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Time-motion analysis and heart rate telemetry of ice hockey play

by

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Abstract

The purpose of this study was to measure the intensity and duration of ice hockey play for six university hockey players (three forwards and three defencemen) and to compare them with the results to a similar study published in 1976. Comparisons of heart rate output and time-motion characteristics between forwards and defencemen were examined as well as differences in intensity between practices and games. The players performed at significantly lower intensity, had less playing time per shift, and had less playing time per game than the players in the 1976 study. Both investigations had similar bench times between shifts. The forwards had significantly different time-motion characteristics from the defencemen but similar playing time intensity. The intensity of games was higher than practices in terms of on-ice intensity but similar in terms of total time above a threshold intensity ($\geq$ 70% of HRmax).

Abstrait

le but de cette étude était de déterminer l'intensité et la durée d'une joute de hockey sur glace de six jouers de hockey universitaires (trois ailiers et trois défenseurs) et de les compare avec les résultats d'une étude similaire publiée en 1976. Une comparison entre le rendement de la vitesse du coeur et les caractéristiques du temps par rapport au mouvement furent examinés entre les ailiers et les défenseurs de même que les différences d'intensité entre les pratiques et les joutes. Les jouers avaient une intensité plus basse de même qu'un temps réduit sur glace par période et par joute, que les jouers de l'etude de 1976. Les deux enquêtes avaient une durée sur le banc semblable entre chaque période. Dans cette étude, les ailiers avaient des caractéristiques de temps par rapport au mouvement très differentes de celles des défenseurs. Par contre, l'intensité du temps de joute était analogue. L'intensité des joutes était plus élevée que dans les pratiques en terme d'intensité sur glace mais semblable en terme du temps total au-dessus du seuil d'intensité ($\geq$ 70% de HRmax).

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Chapter 1

Introduction

1.1 Nature and Scope of the Study

"Henderson has scored for Canada."

Paul Henderson's goal in the 1972 Soviet versus Canada hockey series sent many Canadians and North Americans into jubilation and sighing in relief as the series came to an emotional end. The series was over, but eyes and ears of North American hockey minds were now open to learn from the Soviet and Europeans. It marked the beginning of renovations to several aspects of the North American game.

Two of the tools utilized by the Soviets were monitoring of heart rate to estimate the intensity of ice hockey work, and detailed analysis of the various actions, skills and time components of the hockey player participating in a game. Science had been applied to Canada's game before, but it was not until 1974-1975 that heart rate telemetry and time-motion analysis were simultaneously performed on ice hockey players in North America (Romet, Goode, Watt, Allen, Schonenberg and Duffin, 1976).

It has been shown in numerous studies that the greater the intensity of exercise, or the greater the exercise workload, the harder the heart must pump blood to deliver oxygen to the working muscles. There is a linear relationship between the intensity of exercise and heart rate (McArdle, Katch, & Katch, 1991).

Studies of time-motion analysis identify and quantify the physical movements and the specific patterns of play that are involved with a sport. For example, Ramet, Goode, Watt, Allen, Schonberg, and Duffin (1978) identified and measured various actions that occurred during an ice hockey practice. The results were contradictory to the coach's objectives. The researchers reported only 20 minutes of skating for one player in a 60 minute practice despite the coach's belief that the players were skating for 45 minutes. Time-motion research has been performed on other sports such as soccer (Mayhew, & Wenger, 1985), rugby (Docherty, Wenger, & Neary, 1988) and handball (Alexander, & Boreskie, 1989). Conducting time-motion observations and telemetering heart rate in synchronicity during an activity, enables the researcher to measure physiological demands for the different physical actions of the game. In addition, it enables them to calculate the time spent per game at particular heart rate intensities and the time spent performing the various time-motion components of the activity. This information is valuable for the understanding of movement patterns of the game, and to the development and prescription of training programs for that particular sport.

1.2 Rationale for the Study

If you were to ask players, coaches and other hockey intellects who have been involved with the game at elite levels (university, junior, professional) for the last 15-20 years, they would tell you that the game

is played at a much faster pace today compared to 15-20 years ago. Not only would they say the intensity of the game is higher, but that the elite teams generally use four lines now where as years before, a team usually went with three lines.

The time-motion measurements and heart rate intensity results of Thoden and Jette (1975); Green, Bishop, Houston, McKillop, Norman, and Stothart (1976), and Leger (1980) on elite hockey players, may not reflect the time-motion characteristics and intensity of ice hockey play in 1994. With the elite level hockey teams utilizing four forward lines, it is presumed that this would have implications in the duration and intensity of play of hockey games. If so, it would suggest that a different physiological output by the ice hockey player, may be necessary to perform optimally in games and in training.

1.3 Statement of the Problem

The game of hockey appears to have undergone changes over the last 15-20 years. Therefore, the purpose of the study is to measure the intensity and duration of ice hockey play and to compare them with the results of the study published by Green et al. in 1976. In addition, the variability in heart rate output and time-motion response between forwards and defencemen is analyzed as well as differences between practices and games.

1.4 Hypotheses

1.4.1 The mean heart rate intensity during on-ice play is higher than the mean heart rate intensity reported by Green et al. (1976).

1.4.2 Time-motion characteristics (playing time per shift, bench time between shifts, and playing time per game) are significantly different than the results reported by Green et al. (1976).

1.4.3 Forwards and defencemen do differ significantly in intensity during on-ice play.

1.4.4 Forwards and defencemen do differ significantly in time-motion characteristics (playing time per shift, bench time between shifts, and playing time per game).

1.4.5 The mean intensity is significantly lower in practices than games.

1.4.6 The total minutes at a heart rate intensity greater than or equal to 70% is significantly higher in practices than games.

1.5 Delimitations

1.5.1 The hockey players in this study were male university hockey players.

1.5.2 Data were collected on only six players from the hockey team.

1.5.3 Data were collected on only three players simultaneously.

1.5.4 Data were collected from six regular season games.

1.5.5 Generalizations can only be made in relation to: (1) hockey players with similar ability; (2) the age range of the subjects; and (3) hockey players who play three, 20 minute stop time periods.

1.6 Limitations

1.6.1 The data from games were collected at various arenas, rather than a single location.

1.7 Operational definitions

Games

Bench time (G1) is the amount of time the player spends recovering on the bench between on-ice shifts.

Playing time (G2) — is the time the player is on the ice and play is in progress.

Stoppage time (G3) — is the amount of time that the player is on the ice where play is interrupted. The time between a whistle and the subsequent drop of the puck at a face-off.

On-ice (G2+G3) — is the amount of time that a player spends on the ice. It is the sum of playing time and stoppage time. One on-ice incident would constitue a shift.

Practices

Bench time (P1) — is the time that the player is on the bench and off the ice.

Low velocity skating (P2) — occurs when the subject is skating at a low velocity. This would include gliding, stretching, taking shots on the goalie and when the subject is stationary on the ice. This skating requires little effort by the player.

High velocity skating (P3) occurs when the subject is skating at moderate or high velocity. The legs and arms of the player are in motion and moving fast. This represents a good to all out effort by the player.

Other (P4) is any condition that does not fit the other conditions. This would include fighting for the puck along the boards or for position in front of the net or fighting amongst the players.

On-ice (P2+P3+P4) is the total time that the player spent on the ice during practices. It negates bench time and it is the sum of low velocity skating, high velocity skating and other conditions.

Chapter 2

Review of Literature

The review of literature has been divided into two sections, with three subsections contained within each. The first section is on heart rate telemetry. The heart rate measurements of subjects during ice hockey practices and tasks are reviewed, followed by a review of heart rate telemetry during actual games, and the heart rates of forwards and defencemen during games are compared.

The second section examines time-motion analysis of ice hockey. This section is divided into time-motion analysis of ice hockey practices, games and a comparison between forwards and defencemen.

2.1 Heart Rate Telemetry

In 1963, Kozar and Hunsicker telemetered the heart rates of 10 young adult men during their participation in various sports. These subjects had significantly higher heart rates when they played tennis, paddleball, badminton and handball than they did when they took part in volleyball or bowling. The heart rates measured for volleyball were also significantly higher than the heart rates for bowling.

There are many types of sports or activities in which an individual can participate. Each sport has physical and physiological demands in order to perform sucessfully in that sport. Thus different sports will

produce different physical and physiological responses from its' participants (Kozar & Hunsicker, 1963).

The telemetering of heart rates during sport is one way of measuring the demands of the activity. Ali and Farrally (1991) recorded the heart rates of soccer players during matches to obtain information about the physiological load imposed on soccer players during a game. Beaudin, Zapeic and Montgomery (1978) measured the heart rate intensity of squash players to determine the aerobic intensity of the game. Noble (1975) gathered heart rates on women performing gymnastic routines in a competitive setting to predict oxygen uptake and Reilly and Thomas (1979) used heart rates as an estimate of the energy expenditure in a professional soccer game. Ice hockey studies have also employed heart rate telemetry to measure the physical and physiological demands of the sport (Seliger, 1968; Thoden & Jette, 1975; Green 1978; Montgomery 1979).

