ICE HOCKEY GOALTENDING: PHYSIOLOGICAL LOADING AND GAME ANALYSIS

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ABSTRACT

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The ice hockey goaltenders have been acknowledged as crucial components of team success in ice hockey. The goaltending position differs greatly from forwards and defensemen and is therefore a very specialized position in ice hockey. As of yet, there has not been any in depth research directed to examine the goaltending game performance. Therefore, this study aimed to investigate the physiological loading of playing a game and also the action and performance during the game.

The measurements were done in the autumn of 2011 during the pre-competitive season. 9 subjects participated in the study of which 4 played in the elite league (SM-liiga), 2 in the second league (Mestis) and 3 in the A-junior elite league (A-SM). The measurements were done prior to-, during and after playing a game of ice hockey. The measurements included physical performance tests (Agility test, CMJ, Standing long jump, Isometric leg press, isometric trunk flexion and extension) that were done prior to and after the game. Blood lactate was measured prior to, during and after the game and heart rate was monitored for the entire game. All games were videotaped and analyzed with three separate video analysis methods. The actions that the goaltenders performed during the game, the working periods and their intensity and game performance were analyzed.

The physical performance tests showed that goaltenders physical performance declined or stayed the same from pre-to-post game and that there is clear inter-individual variation in physical performance from pre to post game. Performance changes correlated with the number of fast/explosive actions that were recorded from the working duration and intensity analysis. Statistically significant correlations were found between the number of fast/explosive working periods in the game and agility performance ($r = -0,708$, $p<0,05$), lower extremity power ($r = -0,713$, $p<0,05$) and sum of all leg measures ($r = -0,803$, $p<0,05$). Blood lactate showed only slight increases from resting levels. Heart rate for the entire game was on average 149 bpm ± 6.3 and averages of 159 bpm, 156 bpm and 154 bpm for each of the periods (1-3 periods). The action analysis showed that horizontal movement by utilizing c-cuts (skating technique) accounted for most of the total number of actions (36% / 140,2 ±34,7) and vertical movement for 17% / 66,8 ±13,6.

The working periods and intensity analysis showed that the subjects performed mostly low intensity working periods, whereas there were still a high number of short duration fast/explosive actions that took place inside of these low intensity working periods. The study indicates that physical performance is prone to decline, but that declines are highly individual. Blood lactate levels indicate that even though there are high intensive working periods in the game, there were adequate recovery periods or amount of low intensity working periods during the game, to allow sufficient recovery. Heart rate data indicated a need for good baseline endurance to endure game performance and promote recovery from high intensive working periods. The video analysis and the results from these analyses yielded important information about the nature of the physiological loading, game performance, demands and trends of the position, which are discussed in further detail in the research.

Keywords: Ice hockey, goaltending, game analysis, physical performance, actions during the game, working periods and intensity, game performance.

CONTENTS

1. INTRODUCTION

Playing as a goalie in ice hockey is demanding both physically and mentally. On the elite level the goalies need to be agile, fast, explosive, have quick reaction skills, good hand-eye coordination, flexibility and be quick in decision making to be able to be successful. (Bell et al. 2008) The technical and tactical skills also have to be well polished, to be able to play at the top level. In addition, the goalie has to be able to handle pressure and control his/her emotions during the game (Magnusson 2008). The goalie is in the spotlight during the whole game and he/she needs to stay focused in every situation and every shot, because otherwise it is highly possible that the opposition scores and the goalie gets the blame. There is a fine line between being a hero or a foe. Making a big save or making a mistake potentially dictates the result of the game.

An ice hockey game (including ice warm-up) can take up to 3,5 hours, with the actual game lasting approximately 2-2,5 hours. The goalie needs to be able to perform at a high level during the whole game; he/she does not get the chance to rest on the bench. Even though the goalie is not always active and gets to rest physically, mentally he/she needs to be aware of what is going on all the time, to be able to be ready for the next upcoming situation. Even though not many studies have been performed with goalies, some of the research has indicated that most of the goalies physical stress during the game is of low aerobic intensity, whereas these low intensity phases are interpreted by medium or high intensity anaerobic phases (Twist & Rhodes 1993; Vescovi et al. 2006). The goalie often has to perform fast, explosive movements of short duration in different game situations, whereas there are also phases where he/she has to maintain readiness and move for longer periods of time (e.g. when killing penalties) (Twist & Rhodes 1993). This is why the goalie needs to have sufficient aerobic endurance to endure the whole game and to be able to recover as fast as possible from the high intensity anaerobic actions (Näckel 2004a). The flow of the game itself dictates the ratio of different working intensities, since the goalie has to e.g. move, maintain ready position and stop pucks according to what happens on the ice.

2. GOALTENDING IN ICE HOCKEY

2.2. Physical performance demands

Ice hockey is a high intensity interval type of sport that sets versatile demands for the athlete in technical-, tactical-, physical- and mental qualities. Ice hockey is played for 3 periods with each period lasting 20 minutes and a possible overtime period. Intermissions last for 15-18 minutes. Before the game there is a 15-20 minute on ice warm-up after which there is a 20 minute break before the game starts. The whole game itself lasts for 2-2,5 hours.

Players shifts last on average 30-60 seconds. During the shift the player skates on average 250-300 meters and 5-7 kilometers during the entire game. The player completes on average 20-25 shifts, with 3-5 minutes of recovery after each shift. The game itself and the skill performances demanded are of short and high intensive nature. The performances are repeated sprint type activities and are mostly of anaerobic nature. To succeed in ice hockey, a well developed- and versatile fitness is needed. Speed, anaerobic-, aerobic endurance and strength abilities are highlighted in the sport performances. (Westerlund & Summanen 2001)

The starting point is different for goalies, since the goalie is on the for the duration of the whole game. The goalies position is very specific in relation to the players and demands well developed technical skills, physical fitness and psychological abilities. To play on the elite level, the goalies need to possess good agility, -speed, -explosiveness, -reaction skills, hand-eye coordination, - flexibility and to be quick in decision making. (Bell et al. 2008)

The actions of the goalies during the game are characterized by fast, explosive movements of short duration, between which there are rest periods and/or periods of lower intensity actions (Twist & Rhodes 1993). The goalies physical characteristics often differ from players. Goalies often achieve weaker results in endurance, strength and power tests in relation to players. On the contrary, goalies often achieve better results in especially flexibility. (Vescovi et al. 2006)

2.2.1. Endurance

In research performed with junior level goalies, approximately 75% of the game performance has been observed to be of low intensity, 21% medium intensity and 4% high intensity (Vescovi et al. 2006). In old timer recreational hockey games average heart rate within 9 subjects was 143 BPM, which is approximately 64% of max heart rate (Montgomery 1988). It is highly possible that these percentages are somewhat different in elite level senior games. It should also be remembered that the level of one's team and/or their level of play effects the demands set on the goalie. The amount of time spent defending and/or attacking as a team directly relates to the amount and duration of scoring situations and shots that the goalie faces.

On the base of the preceding, the goalie's game performance consists of both anaerobic and aerobic actions and therefore the game performance is divided in two dimensions. In scoring situations or when the opposition has the puck in the goalies own defensive zone, the goalie is often obligated to perform fast and explosive actions for which energy is produced mainly through immediate energy sources (ATP & PCr). The goalie may have to maintain ready in the basic stance and move for longer periods of time and/or make several saves in a short period of time for which energy is produced mainly through glycolysis. In these situations a significant amount of lactic acid is produced and acidity is increased. Post game lactate measurements have indicated that blood lactate values of goalies are usually not significantly higher than before the game. (Twist & Rhodes 1993)

Aerobic energy production is most evident when the game is not in the goalies end and/or there is no immediate scoring threat. The goalie is still involved in the game at all times and that is why the level of aerobic endurance needs to be sufficient to endure the whole game and to be able to recover as fast as possible from the high intensity anaerobic actions (Näckel 2004a) On the basis of the previous indications, one could assume that the lower intensity periods during the game and the intermissions makes removal of lactate possible and thereby the goalie is able to recover from these anaerobic actions quite well already during the game.

2.2.2. Strength

As mentioned already earlier, the game actions of the goalie is characterized by fast and explosive movements of short duration which are separated by periods of rest and/or lower intensity actions (Twist & Rhodes 1993). This would indicate that especially power and explosive strength qualities are highlighted in the game performances. In goaltending, most vital is the amount of force produced in a short period of time. Explosive strength and power is highlighted especially in the upper body, because the saving actions of the upper body (arms) are most often fast and explosive. Still the goalie needs some basic strength in the upper body as well for e.g. stick handling. (Näckel 2004a)

The strength demands on the lower extremities are clearly more versatile.(Näckel 2004a) For example muscle endurance plays a key role in e.g. situations where the goalie has to stay in the basic stance for longer periods of time (Twist & Rhodes 1993). To be able to move fast and explosively (Twist & Rhodes 1993; Vescovi et al. 2006; Bell et al. 2008), demands are set on explosive and power qualities.

2.2.3. Speed

The game demands very fast reaction speed, agility and sport specific movement speed of the goalie to be able to save and move quickly while maintaining readiness during the entire situation. Research on NHL goalies indicate that goalies should have good be fast, explosive and agile and in addition have sufficient endurance to be able to repeat fast lateral-, vertical and up-and-down actions for the entire 60 minute game. (Bell 2008 et al. 2008)

This indicates that the goalie needs to have good skating-, movement-, reaction speed and agility. In goaltending the most highlighted parts of speed are reaction speed, explosive speed and “speed skill”/agility (Näckel 2004a). An additional challenge is set on the goalie due to the bulky equipment and that is why sport specific speed and agility is vital.

2.2.4. Flexibility

Goalies usually possess greater flexibility qualities than the players. This is to be expected, since the goalie is expected to have good flexibility and it has been emphasized in goalie training (Twist & Rhodes 1993; Vescovi et al. 2006). The goalie often has to react fast and move his/her body through large ranges of motion (Vescovi et al. 2006). This means that for optimal performance, the goalie needs to have sufficient range of motion in different joints. The power, speed and precision of the performance are compromised if flexibility qualities are not sufficient. (Näckel 2004a)

Flexibility is highlighted in many situations, because the goalie has to be able to reach as high range of motion as possible in many saves, to be able to stop the puck and to still maintain a well balanced position. (Vescovi et al. 2006; Näckel 2004a)

2.2.5. Motor skills

Goalies need to have good movement skills, coordination, balance and body control. The goalie needs good movement skills and coordination, for example, to perform different save techniques and to save the puck. In addition, it is vital that the goalie is able to control and balance his/her body extremely well to e.g. be able to maintain readiness to stop the puck while scoring chances follow each other.

General motor talent is to some extent hereditary and a goalie with good motor talent learns new movements faster and has a larger movement model "bank" in his/her use The reach the elite level, the goalie has to have motor talent and skills to be able to quickly interiorize and perform different sport specific actions. (Näckel 2004a).

2.3. Psychological demands

The playing position of the goalie is mentally one of the most demanding, if not the most demanding in ice hockey. The goalie has to be able to concentrate for the duration of the entire game and still be able to focus his/her attention to each single situation at a time. The goalie is in a very centered position when thinking of the outcome of the game, his/her performance can determine the win or loss of the team. Under this pressure, the goalie has to be able to manage the pressure situation and preferably even feel more at home when the pressure increases. (Magnusson 2008)

Elite level goalies are most often controlled and mentally balanced, even if he/she has let in a goal or made a great save. Players often sense if the goalie is calm and confident, or if he/she get aroused easily or acts nervous on easy shots. An elite goalie often ”glows” of confidence by stopping pucks, of course, but also by controlling his/her emotions in every situation. (Miller 2001) Mental preparation is vital and the goalie needs to practice to cope with the game situation. When the goalie learns to control his/her emotions and thoughts, he/she is better able to control anxiety and pressure situations. (Magnusson 2008)

2.4.Technical skills

Game stance

The game stance is one of the first things that a goaltender should learn to be able to have good game- and save readiness. All movements and actions that the goalie does should start form and end in the game stance. The goalie can make e.g. saves or skating motions, but should always aim to recover to the game stance. A good stance is one from which the goalie can move well in any direction and where the goalie can stay for longer periods of time. (SJL 2002; 2008)

The stance is very individual and it is dependent on the goalies style of play. Generally one could say that there are three different game stances; narrow stance (a stand-up goalies stance), wide stance (often used by butterfly style goalies, FIGURE 1) and a hybrid stance (a intermediate version between the narrow and wide stance). Nowadays most goalies prefer to use the wide or hybrid stance, because they make dropping down on the ice into the butterfly position faster and make skating (moving) more efficient when the angle of the skate blade is more optimal against the ice. (Daccord 2008) Playing with a wide basic stance may make lateral movement somewhat more difficult and that is why the goalie should have good skating skills and edge control. (Magnusson 2008)

The basic elements of the game stance are:

- Feet slightly over shoulder width apart and knees bent
- Back straight and upper body slightly tilted forward
- The blade of the stick on the ice and covering the five hole
- Gloves in front of the body, out from the body, about at the same lateral level and directed towards the puck
- Weight evenly distributed on both skates
- Upper body relaxed
- Eyes on the puck

FIGURE 1. Wide stance (Ropponen 2002)

Skating and movement techniques

The goalies skating can be divided into so called normal skating, which is the same as with players, and so called technical skating, which is goalie specific skating. The basic conditions for good technical skating is good basic skating skills and the right basic stance, good balance, -agility, -speed, -coordination and - game sense. In game situations it is important that the goalie always moves according to- and stays square to the puck, maintain a solid basic stance, maintains readiness to make a save, moves with correct timing and strives to always stop into the game stance before the save (making the save while stationary). The goalie should strive to never needing to hurry to make the save, rather always being able to move and stop before the shot. (SJL 2002;2008) Skating skills are the foundation to goaltending and a goalie that moves well is also often a goalie who succeeds. This is something that sets a challenge for both technical skills and physical abilities. (SJL 2008, Magnusson 2008)

According to the Finnish Ice Hockey Association (SJL 2002;2008), the skating techniques can be divided as follows:

TABLE 1. Ice hockey goaltender movement techniques (Modified SJL 2002; 2008)

Horizontal movement
- C-cuts
- T-push
Lateral movement
- Shuffle
- T-push
- Sculling
- Crossover start
Stopping techniques
- Two foot plow stop
- One foot stop
Movement techniques while down on the ice
- Half-butterfly movement
- Paddle down movement
- Moving in the butterfly position
Recovery techniques

Positioning

The primary aim in goaltending is to be positioned between the centre of the net and the puck at the moment of the shot. The goalie aims to cover or by using some save technique, prevent the opponent from scoring in different goal scoring situations. Through optimal positioning the goalie aims to cover as much of the net as possible. This means that the goalie must master both lateral- and vertical positioning. Positioning can be thought of as a part of the save, because through optimal and optimally timed positioning the goalie gives him-/herself a better chance of making the save and prevent the opposition form scoring. The primary target is that the goalie should always strive to be able to move and get positioned optimally before the initial scoring chance or shot and this way be able to focus maximally on making the save. The foundation for optimal positioning is good game sense, -skating technique and – physical abilities. (SJL 2002; Ekholm & Nykvist 1996)

In most situations, the goalie should aim to be positioned horizontally on the top of the goalie’s crease. When the goalie is positioned on top of the crease, he/she covers most of the net effectively and is able to save shots from further away through reacting. Horizontal positioning becomes even more important when the play is close to the net, because there is very little time to react and this is why the goalie often has to rely on stopping the puck through maximally covering with some save technique (most often the butterfly technique). (Mikkola 1987)

Still it should be kept in mind that the goalie should not position him-/herself wrong horizontally or laterally. If the goalie plays too deep in the net he/she doesn’t cover as well and this opens up more space for the opposition to score. By playing too far out of the net, the goalie puts him-/herself in danger of playing him-/herself out of the situation in case of a pass or a fake. If the goalie positions him-/herself wrong laterally, this means that some part of the net is more open for scoring. (Mikkola 1987)

Save techniques

The goalie should have a wide collection of save techniques, which he/she modifies and uses in different situations. Game analysis have revealed that in modern goaltending, the goalie saves most shots by dropping down on the ice into the butterfly position. This is why the butterfly save has become the most used save technique in the modern day.

