian players were characterized as stronger and more powerful. In addition, the Canadian players performed better than the Swedish players on the MRSS, which suggests a greater anaerobic capacity on-ice (Table 11).

Table 10: Anthropometric and fitness data (mean ± sd) by country.

<table>
<thead>
<tr>
<th></th>
<th>Canada n=64</th>
<th>Sweden n=45</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body fat (%)</td>
<td>23.99 ± 5.36</td>
<td>21.39 ± 3.35*</td>
<td>0.58</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>51.64 ± 4.32</td>
<td>54.64 ± 6.34*</td>
<td>0.55</td>
</tr>
<tr>
<td>Beep test (m)</td>
<td>1337.08 ± 301.81</td>
<td>1702.73 ± 253.76*</td>
<td>1.31</td>
</tr>
</tbody>
</table>

* Significant differences by country p<.05. Cohen’s d: the standardized mean between samples.

Table 11: Anthropometric and fitness data (mean ± sd) by country.

<table>
<thead>
<tr>
<th></th>
<th>Canada n=64</th>
<th>Sweden n=45</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric strength (kg)</td>
<td>122.95 ± 19.19*</td>
<td>114.29 ± 16.51</td>
<td>0.48</td>
</tr>
<tr>
<td>Standing long jump right (m)</td>
<td>1.78 ± 0.14*</td>
<td>1.68 ± 0.18</td>
<td>0.62</td>
</tr>
<tr>
<td>Standing long jump left (m)</td>
<td>1.77 ± 0.14*</td>
<td>1.69 ± 0.18</td>
<td>0.49</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.33 ± 0.14*</td>
<td>3.52 ± 0.16</td>
<td>1.26</td>
</tr>
<tr>
<td>Modified repeat skate sprint total time (s)</td>
<td>62.35 ± 4.94*</td>
<td>64.75 ± 4.97</td>
<td>0.48</td>
</tr>
</tbody>
</table>

* Significant differences by country p<.05. Cohen’s d: the standardized mean between samples.

Furthermore, the finding from this study showed no significant differences between forwards (F) and defenders (D).
**Discussion**

The pursuit of excellence in sport is a complex process and physiological qualities are fundamental to develop performance in ice hockey. The results from the positional profiling study (Paper IV) showed significantly differentiated physical profiles when female Swedish and Canadian players were compared. The Canadian profile appeared to be more adapted to women’s ice hockey. However, the different physiological profiles may be based on various socio-cultural conditions rather than differences in skill. The findings from the interviews (Paper I) and the RAE-study (Paper II) suggest that socio-cultural conditions are important for development of physiological qualities, as well as of sport development. This thesis provides an important contribution to the existing research, since it investigates the conditions for female ice hockey players from various socio-cultural contexts. Similar to previous research that investigated socio-cultural conditions in Canada (Etue & Williams, 1996; Reid & Mason, 2015; Weaving & Roberts, 2012) and in Sweden (Gilenstam et al, 2008), the findings from the interviews (Paper I) described superior opportunities in Canada compared to those in Sweden. However, regardless of country, women’s ice hockey struggled for proper support and acceptance compared with men’s ice hockey. Thus, the coaches stressed the importance of adopting a holistic approach to coaching to be able to optimize the use of available resources. In addition, the results from the RAE-study (Paper II) showed that relative age effect (RAE) differed in Sweden and Canada. Thus, sport selection criteria for female ice hockey players are probably also affected by socio-cultural conditions.