2.1.1 Heart Rate Telemetry During Ice Hockey Practices and Tasks

Seliger (1968) published the first heart rate data on ice hockey. His focus was to assess the energy expenditure for various physical activities. For hockey, he measured the heart rates of 15 junior players (16-20 years old) in a model match. The subjects played for 90 seconds and then recovered for 180 seconds. This pattern was repeated three times. The player's heart rates averaged 160 beats per minute (bpm) with a peak of 177 bpm.

Later, Seliger et al. (1972) measured heart rates on hockey players

during a simulated match. Subjects were 13 players from the Czechoslovakian National team. The players were on the ice for approximately 60 seconds and off the ice for 180 seconds. This pattern was repeated six times resulting in an average heart rate of 152 bpm. It was noted that the heart rate increased slightly from the first to last repetition. Seliger et al. (1972) indicated that these heart rate results generally agreed with his results found previously on the junior hockey players.

Romet, Goode, Watt, Allen, Schonberg and Duffin (1976) measured the intensity of ice hockey activity by monitoring heart rates of three players during three practice sessions. During the first practice, one player had a heart rate above 150 bpm on six different occasions, for a total of 14 minutes during a 60 minute practice. The following practice, players 2 and 3 displayed heart rates above 150 bpm, on 12 and 18 occasions respectively, for a total of 21 and 30 minutes during the 60 minute practice. Romet et al. (1976) published only the results of one player for the first practice and the results of the two other players during another practice. This study did not compare the intensity of play among the players during practices. The authors noted that the coach intensified the latter practice from the previous one.

Green (1978) measured the heart rate during continuous and intermittent ice skating. The subjects in the continuous group, skated for one hour at a velocity corresponding to 60% of VO2max. The intermittent group skated for one minute at a velocity corresponding to 120% of VO2max. The intermittent group repeated this work bout ten times with five minutes of rest between every skating bout. The heart rate

results for the continuous group averaged 140 bpm at the 12th minute, slightly higher at the 26th minute and 150 bpm at the 53rd minute. For the intermittent group, the average heart rates after the 2nd, 4th and 9th workbouts, were 180 bpm or greater at all three measurements.

Montpetit, Binette and Taylor (1979), measured the heart rates of eight university students during an intermittent hockey task. The subjects had played varsity hockey or better. The task was designed to mimic a game in that it took 27-30 seconds to complete once and was performed a second time after a 40 second break which corresponded to a stoppage in play. The subjects repeated this procedure four times, to represent a period and they completed two more periods, to depict playing a full game. The mean heart rate was approximately 171 bpm. This is higher than those heart rates reported by Seliger (1968) and Seliger et al. (1972) for simulated game conditions, yet lower than the study by Green (1978) for an intermittent skating experiment. It would be reasonable to assume that if Montpetit et al. (1979) had his subjects perform the 27-30 second drill twice with no rest in between, the heart rate results would be higher and similiar to Green's (1978).

In a very recent study by Horne, Wenger and Wiley (unpublished), heart rate was monitored in eight intercollegiate hockey players during both practices and a game. During practice, the heart rate was equal or greater than 90% of maximum heart rate for 22.8% of the practice, 80-89% of HRmax for 33.6% of the practice time, and 70-79% of HRmax for 20.8% of the practice. Approximately 56% of the practice time was spent at an intensity greater than 80% of HRmax. The pulse recordings during the games, resulted in significantly different values. Nearly 65% of the game

time was spent at intensities equal to or greater than 80% of HRmax. Based on a mean maximum heart rate of 183 bpm for the study, 90% of HRmax = 164.7 bpm and 80% of HRmax = 146 bpm. These values would tend to reflect an intensity level of hockey play comparable to that of Seliger et al. (1972). It is interesting to note that although Green (1978) recorded mean heart rates in excess of 180 bpm for the intermittent skating protocol, his subjects had an average max heart rate of 199 bpm. Horne et al. (unpublished) and Seliger et al. (1972) had study groups with an average heart rate max of 183 and 184 respectively. The difference in heart rates between Green (1978) and the other two investigations would decrease if they are all expressed as a percent of HR max. However, there is still significant discrepancy among these studies.

2.1.2 Heart Rate Telemetry During Ice Hockey Games

In 1974, Wilson and Hedberg monitored the heart frequency of Swedish National hockey players during three games. The average heart rate while on the ice was 180 bpm. The author's noted that the average heart rate for the game against the Soviet National team was higher than the three game average. In that game, nearly every player on every shift, reached their maximum heart rate level. Data published on one subject, Anders Hedberg, revealed heart rate averages of 179, 183 and 173 bpm for the three games. The peak average heart rates for the games were respectively 191, 197 and 187 bpm. The average heart rates ranged from 160 bpm for a 9 second shift to 192 bpm for a 129 second shift.

Similarily, Paterson, Cunningham, Penny, Lefcoe and Sangal (1977) found heart rate results that agreed with Wilson and Hedberg's (1975) but their subjects were 10 year old boys. Competitive (n=14) and house-league (n=14) hockey players had their heart rates monitored during games. The average heart rate on the ice was 182 bpm (92.3% of HRmax.) and 187 bpm (94.7% of HRmax.) respectively for the groups. The mean peak intensity was 190 bpm for the competitive group and 198 bpm for the house-league group. The mean off-ice heart rate was 135 bpm (68.4% HRmax) and 141 bpm (71.1% HRmax) respectively for the higher and lower skilled 10 year olds. The 10 year olds in this study nearly reached their HRmax on every shift.

A later investigation by Paterson (1979) supported for his earlier findings in young boys. This time, heart rate telemetry was used with three groups of competitive players ranging in age from 10 to 15 years. The mean on-ice heart rate was 90% or more of HRmax. The mean peak on-ice heart rate was equal to or greater than 95% of HRmax and the bench heart rate was between 60 to 75% HRmax.

Green, Bishop, Houston, Mckillop, Norman and Stothart (1976) had 10 university hockey players wear heart rate monitors for 6 games to assess the time-motion characteristics and matching physiological changes that occur at the various player positions. The mean playing time heart rate was 173 bpm. Using the mean heart rate max of 195 bpm for the group, 173 bpm equates to 89% of HRmax. Green, Daub, Painter and Thomson (1978), did a follow up study, where they found the varsity players to have a mean on-ice heart rate equal to 90% of HRmax. When the subjects were recovering on the bench, the heart rate seldom dropped below 125 bpm.

Not only has there been heart rate monitoring of exercise intensity

of hockey players at the national, intercollegiate and youth levels but Montgomery (1979) performed research on the intensity and duration of play in adults (old timers). Twelve forwards having a mean age of 32 years were monitored during various Old Timer hockey games. The mean heart rate over the various games was 160.8 bpm. The mean heart rate was 89% of HRmax. This is practically identical to Green et al's results (1976). The mean peak intensity for the shifts was 94.4% using the Karvonen method and this would be higher if one simply divided the peak heart rate by the maximum heart rate. The average heart rate on the bench was 126 bpm or 70% of HRmax. These results are similar to the findings of Paterson's (1979) with 10 to 15 year old boys and to Green et al (1976, 1978) with intercollegiate hockey players.

Recently, Davis (1991) telemetered heart rate on four members of the NHL Calgary Flames over a period of 5 games. The mean heart rate during a shift was 168 bpm. The mean heart rates ranged from 145 to 191 bpm. Between shifts the mean heart rate was 120 bpm.

Mentioned previously was the monitoring of heart rates during practices and games by Horne et al. (unpublished). The varsity athletes had heart rate intensities equal or greater than 90% HRmax (> 164.7 bpm) for 34.87% of their on-ice play and had an intensity level of 80-89% HRmax (> 146.7 bpm but < 164.7 bpm) for 30.2% of their play. Even though 65% of the game was played at heart rates of 80% or greater, the researcher's heart rate results are lower than those of Paterson et al. (1977), Paterson (1979), Green et al. (1976), Green et al. (1978) and Montgomery (1979).

It is difficult to draw comparison to the study by Davis (1991) with

the others, as the mean maximum heart rate of the four NHL players, was not given. A comparison with Wilson and Hedberg's research (1975) is possible. Based on the data of Anders Hedberg, if his highest recorded heart rate, which was 204 bpm, is used as his max heart rate, then the average on-ice heart rate would be 86.5% of HRmax. His average peak heart rate would be approximately 94%. These are slightly lower values than Paterson et al. (1977), Paterson (1979), Green et al (1976), Green et al. (1978) and Montgomery (1979) but definitely in the same agreement group with them.