By utilizing the butterfly save, the goalie gains good coverage and a good readiness to make the save. (Näckel 2004b) The butterfly save is very effective to save shots on the ice and low shots. In the butterfly save, the goalie drops down on both knees, the pads and stick covers the five hole and by bringing the arms and gloves out, one is able to cover the armpits. The butterfly position should be stable, upright and the hip should stay high. (SJL 2008)

One should be able to use the butterfly save in the right place and right time, but it should be remembered that it is not the only possible save technique (Korn 2005). The different save techniques can be divided according to the height of the shot (FIGURE 2). The shots can be divided into shots on the ice, low shots and high shots. The shots of different height can be caught with the glove, smothered into the body or directed away from the net by using the stick or other equipment. (SJL 2002; 2008)

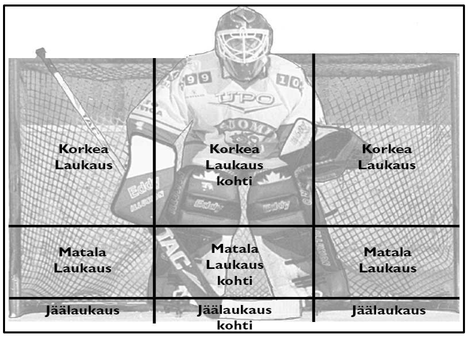

FIGURE 2. Save techniques divided according to shot height (SJL 2002).

Even though the height of the shot to some extent determines the selection of the save technique, the goalie often uses the same technique to save shots of different heights (e.g. butterfly save). Save techniques are also often divided into stand-up saves and saves while down on the ice. Stand-up saves are characterized by the fact that both skates stay on the ice whereas saves on the ice are often butterfly saves where both pads are on the ice. The principle behind all the different save techniques is that the goalie should be able to select the most proper save technique according to the game situation. (SJL 2008; Magnusson 2008)

Stickhandling

The goalies ability to handle and play the puck has become more and more important in modern ice hockey. The goalie needs to be able to contribute both to prevent scoring and by playing the puck to promote the play of his/her own team. The goalie has to master the different stick handling techniques, because he/she needs to able to take part in the game both close to the net and outside the goalies crease. The goalie has to be able to e.g. pass the puck, intercept passes, play loose pucks and clear the puck out from the own defensive zone. (Daccord 2008; SJL 2007) Stick handling techniques can be divided into passing and clearing with a two hand grip or with one hand grip, poke checks, stopping shoot-ins and intercepting passes. (SJL 2007)

2.5. Tactical skills

Game sense

In the Finnish Ice Hockey Associations education material (2008) game sense is divided into understanding the game, reading the game and decision making. In goaltending game sense is the ability to make right decisions with respect to preventing the opposition from scoring and the transition game. Additionally, it is an understanding of the right models of action, right movements and actions and their execution in the right time and place in different game situations. The goalie has to understand and read the game correctly, to be able to function and make decisions according to the game situation.(SJL 2008)

Understanding the game in a wider perspective is related to understanding the basic principles of the offensive- and defensive game. Understanding the game specifically form the goaltending perspective is an understanding of the aims of goaltending and the principles of cooperation with the players of one’s own team. The goalie has to understand the meaning of optimally timed and executed positioning and movement in different game situations. The goalie has to understand the effects of the players and pucks movement, -direction and speed on the game and be able to understand and observe these. (SJL 2008)

Reading the game requires the ability to interpret and read the scoring game. It requires the observation of the puck, opposition and own players and their location, direction of movement and speed in relation to the ice surface and situation. The key in reading the game is the ability to anticipate and react to the forthcoming scoring situation in the right way. The goalie has to be able to pay attention to the oppositions puck carrier and the most dangerous non puck carriers. (SJL 2008)

The goalie has to be able to choose a relevant game skill in accordance to the scoring situation based on his/her understanding and reading of the game. The goalie cannot anticipate the save action, although he/she can based on so called advance information estimate where the shot is going to be directed. (SJL 2008)

Horizontal/Depth positioning

The horizontal positioning of the goalie was already discussed in the earlier part, here there will take a more closer look at depth positioning. Many different sources favor the top of the goalie areas crease to be a good starting point in most cases for depth positioning (Daccord 2008; Näckel 2004a; SJL 2008). When the goalie plays on top of the crease he/she covers the net sufficiently and is still able to react to shots and cannot be played out of most situations e.g. following a lateral pass. In addition, when the goalie is positioned on the top of the crease, save movements are shorter in relation to playing deep in the net which improves save quality and puck control. (Näckel 2004a)

On the contrary if the goalie is positioned far over the top of the crease, moving to e.g. rebounds becomes much more difficult and the goalie easily plays him-/herself out of the situation (Näckel 2004b). The depth positioning of the goalie in game situations is constricted by e.g. open players at the back post, screens and traffic in front of the net and coming late into a situation when the primary goal is to get centered to the puck. (SJL 2002)

Net coverage

Background: reacting. The basis for positioning in different game situations is to some extent based on physiology, namely reacting. Reaction has two phases: reaction time and reaction movement (response time). Reaction time is intrinsic reaction and there is no movement involved. Not until the reaction time has passed, reaction movement (save movement) can start. The goalies reaction time in a game situation is approximately 0,2 seconds and not until this time the goalie can perform a reaction movement(save movement). There is also a slight delay involved in the save movement, depending on the movement and the limb that performs the movement. In addition, e.g. the weight of the gear affects the speed of the movement. (Mikkola 1987)

The fastest save movement is the movement of the glove hand approximately 0,2 seconds. Saving a low shot with the pad can last 0,4 seconds. Based on the previous, the goalies time to make a save can be calculated by computing the reaction time and save movement time together, which means the time from the observation to the actual save. The time it takes to make a save in adults vary between 0,25-0,6 seconds depending on the situation and individual. (Mikkola 1987)

When relating this to a game situation, if a player makes the slap shot at 115 km/h from 10 meters away, the goalie has 0,31 seconds time to make the save. The time the goalie has to make the save is based on the distance to the net and the speed at which the puck is shot. The goalie usually makes the save when he/she has more time than what is needed to make the save. Whereas if the time that the goalie has to make the save is less than what is needed, the puck will go in if it doesn't hit some body part of the goalie. The goalie can decrease the time needed to make a save if he/she is able to anticipate the direction of the shot according to a visual cue just before the shot. An anticipation of even a split of a second may result in a save instead of a goal. (Mikkola 1987)

Net coverage and blocking. In close situations the goalie doesn't have time to properly react to shots and most often strives to stop the puck by blocking, positioning and moving. Timing is very important when performing a blocking save. In blocking situations the goalie can often through advance information of the situation, make the selection of performing a blocking save. It is vital that the save is not performed to early, because then the puck carrier can change his/her decision and for example move laterally with the puck. The closer the puck is to the net, the more the goalie is able to cover of the net. On the contrary, the further away from the net the puck, the less is the advantage of coverage. (Mikkola 1987)

Depth positioning is the most vital thing in regard to net coverage and its meaning is increased the closer to the net the shot comes. The butterfly save is a effective save technique to cover especially low- and shots on the ice. The goalie covers quantitatively more of the net in the butterfly position than in the basic stance. (Mikkola 1987) Even though the goalie is essentially striving to cover/block the shot, he/she should strive to keep his/her arms and gloves actively in front of the body and directed towards the puck. This way he/she is able react to situations, shots, rebounds and to optimally cover high shots to which he/she doesn’t have time to react. (Daccord 2008; Näckel 2004b; Ropponen 2002)

Save selection

The goalie should select the type of save used based on the area and place where the shot comes from. The defensive zone can be divided into four different sectors when looking from the scoring perspective and from the goalies perspective, which type of save is reasonable to use from different sectors. With respect to the selection of the save, it is important notify how much of the net one can cover with different saves, how much time one has to make the save (reaction) and what type of save is most reasonable for being ready for continuum of the game. The defensive zone can be divided into shots from distance, shots from narrow angles, shots from the scoring area and close situations. (Näckel 2004a)

Shots from distance. Shots from distance mean shots from that distance from where the goalie has time to react to the shot. It is may be difficult to define the exact line where this distance is since it is affected by the size of the rink, quickness and speed of the shot and the goalie’s individual reaction ability, but in general it can be thought of as been at the level of the top of the face-off circle and above (FIGURE 3). Shots form distance should be stopped by reacting and the save can be performed either by using a stand-up save or a save on the ice. It is essential that the goalie doesn’t anticipate the shot and that the he/she is patient to read where the shot is directed. (Näckel 2004a)

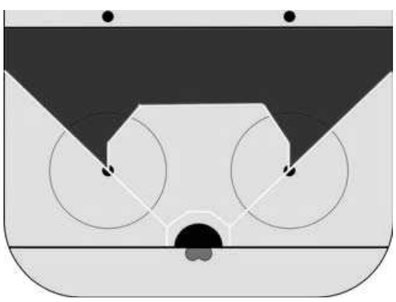

FIGURE 3. Shots from distance

Shots from narrow angles. Shots from narrow angles mean shots that are shot from the outside of the face-off dots in the defensive zone (FIGURE 4). As a general rule in these shots is that the goalie saves these shots by using stand-up saves. The narrower the angle, the more beneficial it becomes to play the situation by standing up, because the net gets narrower (viewed from the puck's perspective) the further the puck is taken to the side whereas the height stays the same. The ice level is well covered with the butterfly save, but the armpits are often left open regardless of the sector form which the shot comes and how far out from the net the goalie plays. By playing in a stand-up position the goalie can cover almost the entire net. It is still vital to remember that the basic stance should be narrowed by bringing the pads together so that the five hole can be covered. (Näckel 2004a)

In narrow angle shots the goalie can play a little deeper in the net positioning wise, because the goalie can cover the net by less depth positioning. When the puck is taken to a zero angle, the goalie should move next to the post and make sure to cover the holes next to the post. (Mikkola 1987) Another save technique that can be utilized in narrow angle shots is the one pad up save or post load save. The post load may be used in narrow angle shots that come closer to the net, walkouts and when the puck carrier drives the net for below the goal-line. (Magnusson 2008)

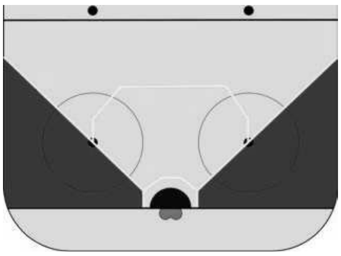

FIGURE 4. Shots from narrow angles (Näckel 2004a)

Shots from the scoring area. Shots that come from the scoring area(FIGURE 5) cannot be saved purely by reaction. The butterfly save technique is often most effective, because covering the net optimally becomes vital in these situations. The goalie should aim to be positioned on the top of the crease when performing the butterfly save, so that he/she is able to cover the ice level as effectively as possible while the arms and glove and blocker covers the top corners. (Näckel 2004a) In fast situations it is still vital to keep in mind that the goalie should first move to get centered to the puck and after that start to narrow down the angles by moving out. (Corsi & Hannon 2002, 144). The goalie must be able to make save movements with his/her arms and gloves in the butterfly position to be able to maintain good puck control and neglect unnecessary rebounds (Näckel 2004a). In some situations where the shot comes from close distance and there is minimal reaction time, it may be better to take a more blocking type of butterfly position and bring the arms and gloves tightly into the body. (Magnusson 2008)

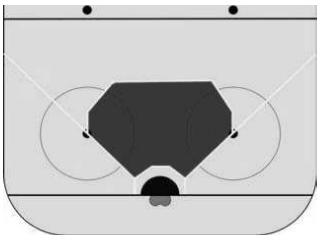

FIGURE 5. Scoring area (Näckel 2004a)

Plays close to the net. Plays close to the net (FIGURE 6) often emerge when a player drives to the net, passes the puck to the net or when a rebound or loose puck is created. These situations are approximately 1m away from the goalies crease or closer and that is why the goalie should preferably utilize the butterfly technique or by using the paddle down technique. Maximal coverage is vital in plays close to the net. The paddle down technique is somewhat wider than the butterfly technique, which may be an advantage if the situation changes slightly laterally. (Näckel 2004a).

In the butterfly save one may reach the same coverage by bringing the arms in front of the body and by closing the armpits (Näckel 2004a). The butterfly save's strength compared to the paddle down, is that it enables one to move more effectively in different directions and thereby brings about better readiness for e.g. rebounds. In close plays, it is vital that the goalie can maximally cover the net and remain readiness to make a save.

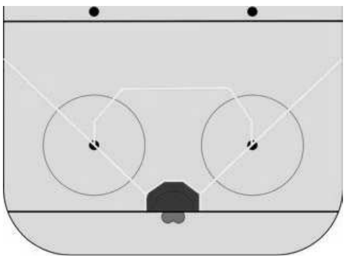

FIGURE 6. Plays close to the net (Näckel 2004a)

Cooperation between the goalie and the players

The cooperation between the goalie and the players in the team has to be on a good level for the team to succeed (SJL 2006). The goalie see's the game and the creation of different situations very well from the net. The goalie should be vocal to guide and help his/her own teams play. When the goalie helps the players, making decisions becomes easier and knowledge of the situation assists the player's decision making. (Daccord 2008)

There are several situations in the game where there is a need for the cooperation and communication between the goalie and the players. For example different scoring situations, screens, dump-ins and rims and guidance of the defensive game requires cooperation and communication. The cooperation, communication and actions in different game situations should be agreed upon in advance, practiced and functional so that it actually serves the game of the team. (SJL 2006)

For example in 2 vs. 1 situations the most common agreed mode of action is that the defenseman plays between the two opponents and strives to position him-/herself so that he/she can cut down the shooting- and passing angle and then preventing the pass and leaving the puck carrier for the goalie. Another example is dump-ins and rims, where communication between the goalie and the players is important so that the goalie knows what to do with the puck after e.g. stopping it behind the net. (SJL 2006)

3. ACUTE METABOLIC AND NEUROMUSCULAR RESPONSES TO REPEATED HIGH INTENSITY EXERCISE WITH REGARD TO TEAM SPORTS

The actions of the goalies during the game are characterized by fast, explosive movements of short duration, between which there are rest periods and/or periods of lower intensity actions (Twist & Rhodes 1993). Physical performance measures in goaltenders from games have not been widely studied and there is limited available information from actual research performed with goalies. Some reports exists that give direction to the physical loading of the game performance.

In research performed with junior level goalies, approximately 75% of the game performance is of low intensity, 21% medium intensity and 4% high intensity (Vescovi et al. 2006), but it is highly possible that these percentages are somewhat different in elite level senior games. Since the goalie’s actions in the game depend to mostly on the flow of the game, the actions may vary from very short single actions to longer phases of actions involving several high intensity efforts. The recovery time between these actions also vary according to the flow of the game.

The goalies actions in the game are both anaerobic and aerobic actions and therefore the game performance is divided in two dimensions. For example, in scoring situations or when the opposition has the puck in the goalies own defensive zone, the goalie is often obligated to perform fast and explosive actions for which energy is produced mainly through immediate energy sources (ATP & PCr). Energy that is derived from the stores of ATP and PCr are considered the alactic component and it has been estimated to contribute between 20-30% of the anaerobic energy in high intensive exercise lasting 2-3min (Bangsbo et al. 1990; Saltin 1990; Medbø et al. 1988).

