Martine Kvam Asp
Mia Røkke Holm
Martine Lund Nyhus

Performance-related elements for propulsion in ice hockey

Bachelor's thesis in Human Movement Science
Supervisor: Gertjan Ettema
May 2022

Bachelor's thesis

NTNU
Norwegian University of Science and Technology
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Department of Neuromedicine and Movement Science

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Kunnskap for en bedre verden

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Acknowledgments

During our last year of a bachelor's degree in Human Movement Science at Norwegian University of Science and Technology, we wrote a bachelor thesis with the topic "Biomechanical aspects in effective propulsion in winter sports focusing on work physiology". Within this topic we chose to write about performance-related elements for propulsion in ice hockey. The bachelor thesis is written with the target group of people with at least a BA in movement science, sports or relevant experience.

The bachelor´s thesis builds further on previous accomplishments within the subjects of “Training and performance”, “Teaching in physical activity” and “Fitness and performance assessment”, where performance assessment and development is something that is clearly repeated. We were therefore familiar with some of the articles that are included in the bachelor thesis beforehand, and we all can agree that this is an incredibly exciting professional field we wanted to investigate more in depth during our bachelor thesis. The preparations and the writing process itself have been above all expectations, and we have really enjoyed the writing- and learning process as a Bachelor's thesis group.

We want to thank Gertjan Ettema for being a great supervisor and a big part of our learning process through good guidance, inputs and feedback. We are beyond grateful. We would also like to say a big thank you to family and friends who have taken the time to read through and evaluate the assignment. Last but not least, a thank you to each other for good cooperation and friendship over the past three years.

Abstrakt

Bakgrunn: Ishockey er en power idrett kjennetegnet av hyppige og raske bevegelser, noe som gjør mekanikken bak idretten vanskelig å forstå. Denne litteraturstudien hadde derfor som formål å analysere hvordan fysiske og tekniske elementer påvirker prestasjonen i ishockey. **Metode:** Pubmed og ProQuest ble brukt som søkedatabase for å finne forskningsartikler hvor inklusjons- og eksklusjonskriterier ble lagt til. Videre ble litteratur om bevegelsesanalyse og antropometri undersøkt nærmere, i tillegg til forskjeller i kjønn. 159 personer (24,07 år ± 4,59) utførte ulike testbatteri både on-ice og off-ice. **Resultat:** Denne litteraturstudien inkluderte åtte studier. Samtlige viser at det stilles krav til biomekaniske, fysiske og tekniske elementer i idretten som påvirkes av ulike faktorer slik som muskelaktivering, biomekaniske aspekter og antropometri. Det var også noen forskjeller mellom kjønn. **Konklusjon:** Biomekanikk og muskelaktivering påvirker fremdriften i fremover skøyting, mens kroppssammensetning kan være betydelig prestasjonsrelatert faktor. Det er vanskelig å trekke faste konklusjoner på kjønns påvirkningskraft. Generelt sett er det et behov for mer forskning på hele fagfeltet.

Abstract

Purpose: Ice hockey is a power sport characterized by frequent and rapid movements, which makes the mechanics behind the sport difficult to understand. The purpose of this literature study was therefore to analyze how physical, and technical elements affect performance in ice hockey. **Method:** Pubmed and ProQuest were used as search databases to find research articles where inclusion and exclusion criteria were taken into account. Furthermore, literature on movement analysis and anthropometry were examined in more detail, in addition to differences between gender. 159 people (24.07 years ± 4.59) performed various test batteries both on-ice and off-ice. **Result:** This literature review included eight studies. All show that there are requirements for biomechanical, physical, and technical elements in sports that are influenced by various factors such as muscle activation, biomechanical aspects, and anthropometry. There were also some differences between the genders. **Conclusion:** Biomechanics and muscle activation affect propulsion in forward skating, while body composition may be significant performance-related factor. It is difficult to draw firm conclusions about the impact of gender. In general, there is a need for more research on the entire professional field.