2.1.3 Heart Rate Telemetry of Forwards versus Defencemen

A person who plays a position on a team sport may not elicit the same heart rate intensity as another player playing a different position for the same sport. For example, Reilly and Thomas (1976) observed variability in heart rates between soccer players who played different positions. Whether or not ice hockey defencemen and forwards elicit distinct or similiar heart rates has also been examined.

Based on the data collected by Green et al. (1976), differences were noted in heart rates between defencemen and forwards. The intercollegiate forwards had an average heart rate of 10-15 bpm higher than the defencemen. Yet in another study by Green et al (1978), there was no discrepancy in the average on-ice heart rates between two varsity forwards and defencemen.

Horne et al. (unpublished), found no significant variations in any

of the heart frequency variables measured between university forwards and defencemen. Paterson (1979) reported similiar heart rate data difference between forwards and defencemen, except for higher recovery heart rate for the defensive position.

Research is inconclusive as to whether differences in heart rate intensity exist between forwards and defencemen.

2.2 Time-Motion Analysis

To study the time-motion characteristics of a sport, a researcher must define and measure the various movement components that are involved with the effective performance of the sport. Time-motion studies, like heart rate telemetry, are used to gain insight into the physical and physiological requirements of an activity. Different sports such as soccer (Reilly & Thomas, 1976, Mayhew & Wenger, 1985), handball (Alexander & Boreskie, 1989), and rugby (Docherty, Wenger, & Neary, 1988) have been analyzed from a time-motion perspective. A better understanding of the time-motion components would allow the researcher to make inferences about the physiological requirements of the game. Furthermore, it provides a basis for the development and prescription of training programs for the sport.

2.2.1 Time-Motion Analysis During Ice Hockey Practices

Romet et al. (1978) recorded the various time motion characteristics that occured during a 60 minute practice. It was not specified whether the subject was a university hockey player or an NHL all-star. The first three minutes of the practice were spent in easy skating to warm-up, and during the 3rd to 8th minute, the player skated hard. Positioning, passing and shooting drills followed for 10 minutes, then skating and passing for four minutes, followed by defensive drills that included gliding, skating and stopping from the 22nd to the 35th minute of the practice. The player then scrimmaged for 15 minutes. The last 10 minutes contained a mixture of skills and drills with some skating being incorporated as well. The investigators determined that only 20 minutes of the one hour practice was spent skating despite the objectives of the coach who intended for the players to skate for 45 minutes.

The actions of a hockey practice for intercollegiate players were broken down into six activities by Horne et al. (unpublished). The practice was categorized by the following activity:

Activity	Percent of Practice Time
Standing	41.8%
Gliding	25.19%
Slow Skating	15.7%
Fast Skating	13.79%
Sprinting	2.7%
Puck Protection	1.1%

Puck protection involves sustained physical contact with another player. These time motion results when compared to the athlete's pattern of play in the games are very different. The players stand and sprint less during the games but glide, slow skate, fast skate and protect the puck much more. If the intent of the coaches was to mimic the actual game then they were unsuccessful.

2.2.2 Time-Motion Analysis During Ice Hockey Games

Thoden and Jette (1975) studied the proportion of time spent in anaerobic or bursting activity, coasting and bench time during three junior hockey games and one National Hockey League contest. The length of the shifts for both elite levels of hockey play averaged between 68-74 seconds per period. The juniors spent more time per shift in anaerobic bursting activity than the professionals (14 s/shift to 10 s/shift). The junior players averaged more bursts per shift and longer average burst times. The amount of ice time was roughly 350 seconds for the two levels of players for the first and second period. However the juniors had a third period average of 420 seconds of ice time while the NHL players had a mean of only 330 seconds of ice time. The researchers summarized their study by stating that the average player is on-ice for a 75-90 second shift, amounting to 5-7 minutes of ice time per period. This is divided into 5-6 shifts/period with 3-4 minutes of rest between shifts.

Wilson and Hedberg (1975) measured the shift lengths of members of the Swedish National Team. Their subjects remained on the ice on average

for about 60 seconds. This is shorter than the shift times found on NHL and junior players by Thoden and Jette (1975). Only the data for one player (Anders Hedberg) were published by Wilson and Hedberg. For the three games that they observed this player, the average shift times were 59, 62 and 58 seconds respectively for each of the games. Out of eight periods that were analyzed, the lowest average shift time for one period for the player was 51 seconds and the highest was 68 seconds. The average ice time per period was 354 seconds calculated from eight periods of play. This is in agreement with ice time per period results of Thoden and Jette (1975). The range was 298 seconds to 444 seconds of ice time for one period of hockey play. The player never had less than five shifts in one period and never more than eight. Anders Hedberg averaged slightly more than six shifts/period.

In 1976, Green et al. performed time motion analysis on 10 members of a varsity hockey team. They found the players to be playing on the ice for an average of 24.5 minutes of a 60 minute game. The subjects averaged 17.4 shifts/game and their shifts/period ranged from 4.5 to 7.3. The average length of the shift was 148 seconds, which consisted of 85.4 seconds of uninterrupted play and 62.3 seconds of stoppage in play. The players had an average of 225 seconds of recovery time on the bench between shifts. Green et al. (1976) also made note of the fact that the playing time per shift, the playing time between stoppages and the time of the play stoppages, all increased over the three periods.

If one presumes that the elite players in Thoden and Jette (1975) and Wilson and Hedberg's (1975) studies, played a 60 minute stop time game, then we can compare ice time with Green et al. (1976). Both 1975

studies found the players to be working on the ice for an average of about 17.7 minutes whereas Green et al. (1976) reported that their group was active on the ice for an average of 24.5 minutes per game. Although shifts/game were similiar for the three studies, Green et al. (1976) found intercollegiate hockey players to be performing on the ice 38% more during a game than the other two studies. (Refer to Table 1).

Green et al (1978) also studied varsity hockey players to measure glycogen depletion during ice hockey play. The time-motion characteristics of eight subjects were recorded. The players averaged 24 minutes of playing time per 60 minute game. They had an average of 7.4 shifts/period which translates into slightly more than 22 shifts/game. Mean playing time per shift was 65.5 seconds with the individuals ranging from 56.7 s to 73.6 s/shift. Stoppages lasted on average for 30 seconds and mean playing time between whistles was 29 seconds. The mean recovery time between shifts was 241 seconds with an individual range of 175 to 301 seconds of recovery between shifts. Compared to the earlier report by Green et al (1976), the players had shorter shifts, but more of them. This resulted in the players having virtually the same playing time per game.

Time-motion analysis has also been used in youth hockey (Paterson et al, 1977; Paterson, 1979). Two groups of 10 year old boys averaged 19 minutes of ice time and 23 minutes of bench time during house-league and competitive hockey games (Paterson et al., 1977). In the next study, Paterson (1979) evaluated the play of these competitive groups averaging 10.7, 12.2 and 14.4 years. The duration of the games were 30 minutes of stop time for the two younger groups and 39 minutes for the oldest group.

Table 2.1 Comparison of time-motion analysis studies

STUDY	N	Mean shift time (s)	Mean playing time/shift (s)	Mean stoppage time/shift (s)	Mean number of shifts per game (#)	Total time on ice (min)	Total playing time per game (min)	Length of game (min)	Mean time on the bench (min)
Thoden & Jette 1975 - junior - professional			68-74		15-18		18.7 16.7	60 stop	3-4
Wilson & Hedberg 1975 - Anders Hedberg	1		60		18.3		17.7	60 stop	
Green et al. 1976 - university	10	148	85	62	17.4	43	24.5	60 stop	3.75
Green et al. 1978 - university	8	135	66	69	22.3	50	24	60 stop	4
Paterson et al. 1977 - competitive - house-league	14 14					19		45 run	
Paterson 1979 - 10.7 years - 12.2 years - 14.4 years	19 28 22		103 89 94		8 8.5 10.5		13.7 12.5 16.2	stop 30 30 39	3.8
Montgomery 1979 - "oldtimers"	12	230	139	91	7.8	29.9	18.9	65 run	
Montpetit 1979 - midget		201	92	109	10.4	34.8	15.9		
Leger 1980 - midget - junior	170 80	91 146	87	59	11.3 12.8	17.2 31.4	18.5	60 stop	2.46 5.5
Horne et al. (unpublished) - university	8	111	47	64	20	37	15.8	60 stop	5.17

For all three groups, the average on-ice time per player was 42% of the game. The number of shifts per game were 8.0, 8.5, and 10.5, respectively for the three groups. Mean shift time was 102.6 s, 88.5 s, and 93.7 s, respectively. The amount of time between play stoppages averaged 40.5 s, 43.7 s, and 41.4 s, respectively. The average recovery time on the bench ranged from 123 to 130 seconds.