The goalie may have to maintain ready in the basic stance and move for longer periods of time and/or make several saves in a short period of time for which energy is produced mainly through glycolysis. In these situations a significant amount of lactic acid is produced and acidity is increased. Post game lactate measurements have indicated that blood lactate values of goalies are usually not significantly higher than before the game (Twist & Rhodes 1993). Aerobic energy production is most evident when the game is not in the goalies end and/or there is no immediate scoring threat.

Many team sports require one to perform several maximal or near maximal efforts of different duration during the game. Therefore it is important to understand the underlying mechanisms that relate to the metabolic effects and fatigue of repeated high intensity exercise. When thinking of the goaltending position, due to the flow of the game dictating the number and duration of different situations, there is great variability in the duration and intensity of actions and also in the recovery time between actions.

Fatigue can be described as a temporary decrease in performance capacity of the muscles and can be usually seen as a failure to maintain or develop expected force or power output. Muscular fatigue may be caused by both central and peripheral mechanisms ranging from the motor centers in the brain to the contractile apparatus in single muscle fibers. The central nervous system as a cause to fatigue has been questioned, but it may play a role in some instances. Most evidence point to changes in the periphery as the major limiting factor to force production in fatiguing conditions. (Enoka 2002; Gardiner 2001)

3.1. Metabolic factors

3.1.1. Energy system contribution

Selinger et al (1972) reported an 69% contribution of anaerobic metabolism and a 31% contribution of aerobic metabolism during a simulated shift. Afterwards Green et al. (1976) estimated the on ice energy requirements to be 70-80% of VO2max in university players. Since many studies have not been performed with ice hockey players in relation to energy system contribution, studies that resemble the actions of the game may give indications for performance indications.

An study in which they investigated the change in muscle metabolism during two 30s cycle sprints separated by 4 min of recovery, reported a 41% decrease in anaerobic energy production in the second sprint. Nonetheless, the decline in the total amount of work was only 18%. The difference in anaerobic energy production and total work was to some extent explained by an 15% increase in oxygen uptake during the second sprint. (Bogdanis et al. 1996) Other studies that have utilized the 30s repeated sprint protocol have also reported great decreases in the rate of glycolysis in the following sprints, whereas the decrease in power output was not as significant as in the rate of glycolysis. (McCartney et al. 1986; Trump et al. 1996) Similar responses have been seen during 6s repeated sprints, which more closely resembles the repeated high intensity actions of many team sports. (Gaitanos et al. 1993; Spencer et al. 2004)

In a study performed by Gaitanos et al. (1993) shorter sprints of 6s were repeated ten times, followed by recovery periods 30s. The rates of muscle glycogen breakdown, PCr hydrolysis and lactate accumulation all declined greatly as the number of the sprints performed increases. Therefore it is not surprising that the decrease in energy production was followed by a decrease in power output and a decrease in the total amount of work done in consecutive high intensive sprints. Interestingly there was no change in muscle lactate during the last sprint even though power output was only 73% of what it was at the first sprint. They suggested that because anaerobic glycogenolysis for ATP production was reduced, power output was supported by energy derived from PCr degredation and increased aerobic metabolism. According to this evidence, aerobic contribution may be of importance to repeated sprints, whereas it does not play a major role in a single sprint.

TABLE 2. Muscle metabolites before and after the first and tenth 6s sprint on cycle ergometer with 30s recovery between sprints. (Modified, Gaitanos et al. 1993)

Metabolite	First 6-s sprint		Tenth 6-s sprint	
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Glycogen	79,00	68,00	55,00	50,00
ATP	6,00	5,20	4,10	4,10
ADP	0,75	0,87	0,67	0,87
PCr	19,10	8,20	9,40	3,10
Glucose	0,40	0,60	2,00	2,10
Lactate	0,20	7,20	29,10	28,10

The energy system contribution during repeated actions seems to be greatly affected by the duration of the sprints or actions. Balsom et al. (1992) investigated the physiological responses to repeated sprints of different duration, 15m, 20m and 40m, with 30s of passive recovery between sprints. They reported that oxygen consumption was increased after the 30 and 40m sprints compared to the 15m sprints. In addition, markedly lower blood lactate values were observed following the 15m sprints than the 30 and 40m sprints. The 15m sprints could be performed without significant decrease in performance, whereas the 40m sprint times started to increase after the third sprint.

Balsom et al. (1992) also investigated the effect of recovery duration in repeated sprint exercise in a study where 15 times 40m maximal sprints were performed with passive recovery durations of either 30, 60 or 120s. As to be expected, sprint performance significantly decreased in both the 30 and 60s recovery protocols whereas no significant decreases in performance, as compared to the other recovery protocols, were observed in the 120s recovery protocol. Higher post-exercise oxygen consumption and blood lactate concentrations were observed after the shorter recovery protocols. This indicates that the duration- and number of repeated actions and recovery duration clearly influences the energy system contribution during repeated sprint or other high intensity sprint type actions.

3.1.2. ATP depletion and resynthesis

Muscle ATP stores do not deplete more than to maximally approximately 45% of pre-exercise levels during repeated sprint or sprint type exercise (McCartney et al. 1986; Hargreaves et al. 1998; Bangsbo et al. 1990; Saltin et al. 1983). Still, the amount of the change in muscle ATP concentration may vary significantly and have been seen in studies where similar exercise protocols have been used. In two different studies using 6s sprints with 24-30s recovery between sprints, declines in muscle ATP have varied between 4-24% of pre-exercise levels (Balsom et al. 1995; Dawson et al 1997). The significant difference in the amount in muscle ATP concentration is likely to result from the intensity of exercise, because the other study utilized maximal exercise and the other high intensity exercise.

In addition, in the study performed by Dawson et al. (1997) they found that ATP concentration was greatly lower than pre-exercise still after 3min of recovery. A possible reason for this phenomenon has been suggested to result from low ATP concentrations and intramuscular acidity that causes a decline in the resynthesis rate of PCr following intensive exercise (Spriet et al. 1989). If this assumption is correct, it would imply an important factor for repeated sprint and high intensity action sports, where recovery between actions is often limited. Although ATP resynthesis may be related to low ATP concentrations and intramuscular acidity, the initial fast phase of PCr resynthesis is also strongly suggested to be related to oxygen availability (Haseler et al. 1999; Harris et al 1976).

3.1.3. PCr reduction and resynthesis rate

Changes in phosphocreatine (PCr) have not been widely studied in ice hockey during a game, but Green et al. (1976) estimated that during a 30s stoppage in play, PCr concentration can be restored to a 60-65% level and can be utilized in the reminder of the shift. In other studies, a strong relationship has been found between 30 sprint performance during repeated sprint exercise and PCr resynthesis (Bogdanis et al. 1996; Trump et al. 1996). Accordingly, Bogdanis et al. (1996) proposed that the ability to produce high power outputs is directly related to the resynthesis of PCr.

In Gaitanos et al. (1993) study where 6s sprints were performed with 30s recovery periods, they found that there was a significant decrement in power output by the fifth sprint and a total reduction of one third by the last tenth sprint. PCr contributed for 50% of the total anaerobic ATP production in the first sprint and PCr contribution increased to approximately 80% in the tenth sprint, although it should be noted that the absolute contribution of PCr to total ATP production greatly decreased from the first to the tenth sprint. The decline in PCr concentration to 57% of pre-exercise values after the first sprint and the progressive decline to 16% after the last sprint clearly demonstrates that the short recovery periods of 30s is not sufficient to resynthesize PCr.

Dawson et al. (1997) completed a similar type of protocol with five 6s sprints interpreted with 24s of recovery between sprints. They found a reduction in PCr to 45% of pre-exercise values and that PCr stores were replenished to 84% of pre-exercise values after 3min of recovery. This data indicates that replenishment of PCr stores may be compromised in team sports where recovery time between sprints may be limited. Creatine supplementation has been shown to have a positive effect on PCr store replenishment in recovery between repeated high intensity actions (Bogdanis et al. 1995; 1996).

The time required for the PCr stores to be replenished is dependent on the level of the degradation of the stores, which is to be expected due to that the resynhesis must begin from a lower level (Dawson et al. 1997). It is possible that PCr stores can be almost completely depleted (Hultman et al. 1990; Bogdanis et al. 1995; Vollestad & Sejersted 1988). On the other hand, after significant PCr depletion, the initial rate of PCr resynthesis increases (Smith et al. 1998; Yquel et al. 2002). There is a fast and slow component in the resynthesis rate of PCr following intensive exercise (Harris et al. 1976; Nevill et al. 1997). The half time of the PCr resynthesis is suggested to range between approximately between 20-60s (Harris et al. 1976; Bogdanis et al. 1995). Creatine supplementation has been shown to increase the rate of PCr resynthesis, possibly due to a decrease in accumulation of inorganic phosphate and a more neutral muscle pH, which yields a higher mean power output during maximal repeated sprint exercise (Yquel et al. 2002).

Spencer et al. (2004) investigated the type of recovery during a field hockey game and concluded that approximately 95% of the recovery was of active nature with most being of jogging intensity. Spencer et al. (2003) conducted a protocol involving six 4s sprints with either 21s of passive or active recovery at 32% of VO2max. They reported a greater decline in power and also lower peak power in the final sprint. They suggested that active recovery may hinder PCr resynthesis during repeated sprint exercise when possible recovery time between sprints is limited.

3.1.4. Glycolysis and glycogenolysis

Repeated type of sprint or high intensity exercise may result in significantly high muscle lactate concentrations and depends much on the exercise duration, number of actions, recovery duration and intensity of the exercise. Protocols utilizing 30s cycle sprints have reported significant increases in muscle lactate, although these may not reflect team sport performance (McCartney et al. 1986; Bogdanis et al. 1996; Hargreaves et al. 1998). Green et al. (1976) reported highest blood lactate concentrations in the first and second period (8,7 and 7,3 mmol/l) whereas lowest values were observed in the third period (4,9 mmol/l). Similar values were observed for defensemen and forwards, whereas goaltenders had only small elevations in blood lactate from pre-game values. The quite low values observed in ice hockey are most likely due to stoppages in play during the shifts. Pauses provide time for PCr resynthesis up to 60-65%, which can be then utilized during the next phase of the shift. (Montgomery 1988)

Glycolysis is associated with accumulation of hydrogen ions that have been related as a cause of muscular fatigue (Sahlin 1992). Even though repeated actions result in higher lactate concentrations than with single actions, glycolysis is declined in the following actions. In Gaitanos et al. (1993) study, with ten times 6s cycle sprints with 30s of recovery, the estimated rate of glycogenolysis, glycolysis and glycogen degradation were significantly greater in the first than in the last sprint. They reported a significant declines in glycogenolysis and in glycolysis in the last sprint (11 fold and 8 fold respectively) although glycogen degradation was reduced by approximately 37%. They found that average power output in the last sprint was 73% of that of the first sprint, indicating that ATP production was mostly derived from PCr and oxidative metabolism.

Significant reductions in muscle glycogen content have been reported during repeated sprint protocols (Bogdanis et al. 1996; Gaitanos et al. 1993; McCartney et al. 1986). Åkermark et al. (1996) report that in a typical game of ice hockey, the muscle glycogen level can drop to a low level, which may decline the performance capacity at the end of the game. Green et al. (1978) reported that depending on the muscle fiber type of the player, both defensemen and forwards exhibited an approximately 60% decrease in muscle glycogen content compared to pre game values during the game. The most pronounced decrease could be found in the Type I muscle fibers, whereas in the Type II fibers glycogen utilization was significantly less. Glycogen content of Type II fibers tend to be quite high, which would indicate that glycogen depletion would not be a cause of fatigue in ice hockey (Montgomery 1988).

Attention should be paid to nutrition, because during a week many games and practices are performed. In a study where a group of players followed a high carbohydrate diet they achieved greater glycogen content than the control group. By application of high carbohydrate diets, they have been able to show significant increases in skating distance, number of shifts during a game and duration of a single shift. (Åkermark et al. 1996; Simard et al. 1998)

3.2. Neuromuscular factors

A common response during repeated high intensity actions is the inability to maintain similar mechanical performance in the following actions if recovery time is less that optimal (Balsom et al. 1992; Dupont et al. 2005). The force-fatigability relationship indicates that the greater the force exerted by a muscle or motor unit during a task, the more the muscle will fatigue (Enoka & Stuart 1992; Hunter & Enoka 2001). This same relationship applies also to repeated high intensity exercise. This means that individuals with high initial power output levels usually experience the greatest decrements in power. (Hoylmard et al. 1987; Hamilton et al. 1991; Bishop et al. 2003; Wadley & Le Rossignol 1998; Bishop et al. 2004).

The factors that underlie the differences in fatigability are somewhat unknown. Some evidence support the fact that greater absolute forces are linked with greater contribution of anaerobic metabolism, which then would result in greater accumulation of metabolites and/or earlier decrement of immediate energy stores. (Hirvonen et al. 1987; Gaitanos et al.1993; Bishop & Edge 2006).

Neuromuscular factors may also have a contribution to the muscle fatigue during repeated high intensity exercise. There are several different suggestions to how neuromuscular factors may affect, but a general consensus has not been reached yet. To be able to maintain a desired power output during maximal sprints or actions, the nervous system would need to recruit all motor unit pools at the highest possible firing rate (James et al. 1995; Krustrup et al. 2004). Some studies have utilized surface EMG measurements have supported this view by showing a steady level of neural activation during repeated sprint-exercise although mechanical performance has been shown to progressively decrease. (Hautier et al. 2000; Billaut et al. 2005).

In other studies with MRI measurements, clear decrements in muscle activation in response to maximal intermittent cycling sprints and a reduction in the central nervous system drive to the active muscles (Mendez-Villanueva et al. 2007; Racinais et al.

2007). Changes and non-optimal motor unit activity may therefore potentially relate to the development of muscular fatigue during maximal repeated actions (Kawakami et al. 2000; Taylor et al. 2000; Racinais et al. 2007).

High- and low frequency fatigue and spinal level factors

In regard to the mechanics involved within the muscle itself, they have been classified into high- and low-frequency fatigue (Jones 1996). High-frequency fatigue results from fluctuation in the action potential propagation over the sarcolemma or t-tubules. Low-frequency fatigue relates to Excitation-Contraction coupling failures. (Perrey et al. 2010).

More evidence has been put forward in the recent years, in addition to peripheral alternations, which indicate that reduced neural activation of the muscles is likely to compromise motor performance during high intensity intermittent exercise (Racinais et al. 2007; Girard et al. 2008). Racinais et al. (2007) used a interpolated-twitch technique before and after a repeated sprint cycling test, which showed that the inability to maintain the power output from repetition to another is associated to significant decrements in neural drive to the working muscles. On the contrary, there are also studies which do not agree with these findings (Billaut & Basset 2007; Hautier et al. 2000).

At the spinal level, H-reflex recordings may be used to detect changes in net synaptic excitatory input and excitability of the motoneuron pool (Perrey et al. 2010). By using this method, they have observed decrements in reflex sensitivity as a result of repeated intensive stretch-shortening cycle (Avela et al. 2006) and prolonged intermittent exercises (Racinais et al. 2007; Girard et al. 2009). The exact mechanisms that are responsible for reduction in the H-reflex are not fully discovered. Yet there is evidence to suggest that accumulation of muscle metabolites with fatigue may play a role in H-reflex modulation. (Perrey et al. 2010) This suggestion is supported by findings that indicate a correlation between hydrogen ion (H+) accumulation and the change in group III and IV muscle afferents discharge rate, which in turn to far extent determine the H-reflex amplitude (Sinoway et al. 1993). When considering the association between the ability for repeated high intensity actions and changes in muscle buffer capacity and blood pH, it could be reasonable to argue that repeated high intensity exercise could significantly impact the spinal loop properties (Perrey et al. 2010).