Socio-cultural conditions must be considered to set the framework for the development of physiological qualities, and thus also for sport- and performance-development. For example, players who have to combine their sport with a job (perhaps with a physically exhausting job), will face difficulties in optimizing training and recovery in order to receive maximum effect, in comparison with professional players or players on a scholarship. Consequently, improved socio-cultural conditions facilitate performance development in sport. In addition, increased financial support as well as increased access to strength- and conditioning coaches would probably lead to a better training outcome. An improved performance may in turn elicit a change in the public opinion of women’s ice hockey to reach equality and improved socio-cultural conditions. Thus, the findings suggest that socio-cultural conditions and physiological qualities must both be considered in relation to performance development.
Women’s ice hockey from a physiological perspective

From a physiological perspective, high-level performance manifests itself differently depending on the requirements of the sport. Women’s ice hockey is a physical sport with both intentional and unintentional body contact (Theberge, 2003). As body checking is not allowed in women’s ice hockey, the physiological requirements probably differ slightly in comparison to the men’s game (Weaving & Roberts, 2012). Physiological qualities that favor the ability to skate or handle the puck should, however, be equally important in women’s hockey as in men’s hockey. No general physiological requirement profile for female ice hockey players is currently available, and the limited number of studies including female players are mostly conducted on North American women (Etue & Williams, 1996; Theberge, 1999, 2003). Investigating players from only one specific cultural context limits the possibility of making generalizations. Thus, the physiological requirements in women’s ice hockey need to be further explored from other cultural contexts.

The results from the RAE-study (Paper II) indicated that female ice hockey players in Sweden and Canada had a greater body mass in relation to the general population. Similarly, Ransdell et al. (2013) found that a greater body mass was related to better performance from an international perspective. Senior players had a greater body mass, greater lower- and upper- body strength, and a greater aerobic capacity, than junior players. A greater body size is probably beneficial in order to handle the physical part of the game, even though body checking is prohibited. The results from the positional profiling study (Paper IV) showed no differences in body size, but displayed two quite different physiological profiles for senior female players in Sweden and Canada respectively. The Swedish players were leaner (less body fat and more lean mass) and performed better on the beep test. The Canadian players were stronger (isometric leg strength) and more powerful (greater acceleration and results in single-leg standing long jump) in the lower body. The Canadian profile had an emphasis on strength- and power-, which was also reflected in a greater repeated sprint ability on-ice. As skating has been identified as a key factor in ice hockey for both men (Fortier et al, 2014; Montgomery, 2000; Pearsall et al, 2000) and women (Bracko, 2001, 2004; Bracko & George, 2001), it seems reasonable to believe that the physiological profile displayed by the Canadian players is better adapted to women’s ice hockey. This statement is further supported by: 1) the ability to produce high amounts of anaerobic energy resembles the energy requirements of the intermittent game characteristics, and the repeated shifts in ice hockey (Montgomery, 2000; Peterson et al, 2016). 2) previous research on men has suggested that repeated sprint ability is an important physiological quality in ice hockey players (Cox et al, 1995; Montgomery, 2000; Peterson et al, 2015b). 3) several previous studies, (made on men), have shown that vertical power production (Burr et al, 2007;
Runner et al, 2015), horizontal power production (Burr et al, 2008; Farlinger et al, 2007), and linear acceleration (Behm et al, 2005), are important to skating performance.

The different physiological profiles found in Sweden and Canada may have occurred due to various reasons, such as different focus in training and rink sizes. Most rinks are smaller in Canada, which may attract a different type of players. The results from the interviews (Paper I) showed that the coaches valued similar qualities in a player regardless of country. However, socio-cultural conditions, such as increased structural support and a larger talent pool of players allowed the Canadian coaches to be more selective in their recruitment process. Canada has roughly 16 times more players than Sweden (IIHF, 2017a), which probably contributes to a fiercer competition among the players. Furthermore, the Canadian teams had access to educated strength- and conditioning coaches, while the Swedish coaches did not have that kind of additional support. For several reasons caution should still be applied when comparing the competitive level in the two samples: 1) The Swedish league is a national league and the Canadian league is a college league. 2) The results from the RAE study (Paper II) revealed several of the Swedish players had qualifications from international competitions (World championships and Olympic games), while no Canadian players had such qualifications. 3) Canada, together with the United States, have been outstanding in the world considering international records. Sweden has never been close to beating Canada in any international competition (IIHF, 2017b).