Keywords: ice hockey, anthropometry, movement analysis, biomechanics, muscle activation, propulsion, gender

1.0 Introduction

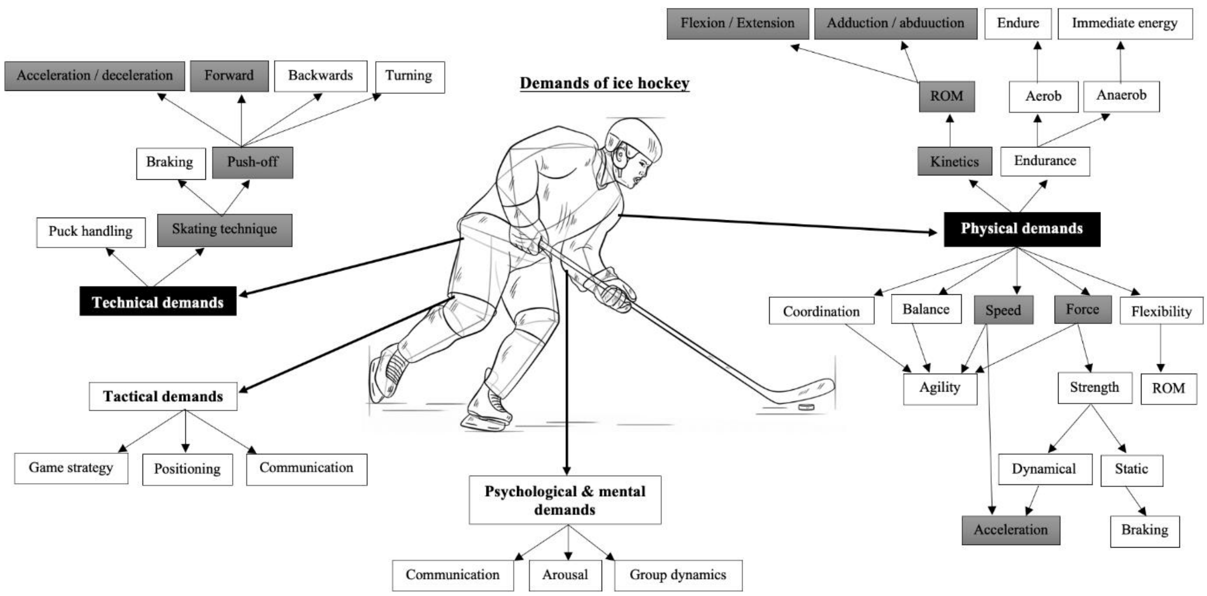
1.1 The game of ice hockey

Ice hockey is a complex team sport that places great demands on the biomechanical aspects and work physiology. The sport characterizes by intense physical contact, high speed, reactive thinking, and periodic, high-intensity work intervals with maximum performance. An ice hockey team consists of 20-25 players, where a maximum of 22 can play during a game (IIHF, 2021, p. 39). At each play-sequence there are six players from each team on the ice at the same time. By observing an ice hockey game one can see that the players play for about 30-80 second per shift, while the goalie usually plays the entire game. After a shift they rest for about 2-5 minutes. There are defense players and forward players, and each of these have different tasks out in the rink. Different physiological requirements are therefore set for each individual position. The game of ice hockey lasts for 60 minutes consisting of three 20 minutes periods.

1.2 Demands of the sport

Various demands must be present for each player to achieve peak performance. An analysis of the demands of the sport is a thorough analysis that presents the requirements that the selected sport requires to achieve good performance (figure 1). It is important to point out the complexity of the sport, which is a compound of different elements that affect each other to a greater extent than figure 1 shows. For the sake of clarity, this figure is simplified and the discussed demands in this thesis are marked grey.

Figure 1 - *Demands of ice hockey*



Based on the demands of the sport, this thesis will analyze how elements have a performance-related effect on propulsion in ice hockey. An interaction between these demands should be present in order to perform. In addition, various factors will affect the performance of ice hockey players, including anthropometry and gender.

1.3 Physical demands: endurance

Ice hockey requires physical capacity both aerobic and anaerobic (Stanula *et al.*, 2014). The aerobic capacity is necessary in terms of oxygen uptake and endurance due to the duration of the game (Plowman and Smith, 2017, p. 57). Anaerobic capacity is necessary, caused by the fact that the player must provide a lot of power within a short period of time (<10 sec). The two most relevant energy systems are the immediate ATP-PCr energy system and aerobic energy system. The ATP-PCr system is responsible for energy release through rapid change of movement and high-intensity intervals. On the contrary, the aerobic energy system is in charge of aerobic endurance during each shift. When repeatedly skating with high intensity, the muscles can accumulate more lactic acid than they manage to get rid of (Plowman and Smith, 2017, p. 71). This can be associated with stiffening the muscles and the skating movements can therefore be hard to complete, which is why it is so important to have frequent and rapid breaks throughout the match. Even though endurance is of importance for the sport, it will not be further analyzed in this thesis.