Ice hockey is also enjoyed by individuals further along the age spectrum. Montgomery (1979) carried out a research study on "oldtimers" that participated in a hockey league to see if physiological demands of the game were significant enough to improve aerobic fitness. The average age of the "oldtimers" was 32 years. The mean amount of playing time for the 12 adults was 18.9 minutes/game which totalled 29% of the 65 minute running game time. This corresponds to the percent of playing time per game recorded by Thoden and Jette (1975) and Wilson and Hedberg (1975). The average time between play amounted to nearly 11 minutes or 15.8% of the game. The number of shifts/game ranged from 6 to 12 with 7.8 shifts/game being the mean. The average shift time was 139 seconds. The stoppages in play occurred on average 3.5 times per shift. The subjects averaged close to 36 minutes on the bench which is slightly more than 55% of the game. Hence, the oldtimers were on the ice on average for 45% or 29 minutes of the game.

Montpetit et al. (1979) designed a simulated hockey task to measure muscle glycogen depletion. This test was developed from a time-motion analysis investigation of hockey players in the Quebec Amateur Hockey Association at the midget level (15-16 years old). The average number of shifts/game was 10.4. The mean shift time was 202 seconds which included

92 seconds of active time and 110 seconds of stoppage in play. Total ice time was about 35 minutes of which 16 minutes would be playing time. Note that compared to the previous time-motion studies that measured the average length of time for game stoppages, only Green et al. (1978) and Montpetit (1979) have found this measure to be longer than the active time between whistles. Length of the game and time between shifts were not reported.

One hundred and seventy midget hockey players were examined by Leger (1980). Leger performed time-motion studies of hockey play on this group. The mean ice time was 17.2 minutes. This ice time would be divided up into approximately 11.3 shifts/game hence the average shift was about 91 seconds. This 91 seconds includes both active and inactive time on the ice. Mean recovery time for the group was 147.5 seconds which is lower than the university and adult hockey players (Green et al. 1976; 1978; and Montgomery, 1979) but higher than their younger counterparts (Paterson, 1979).

Leger (1980) also investigated the movement patterns of 80 junior hockey players. These players were on the ice longer than the midgets in the same study, resulting in a mean shift time of 146 seconds. This shift included 87 seconds of active time and 59 seconds of on ice inactivity. Average shifts per game were 12.8. The sum of the shift times indicated that the junior players were on the ice for 31.4 minutes and were active for 18.5 minutes of this time. The mean recovery time between shifts was greater than that reported by other time-motion studies. Leger found these hockey players to rest for an average of 329 seconds between shifts, which is nearly 5.5 minutes. This is 88 seconds longer than the average

bench time of intercollegiate hockey players (Green et al., 1978) and over 3 minutes longer than midget hockey players (Leger 1980).

Finally, the most recent time-motion study that has analyzed the patterns of play for hockey was conducted by Horne et al. (unpublished). Eight members of a varsity team were each observed during one entire game. These players averaged 20 shifts/game in a normal 60-minute, three period, stop time game. The mean shift time was 111 seconds of which 47 seconds was active time and 64 seconds was inactive on ice time. Thus 57% of the athlete's ice time was not engaged in play. Montpetit et al. (1979) and Green et al. (1978) also measured greater amounts of stoppage time than active playing time. Playing time averaged 15.77 minutes per game or 26% of the game and reflects the usage of four lines by the coach. Similiar to the recovery results of junior hockey players (Leger, 1980), these university hockey players had a mean bench time of 310 seconds or 5.17 minutes between each shift.

2.2.3 Time-Motion Analysis of Forwards versus Defencemen

Athletes that play a position in a team sport don't necessarily perform the same activities that another player would at a different position for the same sport. An offensive lineman in football and the punter are both football players but it is obvious that their patterns of play are very unique from each other. The question of whether the time motion characterisics of a forward and a defenceman hockey player are distinct, has also been researched.

In the study by Thoden and Jette (1975), the junior forwards averaged about 80 seconds less ice time per period compared to the junior defencemen. This translates into four more minutes of ice time per game. The defensive players at the professional ranks had 40 seconds more ice time than the professional forwards in one period and about 150 seconds more ice time in another period. On average, the NHL forwards had about 100 seconds less ice time per period than their defensive team mates. Although the junior players had more ice time compared to the pros, the NHL defencemen averaged more ice time than the junior forwards.

In Leger's (1980) study, the junior forwards averaged 30 minutes on the ice of which 18 minutes was active and 12 minutes was consumed by stoppages in play. The defencemen were on the ice for 32 minutes of the game which was 7.2% more than the forwards. The defencemen had 19.4 minutes of playing time and 13 minutes of stoppage time. The mean number of shifts/game were 12.2 for the forwards and 13.7 for the defencemen. The average shift length, playing time and stoppage time per shift were only 4% higher for the defencemen. Mean recovery time for the defencemen was 297 seconds which was 12% less time on the bench than the forwards.

In the same study by Leger, a very different pattern of play emerges between the two positions for the midget hockey players. The average midget defencemen was on the ice for 117.6 seconds, off the ice for 129.4 seconds and this occured over 11 shifts during the game. The midget forward averaged 79.4 seconds of ice time per shift, recovered on the bench for 159 seconds and repeated this 11.4 times during the game. The midget defencemen averaged 32% more time per shift, 18.5% less recovery time and had virtually the same number of shifts/game as the forwards.

The big differences in patterns of play between the junior and midget forwards and defencemen can partially be explained by the number of forward lines and defensive pairs for the two groups. The junior teams that were sampled had an average of 3.3 forward lines and 3.1 defensive pairs. The midget teams had 3.0 forward lines and 2.1 defensive pairs.

Time motion characteristics of youth players on a team using three forward lines and two sets of defencemen were analyzed (Paterson, 1979). The defence played on average 50% of the game and the forwards had a mean game time of 35%. The defencemen had more shifts than the forwards as well as a decreased recovery time on the bench compared to their offensive team mates. This was contrary to a previous time-motion study on competitive and house-league players by Paterson et al. (1977), in that the forwards and defencemen had similar time-motion characteristics.

Green and colleagues (1976, 1978) have observed time-motion characteristics of university players in two studies. A comparison of the findings from these studies is presented in Table 2. It appears that the two teams that were observed by Green et al. (1976, 1978) used three forward lines and two pairs of defencemen. The results of the recent study by Horne et al. (unpublished) reveals a shorter playing time per shift, a greater amount of time on the bench between shifts, and a decreased amount of playing time per game compared to Green et al. (1976, 1978). It would appear that the team observed by Horne et al. used four forward lines and three or more pairs of defencemen.

Table 2.2 Comparison of time-motion characteristics of forward and defencemen in university hockey

STUDY	n	Mean shift time (s)	Mean playing time/ shift (s)	Mean stoppag time/ shift (s)	Mean number of shifts/ game (#)	Total time on ice (min)	Total playing time/ game (min)	Length of game (min)	Mean time on the bench (min)
Green et al. 1976									
- Forwards	7	146	88	58	15.6	40	22.9	60 stop	4.3
- Defencemen	3	147	81	66	20.7	50	28		2.7
Green et al. 1978									
- Forwards	3	116	58	58	20.2	39	19.2	60 stop	4.9
- Defencemen	3	152	73	79	24.3	62	28.7		3.15
Horne et al. unpublished									
- Forwards	5	109	46	64	20.4	37	15.5	60 stop	5.1
- Defencemen	3	114	50	63	19.3	37	16.2		5.4

Thoden and Jette (1975) stated that the average hockey player was on the ice for 75-90 seconds per shift. Green et al. (1976) reported that the typical shift, averaged 85 seconds of playing time for college hockey players. It appears that Green thought somewhat differently later as he claimed that

> "wide differences exist in the charcteristics of each shift.....shift durations are usually between 30 and 120 s.....within the continuous play time of each shift segment, movement patterns are not only highly variable but range considerably in intensity."(Green, 1987)

In the review article "The Physiology of Ice Hockey" (Montgomery, 1988), it was stated that

> "although detailed study of time-motion characteristics of play are published, it is time to once again re-examine the pattern of play since shift duration is now shorter and intensity of play is higher.....most elite teams now utilise 4 units with a playing time of about 40 seconds per shift."

Montgomery's statement strengthens the notion that another study of ice hockey intensity and time-motion characteristics is necessary to examine hockey play in 1995.

Chapter 3

Methods and Procedures

3.1 Subjects

Six male hockey players, three forwards and three defencemen, from the McGill University hockey team participated in the study. The players were between the ages of 19-23 years. This group of players was selected since they play the regulation three, 20 minute stop time periods. All the players were on the regular roster and they could expect a reasonable amount of playing time.