4. PURPOSE OF THE STUDY

4.1. Objectives

The primary objective of this study was to provide an in depth analysis of the ice hockey goaltending game performance and the demands of the position. Ice hockey goaltending has not widely been studied and the aim for this study was therefore to provide information on the goaltending performance. Pre- and post-game physiological measurements will provide a picture of the physical performance of the subjects and also provide information of the physiological loading of the game performance. In addition the blood lactate measurements and heart rate monitoring will give information of the physiological demands of the position. The game action- and working period and intensity analysis will provide information on the actual events during the games and thereby provide facts of what the game performance consists of. The performance analysis will provide information of shots on goal and scoring situations in the game and how the goaltenders act in those situations to prevent scoring. The main aim was to provide a factual base and description for ice hockey goaltending performance, which then may be utilized for evaluation of performance and utilized for purposes in practice.

4.2. Hypothesis

Physical performance. The hypothesis for the physical performance measurements are that all performance areas will show a decline from pre-game to post-game. Due to that each game may differ in the amount of action that the goaltender faces, there will be inter-individual variation in the level of performance from pre to post game. Lactate values is to be expected to remain quite low. Heart rate is to be expected to show averages that stay within moderate intensity.

Action analysis. It is to be expected that most actions will relate to moving-/skating techniques, because goaltenders move quite much even though they do not skate in a similar fashion as skaters. In addition, it is to be expected that there will be a quite high number of vertical movements, because goaltenders most often strive to use save techniques that require them to drop down on the ice. The most often used save technique will highly likely be the butterfly save technique, because that is the most used save technique in modern goaltending.

Working periods and intensity analysis. The hypothesis is that goaltending performance is not just purely continuous, but rather a mixture of high and low intensity working periods interpreted by recovery periods or periods of low intensity action.

Game performance analysis. Most of the shots will likely come from areas 2 and 3 (rink area between the face off dots and blue line in the defensive zone) and that most shots will be directed at the lower part of the goal. The most frequent scoring situation will likely be “regular shot”. The subjects will likely be positioned inside the goaltender’s crease area on most of the shots and that they will likely be in the game stance prior to most of the shots.

5. METHODS

5.1. Subjects

A total of 9 subjects took part in the study of which 8 took part in all of the measurements and analysis (TABLE 3). One subject did not perform the physical performance tests due to injury.

TABLE 3. Subject characteristics.

	Subjects										
N = 9	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean**	**SD**
Age	18,0	24,0	22,0	19,0	23,0	23,0	18,0	19,0	21,0	20,8	2,3
Height	180,0	177,0	175,0	185,0	188,0	175,0	179,0	184,0	184,0	180,8	4,7
Weight	75,0	89,0	78,0	78,0	81,0	78,0	78,0	74,0	80,0	79,0	4,3

Four of the subjects played in the Finnish elite league (SM-liiga), three played in the second highest senior league (Mestis) and two played in the highest junior league in Finland (A-SM-liiga). The anthropometric data was obtained from the latest team test from the teams in which the subjects played.

5.2. Measurements

The measurements consisted of tests and analysis that were done prior to, during and after a competitive game. Each of the subjects were tested for their physical performance prior to and after they played a game. Heart rate was monitored for the duration of the entire game. Blood samples for lactate analysis were taken prior to, between periods and straight after the game. Videotaping was done for the entire game and the video was analyzed from several different perspectives. The testing and videotaping was carried out during the pre-competitive season between August and September of 2011.

5.2.1. Physical performance tests

The physical performance tests were performed at the game location, in appropriate indoor conditions. Performance tests included an *agility & speed* test for testing agility and speed performance. *Power tests* included the countermovement jump- and standing broad jump test. *Maximal strength tests* included MVC:s in isometric leg press, trunk flexion and trunk extension. Each subject had been familiarized to the testing protocol prior to the actual testing and the warm-up also included sub-maximal performances in the tests. The subjects performed a 15min warm-up prior to the testing. The subjects had two maximal trials on each of the tests. There was two minutes of recovery between each of the test performances.

Agility & speed test. The agility and speed test was created to replicate the type of movement patterns that goaltenders perform on ice. A similar type of test has been used on ice by the Finnish Ice Hockey Association. Performance time was recorded by using a contact mat. The subjects were standing on the mat and started by own initiative. When the subject's feet left the mat, the device started to record time and time recoding stopped when the subject stepped on the mat at the finish. The test consisted of running through a cross-like figure, which included running forward, backward and lateral shuffle where no crossover steps allowed. The subjects started facing forward on the contact mat and had to face the same way for the entire test by changing between running forward, shuffling laterally or running backwards. The subject had to touch over a line that was marked in the ground at each change of direction point of the test (FIGURE 7).

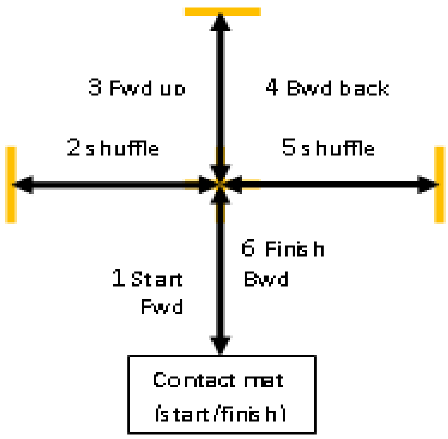

FIGURE 7. Agility test.

C*ountermovement jump.* The countermovement jump test was chosen as a measure of lower extremity power (Komi & Bosco 1978). CMJ was performed on a contact mat with subjects standing about shoulder width apart. Hands were held on the waist for the entire performance and the subjects were instructed to bend down to a approximately 90 degree knee angle, not stopping at the bottom of the movement and to jump up as fast and explosively as possible. The body had to be remained straight and landing was to be performed on the balls of the feet with no knee bend. Flight time was recorded for each of the jumps.

Standing broad jump. The standing broad jump was chosen as a measure for lower extremity power (Horita et al 1991). The SBJ was performed from a standstill position where subjects had their feet behind a line that was marked on the ground. The distance of the jumps were measured from the starting line to the landing point of the trailing foots heel.

Isometric leg press. Isometric leg press was chosen as a test for lower extremity maximal strength (Häkkinen et al. 1985). The test was performed on a leg press device (build at Jyväskylä University) with a 107 degree knee angle. The subjects were told to follow the instructions and commands of the tester and to press as hard as they can until the tester tells them to stop. The tester used the commands “are you ready?”, “push” and “stop”. The subjects were strongly verbally encouraged prior to and for the entire duration of the test. The top value in Newton for each trial was recorded from the tracking monitor that was attached to the leg press device and the result was then transformed into kilograms in the analysis.

Isometric trunk flexion and extension. The isometric trunk flexion and extension tests were chosen as measures of maximal strength for the core muscles (Keskinen et al 2007). The maximal strength isometric body flexion and -extension were performed on a device (build at Jyväskylä University) were subjects were in a standing position and pushing against an immovable board. The upper board was adjusted at chest level just under the collar bone level of the subjects. The subjects were attached to the device by strapping a belt tight around their waist. The flexion test was performed facing the upper board and the extension test with the back against the board. The subjects were asked to push against the board as hard as they can and to act on the commands: “are you ready?", "push" and "stop". The top value in kg's for each trial was recorded from the tracking monitor that was attached to the flexion-extension device.

5.2.2. Blood lactate measurements and heart rate recoding

The lactate measurements were done by collecting blood samples from the fingertips of the subjects. Four different blood samples were taken. Resting blood lactate was measured 2,5h prior to the game, prior to the physical fitness tests. Blood lactate samples were collected at the first and second intermissions straight after the period and also straight after the game. The blood samples were analyzed with a analyzing device (EKF Diagnostic, Biosen C-line, Germany).

Heart rate was monitored for the entire duration of the game by utilizing a heart rate monitor (Polar RS800, Polar Electro OY, Kempele, Finland). Average heart rate for the entire game and for each period was analyzed by utilizing a heart rate analysis software (Polar Protrainer 5, Polar Electro OY, Kempele, Finland).

5.2.3. Videotaping

Videotaping was done for the entire duration of the game and actions-, working periods and intensity, and performance during the game was analyzed.

***Action analysis*.** An analysis was performed to record the game actions that the subjects perform during the game. The action analysis framework was designed by the author. The action analysis consisted of different skills that the goalie executes during the game and they were also divided into being either low intensity or fast/ explosive in nature (TABLE 4). All together there was 16 different categories that were included in the analysis, consisting of skating and movement techniques, vertical movement and other technical skills that goaltenders naturally perform in game situations. Each action was recorded and the total numbers of the actions were counted for each period individually and for the entire game.

TABLE 4. Action analysis categories.

Goalie movements/actions	1-3 period	
	Fast	Slow
lateral movement		
shuffle		
t-push		
ice		
horizontal movement		
c-cuts		
t-push		
ice		
Vertical movement		
full butterfly		
half butterfly		
Butterfly-/Half BF slide		
Stand-up save		
Other save technique(VH)		
Sprawl		
Poke check		
Playing the puck		
Skating out of net		

Working periods and working intensity analysis. A second analysis was performed to record the working period durations and working intensities. The analysis tool was designed so that it could widely take into account the multiple different working period durations and the intensity of the working periods. The working period durations were divided into different time windows according to the length of the action (0,5-3sec, 3-8sec, 8-15sec, 15-30sec and over 30sec). Time was measured by using the timer of the video software (VLC media player, VideoLAN). The intensity of the working periods were categorized into slow/low intensity, fast/explosive and fast/explosive inside a low intensity working period. The condition for the actions to be accounted for was that the subjects had to be moving or staying in the goaltending basic stance and follow the play. The intensity of the action was recorded visually according to movement and game speed.

TABLE 5. Action time and intensity analysis categories.

Goalie action time & intensity			
1-3 period	Slow/low intensity	Fast/explosive (only)	Fast/exp inside low intensity
0,5-3sek			
3-8sek			
8-15sek			
15-30sek >			
30sek >			

Game performance analysis. Game performance analysis was done to evaluate and analyze the actual goaltending performance and the actions that relate to the game performance. The analysis tool was designed by the author. In the performance analysis, all the shots on goal that were taken by the opposing team were accounted for and analyzed. Each shot on net was analyzed through 8 different categories (TABLE 6). The area from which the shot left, where the shot was directed and the type of scoring situation were analyzed. The positioning and readiness of the subjects and the used save technique and used equipment to make the save were analyzed. Finally, the outcome of the shot on net was analyzed as to if the subjects were able to make a controlled (puck smothered or directed into areas 4 or 5), or uncontrolled save (rebound into areas 1-3) or if the shot resulted in a goal.

In addition, a *scoring analysis* was also performed, but it was not included in the main part of the study. This analysis was done by using the same categories and the results may be found in the appendix part(APPENDIX 2-3). This analysis shows how goals were made and the goaltenders action in those situations.

TABLE 6. Game performance analysis categories.

1 Shot area	**2 Shot direction**	**3 Type of shot**	**4 Positioning**
Area 1	High left	Regular shot	Top of crease
Area 2	High right	Lateral movement	Inside crease
Area 3	Low left	Breakaway	Post
Area 4	Low right	Vertical pass	Out of position
Area 5	5 hole/stomach	Lateral pass	
	Empty net	Break in to goal	
		Break-in (corner)	
		Rebound	
		Screen shot	
		Deflection	
		Other	
5 Readiness	**6 Technique**	**7 Equipment**	**8 Result**
GS stand-up	Butterfly	Body	Controlled save
GS ice	Half butterfly	Glove	Uncontrolled save
Not GS Stand-up	Stand-up	Blocker	Goal
Not GS ice	BF-/half BF slide	Stick	
In mov stand-up	Post load/VH	Pad	
In mov ice	Other		
Outplayed			
(GS= Game stance)			

5.3. Data analysis

Physical performance, blood lactate & heart rate. Physical performance results and individual changes were analyzed from pre-to post-game. Blood lactate was analyzed pre, during and post game. Heart rate was analyzed for the entire game and for each period. Physical performance changes from pre to post game were also correlated with the results from the working period and intensity analysis results. The percentile changes in the physical performance tests from pre- to post-game were correlated with the number of fast/explosive periods that took place during the games.

Action analysis**.** The action analysis was based on visual observation of the actions as they happened during the game and each repetition of the action was recorded. The actions were also classified into being either fast or slow based on visual observation of the action being performed. Additionally, an analysis was performed that separated skating and movement skills and other actions. Relating to the analysis of the different actions, there is some clarification that is necessary to some of the categories, to be able to fully understand the criteria in the analysis. In the movement techniques, the horizontal movement with c-cuts was accounted for when the goaltender moved all the way to the top of the goaltenders crease level. Vertical movement criteria was that the goaltender had to drop down on the ice and get back up by either dropping both knees or a single knee on the ice. Sprawling or falling down otherwise on the ice and getting up was also counted.

Working period and intensity analysis**.** The working periods of the goalies were timed and the criteria for counting the working period was that the goaltender had to clearly be in and remain the game stance and follow the play. This basically means that every time the goalie had to be active to maintain readiness to stop a puck or was actually performing game skills in scoring situations. The intensity analysis was based on visual observation in relation to movement speed and power that was needed to play a game situation.

Game performance analysis. Each shot that was directed towards the net was analyzed and the shot was analyzed in relation to the shot or scoring situation itself and in relation to the goaltender action in each of those shots or situations. The shots were analyzed based on the area where the shot was taken, the direction of the shot on goal and what type of situation the shot came from (FUGURE 8-9). Additionally, each shot on goal was classified as one of the ten different scoring situation types.

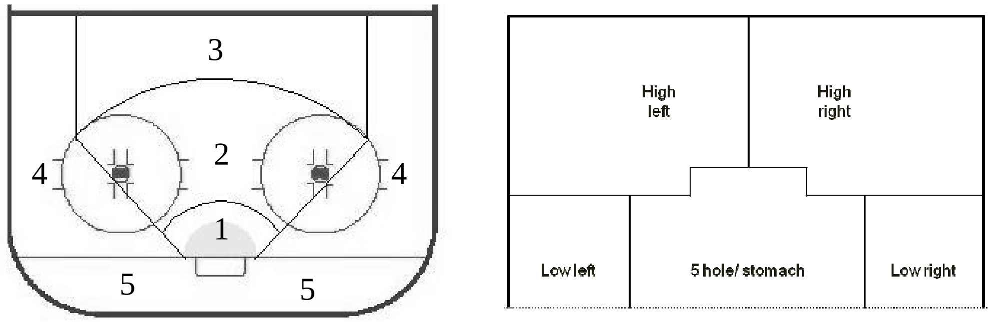

FIGURE 8-9. Shooting areas and shooting direction.

The goaltender action in the situations were analyzed prior to the shot and then at the moment of the shot. Goaltender positioning and readiness was analyzed prior to the shot. Positioning criteria was either at the top of the goaltenders crease area, inside the crease, at the post or out of position. Readiness criteria was either in the game stance standing up or -on the ice (butterfly- or post load position), not in game stance standing up or –on the ice (not in full readiness to stop the shot), in movement standing up or –on the ice (e.g. due to lateral movement to a pass) and outplayed (situation where the goaltender ,for example, ends up laying on the back and has no possibility to get in line with the puck).

The save technique that the goaltender used and the equipment or body part that the goaltender used to stop the puck were recorded. The outcome of the shots on goal was then finally defined as controlled save, uncontrolled save or goal. Controlled save criteria was that the goaltender had to smother the puck or be able to direct it to areas 4 or 5. Uncontrolled save criteria was if there was a rebound following the initial shot that ended up in area 1-3.