1.4 Physical demands: kinetics

The biomechanics of ice hockey are very complex and vary for the different positions in the sport due to different movement patterns (Pearsall, Turcotte and Murphy, 2000). These are characterized by several voluntary movements and are influenced by various factors. The biomechanical aspects describe the relationship between the mechanical forces: kinetics and dynamics. Kinetics is defined in this thesis as the part of mechanics that looks at a body's movement without considering different forces and masses, as opposed to dynamics which looks at the connection between the body and its influence of external forces.

Several studies have attempted to understand the most effective way for propulsion (Chang, Turcotte and Pearsall, 2009; Buckeridge *et al.*, 2015; Shell *et al.*, 2017). The ability to accelerate and decelerate fast will be beneficial for the performance in ice hockey as the sport is characterized by rapid movements, duels and turns, where gaining speed quickly will be necessary. Any change in speed and direction, i.e., acceleration, requires considerable force that exceeds any external opposing force. Agility needs to be present to be able to change direction without losing speed or accuracy in the movement (Hoffman, 2014, p. 175). Thus, like pure acceleration, such dynamic motion requires strength and power (=force x speed), but moreover, balance and coordination. Coordination requires an interaction between joints and muscles. Furthermore, degree of muscle activation will affect skating propulsion. Muscle activation in this thesis is measured as the percentage of maximum voluntary contraction (MVC%). For an ice hockey player, high demands are placed on muscle strength and endurance. During play, the whole body is in motion, but the muscle activation occurs mostly in the hip, knee, and ankle (Chang, Turcotte and Pearsall, 2009; Buckeridge *et al.*, 2015; Budarick *et al.*, 2020; Kaartinen *et al.*, 2021). Therefore, this thesis will focus on the role of muscles of the lower extremity.

1.5 Body composition

Although propulsion is clearly influenced by force and kinetics, there are other factors such as physical capacity and anthropometry. Anthropometry is about measuring body composition, by using specialized measuring devices and is defined as the measurements of the human body (Liguori, 2018, p. 63). Body composition (BC) is defined as the relative proportions of fat and fat-free mass tissue in the body (Liguori, 2018, p. 53). This refers to the relative % of different types of body tissue that are related to health (Liguori, 2018, p. 3). The most common measure of the body is the total amount of body fat percentage (%BF). Potteiger *et al.* (2010) and Roczniok *et al.* (2016) have investigated whether %BF has any effect on performance in ice hockey. Gilenstam, Thorsen and Henriksson-Larsén (2011) compared the skating performance to lean body mass (LBM) which is the fat free mass of the body. They also found specific differences between female hockey players and male hockey players among the anthropometric data.

1.6 Study questions

Ice hockey is a high-intensity team sport where good skating skills, high skating speed, acceleration, and agility are important abilities. In order to be able to develop the best possible ice hockey player, it will be appropriate to look at the presented physical and technical demands and how they are performance-related for propulsion. In this thesis, we focus on the relationship between kinetics and level of muscle activation on forward skating propulsion performance. In addition, we discuss the role of body composition and gender differences.

2.0 Method

The thesis addresses the study question through literature review and qualitative analysis. That includes obtaining results from literature to gain a comprehensive understanding and knowledge of the thesis study questions. A systematic literature search was performed in PubMed and ProQuest (table 1). These are well-known databases that consist of medical and biological-physiological articles, which is relevant for answering our study questions. In addition, ProQuest includes a wide range of other topics that allows us a more expanded search within sports. Searches have been performed at different dates with various search queries and time ranges. Different time ranges were covered because of practical reasons in the two databases. Table 1 shows the structure of our search process, which includes both databases and selected search query.

Table 1 – *Systematic search for research articles*

Date of search	Database	Search query	Time range	n
2022.02.14	Pubmed	((Ice Hockey) OR (short track speed skating)) AND ((aerobic work capacity) OR (anaerobic work capacity) OR (muscular strength) OR (muscular endurance) OR (muscle activity) OR aerobic OR anaerobic OR (aerobic exercises) OR (anaerobic exercises) OR (lactate thresholds) OR (work physiology) OR (physiology of effort) OR (anthropometry)) AND ((speed development) OR (developing speed) OR propulsion OR biomechanics OR mechanics OR technique OR push-off)	< 15 years	469
2022.02.17	ProQuest		< 10 years	1108

n = Number of articles found from the initial search

2.1 Inclusion- and exclusion criteria

The inclusion and exclusion criteria have helped us to expand, but at the same time narrow our search. The inclusion- and exclusion criteria are presented in table 2.