A study by Ransdell & Murray (2011) presented physiological data from the players that tried out for the 2010 United States national team -“elite players”. The results reveal exceptional physiological qualities to support their superior international record. In comparison to the players included in the positional profiling study (Paper IV), the elite players were older (24.7 y to 19.7 y), heavier (70.4 kg to 68.7 kg), had less body fat (15.8% to 22.9 %), performed better in standing long jumps (2.14 m to 2.04 m) and they were stronger in the upper body (65.3 kg vs 47.1 kg). Although one should be critical when comparing results from different studies, the relation between the international records and physiological qualities is apparent. The physiological profiles were also investigated in relation to position (Paper IV). Interestingly, no positional differences were found between forwards and defenders. Previous studies on women have presented contradictory results, where Ransdell et al. (2013) reported no significant differences by position, whereas Geithner et al. (2006) did. A personal reflection is that ice hockey is becoming more and more all round. Coaches prefer fast, technical and agile players regardless of position. Recent rule changes in response to foul play, holding and hooking, make body size less important than before. Although there is no scientific support for this theory, future discussions regarding physiological profiles by position will be interesting to follow.
**Physiological Assessments**

Valid assessment methods are essential in order to make accurate technical, physiological, and morphological measurement. When selecting physiological assessments, the possible effect should always correspond to the investment in time, money, and potential risk of injury (Atkinson, 2003). The results from the skating performance study (Paper III) showed that field-based and laboratory-based assessments were valid predictors for repeated sprint ability, and long crossover cornering ability. Although not significant, the field-based assessments trended towards stronger predictive models for all tests. Since field-based assessments are generally more cost- and time efficient compared with laboratory-based assessments, they also provide great tools for teams with less resources. Neither the field-based nor laboratory-based assessments methods provided strong predictive models for cone agility. It is suggested that cone agility and transitional agility were more technically demanding than MRSS and cornering s-turn, which may reduce the possibility of detecting physiological differences in these tests. The cone agility test might have unexplored potential as an indicator of hockey performance as it measures skill rather than physiological capacities.

Furthermore, the results from the skating performance study (Paper III) showed that single-leg assessments were superior to two-leg assessments, such as squats and vertical jumps, in predicting various key skating characteristics. Single-leg standing long jump was the single strongest predictor. According to the principle of specificity, the result is not surprising since many movement patterns in skating are largely performed standing on one leg (Bracko, 2004; Fortier et al, 2014). The results also indicated that many physiological assessments frequently used in ice hockey research were not valid predictors of skating performance. It is important to establish relevant relations between physiological assessments and performance criteria (Jones & Wilson, 2009). There has been criticism whether frequently used methods provide useful information in relation to ice hockey performance (Allisse et al, 2017). For example, Peterson et al. (2016) suggest that conventional off-ice anaerobic assessments, such as the Wingate test, do not predict 20 repeated-shift ability in a game. Hockey players should be tested in a more sport-specific manner to provide reliable results (Durocher, Leetun, & Carter, 2008). This knowledge is important for coaches when selecting valid assessment methods and still more important for teams with limited resources. Future tests should be more sport-specific and try to mimic the movement patterns in ice hockey, as ice hockey includes repeated high-intensity intervals in a 360 plane of motion (Carey et al, 2007; Peterson et al, 2015a).
Women’s ice hockey from a gender perspective

The results from the interviews (Paper I) reported that the Canadian teams had superior socio-cultural conditions compared with the Swedish teams. Regardless of country, women’s ice hockey had low priority in the ice hockey community, in comparison to men’s ice hockey. The results are consistent with previous research in Sweden (Gilenstam et al, 2008) and in Canada (Etue & Williams, 1996; Theberge, 2003; Weaving & Roberts, 2012). The coaches stressed the need for a holistic approach to coaching in order to be able to evaluate and target their resources. This approach is probably present in many other sporting contexts.

The interviews (Paper I) indicated that conditions had improved slightly, and that women’s ice hockey had received increased attention during the last few years. For example, some leagues were broadcasted on television, and an all-professional women’s league (NWHL) started 2015 in Canada. However, from an equality perspective, the situation had not changed significantly. Consistent to previous research (Gilenstam et al, 2008; Theberge, 1997; Weaving & Roberts, 2012) men’s ice hockey was still considered the norm, and women’s ice hockey still constantly compared to “real” ice hockey (Gilenstam, 2009).