3.2 Treatment of Subjects

Prior to testing, the subjects signed a consent form which confirmed their acceptance to participate in the study and indicated their understanding of the requirements involved for the study. The subjects' age, weight, and height were recorded before the start of data collection. The subjects' maximum heart rate was taken as the peak heart rate achieved in a practice, game or cycle ergometer VO2max test performed during the season.

Data were collected for three games and four practices on each hockey player during the months of January and February. Players were notified in advance of the practices and games when they were wearing the

heart rate monitor. Data could not be collected on more than three players simultaneously, due to equipment and manpower restraints. Prior to stepping on the ice, the researcher attached the heart rate monitor and transmitter to the subject in the dressing room. The transmitter was secured by wrapping a tensor bandage around the body of the individual and secured with a safety pin. The heart rate monitor was worn around the player's wrist. Just before the player stepped onto the ice, the wrist monitor was turned on to begin recording the heart rate. At the same time the heart rate monitor was activated, a stop watch was also started. The player was not given any further instructions other than to go out and play or practice as they normally do. After both the heart rate monitor and the stop watch were turned on, there was no contact with the player until he stepped off the ice at the end of a practice or game. Once in the dressing room, the recording of heart rate was stopped and the transmitter and monitor were removed from the player. The heart rate data were stored on the computer for later analysis.

3.3 Measurement Techniques

3.3.1 Time-Motion Analysis

Collection of time-motion data was performed for three games and four practices on each subject. For practices, the movement patterns of the player were classified as being one of four conditions;

Condition	Abbreviation
Bench time	P1
Low velocity skating	P2
High velocity skating	P3
Other	P4

During practices, the first recording of a movement occurred no more than 15 seconds after the player stepped on the ice. For games, the first time-motion recording occurred at the drop of the puck at the opening face-off. The last time-motion data for a session was recorded when the player left the ice at the end of a practice or game. When the player left the ice or bench at the end of the first or second period of play in a game, the compiling of time-motion data was stopped until the opening face-off of the next period.

Each hockey player was observed by one person. The time-motion results were recorded on a designed data sheet (see Appendix 1). The movement condition and the time of occurrence were recorded on the data sheet. Every time the player changed conditions, the recorder made note of both the time and subsequent condition. The time of the condition for a subject was measured by a stop watch that was previously and simultaneously started with the heart rate monitor for that individual subject. The stop watch remained running for the entire testing session, thus the running time was noted each time the movement condition changed. The time of one recorded condition was the difference in running time between that condition and the beginning of another.

Due to the skill needed to record the various time-motion movements

of a player during practice, all the data collectors watched a video of a practice to come to a concensus on the four conditions, primarily the difference between low velocity skating and high velocity skating. To ensure observer objectivity, the researcher and the assistants recorded time-motion data on the same player during a practice for an hour and the assistants results were checked against that of the researcher's. All observers needed to match 90% or better the results of the expert before they could collect time-motion data. As a check on the data collectors, the researcher randomly coded the time-motion of one of the players being observed at a practice and checked the assistants results against his. If any results were below 90% agreement, they were rejected. From the statistically reliable time-motion data collected during practices, the amount of time that the four conditions occurred was calculated for each player for all four practices.

For games, the movement patterns of the player were classified as being one of three conditions;

Condition	Abbreviation
Bench time	G1
Playing time	G2
Stoppage time	G3

From the time-motion data compiled during games, the amount of time for the three game conditions was summed. Using the game data for each player, the following variables were calculated: mean number of shifts per game, mean playing time per shift, mean playing time for the game, mean

stoppage time per shift, total time the player was on the ice, mean recovery time on the bench between shifts and total time to play the game. The time-motion results of this study were compared to the results of earlier time-motion hockey studies. Time-motion results were also compared between forwards and defencemen.

3.3.2 Heart Rate Telemetry

Heart rate was measured with the Polar Vantage XL monitor made by Polar CIC Inc. It is the equivalent of the PE 3000 Sport Tester made by it's allied counterpart Polar Electro Ltd. The accuracy and reliability of the PE 3000 Sport tester has been previously validated (Burke, & Whelan, 1987; MacFarlane, Fogarty, & Hopkins, 1989).

The heart rate monitor was put on the subjects inside the dressing room before the practice or game. The transmitter was secured by an elastic strap which fit around the player's torso at the level of the xiphoid process. To ensure that the transmitter would stay in place during a hockey game, it was wrapped with a tensor bandage. The heart rate monitor, worn like a watch around the wrist, was programmed to store the beats per minute every 15 seconds. The monitor was activated after the player left the dressing room but before he stepped onto the ice. At the end of the practice or game, the researcher stopped the heart rate monitor from recording further and removed both transmitter and monitor from the player. The data were saved in a computer file.

Once in the laboratory, the data file was downloaded from the

monitor into a computer using the Polar Computer Interface program. The heart rate data compiled during a practice was analyzed and the mean heart rate intensity and the time spent at relative percentages of HRmax were calculated for each player. The variability of heart rate response between practices for each individual player was determined. Mean playing time intensity, mean heart rate intensity on the bench, mean peak heart rate intensity and the time spent at relative percentages of HRmax were calculated for each player during games. These results were compared to previous heart rate results on hockey players. The variability of heart rates between games and practices as well as forwards and defencemen were analyzed.

3.4 Treatment of Data

For the six subjects as well as the forwards and defencemen, means and standard deviations were calculated for age, height, weight and HRmax

Data were presented for three games and four practices. The means of the time-motion characteristics, heart rates and intensities were calculated. Means were calculated for forwards and defencemen and for single game and practices. The final average and standard deviation of the measured variables represents a mean and standard deviation of the entire data set for all games and practices. It is not an average of three game means or four practice means.

The statistical treatment of the data is outlined in Table 3. A criterion level of probability of 0.05 or less was selected as the level where significance existed between the different data sets. The statistical analyses were performed on a Apple MacIntosh computer using Systat version 5.2.

Table 3.1 Statistical analysis

Hypothesis	Statistical Test
1	t test for independent samples
2	t test for independent samples
3	One way ANOVA
4	One way ANOVA
5	One way ANOVA
6	One way ANOVA

Chapter 4

RESULTS

4.1 Descriptive Data

The age, height, weight and maximum heart rate of the six hockey players are presented in table 4.1. The defencemen were slightly older and taller than the forwards and had lower maximum heart rates.

Table 4.1 Physical characteristics of the subjects.

Variable	Age (yr)	Height (cm)	Weight (kg)	HRmax (bpm)
Forwards				
1	21	177.8	74.1	216
2	21	175.3	81.8	203
3	22	172.7	82.3	195
Defence				
1	23	177.8	80.5	197
2	22	185.4	84.1	194
3	23	177.8	80.0	196
Mean	22	177.8	80.5	200
S.D.	1	3.9	3.1	8

4.2 Time motion analysis of games and practices

The time-motion results for games are presented in table 4.2. The average number of shifts per game was 17.8 with the defencemen having more shifts than the forwards (19.7 to 15.9) and more playing time per shift (66.0s to 58.5s). The mean playing time per game for the group was 18.6 minutes and the average time on the bench between shifts was 237.4s . The defencemen averaged 21.6 minutes of playing time per game compared to 15.5 minutes for the forwards and were on the bench for much less time than the forwards (192.5s to 282.2s).

The results of the time-motion data collected during practices are presented in table 4.3. The average length of a practice was 70.4 minutes. The hockey players skated at a low velocity for approximately 59.4 minutes of the total practice time. Thus 84% of the practice was performed at a low skating velocity. High velocity skating occured on average for only 1.8 minutes of the practice. The players spent an average of 8.6 minutes on the bench with the forwards (11.0 min.) spending roughly twice as much time on the bench as the defencemen (6.2 min.). Players fighting for the puck, position or each other accounted for only 0.6 minutes of a practice.

Table 4.2 Time-motion characteristics during games.

Variable	Game 1	Game 2	Game 3	X ± Std
Average shifts/game (#)				
Forwards	15.7	16.0	16.0	15.9 ± 3.7
Defence	19.3	17.3	22.3	19.7 ± 2.1
Total	17.5	16.7	19.2	17.8 ± 4.0
Mean playing time/shift (s)				
Forwards	58.5	57.2	59.7	58.5 ± 5.5
Defence	63.9	67.7	66.2	66.0 ± 7.5
Total	61.2	62.5	63.0	62.3 ± 7.7
Mean playing time/game (min)				
Forwards	15.5	14.9	16.0	15.5 ± 3.9
Defence	20.5	19.6	24.7	21.6 ± 4.2
Total	18.0	17.3	20.4	18.6 ± 5.1
Average bench time/shift (s)				
Forwards	262.9	284.2	299.5	282.2 ± 85.9
Defence	198.9	219.6	159.0	192.5 ± 43.6
Total	230.9	251.9	229.3	237.4 ± 80.0
Mean stoppages/shift (#)				
Forwards	1.7	1.3	1.6	1.5 ± 0.3
Defence	1.8	1.9	1.7	1.8 ± 0.3
Total	1.8	1.6	1.7	1.7 ± 0.3
Mean stoppage time (s)				
Forwards	29.2	29.3	32.1	30.2 ± 4.5
Defence	33.1	35.3	32.5	33.6 ± 2.2
Total	31.2	32.3	32.3	31.9 ± 4.0

Table 4.3 Time-motion characteristics during practices.