Table 2 – *An overview of inclusion criteria and exclusion criteria for primary literature*

Inclusion criteria	Exclusion criteria
Research studies	Research articles more than 15 years old
Studies that include performance development, physiological elements and biomechanical aspects in propulsion	Studies that deal with rehabilitation and injuries within the chosen topic
Anthropometric measurements (%BF, %LMB, BW)	
Adults >18yrs	
Muscle activation, kinetics, and body composition	
Lower extremity muscles	

Includes primary on-ice test(s), may include off-ice test(s)	

2.2 Systematization of literature

With the selected search query, a large quantity of research articles was found. Various articles were examined, and only a few of these were found relevant for our thesis. Every abstract was read, and the most relevant articles were chosen to read thoroughly while taking notes. The ‘snowball effect’ was also used by using the reference list of different research articles or related articles to find additional articles that were relevant and matched our inclusion and exclusion criteria (Kirchherr and Charles, 2018). In the end, articles were sorted into main and secondary literature based on the inclusion- and exclusion criteria (table 2). The primary articles included in this bachelor thesis are further presented in table 3.

3.0 Results

The thesis includes eight studies with a total of 159 participants, which analyzed body composition, biomechanical aspects in propulsion movement, and muscle activation in ice hockey. In addition, three of the studies also included how gender affects skating performance. In all studies, tests were performed on ice where seven of them also analyzed off-ice testing. Table 3 presents an overview of the primary literature that was included in this literature study where the findings for each study are described more in detail. The results presented are statistically significant with a p-value below 0.05 (table 3).

Table 3 - *An overview of primary literature*

First author, (year)	**Participant characteristics (n, gender & age (yrs))**	**Type of tests (on/off-ice) and measurement of capacity**	**Main significant findings**
Kaartinen *et al.*, 2021	n = 12 Males 20.5 yrs ± 1.5	Test(s): On-ice Measurement(s): Kinetics, muscle activation and propulsion	- Knee- and hip extension is greatest during propulsion. - During propulsion, gluteus and muscles of the lower leg register highest activity (%MVC)
Potteiger *et al.*, 2010	n = 21 Males 20.7 yrs ± 1.6	Test(s): On-ice and off-ice Measurement(s): BC, muscular strength, and propulsion	- A lower %BF correlates with increase in performance.
Shell *et al.*, 2017	n = 19 Both genders Adults, yrs not specified	Test(s): On-ice Measurement(s): Kinetics, muscular strength and propulsion	- Men show a greater explosive unilateral leg strength than men - Men has a greater hip extension and flexion than women - Women are more adducted than men - Men had wider stride width than women
Roczniok *et al.*, 2016	n = 42 Males 24.8 yrs ± 6.7	Test(s): On-ice and off-ice Measurement(s): BC and propulsion	- A lower %BF correlates with increase in performance.
Gilenstam, Thorsen and Henriksson-Larsén, 2011	n = 21 Both genders 24 yrs ± 3.0 (F) 23 yrs ± 2.4 (M)	Test(s): On-ice and off-ice Measurement(s): BC, muscular strength, and propulsion.	- Men had a stronger unilateral leg strength and higher %LBM than woman - Men skated faster than woman - Acceleration and speed were sig. to BW for women
Budarick *et al.*, 2020	n = 19 Both genders 21 yrs ± 1 (F) 22 yrs ± 1 (M)	Test(s): On-ice and off-ice Measurement(s): Kinetics, muscle activation, muscular strength and propulsion.	- Correlation between BW for women with skating performance and anthropometry
Buckeridge *et al.*, 2015	n = 18 Males 25.7 yrs ± 3.7 (H) 36.9 yrs ± 5.3 (L)	Test(s): On-ice Measurement(s): Kinetics, muscle activation and propulsion	- (H) had greater hip abduction during propulsion - Gluteus and muscles of the lower leg register high activity during propulsion (%MVC)
Chang, Turcotte and Pearsall, 2009	n = 7 Males 22.1 yrs ± 1.2	Test(s) On-ice Measurement(s): Kinetics and muscle activation	- Adductor magnus showed the largest total changes in activation size and activation time (%MVC) - Frequency of hip abduction increased with activation of the adductor magnus

n = Number of participants, F = Female, M = Male, H = High skilled group, L = Low skilled group

We have not chosen to take a closer look at the duration of the studies, type of tests and level of participants. Validity and reliability of the selected studies were not examined in this thesis in detail. However, the following aspects of the research design, protocol were briefly checked: All studies allowed for ample time for the athletes to recover between tests; All studies involved highly skilled athletes, though not always of elite level; Among studies, different tests may have been used for the same capacity factor.