Cultural Theoretical Perspective

Identity and behavior are constantly encouraged and shaped by our culture, which allows gender differences in sports to be shaped and enforced by the gender regime of sport (Harding, 1986). In order to understand the basis of gender differences in ice hockey, one must consider that women and men have different potential due to social and cultural constructions of gender, and from inherited biological qualities (Theberge, 1998). The coaches (Paper I) were constantly using the men’s game as a benchmark, in terms of norms and values, for the women’s performance. They implied that women were not as fast and strong as men, and that their game was less developed. This attitude seem to originate from social and cultural notions of femininity and masculinity in sport (“appropriate” and “natural” for men and women, respectively) (Hargreaves, 1994). Most likely, the coaches were unaware that their own attitude and behavior probably contribute to maintain gender differences in ice hockey. It is however, understandable why women are always compared to men, because all physiological requirement profiles in ice hockey are designed by men, and for men (Weaving & Roberts, 2012). The major part of the research studies on ice hockey has been conducted on men, and are often applied directly to the women’s game in an unreflected manner (Capranica et al, 2013). Gender is perpetuated and embedded in the culture of sports (Hoeber, 2007). This supports the underlying assumption that female athletes entering male sports, should accept and assimilate the dominant masculine norms (Scraton et al, 1999). Hargreaves (1994) argued that if men have
such influence, they will inevitably impose their own values and practices and women athletes will be inclined to copy what men do.

Although the norms and values in male-dominated sports will have considerable influence on the female players, they will, consciously or unconsciously, incorporate their own values into their sport (Scranton et al, 1999). In spite of describing the men’s game as better, due to physiological reasons, the coaches (Paper I) still described the women’s game as” the purest form of ice hockey right now”. They explained that the violence in men’s ice hockey ruined the interesting parts of the game, such as speed and technique, and that the men’s game should be more like the women’s game. They also mentioned the increased risk of injuries as another negative effect of the violent game. Interestingly, in contrast to their previous descriptions, this statement actually suggests that they considered the women’s game as the norm.

**Structural theoretical framework**

Women’s ice hockey is progressively changing from an amateur sport based on idealistic motives and volunteer efforts, towards a professional sport based on profit and commercial interests. Sufficient structural support has been mentioned as a necessity to provide opportunities for development in women’s ice hockey (Gilenstam et al, 2008; Theberge, 2000). Accordingly, the results from the interviews (Paper I) suggest that financial support is necessary for the sport to develop. Furthermore, the results indicate that sport development takes time and patience. The long history of women’s ice hockey in North America is a factor that explains their superior international records. The results from the interviews (Paper I) also reveal superior socio-cultural conditions for women’s ice hockey in Canada in comparison to the situation in Sweden. The educational systems in Canada (CIS) and in the United States (NCAA) are described as an important factor of support incorporated in the systems. This finding is supported by a previous study (Ransdell et al, 2013). The players have the opportunity to play ice hockey full-time while studying on a scholarship, which is described to make the players more committed to the sport, and thus more likely to invest time and energy for a longer period of time. In contrast, the Swedish educational system only provides support for female ice hockey players until they turn 19. Consequently, after graduation the players are compelled to work or continue their studies, and play ice hockey on the side. This situation is described to prevent the players from being able to fully invest in their sport.

Many female athletes have benefited from Title IX of the Education Amendments of 1972 (United States Department of Labor, 1972) as it constitutes equal opportunities for female and male athletes that participate in the United States university programs. However, despite the legislation of Title IX, a study by
Dworkin and Messner (2002) found that male athletes were still favored compared to female athletes. In ice hockey, female players still face considerable resistance in their effort to develop their sport (Etue & Williams, 1996). The gender order in society provide a framework of norms regarding body and gender, which limits the potential development of women’s sport.