Statistical analysis

The data from the tests and analysis was analyzed with computer software (Microsoft Office Excel 2007). For all acquired data, individual and group means and standard deviations were analyzed. One of the subjects did not perform the physical performance tests due to injury and was thereby not included in the analysis of the physical performance test data. Mean-, percentile and standard deviation values were analyzed from all data. Pearson's correlation was used for correlation analysis.

6. RESULTS

6.1. Physical performance

TABLE 7. Physical performance mean and standard deviation from pre to post game and percentile change in performance (N=8).

Physical perfomance					
	Pre	SD	Post	SD	Change %
Agility test (sec)	7,70	0,48	7,77	0,52	-1 %
CMJ (cm)	44,9	7,8	44,9	9,1	0 %
Standing long jump (cm)	254,13	20,63	256,88	20,34	1 %
Isometric leg press (kg)	540,4	119,1	523,1	112,9	-3 %
Trunk flexion (kg)	87,8	14,4	86,3	14,6	-2 %
Trunk extension (kg)	114,1	16,08	109,8	17,10	-4 %

The mean values for the entire subject group in the physical performance tests from pre to post game and percentile change in performance was recorded (TABLE 7). Results showed decline in performance in most of the performance tests. Leg and core strength declined most from pre to post game. The countermovement jump stayed at the same level as pre-game and standing long jump has even slightly increased. There was large inter-individual variation in the performance changes from pre to post game (FIGURES 10 & 11).

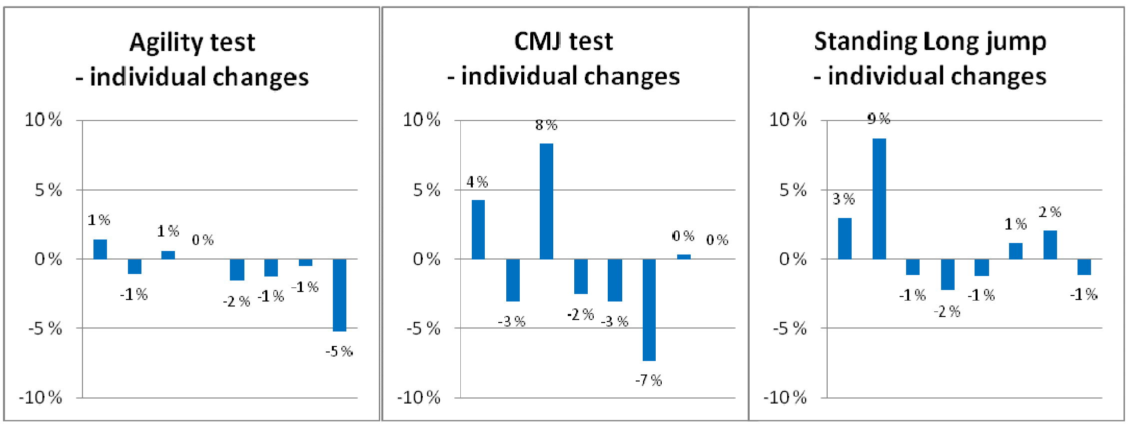

FIGURE 10. Individual percentile changes in the physical performance measures from pre- to post-game (N=8).

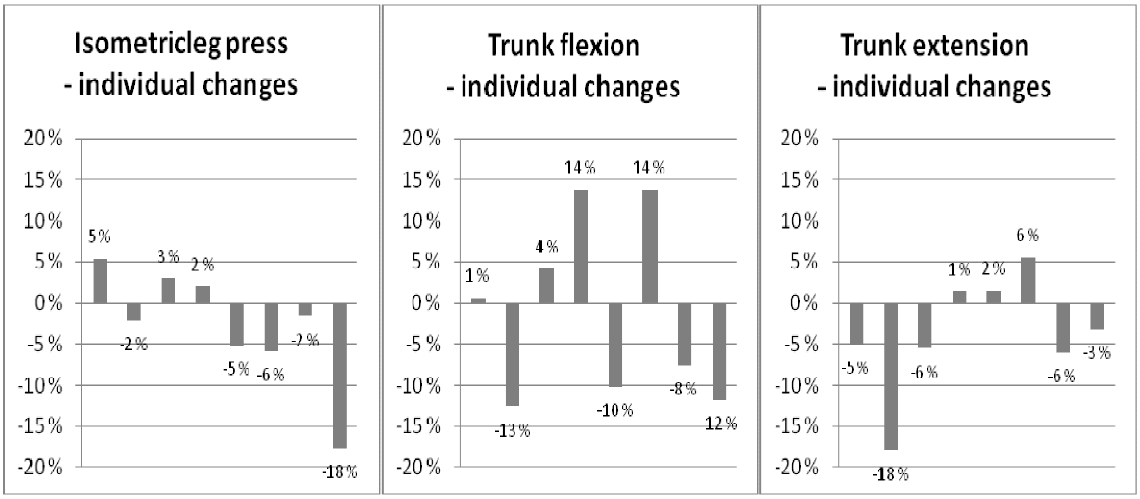

FIGURE 11. Individual percentile changes in the physical performance measures from pre- to post-game results (N=8)

6.2. Blood lactate and heart rate

Blood lactate measurements showed only a slight increase from resting levels. Mean values of all 9 subjects for blood lactate (mmol/l) in rest was 1,74 ±0,40, after 1st period 2,70 ±0,95, after 2nd period 2,43 ±0,95 and after 3rd period 2,21 ±1,16.

Average heart rate for the entire game was 149 ± 7 beats per minute. The average heart rate for the entire game was analyzed from the beginning of the 1st period to the end of the 3rd period (including intermissions). Average heart rates for each period were accounted for (FIGURE 12). One of the heart rate recordings failed due to connection problems and therefore only 8 subjects were included in the analysis.

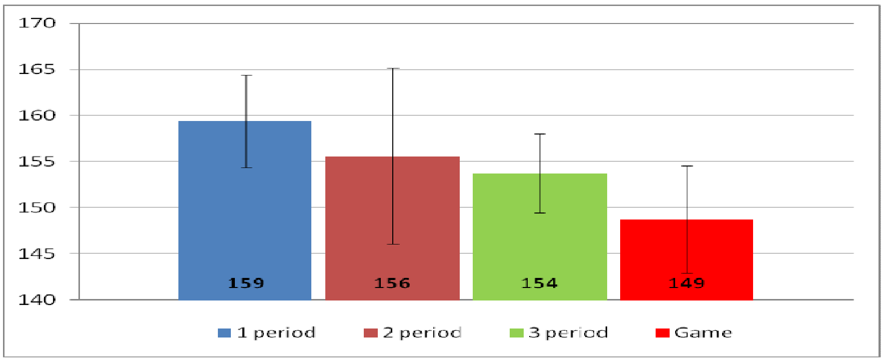

FIGURE 12. Average heart rates for each period and average of the whole game (N=8).

6.3. Video analysis

6.3.1. Action analysis

The action analysis clearly showed the amount of different actions that take place during the game. Horizontal c-cuts accounted for 36% for the total of all actions. Vertical movement accounted for 17%, lateral shuffle for 14% and full butterfly for 11%. The other actions ranged between 0-4% of the total of all actions (FIGURE 13). The absolute values for each category can be found in the appendix part (APPENDIX 4).

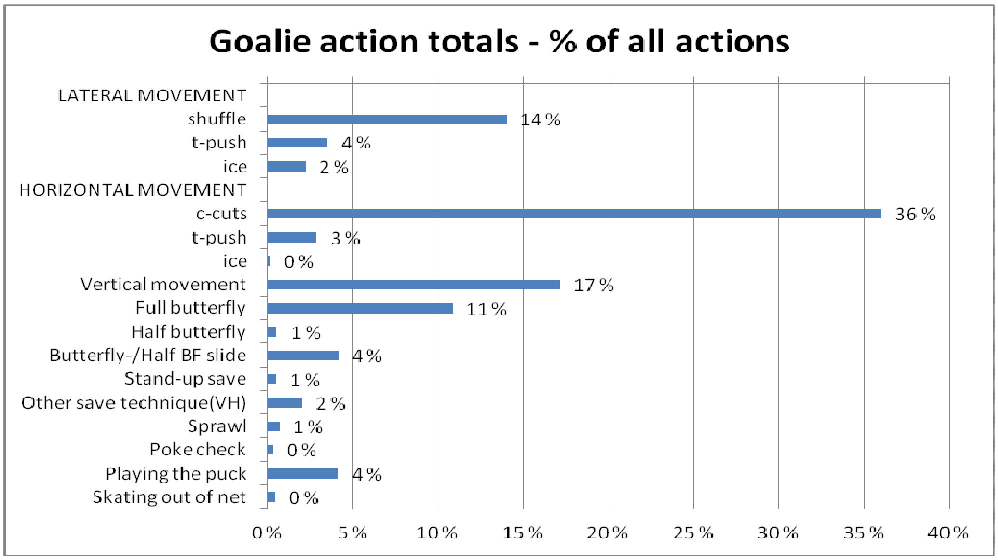

FIGURE 13. Percentile division of the total number of all actions during the game.

When skating and movement skills were accounted for separately, slow horizontal c-cuts accounted for 58% of the total amount of movement skills during the game. Fast lateral shuffle accounted for 13% and slow lateral shuffle for 11%. The reminder of the fast and slow movement skills ranged from 0-4% (FIGURE 14).

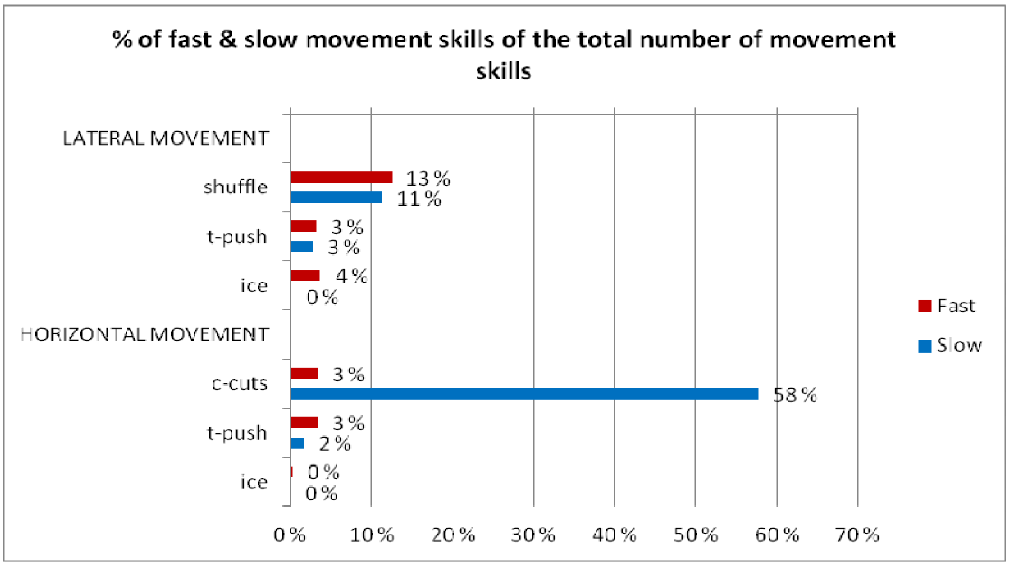

FIGURE 14. Mean percentile values of fast and slow movement techniques of the total number of movement skills.

When skating and movement skills were excluded, for the total number of other actions fast vertical movement accounted for 35%. Dropping down fast into the butterfly position accounted for 26% and fast butterfly- or half butterfly slide for 10%. (FIGURE 15).

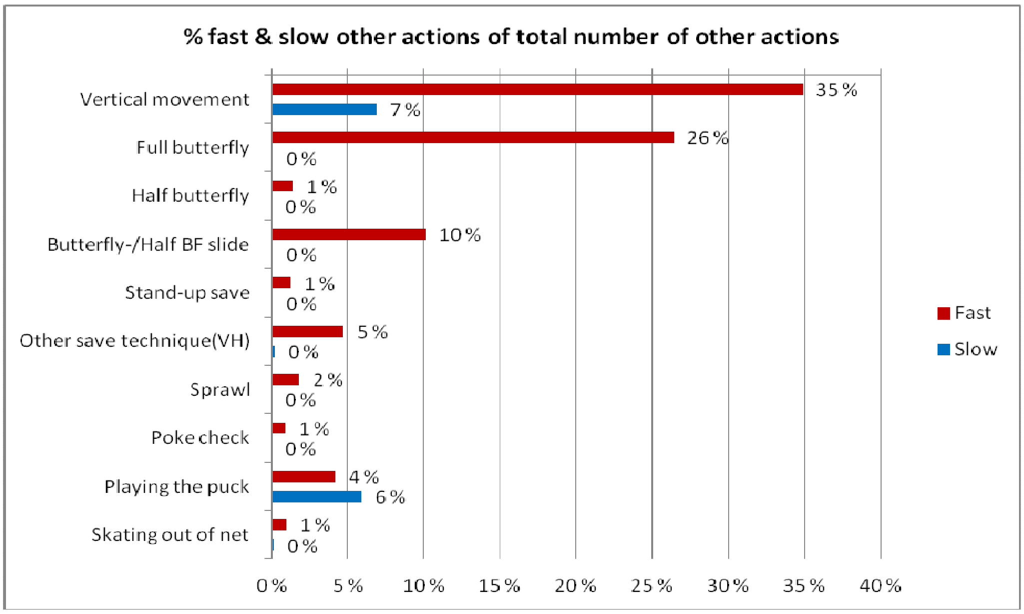

FIGURE 15. Mean percentile values of fast and slow actions other than movement skills of the total number of other actions.

6.3.2. Working periods and intensity

Low intensity working periods were more widely distributed in all of the analysis categories (FIGURE 16). Notable was the high amount of fast/explosive actions of 0,5-3sec that take place inside the low intensity working periods. Low intensity working periods take place over the whole working period spectrum, whereas the fast/explosive actions mainly take place inside the low intensity periods and last for 0,5-3sec or at most for 3-8sec. Of fast/explosive working periods inside low intensity periods, the 0,5-3sec periods accounted for 34%. Low intensity periods of 3-8sec accounted for 27%. The absolute values for the analysis can be found in the appendix part (APPENDIX 5).

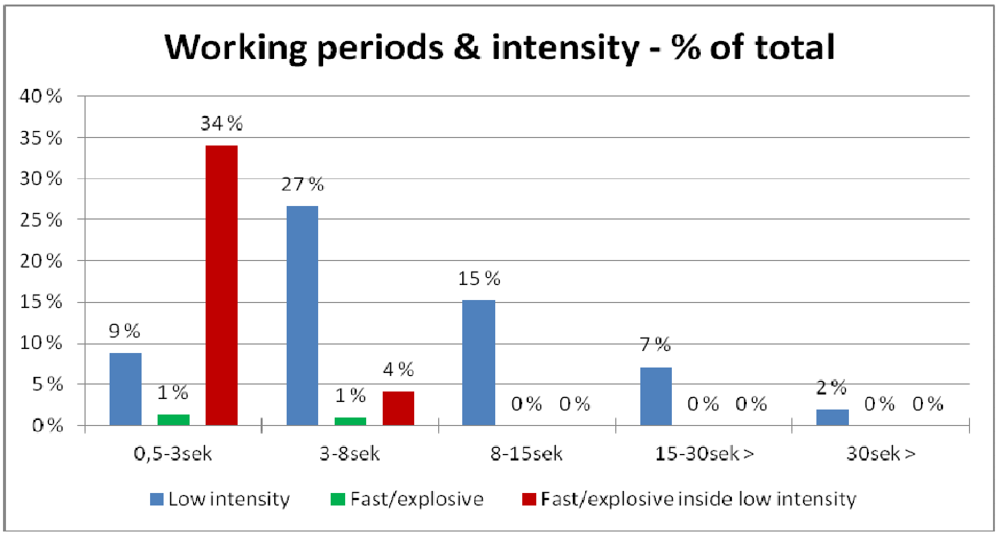

Figure 16. Percentile values of different working periods and intensities.