3.1 Physical demands: kinetics

In the studies by **Chang, Turcotte and Pearsall (2009), Buckeridge *et al.* (2015) and Kaartinen *et al.* (2021)** degree of muscle activation during propulsion was analyzed. Kaartinen *et al.*, 2021 found that m. vastus lateralis and m. soleus registered high activity of muscle activation (%MVC) during the propulsion phase. Buckeridge *et al.* (2015) show that m. vastus lateralis and m. vastus medialis registered a higher activity during constant speed and that m. medial gastrocnemius had higher muscle activation (%MVC) during the acceleration phase. Chang, Turcotte and Pearsall (2009) showed that m. adductor magnus had the biggest total change in activation size and time.

Joint kinematics and biomechanics were further analyzed in the studies by Chang, Turcotte and Pearsall (2009), Buckeridge *et al. (*2015) and **Shell *et al.* (2017**) by looking at movements of the lower extremity. According to Shell *et al. (*2017), women showed a greater hip adduction than men in addition to men having a greater flexion and extension of the hip. Both genders had the same stride length, but men had significantly wider stride width. Additionally, significant main effects of strides, gender and their interaction for forward speed were found. Buckeridge *et al. (*2015) found that the highly skilled group of players had a greater hip abduction during acceleration and steady state phase than the lower skilled group. Chang, Turcotte and Pearsall (2009) showed that the speed of hip abduction increased in parallel with activation of m. adductor magnus.

3.2 Body composition

For those studies that analyzed anthropometry while also taking differences between genders into account, Shell *et al.* (2017) and **Budarick *et al. (*2020**) showed significant differences in speed development and power. Both studies refer to a greater unilateral leg strength, which was correlated with men skating faster than women. On the other hand, **Gilenstam, Thorsen and Henriksson-Larsén (2011)** found no correlation on gender differences and skating performance ($p>0.05$). Furthermore, **Potteiger *et al.* (2010) and Roczniok *et al.* (2016)** referred to a negative correlation between %BF and skating performance. Gilenstam, Thorsen and Henriksson-Larsén (2011) showed a negative correlation between performance on the speed test and percentage of LBM.

4.0 Discussion

The eight included research articles analyzed performance-related elements for propulsion in ice hockey. Based on the results in table 3 and demands of the sport in figure 1, physical and technical demands are important to provide high performance in ice hockey. In connection to this, this thesis wants to discuss how these elements affect forward skating.

4.1 The effect of kinetics and muscle activation on propulsion in forward skating

Propulsion can be described, in this context, as the athlete's ability to move forward on the ice. Therefore, it may be useful to look at the kinetics in the different stages of the skating movement. A player must skate as fast as possible to reach a wanted location on ice, and five of the studies have analyzed kinetics in forward skating to understand the biomechanics behind. During propulsion it is known that extension of the knee and hip will create a push-off movement from the surface. Kaartinen *et al.* (2021) confirms this with results that measure the knee and hip extension to be greatest during the propulsion movement. In relation to this, a greater hip flexion and hip extension creates a greater range of motion (ROM) (Buckeridge *et al.*, 2015). In addition to a large ROM, angular velocity of the joints will be important. Players who had a higher extension speed in both hip and knee joints performed significantly better. This indicates the importance of a complete ROM to achieve as high skating speed as possible. An increased extension speed means that the player spends less time extending the joint, which may indicate more power development in each movement.

To create power, accurate muscle activation in the lower extremity must be present. A professional ice hockey player who glides on the ice can look very graceful, but by analyzing the mechanics one can see that skating on the ice is a complex of leg and body movements to achieve the best possible performance (Haché, 2002). As initially mentioned, the movements consist of fast acceleration speed and rapid turns which places great demands on muscle activation. According to findings in four of the studies, there is different muscle activation in different parts of the propulsion movement. Chang, Turcotte and Pearsall (2009), Buckeridge *et al.* (2015) and Kaartinen *et al.* (2021) showed that the primary muscles being used during propulsion in ice hockey were quadriceps, adductor and the lower leg muscles. This corresponds to the movements during propulsion, for example, when quadriceps muscles primarily extend the knee joint during push-off. A review by Haché (2002) supports that these muscles provide most energy to move the ice hockey player forward. In addition, it may be useful in subsequent research to look more closely at the timing of activation, as muscle activation should occur at the right time for optimal movement.