Practice #	Practice 1	Practice 2	Practice 3	Practice 4	X ± S. D.
Total time (min)					
Bench Time					
Forwards	13.5	11.6	8.5	10.5	11.0 ± 9.1
Defence	9.7	2.1	5.3	7.5	6.2 ± 3.8
Total	11.6	6.9	6.9	9.0	8.6 ± 7.2
Low velocity skating					
Forwards	69.2	53.4	55.8	54.8	58.3 ± 13.4
Defence	78.1	57.3	47.3	58.9	60.4 ± 11.1
Total	73.7	55.4	51.6	56.9	59.4 ± 14.7
High velocity skating					
Forwards	3.3	1.7	0.9	1.1	1.8 ± 1.2
Defence	2.7	1.1	1.8	1.0	1.7 ± 1.2
Total	3.0	1.4	1.4	1.1	1.8 ± 1.2
Other					
Forwards	0.2	0.2	0.1	0.6	0.3 ± 0.2
Defence	1.1	1.1	0.3	0.8	0.8 ± 0.7
Total	0.7	0.7	0.2	0.7	0.6 ± 0.6
Total Time (min)	89.0	64.4	60.1	67.7	70.4 ± 17.1

4.3 Heart rate intensity of games and practices

The heart rates and percent intensity during the games are found in table 4.4 and table 4.5. The mean heart rate for the group of hockey players while playing on the ice was 165.6 bpm which translates into an intensity of 82.5% HRmax. The mean heart rate measured during stoppage time was nearly as high as that measured for playing time. During stoppage time the mean heart rate was 161.5 bpm or approximately 80.5% of HRmax. The average heart rate for the players while on the bench was 138.5 bpm. This results in a bench time intensity of 69.1% of HRmax.

The heart rates and percent intensities for the practices are illustrated in table 4.6 and table 4.7. The highest mean heart rate occured while the players were fighting for puck, position or each other (145.6 bpm). This equals an intensity of 72.7% HRmax. This was virtually the same intensity found for high velocity skating which had a mean intensity of 72.3% HRmax. Most of the practice consisted of low velocity skating which produced a mean heart rate of 136 bpm (68.4% HRmax). The lowest intensity recorded was while the players were on the bench (60.6% of max HR).

A comparison between practices and games for the total minutes on-ice and at an intensity $\geq$ 70% HRmax is presented in table 4.8. During games, the players spent an average of

34.8 minutes on the ice. This ice time was nearly doubled during practices as they were on the ice for a mean of 61.7 minutes. Of the 34.8 minutes of ice time during games, 29.4 minutes (84.5% of the time) were performed at an intensity that was $\geq$ 70% the players' HRmax. During practices, the players spent 28.0 minutes at an intensity that was $\geq$ 70% HRmax. This amounted to 45.4% of the practice time.

Table 4.4 Heart rate (bpm) during games.

Game #	Game 1	Game 2	Game 3	X ± S. D.
Bench time (G1)				
Forwards	140.8	137.0	135.7	137.8 ± 10.1
Defence	136.3	134.1	146.8	139.1 ± 7.5
Total	138.6	135.6	141.3	138.5 ± 8.9
Playing time (G2)				
Forwards	170.5	169.2	167.7	169.1 ± 4.3
Defence	161.3	161.3	163.6	162.1 ± 5.6
Total	165.9	165.3	165.7	165.6 ± 5.8
Stoppage time (G3)				
Forwards	167.8	164.8	161.6	164.7 ± 8.8
Defence	157.4	155.8	161.6	158.3 ± 10.1
Total	162.6	160.3	161.6	161.5 ± 10.6
On-ice (G2+G3)				
Forwards	169.3	167.0	164.9	167.1 ± 6.3
Defence	159.5	158.6	164.1	160.7 ± 4.2
Total	164.4	162.8	164.5	163.9 ± 5.7

Table 4.5 Percent intensity (%HRmax) during games

Game #	Game 1	Game 2	Game 3	X ± S. D.
Bench time (G1)				
Forwards	68.9	67.1	65.1	67.0 ± 6.3
Defencemen	69.7	68.6	75.0	71.1 ± 4.2
Total	69.3	67.9	70.1	69.1 ± 5.7
Playing time (G2)				
Forwards	83.4	82.8	80.2	82.1 ± 4.2
Defencemen	82.4	82.5	83.6	82.8 ± 2.6
Total	82.9	82.7	81.9	82.5 ± 3.5
Stoppage time (G3)				
Forwards	82.1	80.7	77.3	80.0 ± 5.2
Defencemen	80.4	79.6	82.6	80.9 ± 2.8
Total	81.3	80.2	80.0	80.5 ± 4.1
On-ice (G2+G3)				
Forwards	82.7	81.6	80.6	81.6 ± 0.9
Defence	81.5	81.0	83.9	82.1 ± 1.3
Total	82.1	81.3	82.3	81.9 ± 0.4

Table 4.6 Heart rate (bpm) during practices.

Practice #	Practice 1	Practice 2	Practice 3	Practice 4	X ± S. D.
Bench time (P1)					
Forwards	126.9	135.5	117.0	126.8	126.6 ± 6.5
Defence	110.9	131.3	110.1	111.4	115.9 ± 8.9
Total	118.9	133.4	113.6	119.1	121.3 ± 7.4
Low velocity skating (P2)					
Forwards	135.0	146.0	139.9	138.9	140.0 ± 3.9
Defence	130.9	145.0	125.9	125.9	131.9 ± 7.8
Total	133.0	145.5	132.9	132.4	136.0 ± 5.5
High velocity skating (P3)					
Forwards	141.6	148.5	147.5	150.4	147.0 ± 3.3
Defence	148.6	151.0	135.2	133.5	142.1 ± 7.8
Total	145.1	149.8	141.4	142.0	144.6 ± 3.3
Other (P4)					
Forwards	156.7	163.7	160.8	131.7	153.2 ± 12.7
Defence	134.1	153.2	131.1	133.0	137.9 ± 8.9
Total	145.4	158.5	146.0	132.4	145.6 ± 9.2
On-ice (P2+P3+P4)					
Forwards	135.3	146.2	140.0	139.0	140.1 ± 3.9
Defencemen	131.6	145.2	126.3	126.1	132.3 ± 7.8
Total	133.5	145.7	133.2	132.6	136.2 ± 5.5

Table 4.7 Percent intensity (% HRmax) during practices.

Practice #	Practice 1	Practice 2	Practice 3	Practice 4	X ± S. D.
Bench time (P1)					
Forwards	62.0	66.2	57.2	52.0	61.9 ± 11.1
Defence	56.7	67.1	56.3	56.9	59.2 ± 8.3
Total	59.4	66.7	56.8	59.5	60.6 ± 9.9
Low velocity skating (P2)					
Forwards	66.0	71.3	70.3	69.8	69.4 ± 6.6
Defence	66.9	74.1	64.3	64.3	67.4 ± 4.8
Total	66.5	72.7	67.3	67.1	68.4 ± 5.8
High velocity skating (P3)					
Forwards	69.2	72.6	74.1	75.6	72.9 ± 5.7
Defence	75.9	77.2	69.1	68.2	72.6 ± 6.4
Total	72.6	74.9	71.6	71.9	72.3 ± 6.1
Other (P4)					
Forwards	76.6	80.0	78.6	64.3	74.9 ± 9.5
Defence	68.5	78.3	67.0	68.0	70.5 ± 6.1
Total	72.6	79.2	72.8	66.2	72.7 ± 8.1
On-ice (P2+P3+P4)					
Forwards	66.3	71.7	70.4	70.0	69.6 ± 6.6
Defencemen	67.2	74.2	64.5	64.4	67.6 ± 4.8
Total	66.8	73.0	67.5	67.2	68.6 ± 5.7

Table 4.8 Comparison between practices and games for the total minutes on-ice and at an intensity ≥ 70% HRmax.

