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Original Research

Individual Fluctuations in Blood Lactate Concentration During an Ice Hockey Game; Differences Between Player Positions

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ABSTRACT

International Journal of Exercise Science 15(6): 985-993, 2022. The main purpose of the current study was to provide an in-depth description of individual player's intra-game physiological responses during an ice hockey game. A secondary aim was to compare these responses between forwards and defensemen. Six elite junior ice hockey players, three forwards and three defensemen, median (interquartile range) 17 (17–17) years, 182 (180–185) cm, and 78 (74– 80) kg were recruited to participate in the study. Capillary blood samples were taken following each shift and analyzed for blood lactate concentration (BLC). Heart rate (HR) was registered continuously throughout the game. The game was filmed and shift lengths were determined retrospectively using a time-motion analysis. All players had BLC ranging between 1.8 and 10.7 mmol/L (mean = 5.5 mmol/L), with forwards reaching a significantly higher value than defensive players ($F_{1, 32} = 75.2$, $p < 0.0001$), a significant effect of time was also observed ($F_{2, 25} = 6.4$, $p = 0.0058$). During the game, the players accumulated 11:18 ± 5:04 (minutes:seconds) above 90% of their maximal heart rate (HR_{max}), but the majority of the time was below 80% of HR_{max}. The fluctuations in BLC and heart rate demonstrate that the intensity is highly variable during games and challenges both aerobic and anaerobic metabolic pathways. The higher BLC of forwards might indicate that they perform more high-intensity work during games than defensive players.

KEY WORDS: Winter sports, junior athletes, applied physiology

INTRODUCTION

Ice hockey is one of the major team sports in the northern hemisphere, characterized by a fast pace, high-speed collisions, and a large individual skill component. Games are played over three 20-minute long periods interspersed with 15-18 minute long intermissions. Throughout a game, players typically accumulate between 10-28 minutes of active time on the ice distributed over 6-10 shifts per period, each usually being in the range of 30-90 seconds in duration (4, 5, 16, 17).

Previous studies investigating player movements and skating patterns show that the players skate between 2300 and 6700 meters during a game and that the intensity is highly intermittent, with players performing an average of seven high-intensity skating bouts every minute (8, 20). Positional differences have also been reported from game situations. Defensemen have been found to stand still, skate more backward, and accumulate a greater total skated distance, while forwards perform more forward sprints and are engaged in more high-intensity skating overall (6, 8). Some of these positional differences have been attributed to the different roles that offensive and defensive players have during games (6, 8). For example, offensive players often carry the puck down the ice looking for scoring chances, while a big part of the game for defensemen is centered around stopping opposing forwards in the neutral, and defensive, zones (6, 14).

Although being a popular winter sport, relatively few studies have focused on physiological aspects of the game. The physiological data that has been collected during games suggests that the sport is physically strenuous, imposing stress on both aerobic and anaerobic metabolic pathways. The aerobic demands have been illustrated by intra-shift heart rates (HR) frequently exceeding 90% of maximum heart rate (HR_{max}), while the anaerobic energy contribution has been demonstrated by considerably elevated blood lactate concentrations (BLC) and profound glycogen depletion (4, 5, 12, 15, 16, 17, 20). Most of these studies have collected the data before and after games, or before and after periods. The major limitation with such an approach is that it likely fails to capture the variability in physiological demands that arise from the intermittent type of play, as suggested in studies where HR, as an example, has been continuously recorded throughout games (16, 17).

For this reason, Noonan (12) aimed to assess the fluctuations in BLC during games as well as to investigate the potential relationship between BLC and shift length. In the latter study, capillary blood samples were collected from six forwards following each shift during the first and third period of a game. The results demonstrated a wide range in BLC, which, despite having an insufficient sample size to perform inferential statistics, highlights the importance of an "intra-game" approach when collecting biological samples during games. Furthermore, the reporting of each player's individual data is interesting in this context. To our knowledge, Noonan (12) is the only study, to date, that has sampled blood repeatedly during a game. Considering their inclusion of only forwards and sampling restricted to the first and third period, this study aimed to track intra-game fluctuations in BLC, in both forwards and defensemen throughout a full game, and comprehensively visualize these individually. A secondary aim was also to compare BLC between the positions during all three periods.