In forward skating, each skating stride will occur diagonally from the direction of movement. Each stride has a force diagonally out to each side, this allows the player to move linearly in a forward direction. When a skating stride is taken, the player will abduct the hip, so the movement takes place away from the midline of the body. It is the abductor and adductor muscles that abduct and adduct the hip during skating. Buckeridge *et al. (*2015) and Kaartinen *et al.* (2021) confirm the importance of muscle activation and point out how activation of gluteus and lower leg muscles are essential for skating performance. The muscle activation correlates with the movements of the skating stride when gluteus muscles abduct, extend, and rotate the hips during propulsion in forward skating and turns. Additionally, the lower leg muscles support the foot, for example when the player rotates the ankle during turns. This emphasizes how muscle activity and coordination of the movements are important for a higher skating speed, which in turn leads to increased skating performance. Although this thesis has chosen to not discuss muscle activation in the upper extremity, it is worth mentioning that the movement of the upper extremity and truncus muscles are necessary to increase performance in terms of keeping the body upright and change of directions.

As presented in figure 1, physical and technical demands are essential for performance. In anaerobic sports such as ice hockey, the importance of both speed and agility is determining for achieving success of an athlete or a team (Hoffman, 2014, p. 169). With a combination of coordination, balance, strength, and power, the player can change from movements performed at maximum speed, to decelerate as quickly as possible and accelerate again into a new direction. Agility requires a lot of force to rapidly change direction, which in this case can be considered as a centripetal force. The radius of the player's path will decrease with a greater centripetal force, which will allow more rapid turns (Pearsall, Turcotte and Murphy, 2000). This requires great strain on the muscles because they must provide force needed for such action. In connection to this, high demands are therefore required of physical capacity. Roczniok *et al.* (2016), confirms this by the fact that the better players had a higher peak power and anaerobic capacity, which indicates that players with a high anaerobic capacity will be able to generate greater power and can in result of this perform better.

The mentioned research indicates that both biomechanics and muscle activation have a major impact on forward skating. It is well documented that a combination of ROM, muscle activation and the interaction between the muscles is crucial for optimal performance for an ice hockey player. Limitations of the studies are that the test groups consist of a low number of participants which can affect the results. Across the studies, various on-ice tests have also been carried out, which makes it challenging to standardize the test battery when they have not examined the exact same thing. Due to practical reasons, our thesis has chosen to not discuss this, but it is useful to include in any subsequent research to increase reliability. Compared with other literature, the studies also refer to the effect of optimal muscle activation and biomechanics. Haché (2002) confirms that skating is an interaction between the muscles of the lower extremity, and Pearsall, Turcotte and Murphy (2000) point out, among other things, that the quadriceps muscles are important for generating power in the knee joint. This contributes to strengthen the notion regarding this sub question.

4.2 The impact of body composition and gender on ice hockey performance

Ice hockey players vary in size and weight depending on which position they play on the field or what type of player they are. Some teams build up heavy teams, focusing on a defensive game tactic. Teams that have an offensive game tactic often build up fast teams, with lighter and faster players. Three of the studies have analyzed whether body composition (BC) has an impact on skating performance and indicates that fat percentage (%BF) is crucial for the best possible propulsion (Potteiger *et al.*, 2010; Gilenstam, Thorsen and Henriksson-Larsén, 2011; Roczniok *et al.*, 2016). It appears that ice hockey players with a higher %BF had a lower skating speed than those with a lower %BF. Roczniok *et al.* (2016), confirms this by pointing out a negative moderate correlation to %BF, indicating that a lower fat percentage increases the performance of the players. This is also examined in the review article by Montgomery (1988). The reason for this is that a higher %BF will lead to a larger body mass (BM) which in turn will affect the force according to Newton's 2nd law. An increased %BF does not directly mean that higher BM will reduce the skating speed, but affects performance because it's a larger mass that doesn't generate power that must be moved (Potteiger *et al.*, 2010). It is obvious that there are anthropometric differences between players and as seen BC has an impact on propulsion in ice hockey. Therefore, it will be interesting to look further at BC considering gender differences.