6.3.3. Game performance analysis

The absolute values for the game performance analysis for all the categories, which are referred to in the below sections, can be found in the appendix part (APPENDIX 1). The results from the scoring analysis can also be found in the Appendix part (APPENDIX 2-3).

Shooting area. Most of the shots on goal in the games were taken from area 2 (33%) and then shots from area 1 (18%), area 3 (18%) and area 4 (23%) were quite evenly divided (APPENDIX 1 & FIGURE 17).

Shot direction. Most of the shots were directed towards the 5 hole or stomach area (34%). Low shots to the right (21%) and left (18%), high shots to the right (15%) and left (10%) (APPENDIX 1 & FIGURE 17).

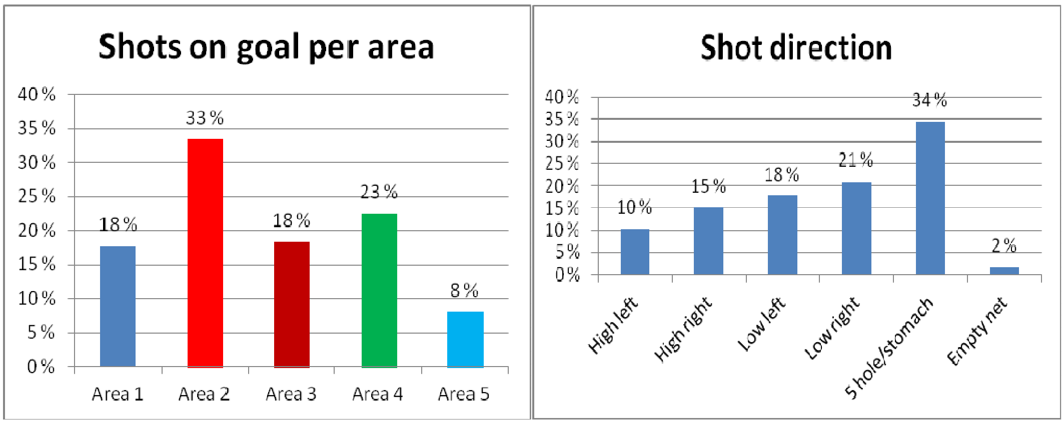

FIGURE 17. Percentile mean values for shots on goal per area and the direction of the shots.

Shot/scoring situation type. The majority of the situations were regular shots (43%), whereas the division for the rest of the shot or scoring situations was quite evenly distributed (APPENDIX 1 & FIGURE 18).

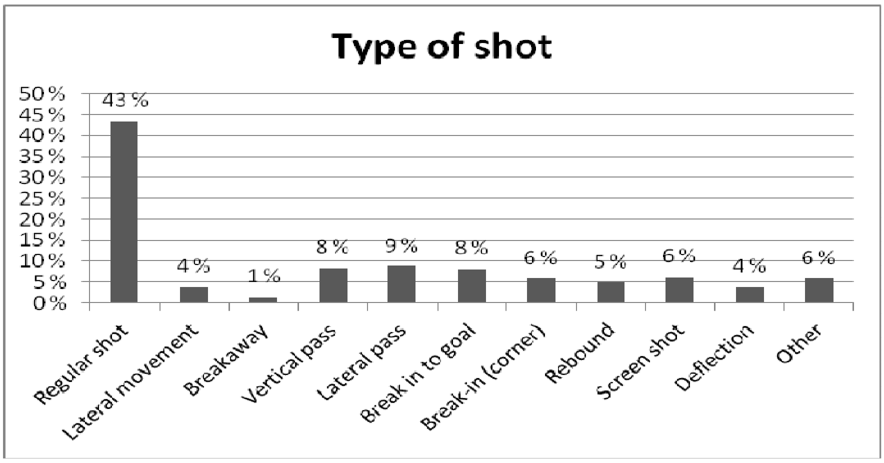

FIGURE 18. Shot/scoring situation type mean percentile values.

Goalie positioning. Goalie positioning at the moment when the shot was taken was for most part inside the goaltenders crease area (54%). Positioning was at the top of the crease on 28% of shots (APPENDIX 1 & FIGURE 19).

Goalie readiness. On most of the shots that were taken towards the net (65%) the goalie was in the game stance standing up on the skates. On 15% of the shots, the goalies were in game stance on the ice (butterfly or post load position). The remaining categories were quite venly distributed. (APPENDIX 1 & FIGURE 19).

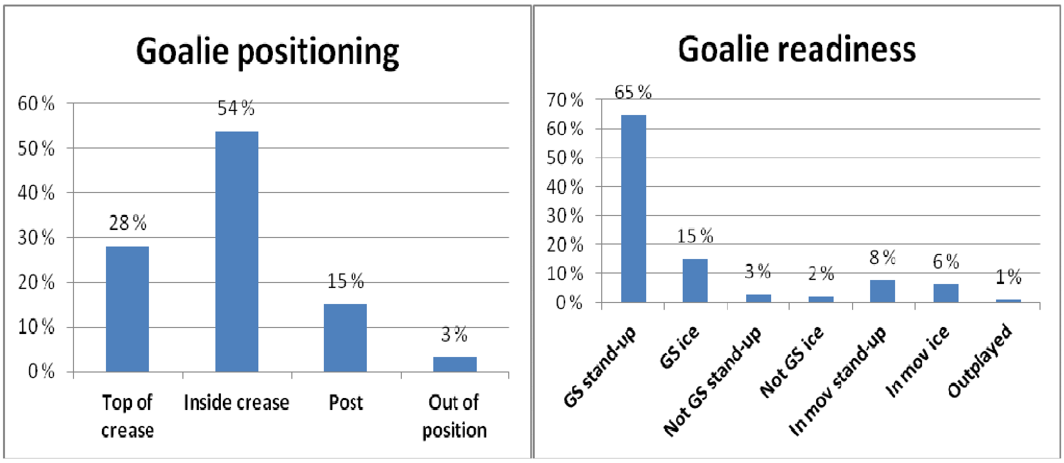

FIGURE 19. Mean percentile values for goalie positioning and –readiness.

Save technique. On most of the shots, the goalies used the butterfly technique on 66% of shots and butterfly- or half butterfly slide techniques on 13% (APPENDIX 1 & FIGURE 20).

Equipment/ body part. The goalies utilized the stick to make most of the saves (28%) whereas pad saves accounted for 23% of the total. Glove saves (17%), body saves (16%) and blocker saves (9%) accounted for the reminder. It should be noted that the percentile values do not reach a full of 100%, since 7% of the shots ended up as goals (APPENDIX 1 & FIGURE 20).

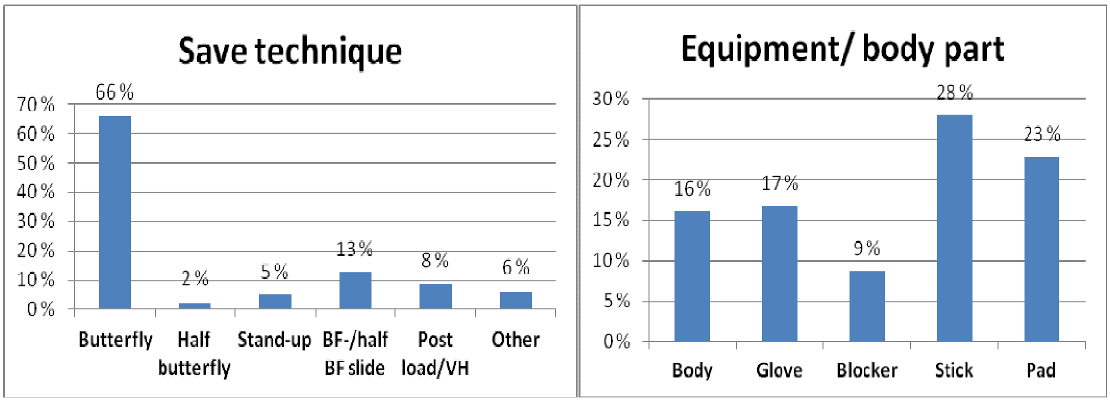

FIGURE 20. Mean percentile values for used save technique and equipment used to stop the puck.

Outcome of shots. The goaltenders were able to execute controlled saves on most of the shots (64%). Uncontrolled saves accounted for 29% or the total and 7% of the shots ended up as goal (APPENDIX 1 & FIGURE 21).

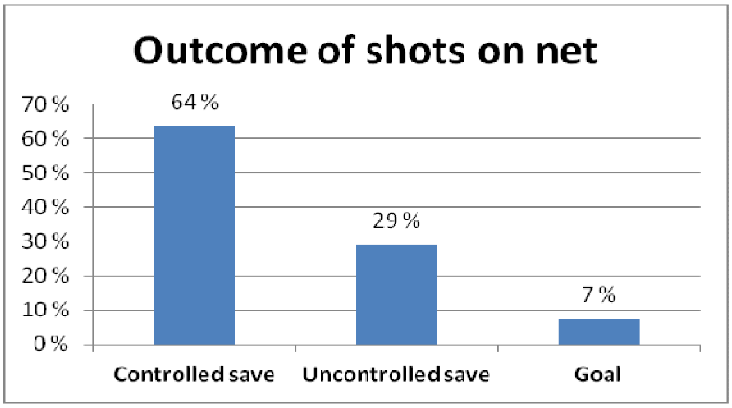

FIGURE 21. Mean percentile values for outcome of the shots on net.

6.4. Relationship between number of fast/explosive working periods and physical performance changes

The percentile changes in performance from pre- to post-game were correlated with the number of fast/explosive working periods that took place during the game. Significant correlations were found between the number of fast/explosive working periods and agility test (r = - 0,708, p < 0,05), power of the lower extremities (r = - 0,713, p < 0,05) and leg measures (r = - 0,803, p < 0,05) (FIGURES 22-23). The power of the lower extremities was counted as the sum of CMJ and standing long jump divided by two. The leg measures consisted of the sum of CMJ, standing long jump and isometric leg press and the result was divided by three.

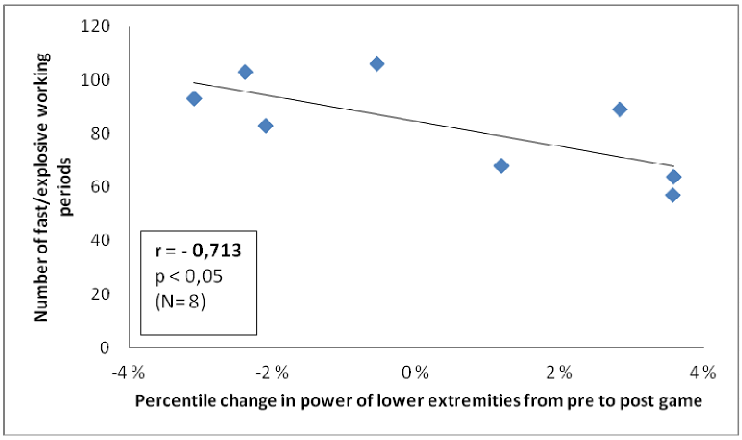

FIGURE 22. Relationship between fast/explosive working periods and percentile change from pre to post game in power of lower extremities (CMJ & SLJ).

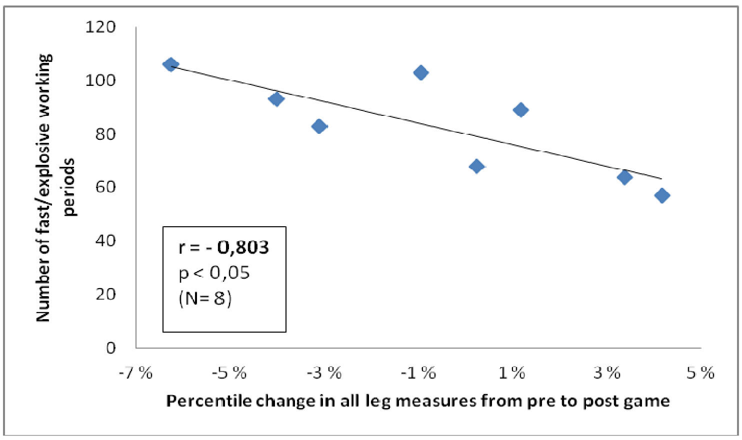

FIGURE 23. Relationship between number of fast/explosive working periods and percentile change from pre to post game in sum of all leg measures (CMJ, SLJ, ILP).

7. DISCUSSION

The present research indicated that physical performance in prone to a decline following a game and that the changes in performance vary between individuals. The heart rate data indicates that goaltenders work on average on a medium to high aerobic intensity, interspaced with high intensity working periods and periods of lower intensity. Blood lactate levels did not increase much during the game indicating that recovery periods and performance intensity allows sufficient recovery from some of the high intensity actions. The video analysis suggested that goaltenders execute variable working periods and at variable intensities, during which most actions related to skating and moving, vertical movement and dropping into the butterfly position.

This study yielded results from many different areas of the ice hockey goaltending performance that may help to create further understanding of the ice hockey goaltending performance. This study may be seen as a starting point to research in this field and thereby the study will hopefully give a boost to further future research in this area.

7.1. Physical performance, lactate & heart rate

The variation in anthropometric characteristics of the subjects were quite small and all were young adults. The physical performance measures before the game showed that there were differences between individuals in the different performance areas. The differences in physical abilities are something that should be notified when looking at the results from pre- to post-game, because it may have an effect on the level of fatigue and the level of performance from pre to post game. The results from pre-to post game showed that the goaltenders physical performance declined, as viewed through group mean values. This was to be expected to happen after playing a full game of ice hockey. A decline in performance during and following a game or match has been shown in many other sports as well (Hornery et al. 2007; Mohr et al. 2004; Hoffman et al 2002; Cormack, Newton & McGuiran 2008). The greatest declines were in leg strength and core strength. Yet, it was still quite surprising that the declines in the some of the performance areas were not as dramatic as to what could be expected. There was great individual variation between the level of performance from pre-to post game between the subjects and this may be seen as one important factor. Some of the subjects were able to improve their results after the game, whereas some had greater declines in all performance areas.

The variation between individuals can most likely be explained by the differences in the game that each subject played in. Due to the flow of the play, some of the subjects had to perform more actions and were faced by more game action and shots than others. It is also likely that the initial level of physical performance of each subject affected the level of fatigue that they experienced. Some subjects had better and higher scores in the different performance tests than others. Therefore, it could be realistic to assume that those who have high level of physical performance could withstand fatigue better. On the other hand, the individuals with better power and strength levels could also be likely to experience greater decline, as compared to pre-game values, because they also likely have higher strength and power output in each of their performances during the game. The force-fatigability relationship indicates that the greater the force exerted by a muscle or motor unit during a task, the more the muscle will fatigue (Enoka & Stuart 1992; Hunter & Enoka 2001). This means that individuals with high initial power output levels usually experience the greatest decrements in performance. (Hoylmard et al. 1987; Hamilton et al. 1991; Bishop et al. 2003; Wadley and Le Rossignol 1998; Bishop et al. 2004). In addition, also style of play and technical skill execution is probably a factor that may differentiate individuals and the level to which they fatigue. In general modern goaltenders play with a quite similar style, but differences may be seen in the execution of different techniques. Goaltenders with smooth technique may make their performances more energy conserving, whereas others with more rough technique may expend more energy and thereby experience more fatigue.