METHODS

Participants

Due to the explorative nature, and mainly individual-based focus of the study, no power analysis was made prior to recruitment. Ten male junior ice hockey players (six forwards and four defensemen) gave their written consent to participate. Due to illnesses leading up to, and injuries during the game, the final sample consisted of six players, three forwards, and three defensemen (Table 1). The median and interquartile range (IQR) for age, body height, and body mass were 17 (17–17) years, 182.0 (180.0–185.1) cm, and 77.6 (74.0–80.3) kg, respectively. The Regional Ethical Review Board of Umeå University, Umeå, Sweden (2018-366-31) approved the study and all participants were fully informed of the nature of the study before providing written consent. The research was carried out in accordance with the ethical set by the International Journal of Exercise Science (11).

Protocol

The data was collected during a pre-seasonal game, following the same standards as a regular-season game. After reporting to the research group, the player's body height and body mass were measured, thereafter, the player followed his own individual preparation, as he normally would do before any game. Each player was equipped with a HR monitor using the Polar Team Pro System (Polar Electro Oy, Kempele, Finland), and HR was monitored throughout the entire game. Capillary blood samples (20 μL) were collected from a fingertip approximately 3-min before the start of each period and immediately following each shift, and analyzed for BLC using a Biosen S-line (EKF diagnostic GmbH, Magdeburg, Germany). The game was videotaped for retrospective determination of shift lengths using a time-motion analysis method. The camera (GoPro Hero 5, GoPro Inc., San Mateo, California, U.S.) was mounted behind and above the bench of the experimental team, with a view capturing both the game clock and bench of the experimental team (Figure 1). A shift was defined as the active playing time on the ice (i.e., play stoppages excluded) from when a player stepped onto the ice until the same player stepped back onto the bench.

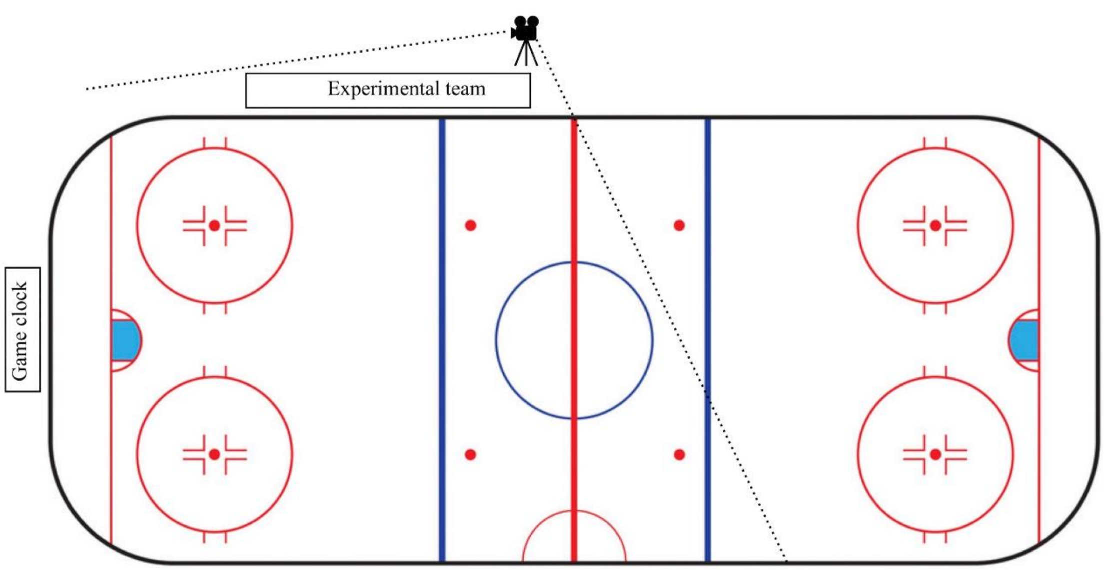

Figure 1. Camera placement during the game, the dashed line shows the area of camera view

The day following the experimental game, each player conducted a 20-meter shuttle-running test to estimate maximum oxygen uptakes (VO_{2max}) and to obtain a HR_{max} that was later used to express the registered HR during the game relative to the player's maximum. The HR recordings from the game (including intermissions and time on the bench) were divided into three zones, < 80%, 80–90% and > 90% of the player's HR_{max}.