According to several studies, there are also differences in BC between men and women in terms of average height and weight, which indicated significant differences in skating performance (Gilenstam, Thorsen and Henriksson-Larsén, 2011; Budarick *et al.*, 2020, 2020). In addition, men have a significantly greater leg strength and higher %LBM than women (Gilenstam, Thorsen and Henriksson-Larsén, 2011). Thus, women will have a higher %BF to move and less muscle mass to generate power, which could affect the propulsion movement. The differences in BC can among other things be explained by the fact that women have a relatively higher %BF than men due to hormonal causes. This results in female ice hockey players not having the same physiological and anatomical prerequisites that the sport requires to achieve peak performance. It seems that it is BC, and not directly the gender differences that are in relation to the performance in ice hockey. On the other hand, it is worth mentioning that Gilenstam, Thorsen and Henriksson-Larsén (2011) found that there was no association between skating performance and LBM in women nor men, but found on-ice performance differences between the genders. There is no clear trend as to whether it is directly BC or other gender differences related to anthropometry that affect performance of ice hockey players. Nevertheless, it is likely that there is an interaction between these that will have an effect on propulsion.

As previously mentioned, kinetics affect propulsion in ice hockey. When analyzing the movements of an ice hockey player, mechanics, anatomy and work physiology should be considered. It is known that women and men are different in terms of anatomical structure in the lower extremity (Shultz, Nguyen and Schutz, 2008). Biomechanical differences in gender may therefore affect propulsion in ice hockey. Results by Shell *et al.* (2017) show that men have larger ROM of the hip joint in flexion and extension compared to women. A larger ROM could affect propulsion in the form of greater freedom of movement so that the choice of movement solutions increases. This is beneficial for an ice hockey player in the sense that a larger active ROM might be able to provide a larger opportunity for optimal muscle contraction, which can allow the muscle to generate more power. It can therefore be drawn lines to the fact that a higher ROM affects acceleration, which is confirmed by Kaartinen *et al.* (2021) that found that during propulsion, a higher ROM of the hip joint was important for higher skating speed. This indicates that the anatomical differences in gender due to ROM may have an impact on skating speed.

There is also a significant difference between men and women in hip abduction and adduction, which is, as mentioned - beneficial for an optimal skating stride. Shell *et al.* (2017) investigated that men were more abducted than women during propulsion. This may be related to the fact that they have a larger stride width which causes more abduction of the hips. The anatomical structure of women and men is somewhat different, such as women having wider pelvis and a more inwardly rotated hip than men (Shultz, Nguyen and Schutz, 2008). Due to this, the angle of the femur can vary between genders, among other things it is seen that women have more valgus knee posture. The angle of the femur affects the abduction and adduction of the hip, which may be correlated to skating stride. This can be seen in connection to the fact that an ice hockey player will depend on fast, efficient, and coordinated skating stride to achieve the most energy-saving movements on the ice. According to Shell *et al.* (2017), men are also somewhat faster than women. A correlation can therefore be seen between abduction of the hip and speed, which indicates that a wider skating stride may create faster propulsion. Based on this, men will most likely have higher prerequisites to skate faster than women. Thus, even though gender differences do exist, they may not play a role of importance for individual evaluation considering that each player is different both anatomically and physiologically.

Based on the main findings, it seems that both body composition and gender are factors that may affect propulsion in ice hockey. Thus, there is a need for more research that mainly examines gender differences to be able to draw more firm conclusions on what is performance-related for each gender. Based on this thesis, it is the individual differences in players that constitute the most significant role in who performs best. Research shows that anthropometry has an impact on propulsion and performance by looking at BC. When measuring BC, the same equipment was used which helps to strengthen the validity. Limitations of the studies are that different tests were used to register gender differences and it can therefore be sources of error that affects the result since the test battery is not standardized. At the same time, questions can be asked about the fact that the studies do not look at gender from the same division, which means that the results are not directly comparable. This is something that should be considered in later studies to strengthen reliability.

5.0 Conclusion

The game of ice hockey may have developed somewhat in recent decades in terms of complexity and intensity in the game, which may result in the biomechanical aspects not only becoming more difficult to analyze, but also more challenging to understand. There is therefore a need for more research within the field to be able to say something more certain about the performance-related elements in the sport. Nevertheless, it is possible to draw lines between recent and older research.