The correlations observed between the changes in physical performance and number of fast/explosive working periods indicated significant relationships especially in the power and strength of the lower extremities. This indicates that the more fast/explosive working periods and actions that the goaltender needs to perform during the game, the more likely it is that it will cause decline in performance, especially strength and power of the lower extremities. This is something that should be notified and it brings about the notion that goaltenders should include sufficient strength and power training in their training regime, to reach optimal level of physical performance for the duration of the entire game. Goaltenders also need to be able to perform powerful actions while somewhat fatigued and thereby it could be suggested that they should perform training that aims to hinder a decline of strength and power qualities during a game and also train for strength and power while fatigued. Additionally, in addition to strength and power training, the endurance level needs to be on a sufficient level to promote recovery from high intensity actions (Hamilton et al 1991; Tomlin & Wegner 2002; Tiikkaja 2002)

Blood lactate measurements showed only slight increases in blood lactate from pre-game. Obviously one of the major limitations was that blood lactate measurements were done after each full period of play. It would be interesting and more informing to be able to perform measurements also during the periods. This type of approach, could have provided more accurate information of the intensity of performance and recovery during the actual playing performance. Yet, the results indicate that even though goaltenders perform also high intensive actions and longer working periods during the game, the flow of the game and stoppages in play allow them to recover quite well during the game.

The heart rate data showed that the goaltenders work on average at a heart rate of 149 BPM during the game. This finding is somewhat in line with previous investigations where average heart rate was 143 BPM (Montgomery 1988). The results from each period indicate that even though there are resting periods during times of play, the goaltenders still need to work on average on a moderate to high aerobic intensity and, thereby, have a good level of endurance to perform at a high level. In addition, this stresses the point that the goaltenders need to have sufficient level of endurance to endure the game and to be able to recover from and be able to perform the high intensity fast/explosive actions.

An interesting finding was that during periods when the goaltenders were not that active and just stood at their goal; their heart rates were still somewhat elevated. This brings about the interesting point of why this happened and which factors overall may have affected heart rate during the game? Obviously being physically active is the major reason for elevations in heart rate, but additionally a reason may be psychological factors that affect to raise the heart rate. A reason for elevated heart rate during periods of recovery could also be due to a low initial level of endurance in some of the subjects, so that they were just pushed to work very hard in relation to some others with higher endurance levels and therefore recovery from working periods was not as efficient. An alternative reason may be the heat, because already just wearing the bulky goaltending gear usually causes clear raise in body temperature and sweating. Logan-Sprenger et al. (2011) reported in their study that the two goaltender in the study sweated on average 2L ±0,7 during a game. This indicates that goaltenders sweat much during a game. It is known that if fluid intake does not match the level of sweat loss it may lead to fluid deficiency, which has been proven e.g. to raise core temperature and heart rate. Already small fluid deficiency has been shown affect performance negatively. (Logan-Sprenger et al. 2011, McArdle et al. 2001) This factor also needs to be considered when interpreting the results of physical performance. The amount of fluid loss during the game could have been measured in this study by e.g. weighting the subjects prior to and after the game.

The heart rate measurements proved to be challenging, because of the high amount of disturbances in the recording signal. Therefore, the data should be approached with some caution, but still it is of high enough quality to provide information of physical loading of the game performance. An interesting point would be to be able to know more precisely how much of the elevated heart rate is due to psychological factors, because all of the data cannot be explained only by physical performances.

In general, the physical performance of goaltenders is likely to decline during and following playing a game of ice hockey. The level of decline is much dependent on the flow of the play, amount of action performed, the nature of the working periods and initial level of fitness. Blood lactate levels show that goaltenders have sufficient time inside the game to recover from previous performances and that the level of intensity in the game performance is on average at a level where energy can be produced mainly through aerobic metabolism. Heart rate recordings indicate that heart rates average at a moderate to high aerobic intensity. Yet, it should be notified that these are only averages and that there are also periods of high intensity anaerobic action and lower intensity aerobic action. A limitation of the present study was that there was no knowledge of the endurance performance level of each individual. This factor would probably add important information that would assist in understanding changes in performance from pre-to post-game and to be able to interpret more precisely the working zones of each individual according to the heart rate.

7.2. Action analysis

The action analysis notified all actions that took place during actual playing time. Actions that took place during stoppages in play were not accounted for. The results from the action analysis show that most of the goaltenders action during the game is related to skating and movement techniques, especially moving horizontally with slow c-cuts (36% / 140,2 ± 34,7). The goaltenders most often utilize these c-cuts to move out from or back towards the net. Most of this movement takes place when the goaltender gets ready for the oppositions attack, follows the play and during different scoring situations. Shuffle technique (55,7 ± 14,8) was also quite frequently utilizes (14% of all actions) and that is to be expected because goaltenders often utilize this technique to move laterally and simultaneously maintain good readiness to play. The division of fast and slow type of skating and movement showed that the majority of techniques utilized during the game, were of slow type. Whereas it should still be noted that especially during different scoring situations, the goaltenders very often need to be able to move very fast and explosively.

The results from the other actions showed that fast vertical movement accounted for much of the action (66,8 ± 13,6), which was 17% of all actions and 42% when skating and movement techniques are excluded. The most used save technique was the butterfly technique (42,3 ± 6,1) that accounted 11% of total actions and 26% when skating and movement techniques are excluded . The general trend was that except for some of the slow type skating movement, the other actions that the goaltender performs is most often of fast/explosive nature and they are usually performed in scoring situations and/or when the puck is in the defensive zone. Goaltenders often prepare for situations by skating and moving to position themselves properly, so that they then are ready to perform the techniques necessary to be able to prevent the opposition from scoring, which often need to be performed very fast.

The action analysis showed great inter-individual variation especially in the slow c-cuts (± 34,7). Most often goaltenders use this technique to move in or out of the net to prepare for an attack or follow the play. Obviously, it can be said that the flow of the game made this difference, but another factor is that some goaltenders may strive to follow the play more actively and thereby strive to have higher readiness for upcoming situations. In general, according to the analysis, it may be said that goaltenders need to be able to skate- and move much and well to follow the play. They also need to be sound technically and physically, to be able to execute many of the actions and techniques correctly multiple times during the game. Additionally, the results show that there is a high number of dropping down into the butterfly position and vertical movement. This stresses that goaltenders need to have sufficient strength, muscle endurance, control and flexibility in the leg-, core- and hip musculature to be able to withstand the loading of these muscles and to prevent injuries.

7.3. Working periods and intensity

The analysis accounted for the periods that took place during actual playing time, so not when play was stopped. The results from the analysis showed that most of the working periods are of low intensive nature. Yet, there is a high number of fast/explosive working periods of short duration (between 0,5-8sek) that the goaltenders performed during the game. The analysis clearly showed that the fast/explosive actions take for most part place inside the low intensive working periods or that they happen at the end of a low intensity-working period.

It is to be noted that by the term “low intensity” it does not generally mean that the goaltenders working intensity is very low. The heart rate analysis already showed that on average goaltenders work at a moderate to high aerobic intensity. The term is meant to differentiate between high intensity or fast/explosive working periods, where the goaltender has to work with very high intensity and power output.

The analysis clearly showed that the goaltender performance is not similar to what the skaters execute. Skaters most often work with high intensity for approximately 40-60sec and then change and rest on the bench on average 3-5min (Green et al. 1976; Montgomery 1988; Westerlund & Summanen 2001). Goaltenders also occasionally have to perform similar type of high intensity working periods, but for the most part the working periods are shorter or at least they vary to a much greater extend and so do the recovery periods. The flow of the game greatly determines the working periods, their intensity and recovery duration. There is a mixture of shorter and low intensity periods, interpreted by some fast/explosive actions, and some longer over 30sec periods. E.g., when the opposition is playing on the power play, the goaltender often has to work hard to maintain continuous readiness and move with the play. In addition, the goaltenders overall game readiness and how actively they follow the game, affects the working periods. As mentioned earlier, the working periods were accounted for if the goaltender was in the game stance or performing game skills. No remark was made when the goaltender was standing still in a “resting” posture at the goal.

A limiting factor to this analysis was that the intensity of the working periods was determined visually through video. As mentioned earlier, e.g. it would have been very interesting to know more precisely, what the actual intensity was, instead of visually observing and determining the intensity. Therefore, the categories were only separated into two, because differentiating between e.g. medium and low intensity would have been impossible just by visually observing. The heart rate recording that was done could have been synced with what happened during the game. This option was notified in the planning, but it proved to be somewhat problematic with the available equipment, so therefore it was not done. Another factor is that not even heart rate alone can accurately enough take in account the intensity of single short duration fast/explosive actions. Another factor that was not accounted for in this study was the length of the recovery periods during the game.

7.4. Performance analysis

The performance analysis was a sport specific analysis that looked more into the technical and tactical aspects of goaltending and what type of shots and scoring situations goaltenders face during the game. The analysis reveals trends of what type of shots and scoring situations take place in the games and how the goaltenders act in those situations. The analysis took into account some of the key areas of the goaltenders actions prior to and during situations when scoring/shooting situations take place. There are many technical and tactical factors, which are stressed in coaching of goaltenders and the analysis brings about some factors that could and should be especially notified.

Additionally, the scoring analysis results (APPENDIX 2 & 3) gives important additional information about how goals are made and how goaltenders act in those situations. Some of the results from the scoring analysis are also discussed in the following sections to support the findings from the performance analysis.

The areas from where the shots on goal came from, where quite evenly distributed, but it showed that shots from area 2 where most frequent. Additionally the scoring analysis also showed that most goals were scored from area 2. This is something that should be notified, because shots from this area are often difficult for goaltenders. On shots from this distance to the goal, goaltenders have very limited reaction time and do not reach the same advantage in net coverage, as in shots that come from closer to the goal (Mikkola 1987). Most of the shots were directed to the lower portion and most frequent was the stomach/5 hole area of the goal (34%). In modern goaltending puck control is very important, because the aim normally is to be able to prevent scoring chances that are caused by unnecessary rebounds and loose puck in the primary scoring area (Näckel 2004; Magnusson 2008; SJL 2008). Shots that are directed toward the lower part of the goal are often challenging for goaltenders to control and thereby may result in a uncontrolled save and a rebound in the primary scoring area. Therefore, it could be suggested that controlling pucks that are shot to the lower portion of the goal, should be emphasized and practiced. Additionally, high shots to the catcher glove side accounted for many of the goals, which is something that should be notified. Goaltenders often drop down on the ice to perform a save and therefore it would be important to keep the arms ready to react for stopping high shots (Ropponen 2002; Näckel 2004; SJL 2008).

The goaltenders were positioned inside the crease area on over half of the shots. Although the goaltenders were still able to make a save on most of these shots, no matter of the positioning, it should be notified that every time the goaltender is positioned on the top of the crease area, then they are able to cover more of the goal. Therefore, it could be important to stress the importance of positioning prior to the shot and scoring situation to be able to give oneself an optimal chance to stop the puck. (Mikkola 1987; Näckel 2004; Magnusson 2008; SJL 2008) On most of the shots, the goaltenders readiness was that they were in the game stance in a standing position. This usually provides the goaltender a good ground to stop the puck and prevent a goal from being scored. The more important are the situations when the goaltender does not either have optimal readiness in a standing position, or while down on the ice level. In these types of situations, the goaltender is often vulnerable, because he/she is not in optimal readiness to make a save. Therefore, a key factor for goaltenders should be that they would have as good readiness as possible in each situation. This stresses the abilities to skate-, move and control one's body. Additionally, being able to read and anticipate the game situations well is crucial. (SJL 2008) The scoring analysis also showed that on many of the goals, the goaltenders were out of position and the goals were scored in an empty net. This indicates that the goaltenders readiness and positioning was not optimal. Usually this is caused by a rebound or pass that puts the goaltender out of position and they do not have time and/or readiness to get re-positioned properly to prevent the goal from being scored.

The most frequent type of shot or scoring situation was the regular shots (43%). These types of shots are most often the easiest ones for goaltenders to stop, but the distance from where the shot comes from should be notified. As mentioned previously, if the shot comes from the primary scoring area (areas 1-2), it is always a challenge for the goaltender. Although in most of these situations, if the goaltender just anticipates the play properly, he/she has time to get properly positioned and maintain proper readiness and thereby also stop the puck. The more important, according to the scoring analysis, are the less frequent but much more dangerous scoring situations. For example, rebounds, lateral- and vertical passes and screen shots are often challenging for goaltenders. These types of situations often challenge the goaltenders positioning and readiness. Often when these situations emerge, the goaltender does not have time to move optimally and be in optimum positioning and readiness. This stresses the fact that goaltenders need to be very fast in their skating and movement and anticipate plays very well, to be able to prevent goals from being scored. Additionally, on screened shots, the goaltenders need to be able to find visual contact to the puck and strive for maximum net coverage to promote one's possibilities for stopping the puck.

The most frequently used save technique was by far the butterfly technique (66%). This is a trend in modern goaltending and is therefore no surprise. The next frequent was the butterfly slide technique. A key notion from the scoring analysis was that in addition to the butterfly technique, the goaltenders had utilized so called other techniques in situations when goals were scored. The relates to the previously mentioned fact of positioning and readiness, as the goaltender often has to turn to more desperate type of methods to try to stop the puck, when they are out of position in relation to the puck and the goal. The most frequently used butterfly technique promotes the goaltenders ability to stop low shots, because then the lower portion of the goal is most often covered. Yet, it should also be notified that one third of the goals were scored high on the catcher glove side. Therefore, if the goaltender utilizes the butterfly technique, he/she must be able to have the arms and hands in readiness to react to high shots (Ropponen 2002; Näckel 2004; SJL 2008)..

Most of the saves, about half of them, were made with the stick or pads. Glove and body saves accounted for 17% and 16% respectively, whereas blocker saves only for 9%. Due to the high amount of low shots, the ability to control these low shots to prevent further situations in the primary scoring area is vital. Additionally, saves made with the body also need to be focused on, since if not controlled, the loose pucks or rebounds often end up in the primary scoring area. The puck control on shots or scoring situations in this research showed that goaltenders were able to perform controlled saves (puck smothered or directed to areas 4 or 5) in most situations (64%). Obviously, the aim for goaltenders on all shots, if possible, is that they would be able to smother the puck or direct the puck to a more non-dangerous area. This should be the starting point for every shot, but in many situations, it is almost impossible (Näckel 2004; Magnusson 2008; SJL 2008). The research also indicated this fact, as 29% of saves were uncontrolled and thereby the rebound or loose puck ended up in areas 1,2 or 3. The aim for each goaltender should be to be able to decrease the number of uncontrolled saves, because it also usually means less goals scored against. Additionally, when the goaltender is able to control the puck well, he/she most often makes the game and each play easier for oneself as he/she does not need to hurry into situations and is thereby able to maintain proper positioning and readiness. The total number of goals scored in total in 9 games was 23, which account for 7% of all shots that were directed on goal.

7.5. Conclusions

The results from the study indicate that goaltenders physical performance is prone to decline due to playing a game. According to the heart rate data, the game performance requires good baseline endurance level to be able to endure the game and to recover from the high intensity working periods. The game performance also sets requirements on the power and strength qualities of the lower extremities and the core. The results showed that the more fast/explosive performances the goaltender performs, the more likely it is that they will also experience greater fatigue in these abilities. Therefore, it should be clear that the goaltender should have a strong endurance performance level and be strong and powerful enough to be able to perform multiple actions in the game and perform on a high level throughout the game.

The video analysis is in support of the previously mentioned notion of the physical performance, because goaltenders are active in the game most of the time and they perform multiple different actions and working periods that require a strong technical, tactical and physical base. The action analysis showed that goaltenders move actively in their net area and that they perform most of the actions necessary to stop the puck by dropping down on the ice, mostly into the butterfly position. This was supported by the working period and intensity and game performance analysis. Therefore, as mentioned previously, the goaltenders need to be able to execute these actions with good technical form and have physical abilities that support them to perform well in the game performance as opposed to being a factor that holds them back. The goaltenders need to be in good physical condition, technically sound and tactically smart to be able to perform at a high level of performance. The performance analysis showed facts from the scoring situations that assists in further understanding the mechanics of shots and scoring situations and thereby which factors are crucial for goaltenders to be able to prevent scoring.