Practice/Game	1	2	3	4	X ± S.D.
Games					
Total time (min)					
Forwards	28.6	25.7	29.7		28.0 ± 8.8
Defencemen	39.5	39.4	45.5		41.5 ± 9.2
Total	34.1	32.6	37.6		34.8 ± 11.3
≥ 70% HR max (min)					
Forwards	22.1	19.5	24.5		22.0 ± 5.5
Defencemen	33.2	35.6	41.7		36.8 ± 8.9
Total	27.7	27.6	33.1		29.4 ± 12.2
Practices					
Total time (min)					
Forwards	72.7	55.3	56.8	56.4	60.3 ± 14.1
Defencemen	82.4	59.4	49.4	60.7	63.0 ± 16.5
Total	77.6	57.4	53.1	58.6	61.7 ± 15.5
≥ 70% HR max (min)					
Forwards	24.5	25.3	32.4	29.8	28.0 ± 8.3
Defencemen	36.3	31.7	24.8	18.9	27.9 ± 15.6
Total	30.4	28.5	28.6	24.4	28.0 ± 12.8

4.4 Comparison of results with Green et al. (1976)

The results from the comparison of studies are presented in table 4.9. An Independant Samples t Test for the difference between two means was used to determine whether there was significance between results of this study and Green et al.'s (1976). Playing time per shift (62.4s to 85.4s) and playing time per game (18.6 min to 24.5 min) were significantly different for the two studies ($p < 0.01$). No significance was found between the bench time per shift for the two separate player groups (237.4s to 225.0s) where $p > 0.05$. Playing time heart rate (165.6 bpm to 173.0 bpm) was significantly different between the studies ($p < 0.05$) with the playing time heart rate measured by Green et al. (1976) being significantly higher.

Table 4.9 Comparison of time-motion characteristics and heart rate between Green et al.(1976) and this study.

Variable	Mean	Std	t test	Probability
Playing time/shift(s)				
Green et al.	85.4	3.1	8.80	$p < 0.01$
This study	62.3	7.7		
Bench time/shift(s)				
Green et al.	225.0	25.0	0.47	$p > 0.05$
This study	237.4	82.4		
Playing time/game(min)				
Green et al.	24.5	1.4	3.59	$p < 0.01$
This study	18.6	5.1		
Playing time HR(bpm)				
Green et al.	173.0	5.3	3.30	$p < 0.01$
This study	165.6	5.8		

4.5 Comparison of forwards and defencemen

The results of a one way analysis of variance between forwards and defencemen are summarized in table 4.10. Both playing time per shift (66.0s to 58.3s) and playing time per game (21.6 min to 15.4 min) were significantly greater for defencemen where $p < 0.05$. Forwards spent significantly more time on the bench between shifts (280.0s to 192.5s, $p < 0.01$). The playing time intensity between forwards and defencemen was similiar (82.1% of HRmax to 82.8% of HRmax). No significant difference was found between the two positions in playing time intensity ($p > 0.05$).

4.4 Comparison of practices and games

Measurements of intensity were collected on each player for three games and four practices. The results of a one way analysis of variance between practices and games is presented in table 4.11. The on-ice intensity during games (81% of HRmax) was significantly higher than practices (68.6% of HRmax). This is reflected in the high F value of 22.3. When intensity was measured in terms of the number of minutes that the player spent at or above 70% of HRmax, no significant difference was found between practices and games, where $p > 0.05$.

Table 4.10 ANOVA of time-motion characteristics and percent intensity between forwards (F) and defencemen (D).

Source of variance	SS	df	MS	F	P
Playing time/shift					
(F vs D)	249.1	1	249.1	5.0	0.04*
Error	746.8	15	49.8		
Bench time/shift					
(F vs D)	32444.3	1	32444.3	6.4	0.02*
Error	76213.6	15	5080.9		
Playing time/game					
(F vs D)	583910.7	1	583910.7	8.6	0.01*
Error	1013151.7	15	67543.4		
% Intensity					
(F vs D)	0.0	1	0.0	0.2	0.63
Error	0.0	15	0.0		

* significant at the 0.05 level

Table 4.11 ANOVA between practices (P) and games (G) for on-ice intensity and total minutes at an intensity ≥ 70% HRmax.

Source of variance	SS	df	MS	F	P
Intensity					
(P vs G)	1719.3	1	1719.3	22.3	p < 0.01
Error	2853.6	37	77.1		
Intensity ≥ 70% HRmax					
(P vs G)	43.6	1	43.6	0.3	p > 0.05
Error	6143.4	37	166.0		

Chapter 5

Discussion

5.1 Descriptive data

The average weight of the group in this study was 80.5 kg which was heavier than the players evaluated by Green et al. (1976, 1978). The recent study by Horne et al. (unpublished) had subjects whose average weight was 83.8 kg. The players' average height was 177.8 cm which was slightly taller than the players in Green et al.'s (1976) study but lower than the mean height (184 cm) of Horne et al.'s study (unpublished). The physical characteristics of the hockey players support the notion that hockey players are bigger today than they were in the past.

The mean age of the university hockey players in this study was 22 years old which was similiar to the reports from Green et al. (1976, 1978) and Horne et al. (unpublished).

The mean HRmax of the group was 200 bpm. This is similiar to the 195 HRmax measured by Green et al. (1976) and the 199 HRmax obtained by Green et al. (1978) for two university hockey teams. The average maximum heart rate reported by Horne et al. (unpublished) was 182.8 bpm for a group of eight players with a mean age of 23 years.

5.2 Comparison of heart rate intensities.

The first hypothesis stated that the mean playing time intensity during games is higher for today's university hockey player than that measured by Green et al. (1976). With an average HR of 165.6 bpm and mean intensity of 82.5% HRmax for this study, playing time intensity was significantly lower than the average of 173 bpm and 88.7% of HRmax by Green et al. (1976). The duration of the shift may explain these findings. There was a significant difference in the duration of the shift. The shorter duration of the shift in this study (62.3s) compared to Green et al. (85.4s) probably contributed to a lower heart rate. In this study, it was observed that if the player was on for a longer shift, then heart rate was higher.

Playing time per shift for youths (Paterson et al., 1977; Paterson, 1979) and for "oldtimers" (Montgomery, 1979), is longer and may explain the higher intensity during playing time for these studies. Two studies have reported high heart rates when the playing time per shift was 60 to 66s. Green et al. (1978) reported the mean heart rate at 90% of HRmax for university hockey players with a playing time per shift of 66s. A case study of Anders Hedberg during three international games has been reported by Wilson and Hedberg,(1975). Heart rate averaged 86.5% of HRmax with playing time per shift approximately 60s.

5.3 Comparisons of time-motion characteristics.

The second hypothesis stated that playing time per shift, playing time per game and bench time between shifts are significantly different than the results of Green et al. (1976). As predicted, both playing time per shift and playing time per game were significantly less than the university hockey players observed by Green et al. (1976). Bench time between shifts was not significantly different from Green et al. (1976). The players in Green et al.'s (1976) study were on the ice for longer shifts. Thus, the forward lines and defensive pair(s) on the bench waited longer for a line change, even though there were probably fewer players rotating into the game compared to this study. Nevertheless, with coaches changing lines more frequently and elite teams having four forward lines and three pairs of defencemen sharing the playing time, one would expect different time-motion characteristics compared to a team that has only three forward lines and two pairs of defencemen.

The 18.6 min of playing time averaged by the hockey players in this study was similiar to the 17.7 min averaged by Anders Hedberg (1975), the 18.7 min for juniors and 16.7 for professionals (Thoden and Jette, 1975) and higher than the 15.8 min reported by Horne et al. (unpublished). For all studies, the games were three 20 minute stop time periods.

Other than the results of Horne et al. (unpublished), it is unknown whether these past results reflect the number of players on the team or the individuals that were monitored (forward/defencemen getting more or less of a regular shift).

An average bench time between shifts of approximately four minutes (237.4s) for this study was similiar to the results of Thoden and Jette (1975) and Green et al. (1978). It was more than a minute less than the players spent on the bench in Horne et al.'s study (unpublished).

It is difficult to compare the time-motion results with previous studies whose players did not play a 60 minute stop time game. However, if the 30 minute and 39 minute stop time games (Paterson, 1979) are projected for 60 minutes, the playing time per game would be 27.4 min, 25.0 min and 24.9 min for the three youth groups.

5.4 Heart rate intensity of forwards versus defencemen.

The third hypothesis stated that forwards and defencemen do not differ significantly in intensity during playing time. Similiar heart rate intensity (82.1% HRmax to 82.8% HRmax) occurred for the different player positions. This is in agreement with Green et al. (1978) and Horne et al. (unpublished) whereby forwards and defencemen in

university hockey were similiar in playing time intensity. Although some team sports may have a player in one position playing at a higher intensity than another position, ice hockey players at the forward and defenceman perform at the same heart rate intensity (Green et al. 1976, 1978; Paterson, 1979; Horne et al., unpublished).