**Interactionist theoretical framework**
Some people argue that persistence against structural standards may be one way to gain legitimacy, and possibly long-term changes (Pelak, 2002). The results from the interviews (Paper I) suggest that the women’s game would benefit from creating its own identity. Accordingly, Hively & El-Alayli (2014) found that women would benefit from focusing on their own performance rather than comparing and highlighting gender differences. However, Theberge (1997) express a concern that by challenging the masculine norm in ice hockey, the women may be considered a threat that might lead to negative consequences. A study by Fasting et al. (2003) suggests that, in order to reach equality in sport, more women need to reach powerful positions in the governing bodies of sport and in society as a whole. More women in the governing bodies of ice hockey may indeed create positive changes regarding equality in the ice hockey community. On the other hand, a concern is that people recruited to power positions in a male dominated environment might embrace and reproduce the dominant norms, regardless of their sex. I.e. also women may share the opinion of male supremacy in ice hockey. In order to improve the situation in women’s ice hockey, the gender regime in sport must change. The underlying gender differences in sports performance are likely influenced by cultural and structural conditions that continues to affect opportunities for female athletes (Capranica et al, 2013).

**Methodological Considerations**
To begin with, women and men are not homogenous groups. Greater variation may be found within the gender groups than between the groups. Thus, caution is necessary when making comparisons. However, both men and women would probably benefit from questioning the masculine norms in ice hockey.

The conclusions drawn in this thesis have not been originated from the players themselves, but rather from the coaches’ experiences. However, it may be assumed that it requires broad knowledge to manage a team. Therefore, coaches are likely to provide a more nuanced understanding about the conditions in women’s ice hockey than players.
In addition, lack of familiarity with the selected assessments was a concern. The potential limitation was minimized by allowing the players practice trials to familiarize with the equipment and the movement patterns of each test. Furthermore, several of the players were not used to performing maximal 1 RM strength assessments, which sometimes made it difficult for them to reach their maximum result in the correct amount of sets. In addition, the level of motivation for performing the physically demanding and fatiguing assessments may be a limitation. However, the players were highly motivated, and the perception is that they performed to the best of their ability.

Last but not least, this thesis provides an interdisciplinary approach where the use of both qualitative and quantitative methods served to investigate the conditions in women’s ice hockey. It is believed that this allowed for a more nuanced understanding of the conditions in women’s ice hockey.
Conclusions

This thesis uses an interdisciplinary approach, with the inclusion of both qualitative and quantitative data. The findings indicate that socio-cultural conditions, such as structural and financial support, are important to support opportunities in women’s ice hockey. Female players in Canada and in the United States have superior opportunities compared to players in Sweden. These advantages are mainly attributed to the support provided by the North American educational systems. Furthermore, the physiological profiles differed between Swedish and Canadian players, possibly affected by the different socio-cultural conditions. The Canadian profile may be better adapted to ice hockey, but due to difficulties in comparing the level of players, further research is needed to understand the relation between physiological requirement profiles and performance. Last but not least, field-based assessments methods were found to be comparable to laboratory-based assessments with the purpose of predicting skating performance. As field-based assessments are more cost- and time-efficient, they may provide a useful tool for teams with less resources. Independent of method, single-leg were superior to predict skating performance.

Knowledge regarding performance requirements and their corresponding assessment methods can provide useful information. With limited resources, it is important to use time and financial resources wisely in order to accelerate development and improve performance in women’s ice hockey. Improving performance may have a positive impact on the way people perceive women’s ice hockey. But for substantial changes to occur, power structures in sport must also change. Women themselves have limited opportunities to change the dominating gender norms and values in ice hockey. For example, women can probably further optimize their physical performance in relation to their current conditions. However, socio-cultural conditions, such as financial support, will set the framework for their potential development.
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References


Gilenstam, K. (2009). *Gender and physiology in ice hockey: a multidimensional study*. (Doctoral thesis), Umeå University, Umeå University medical dissertations, ISSN 0346-6612 ; 1309.


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