The 20-meter shuttle-running test, sometimes referred to as the Beep test, consisted of continuous running between two lines separated by 20 meters with a 0.5 km/h increase in speed at approximately every minute (13). Briefly, the test started at 8 km/h and increased by 0.5 km/h per level (except for the first level which had an increment of 1 km/h), the maximum number of levels in the test is 21, which corresponds to a total accumulated distance of 4940 meters in roughly 22 minutes. Maximal oxygen uptake was estimated from the level and number of shuttles completed. The test was performed in a gymnastic hall with the pace set by auditory feedback, meaning that the athlete paced himself to reach one of the lines every time a signal was given. The test was terminated when a player could not keep up the pace and reach the designated line two signals in a row, or when the player reached volitional fatigue.

Statistical Analysis

All data handling was performed in R (R Core Team, 2019) using ggResidpanel (3), ggpubr (7), Tidyverse (18), and ggridges (19). All summary statistics are, unless otherwise stated, presented as means and standard deviations (SD) or medians and interquartile ranges (IQR). Although the main purpose of the study was to track and visualize BLC at an individual level throughout the game, data were also aggregated according to player position (forwards and defensemen) for comparative purposes. The normality of the dependent variable (BLC) was checked with visual inspections of histograms and Q-Q plots, as well as with the Shapiro-Wilks test, the latter suggested no significant deviation from normality, however, the former did for some levels. A linear model was fitted, where normality of the standardized residuals was checked by visual inspections of histograms and Q-Q plots, neither suggested significant deviations from normality. The assumption of sphericity was met according to Mauchly's test, however, the scale location plot and the residuals versus fitted plot indicated non-equal variance between the positions, and heteroscedasticity, which was confirmed by a subsequent Levene's test. Because of these violations, and for caution due to the explorative approach of the study, a robust mixed effect analysis of variance (ANOVA) with a 20% trim was used (10). Briefly, this method builds on the idea of trimming the data, i.e., ignoring a certain percentage of data points at the top and bottom of the distribution to produce a test statistic robust to violations of normality and heteroscedasticity (2). Alpha was set to $p \leq 0.05$.

RESULTS

Descriptive statistics of the players are shown in table 1. Each player's individual BLC pattern is visualized in Figure 2A. The intra-game ranges in BLC for each player were 2.8-10.7 (Player 1), 3.0-10.3 (Player 2), 2.7-8.9 (Player 3), 1.8- .7 (Player 4), 1.8-4.9 (Player 5), and 2.3-7.5 (Player 6) (Figure 2B). The individual means in BLC for each player over the whole game were 6.8 (Player 1), 7.9 (Player 2), 6.2 (Player 3), 3.4 (Player 4), 3.5 (Player 5), and 4.9 mmol/L (Player 6) (figure 2B). Individual relationships between BLC and shift length are displayed in figure 2C. The total accumulated time in each heart rate zone for each player is shown in Table 2.

Table 1. Descriptive data for the players. The maximal heart rates oxygen uptakes are estimated from the 20-meter shuttle run, the resting heart rates were obtained before the shuttle run.

Player	Position	Age	Height (cm)	Body mass (kg)	HR_{rest} (b/min)	HR_{max} (b/min)	VO_{2max} (ml/kg/min)
1	Forward	17	186.0	80.4	64	199	57.1
2	Forward	17	179.5	73.5	60	198	61.2
3	Forward	18	182.5	82.6	48	205	56.8
4	Defenseman	16	187.7	75.3	55	197	44.6
5	Defenseman	17	181.5	79.9	58	198	54.9
6	Defenseman	17	171.8	64.9	56	211	54.3

HR_{rest} = resting heart rate, HR_{max} = maximal heart rate, VO_{2max} = maximal oxygen uptake

The players completed (median and IQR) 22 (20-23) numbers of shifts, with a mean duration of 63.0 ± 22.5 seconds. When divided according to position, the corresponding numbers were 23 (23-24) and 64.0 ± 23.6 seconds for forwards and 20 (20-21) and 61.8 ± 21.2 seconds for the defensemen (Table 2). The mean BLC were 7.4 ± 2.2, 7.1 ± 2.0, and 6.4 ± 1.7 mmol/L for forwards in period 1,2 and 3 respectively, while the corresponding values for the defensemen were 4.3 ± 1.4, 4.3 ± 1.2, and 3.1 ± 0.8 mmol/L. The robust mixed ANOVA revealed a main effect of group ($F_{1,\ 32}$ = 75.2, p < 0.0001), and time ($F_{2,\ 25}$ = 6.4, p = 0.0058), but no interaction ($F_{2,\ 24}$ = 0.08, p = 0.9275) (Figure 3).