The purpose of this literature study was to look at the presented physical and technical demands and how they can be related to performance. As team composition and the tasks of each position vary, it can be challenging to compare which elements needs to be present to achieve peak performance. This can be because it can vary whether the team is built as a defensive or offensive team, and it is therefore a need for more research on this professional field. Without drawing any conclusion, we can, based on the findings from the eight included studies, give a pointer to the fact that kinetics and muscle activation affect propulsion in forward skating, while BC might be a significant performance-related factor. To reach a clearer conclusion regarding gender, more research is needed that specifically examines how this factor affects performance.

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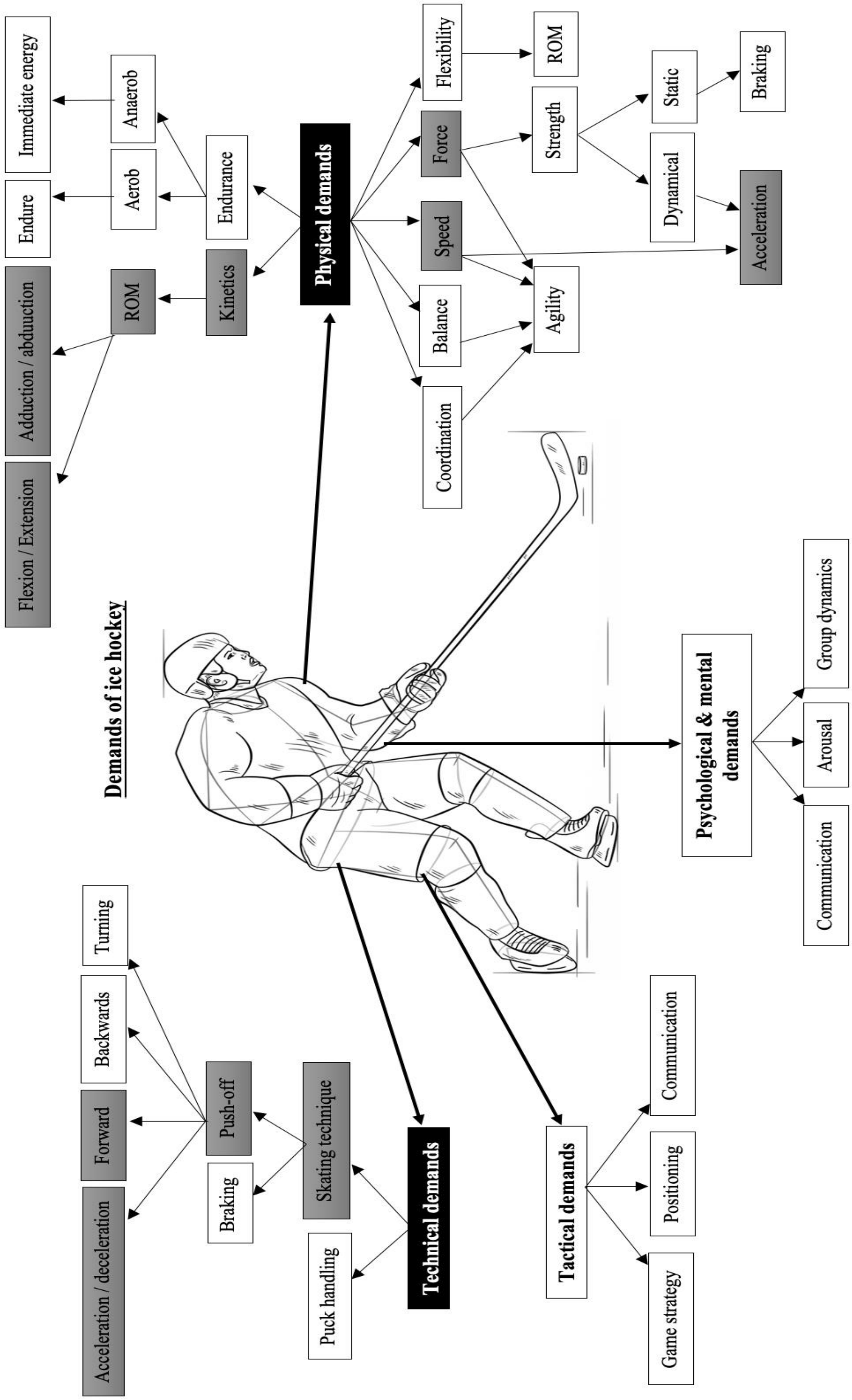
Appendix

Figure 1 – *Demands of ice hockey*



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