5.5 Time-motion analysis of forwards versus defencemen.

The fourth hypothesis stated that forwards and defencemen differ significantly in playing time per shift, playing time per game and bench time between shifts. Significance was measured between forwards and defencemen for all three time-motion characteristics. The forwards had less playing time per shift, less playing time per game and more bench time between shifts compared to the defencemen. Having four forward units sharing 60 minutes of playing time and only three defensive units sharing the same amount of playing time, it is logical that the defensemen would play more of the game. As predicted, the defencemen achieved more playing time per game by having more playing time per shift (66.0s to 58.5s), more shifts per game (19.7 to 15.9) and less time between shifts (192.5s to 282.2s).

These three time-motion results are similiar to those of Green et al. (1978). Thoden and Jette (1975) found that

junior and NHL defencemen play four to five minutes longer per game than their forward team mates. Green et al. (1976) reported the defencemen playing more during a game and being on the bench for less time. Contrary to this study, playing time per shift was less than that of the forwards.

Defencemen were on the bench longer than the forwards in the study by Horne et al. (unpublished). Playing time per shift and playing time per game were longer for the defencemen than the forwards, however there was only a four second difference in playing time per shift and a 0.7 minute difference in playing time per game.

There was little difference in time-motion characteristics between the junior forwards and defencemen in the study by Leger (1980) with the teams averaging 3.3 forward lines and 3.1 defensive units.

5.6 Intensity of practices versus games.

The fifth hypothesis stated that the mean heart rate intensity is significantly lower in practices than games. This was clearly shown as the on-ice intensity during games (81.9% HRmax) was significantly higher than the on-ice intensity during practices (68.6% HRmax). The work intensity and effort during hockey games were higher than the practices. With the players skating at a low velocity

for most of the practice, the heart rate seldom approached maximum levels. Drills that focus on various aspects of the game; offensive play, forechecking, defensive play and positioning, were performed but at a lower intensity than in games. It was rare that a player would skate at high velocity for longer than ten seconds at a time in practices. Many drills required the players to be active for longer than ten seconds. However, the players may not have had to skate that hard during the drills or simply did not skate as hard as they should have for the drills.

The sixth hypothesis stated that the total minutes at a heart rate intensity greater than or equal to 70% HRmax is significantly higher in practices than games. Even though the amount of ice-time for a player during a practice (61.7 min) was nearly double that of a game (34.8 min), there was no significant difference in the total minutes at a heart rate intensity greater than or equal to 70% of HRmax between practices (28.0 min) and games (29.4 min). Players simply did not skate as hard as they could have or did not have to work as hard during practices as compared to games.

Measurements on the subjects were conducted during the second half of the hockey season. Therefore, very few conditioning drills which involve repeated bouts of hard skating, were performed by the players at the time of data collection. At this point in the season, the aerobic and anaerobic energy systems were trained with the emphasis on

maintenance of fitness. Also, during the month that data were collected, there was a time that the subjects played seven games in 16 days. It was the coach's intent not to work the players too hard in practice during this portion of the schedule.

Although there have been some studies that measured heart rate intensity during hockey practices or tasks, only Horne et al (unpublished) has made these measurements on the same subjects for both practices and games. For games, their subjects on-ice intensity was $\geq$ 70% HRmax for 87.2% of the total on-ice time compared to 84.5% of the total time for this study. For practices, their subjects performed at an intensity that was $\geq$ 70% HRmax for 77.2% of the total on-ice time compared to only 45.4% of the total time in this study. It is not known how long the players were on the ice during practices in Horne et al.'s (unpublished) study. The discrepancy for the practice results may relate to the segment of the hockey season when the practice data were collected, the structure and the objectives of the practices.

Chapter 6

Summary, Conclusions and Recommendations

6.1 Summary

The purpose of this study was to measure the intensity and duration of ice hockey play and to compare the results with a similiar study that was published by Green et al. (1976). In addition, the variability in heart rate output and time-motion characteristics between forwards and defensemen of this study were examined. Differences between practices and games in terms of intensity were also measured.

Six university hockey players, three forwards and three defencemen, participated in the study. The intensity during practices and games was measured using a heart rate monitor. The monitor was set to measure heart rate every 15 seconds. The duration of ice hockey play during practices and games was measured using time-motion analysis where there were four conditions for practices and three conditions for games. The heart rate monitor and the stopwatch for collecting time-motion data were synchronized so that the intensity of the different time-motion conditions could be calculated. Data were collected for three games and four practices on each hockey player.

The first hypothesis tested the intensity of on-ice play so that a comparison could be made between the intensity of ice hockey today and that of the past. The on-ice intensity found for this study was 82.5% of HRmax. The on-ice intensity of Green et al. (1976) was 88.7% of HRmax. Based on these results, the intensity of on-ice play in this study was lower than the intensity of on-ice play in the study by Green et al. (1976). Since the players in this study averaged 23s less of playing time per shift, this probably contributed to the resulting lower intensity of on-ice play.

The second hypothesis examined the time-motion characteristics of playing time per shift, playing time per game and bench time between shifts so that a comparison could be made between these results for this study and that of a previous study by Green et al. (1976). Playing time per shift was 62.3s which was a shorter amount of time compared to the 85.4s playing time per shift reported by Green et al. (1976). Playing time per game was 18.6 min which was less time than the 24.5 min of playing time per game measured by Green et al. (1976). Based on these results, playing time per shift and playing time per game were significantly less than the results of Green et al. (1976). Bench time between shifts was 237.4s which was not significantly different than the 225s of bench time between shifts reported by Green et al. (1976). Even though there

is one less forward and defensive unit, the players in Green et al.'s (1976) study were on the ice for longer shifts. Thus, the bench time between two long shifts may result in a similiar bench time between three shorter shifts.

The third hypothesis tested for a difference in on-ice intensity between the forwards and defensemen in this study. The forwards had an on-ice intensity of 82.1% HRmax and the defencemen had an on-ice intensity of 82.8% HRmax. Based on these results, there is no significant difference in on-ice intensity between the two distinct player positions of forward and defence.

The fourth hypothesis stated that forwards and defensemen are significantly different in the time-motion characteristics of playing time per shift, playing time per game and bench time between shifts. Forwards had a playing time per shift of 58.5s whereas the defencemen had a playing time per shift of 66.0s. Playing time per game was 15.5 min for forwards and 21.6 min for defensemen. Bench time between shifts was 282.2s for the forwards and 192.5s for the defensemen. With four forward lines and three sets of defencemen, the time-motion characteristics were significantly different for the two distinct player positions.

The fifth hypothesis measured the difference in on-ice intensity between practices and games. The mean on-ice intensity was 68.6% of HRmax during practices and 81.9% of

HRmax during games. Based on these results, the players were performing at a significantly higher on-ice intensity during games compared to practices.

The sixth hypothesis tested the difference between practices and games for the total time on-ice that the players would perform at an intensity greater than or equal to 70% of HRmax. The amount of time that the players averaged with the intensity $\geq$ 70% of HRmax was 28 min for practices and 29.4 min for games. There was a significant discrepancy in the ice time that the players averaged for games (34.8 min) and practices (61.7 min). However, in answering the sixth hypothesis, there was no significant difference in the total minutes at a heart rate intensity greater than or equal to 70% HRmax between practices and games.

6.2 Conclusions

Within the limitations and delimitations of the study, the following conclusions can be made:

1. The intensity of on-ice play during games is similiar today compared to 1976.

2. Differences in time-motion characteristics exist between the game of hockey today and the past.

3. Forwards and defencemen play the game of hockey at the same intensity.

4. Differences in time-motion characteristics exist between ice hockey forwards and defencemen.

5. Games are performed at a higher intensity than practices.

6. The sum of practice time performed at a high intensity is similiar to that of games.

6.3 Recommendations

Future studies should examine the time-motion and heart rate effects of ice hockey games at the beginning, the middle and at the end of a season. Comparisons on playing time intensity, playing time per shift, playing time per game and heart rate recovery after a shift for the three different segments of the hockey year would be valuable.

Training should contain specific components or resemble what it is that you are training for. It would be interesting to study the variability in time-motion characteristics and heart rate response between practices and games. Then the couch and sport scientist should design practices based on the time-motion characteristics and heart rate response of games. The movement patterns and intensity of the subjects in the designed practices should be measured and the results compared to time-motion and heart rate results of games. Practices that produce results similiar to those of games could then be used by teams to prepare for competition.

Appendix 1

Data collection sheet for time-motion analysis

Condition time	Condition	Running time
3:41	G1	9:53
0:24	G3	13:34
0:25	G2	13:58
0:27	G3	14:23
0:36	G2	14:50
4:10	G1	15:26
	G2	19:36

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