Table 2. Number of shifts per period for each player and total time accumulated in each heart rate zone during the game. The heart rate zones are based on the maximal heart rates (HR_{max}) recorded during the shuttle run, where zone 1, 2, and 3 represent < 80, 80-90, and > 90% of HR_{max}, respectively. The times are presented as minutes:seconds, and also includes time spent resting on the bench and between periods.

Player	Number of shifts period 1	Number of shifts period 2	Number of shifts period 3	Zone 1	Zone 2	Zone 3
1	8	6	8	60:40	26:08	13:28
2	8	6	9	57:58	24:09	17:51
3	8	7	9	63:02	27:13	07:39
4	7	7	6	70:46	19:40	03:29
5	7	7	7	65:13	17:29	13:53
6	7	6	6	70:36	17:50	11:23

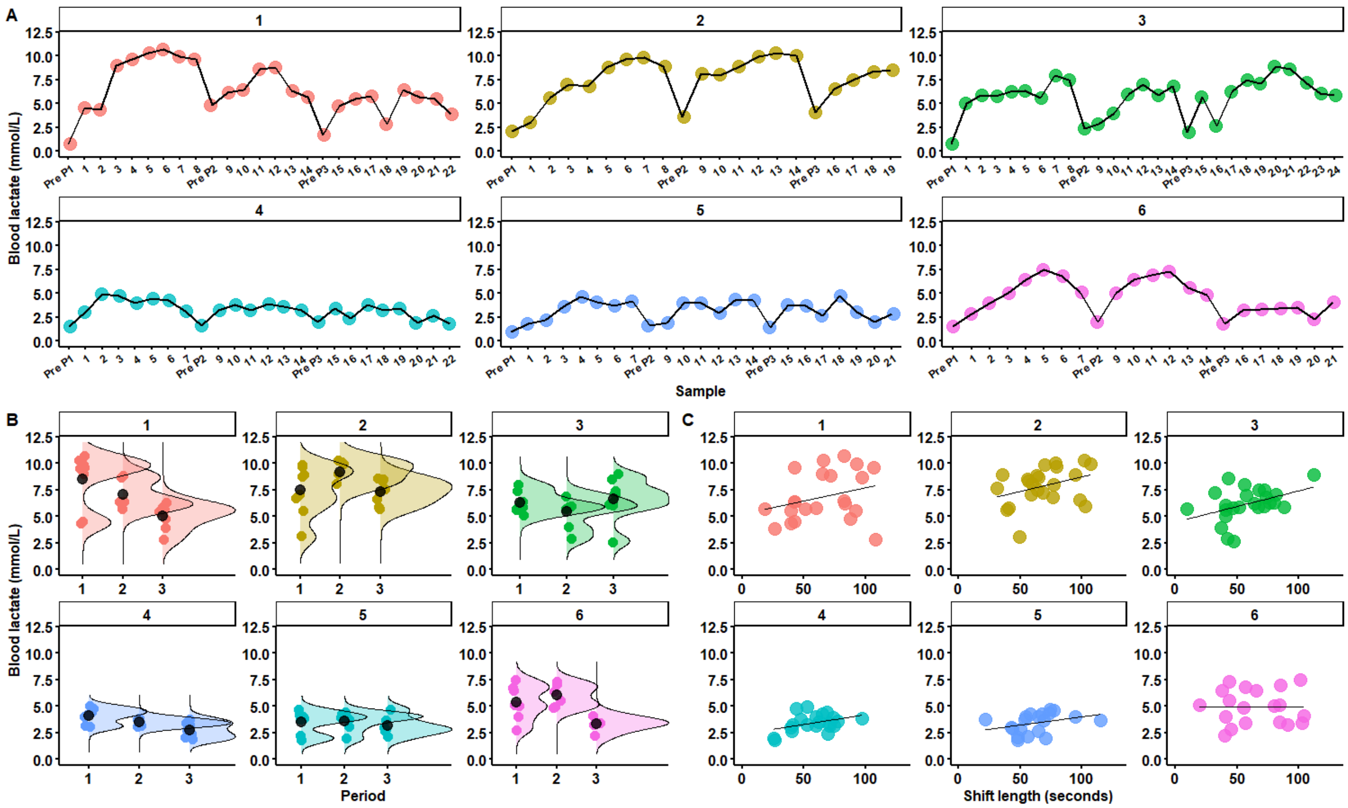

Figure 2. Blood lactate concentration following each shift throughout the ice hockey game for each individual player (A). Densities, means (black circles) and individual values (colored circles) of blood lactate concentrations for each player in each period (B). Blood lactate concentrations and shift lengths with the black line indicating the direction of the relationship (C). Note that no correlation analysis has been made.

DISCUSSION

This is the first study, to our knowledge, to measure BLC following each shift for both forwards and defensemen during a complete ice hockey game. The main purpose was to track and describe the intra-game BLC on an individual basis, which was fluctuating from shift-to-shift, reflecting the intermittent work-patterns previously described by others (8, 20). The results from the current study further emphasize the necessity of frequent, repeated sampling methods when collecting data during game situations. As an example, the average increase in BLC from pre- to post-values is in line with findings from Green et al., (4), who found that BLC increased approximately four-fold between measures taken before and after a game. However, as seen in figure 2A, a lot of information is likely lost when sampling as infrequently as that, and a single value, or fold change, might not necessarily be very informative.

Noonan (12) reported similar fluctuations in BLC, but a mean of 8.2 mmol/L, which is somewhat higher compared to 5.5 mmol/L, found in the current study. Two clear differences between the studies are that they included forwards only and limited the sampling to the first and third period (12). If the data in the present study is aggregated according by position, with the second period excluded, forwards showed an average BLC of 6.9 mmol/L, which is more similar to the values reported by Noonan (12).