Future research suggestions. The present study may be seen as a starting point for research on ice hockey goaltenders and there is yet many things to investigated. All of the areas researched in this study should and could be further investigated. Here, some topics will be presented that could bring further important information. Relating to physical performance, it would be interesting to know how much the initial level of endurance performance affects the level of fatigue that the goaltender experiences during the game and how this affects performance. The working periods during the game is something that could also be further studied so that e.g. the heart rate date could be synced with what actually takes place on the ice. Additionally it would be interesting to know more of how much playing a game elicits fatigue in some of the key supporting muscle groups e.g. groins, deep core muscles and muscles of the hip and gluteal area. These muscles are of high importance in maintaining sufficient support and stability for performing many of the techniques in the game. This could bring key information for training and for injury prevention.

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APPENDIXES

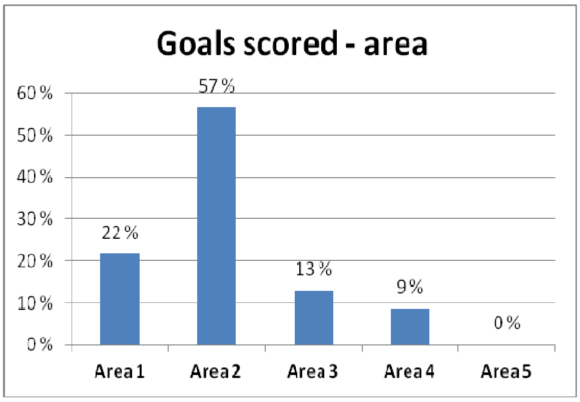
APPENDIX 1. Game performance analysis results.

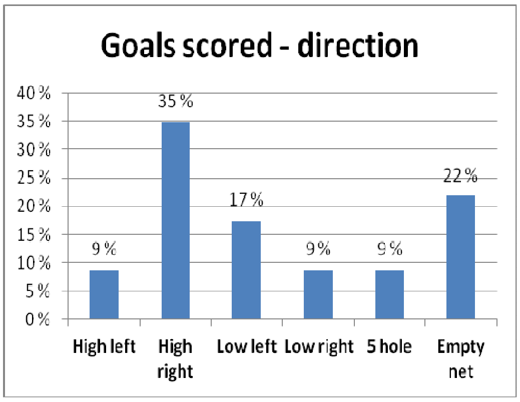
Subject (N=9)		1	2	3	4	5	6	7	8	9	Mean	SD	% of section
Number of shots on goal		28	39	32	38	26	40	41	44	23	**34,6**	7,5	
SHOT AREA	Area 1	1	5	4	10	7	4	9	12	3	**6,1**	3,6	**18 %**
	Area 2	10	14	12	14	6	16	14	10	8	**11,6**	3,3	**33 %**
	Area 3	5	7	3	3	4	11	10	8	6	**6,3**	2,9	**18 %**
	Area 4	9	10	9	7	8	7	5	10	5	**7,8**	1,9	**23 %**
	Area 5	3	3	4	4	1	2	3	4	1	**2,8**	1,2	**8 %**
SHOT DIRECTION	High left	2	5	6	4	2	5	4	4	0	**3,6**	1,9	**10 %**
	High right	3	4	4	7	1	11	6	8	3	**5,2**	3,1	**15 %**
	Low left	6	5	6	6	4	8	8	7	5	**6,1**	1,4	**18 %**
	Low right	6	10	7	10	9	1	9	8	5	**7,2**	2,9	**21 %**
	5 hole/stomach	11	14	8	11	10	15	13	15	10	**11,9**	2,5	**34 %**
	Empty net	0	1	1	0	0	0	1	2	0	**0,6**	0,7	**2 %**
SHOT TYPE	Regular shot	14	16	16	15	10	21	15	17	11	**15,0**	3,2	**43 %**
	Lateral movement	0	0	1	1	0	3	3	2	2	**1,3**	1,2	**4 %**
	Breakaway	1	0	2	0	1	0	0	0	0	**0,4**	0,7	**1 %**
	Vertical pass	2	7	2	5	0	4	3	2	1	**2,9**	2,1	**8 %**
	Lateral pass	2	4	5	3	4	0	4	4	1	**3,0**	1,7	**9 %**
	Break in to goal	1	4	1	2	3	4	4	4	2	**2,8**	1,3	**8 %**
	Break-in (corner)	2	0	1	4	2	1	4	3	1	**2,0**	1,4	**6 %**
	Rebound	1	1	1	3	1	0	3	4	1	**1,7**	1,3	**5 %**
	Screen shot	3	3	1	1	1	3	2	4	1	**2,1**	1,2	**6 %**
	Deflection	1	2	0	2	2	2	1	1	1	**1,3**	0,7	**4 %**
	Other	1	2	2	2	2	2	2	3	2	**2,0**	0,5	**6 %**
POSITIONING	Top of crease	3	13	13	9	5	15	14	4	11	**9,7**	4,6	**28 %**
	Inside crease	23	21	12	22	13	20	19	30	7	**18,6**	6,9	**54 %**
	Post	2	3	6	6	6	5	6	8	5	**5,2**	1,8	**15 %**
	Out of position	0	2	1	1	2	0	2	2	0	**1,1**	0,9	**3 %**
READINESS	GS stand-up	20	29	16	20	14	30	29	25	18	**22,3**	6,1	**65 %**
	GS ice	4	1	4	5	7	3	6	13	4	**5,2**	3,4	**15 %**
	Not GS stand-up	2	1	0	3	0	1	1	1	0	**1,0**	1,0	**3 %**
	Not GS ice	0	1	1	4	1	0	0	0	0	**0,8**	1,3	**2 %**
	In mov stand-up	1	6	5	2	2	5	2	1	0	**2,7**	2,1	**8 %**
	In mov ice	1	1	5	4	2	1	2	3	1	**2,2**	1,5	**6 %**
	Outplayed	0	0	1	0	0	0	1	1	0	**0,3**	0,5	**1 %**
TECHNIQUE	Butterfly	20	27	21	21	16	30	29	25	16	**22,8**	5,2	**66 %**
	Half butterfly	1	1	2	0	0	1	1	0	1	**0,8**	0,7	**2 %**
	Stand-up	2	2	0	1	1	5	0	3	1	**1,7**	1,6	**5 %**
	BF-/half BF slide	4	6	5	9	2	2	5	4	2	**4,3**	2,3	**13 %**
	Post load/VH	1	1	2	3	2	2	4	8	3	**2,9**	2,1	**8 %**
	Other	0	2	2	4	5	0	2	4	0	**2,1**	1,9	**6 %**
EQUIPMNENT	Body	3	6	10	4	4	7	7	5	4	**5,6**	2,2	**16 %**
	Glove	5	5	3	6	3	8	7	10	5	**5,8**	2,3	**17 %**
	Blocker	2	3	1	5	1	4	5	4	2	**3,0**	1,6	**9 %**
	Stick	10	14	9	8	8	11	8	12	7	**9,7**	2,3	**28 %**
	Pad	4	8	5	10	10	6	13	10	5	**7,9**	3,1	**23 %**
RESULT	Controlled save	22	30	19	24	15	26	22	24	16	**22,0**	4,8	**64 %**
	Uncontrolled save	3	6	9	9	11	10	18	17	7	**10,0**	4,9	**29 %**
	Goal	3	3	4	5	0	4	1	3	0	**2,6**	1,8	**7 %**

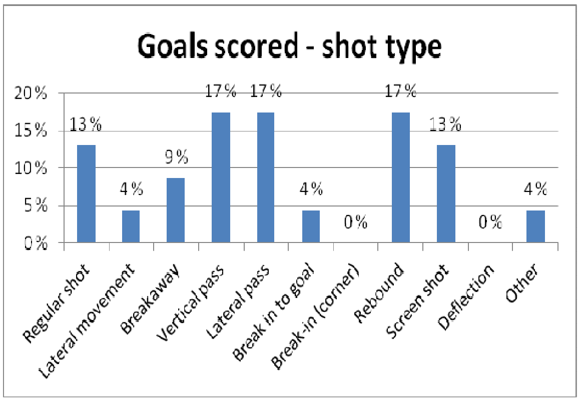
APPENDIX 2. Scoring analysis results.

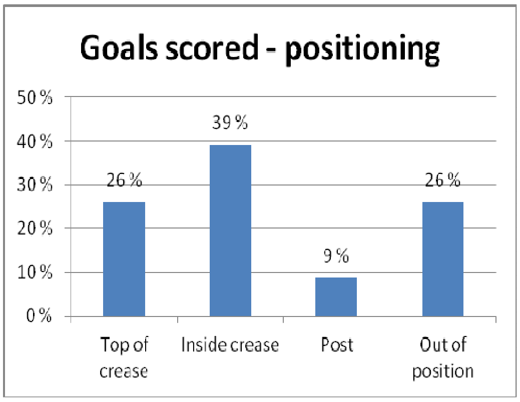
N=9 (all goals included)		Total	% of section
SHOT AREA	Area 1	5	22 %
	Area 2	13	57 %
	Area 3	3	13 %
	Area 4	2	9 %
	Area 5	0	0 %
SHOT DIRECTION	High left	2	9 %
	High right	8	35 %
	Low left	4	17 %
	Low right	2	9 %
	5 hole	2	9 %
	Empty net	5	22 %
SHOT TYPE	Regular shot	3	13 %
	Lateral movement	1	4 %
	Breakaway	2	9 %
	Vertical pass	4	17 %
	Lateral pass	4	17 %
	Break in to goal	1	4 %
	Break-in (corner)	0	0 %
	Rebound	4	17 %
	Screen shot	3	13 %
	Deflection	0	0 %
	Other	1	4 %
POSITIONING	Top of crease	6	26 %
	Inside crease	9	39 %
	Post	2	9 %
	Out of position	6	26 %
READINESS	GS stand-up	9	39 %
	GS ice	3	13 %
	Not GS stand-up	1	4 %
	Not GS ice	1	4 %
	In mov stand-up	3	13 %
	In mov ice	3	13 %
	Outplayed	3	13 %
TECHNIQUE	Butterfly	14	61 %
	Half butterfly	0	0 %
	Stand-up	0	0 %
	BF-/half BF slide	3	13 %
	Post load/VH	2	9 %
	Other	4	17 %
EQUIPMNENT	Body	*na*	*na*
	Glove	*na*	*na*
	Blocker	*na*	*na*
	Stick	*na*	*na*
	Pad	*na*	*na*
RESULT	Controlled save	*na*	*na*
	Uncontrolled save	*na*	*na*
	GOALS	**23**	

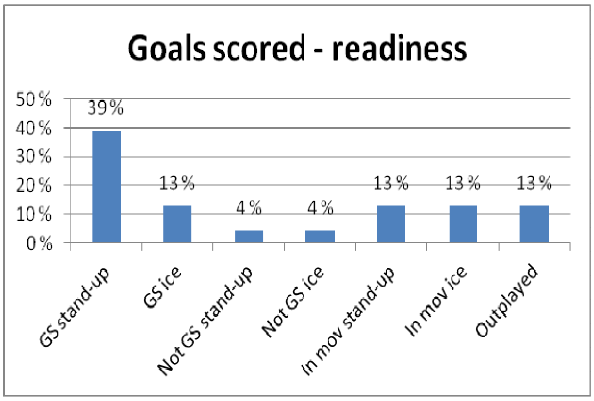
APPENDIX 3. Figures of scoring analysis results.

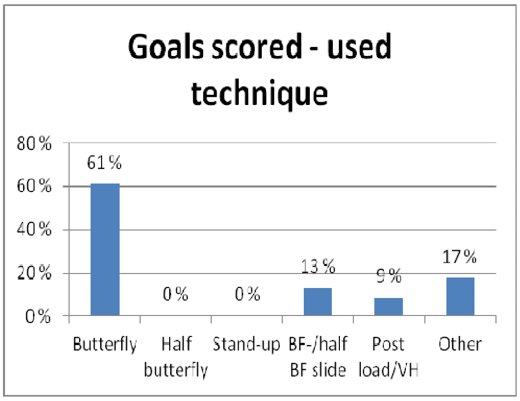












APPENDIX 4. Action analysis values.

GOALIE ACTIONS	**Mean & SD** (fast/slow)				**Mean, SD & % of total actions**		
	Fast	*SD*	Slow	*SD*	**TOT** (f + s)	**SD** (f + s)	% of total
LATERAL MOVEMENT							
shuffle	28,7	10,9	26,0	6,9	54,7	14,8	14 %
t-push	7,3	4,2	6,4	5,1	13,8	8,5	4 %
ice	8,4	2,7	0,2	0,4	8,7	3,0	2 %
HORIZONTAL MOVEMENT							
c-cuts	7,8	7,2	132,4	34,8	140,2	34,7	36 %
t-push	7,6	4,7	3,8	2,4	11,3	4,2	3 %
ice	0,7	0,9	0,0	0,0	0,7	0,9	0 %
Vertical movement	55,8	11,6	11,0	4,0	66,8	13,6	17 %
Full butterfly	42,2	6,2	0,1	0,3	42,3	6,1	11 %
Half butterfly	2,2	1,7	0,0	0,0	2,2	1,7	1 %
Butterfly-/Half BF slide	16,2	6,9	0,1	0,3	16,3	6,9	4 %
Stand-up save	2,0	2,1	0,1	0,3	2,1	2,0	1 %
Other save technique(VH)	7,6	4,9	0,3	0,7	7,9	4,7	2 %
Sprawl	2,9	1,7	0,0	0,0	2,9	1,7	1 %
Poke check	1,4	1,3	0,0	0,0	1,4	1,3	0 %
Playing the puck	6,7	4,8	9,4	3,1	16,1	4,2	4 %
Skating out of net	1,6	1,1	0,2	0,4	1,8	1,0	0 %
OVERALL	**199,0**	35,6	**190,2**	46,0	**389,2**	68,5	100 %

APPENDIX 5. Working periods and intensity analysis values.

Working periods and intensity											
***N*= 9**	1	2	3	4	5	6	7	8	9	**Mean**	**SD**
Slow/low intensity											
0,5-3sek	24	25	19	23	26	17	12	15	9	**18,9**	6,1
3-8sek	57	84	52	45	72	52	41	53	60	**57,3**	13,4
8-15sek	14	23	35	39	32	47	24	45	34	**32,6**	10,7
15-30sek >	6	8	10	19	20	26	19	15	15	**15,3**	6,4
30sek >	0	1	2	4	1	7	9	10	3	**4,1**	3,7
Fast/explosive (only)											
0,5-3sek	5	5	8	1	1	2	2	1	1	**2,9**	2,5
3-8sek	5	4	4	0	3	0	0	1	1	**2,0**	2,0
8-15sek	-	-	-	-	-	-	-	-	-	**-**	-
15-30sek >	-	-	-	-	-	-	-	-	-	**-**	-
30sek >	-	-	-	-	-	-	-	-	-	**-**	-
Fast/exp inside low intensity											
0,5-3sek	53	79	60	93	75	83	58	92	65	**73,1**	14,8
3-8sek	4	10	4	10	8	10	10	14	9	**8,8**	3,2
8-15sek	-	-	-	-	-	-	-	-	-	**-**	-
15-30sek >	-	-	-	-	-	-	-	-	-	**-**	-
30sek >	-	-	-	-	-	-	-	-	-	**-**	-
Total	168	239	194	234	238	244	175	246	197	**215,0**	31,3