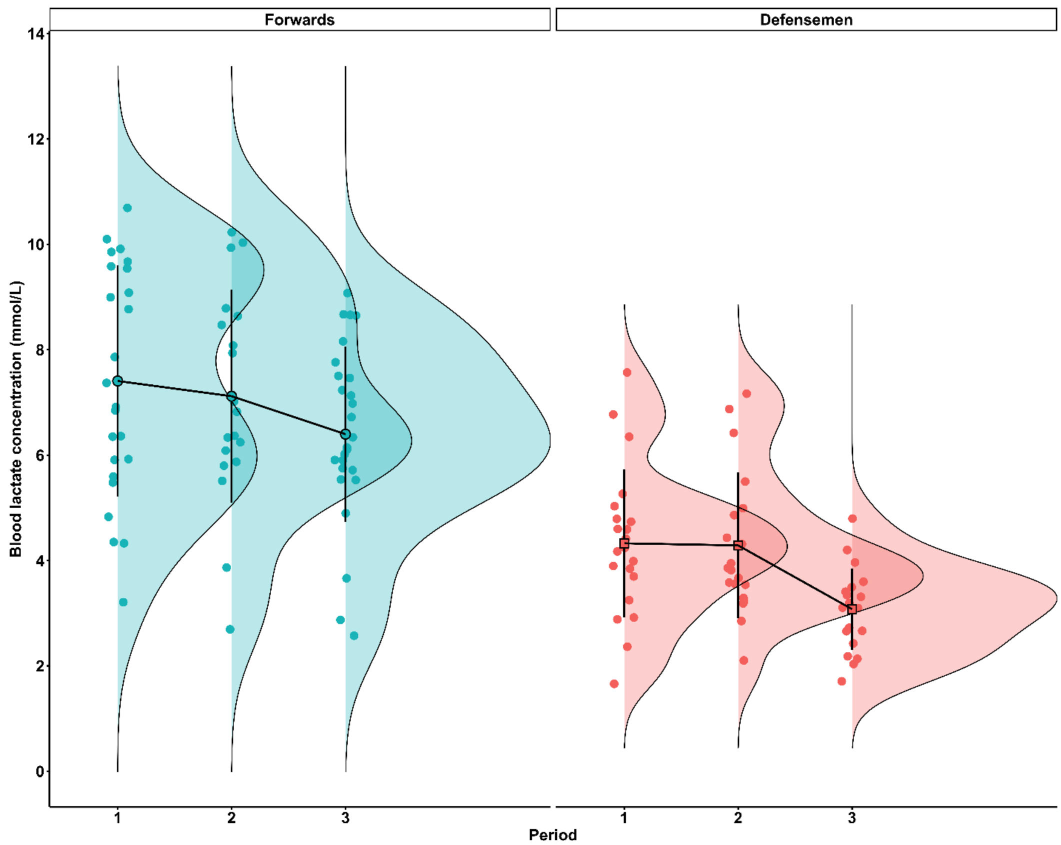

Figure 3. Untrimmed mean ± SD (black outlined circle and vertical lines) blood lactate concentrations for forwards (blue) and defensemen (red). Blue and red circles illustrate individual values for forwards and defensemen, respectively, and the densities show the distributions.

The aggregation also revealed two emerging patterns, differences in BLC between forwards and defensemen, and, as the game progressed, a downward going trend in BLC for players on both positions (Figure 3). Indeed, the robust mixed effect model showed significant differences in BLC between forwards and defensemen, as well as a significant effect of time. The higher BLC displayed by forwards could be indicating that they were engaged in more high-intensity work/skating than defensemen during the game, something that would be in agreement with findings from both time-motion analyses and indoor positioning systems from previous studies (6, 8). As to the observed decline in BLC over time, previously published data has shown that players cover less distance at higher intensities later in games, (8) which would fit with the lower BLC observed later in the game in the current study. Unfortunately, the time-motion analysis method used in the present study did not enable the determination, or quantification of actions like the number of sprints, speed changes, or battling for the puck on the ice. In addition, the sample size was small, and as mentioned in the methods section, two underlying assumptions were violated. Therefore, these results should be taken with caution and need to be replicated using a larger sample.

The heart rate recordings in the present study showed that players spent most of the game < 80% of their estimated maximum heart rate. These results seem to be in reasonable agreement with previous studies by Stanula et al. (16) and Stanula and Roczniok (17) who found that players spent the greatest part of the game < 85% of their HR_{max}. One notable difference though is that they found the players to accumulate >16 minutes above 90% of their HR_{max}, which is ~45% longer than in the current study. As shown in Table 2, two players spent considerably less time above 90% of HR_{max} than the other four, something that is likely to influence the mean in a small sample and could be a potential explanation for the marked difference. Moreover, HR as a measure is known to be quite variable, especially during intermittent activities (1), and can be affected by hydration status due to changes in plasma volume, something that has been observed during ice hockey games before (9). Taken together, the difference between the current study and previous studies (16, 17) is likely to be noise.

There are some clear methodological limitations of the current study. Firstly, the camera setup did only allow a time-motion analysis approach adequate to determine shift lengths (Figure 1), with the implication that there was no possibility for further determination of the on-ice skating characteristics. This means that any attempt to explain differences in BLC between periods or player positions is left to be speculative since no objective measure to explore those differences was included. The small sample size, both in the number of players and that they were only sampled during one game, are other weaknesses that need to be considered.

The present study explored the fluctuations in BLC at the individual level following each shift in both forwards and defensemen over a full game of ice hockey. The primary finding was that the fluctuations in BLC were large throughout the game, reflecting the varying metabolic demand of ice hockey. The forwards produced higher BLC compared to the defensemen, which might indicate that they were performing more skating at high to maximal exercise intensities. The BLC appeared to decrease as the game progressed, for players on both positions, something that might be indicative of less high-intensity work later in the game, which potentially could be due to fatigue. If the declining BLC observed here is typical during games, and due to fatigue, these results might be of importance for coaches and/or other staff members to consider when planning training sessions following games to manage the weekly load. Moreover, it might be appropriate to consider the positional differences as well, for the same reason. Future studies should consider combining the continuous blood lactate sampling approach used in the current investigation with an indoor positioning system for determination and evaluation of the performed work on the ice, ideally over multiple games.

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