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Practice and Match Load Characteristics of Elite Men's Ice Hockey

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ABSTRACT

The purpose of this study was to record and present data related to the external workload demand of elite male ice hockey players, in both matches and practices, including the differences between positions, as well as time on ice values for the population. External workload monitoring was performed using a Catapult™ inertial measurement unit system and data was collected for the duration of one full season in the Kontinental Hockey League (Russia). The study found forwards had significantly higher ($p \leq 0.05$) absolute and relative values in both matches and practices for most metrics, when compared to defensemen, and regardless of position, matches had significantly higher workload demands than practices. Furthermore, defensemen had significantly higher ($p \leq 0.05$) time on ice values than forwards. Ice time was not spread evenly between players of the same position, but was consistent for each individual athlete. The findings can be used by coaches to assist in the planning of on-ice training to optimize player performance and readiness.

Keywords: External workload, monitoring, player optimization

INTRODUCTION

Ice hockey is popular around the globe, with elite leagues in North America, Russia, and Europe. Ice hockey is a high intensity, intermittent team sport where the nature of play uses regular substitutions, similar to basketball (although basketball players can only rotate during a stoppage in play, whereas ice hockey players can rotate during match play). Unlike team sports such as soccer, rugby, netball and field hockey, where "starting" players will play all or most of the duration of a match, ice hockey players (with the exception of the goalkeeper) compete in shifts of around 45 to 60 seconds before returning to sit "on the bench" (2, 3, 28). Despite the rolling shifts, not all players amass equal amounts of ice time per match. The coach's subjective opinion on the ability and skill of a player, and tactical coaching decisions will impact how much ice time each player receives. A seminal study by Green et al (1976) in male varsity ice hockey determined that defensemen played 21.2% more than forwards, with a greater number of shifts and less recovery time between shifts. Since this work, there have been no further studies detailing position specific ice time characteristics, which may have changed due to evolution of the game. For example, Quinney et al (2008) found that during a 26-year study of the National Hockey League, players demonstrated consistent changes in anthropometric and physiological values, and with increased physiological capacity, the time-motion characteristics of the game may have changed. Whilst the physical and physiological characteristics of different ice hockey playing positions have been well researched (10, 15, 24, 25), to date information pertaining to detailed individual playing time at the elite level has not been published in scientific literature.

Individual player time on ice (TOI) has traditionally been used by coaches as a proxy measure of 'workload'. In elite female basketball, where similarly to ice hockey, regular substitutions of players are made in-match, Paulauskas et al (23) found that high minute players had a significantly higher match external workload compared to low minute players, although the relationship between TOI and external workload has not been determined in hockey. Whilst research suggests that regular exposure to playing time during the season limits the decline of, or improves, physical fitness across the duration of the season (26), an increase in playing time may increase the risk of sustaining an injury, as injuries in hockey matches are more than 6 times more common than during practice (5, 9, 16). Additionally, sudden spikes in match workload have been shown to increase injury risk (20). However, in-match workload may not be accurately reflected by TOI as defenders consistently play more minutes than forwards, but spend significantly more TOI engaged in very low intensity activity (e.g., gliding) (12). Therefore, knowledge of TOI and workload characteristics may be an essential tool for coaches to inform practice strategies, in-season periodization, and to optimize individual player readiness.

External workload monitoring through the use of Global Positioning Systems (GPS) has been used abundantly in soccer, rugby, Australian rules football (AFL) and field hockey for 20 years (4, 17). Initially used to quantify match and practice demands, practitioners have also used external load monitoring as a tool to help with practice planning and periodization strategies (4). GPS systems require clear signal between the athlete-worn device and receiver satellites, which has until recently made its use in indoor sports impossible. However, with advancements in microsensor technology (including Local Positioning Systems [LPS] and micro-electromechanical sensors [MEMS]), this technology is now increasingly being used in ice hockey to monitor workloads (7, 19). The use of MEMS for determining external workload for ice hockey was investigated by Van Iterson et al (27), who found that triaxial accelerometer data demonstrated moderate-to-high reliability in a range of ice hockey specific simulated game situations, supporting the use of this technology to accurately determine external workload values.

As the use of MEMS is relatively new to ice hockey, protocols for assessing and reporting external workload has varied across the published research. Most commonly, the Catapult™ system has been used, reporting metrics PlayerLoad™ (PL) and relative PL (PL/min), Explosive Efforts (EE) and relative EE (EE/min) (6, 8, 18). However, additional metrics reported have included Skating Load, Explosive Ratio, and percentage of High Force Strides (6), total High Force Strides and Average Stride Force (18), and On-Ice Load (OIL) and OIL/min (1).

PlayerLoad™ is a summation of all forces in movements recorded from the anteroposterior, mediolateral and vertical accelerometers, whereas Skating Load is a summated peak acceleration metric of movements recorded during a skating stride, which is subsequently multiplied by the athlete's mass. On Ice Load is similar to PL, in that it is a summated metric of forces in movements recorded from the anteroposterior, mediolateral and vertical accelerometers, however, to differentiate it from PL, OIL does not include movements below a threshold of $0.3 m.s^{-2}$, therefore removing periods of very low activity (for example, when a player is sitting on the bench, or standing waiting for a restart of play). High Force Strides is a frequency count of the total number of strides taken in the high force band, which according to manufacturer recommendations, is any stride above 190 au SL for males. Explosive efforts (EE) are a frequency count of total efforts over the duration of an activity. For a movement to be counted as an 'explosive effort' an action must occur at a rate greater than $2.0 m.s^{-2}$ in any plane. Regardless of which metrics are chosen, metrics have most commonly been reported as a mean value for practices and/or matches, and often distinguished by position (defense vs forwards, as goalkeepers are excluded from analysis due to the stark difference in playing style).

Having an in-depth understanding of the external workload of matches and practices allows coaches to adopt strategic approaches to designing training sessions, with the intention of maximizing physiological adaptations from training whilst minimizing the effects of fatigue. To date, only one study has provided information on elite male ice hockey practice and match external workload demands (1). Therefore, the aim of this study is to describe positional differences in TOI and external workload for practices and matches in elite male ice hockey, to understand if there are clear positional differences.

METHODS

Experimental Approach to the Problem

A cross-sectional design was implemented during the 2019-20 Kontinental Hockey League (KHL - Russia) season. While the National Hockey League (NHL – North America) is considered to be the most elite league in the world, the KHL is universally considered to be the second most elite league. Microsensor data was collected during

57 competitive regular season matches, and 72 practices. For the purpose of this study, practices on a match-day, called "morning skates", were not included. Each player was required to wear the microsensor for the full match or practice. In circumstances where this was not achieved (the player was injured and subsequently left the match/practice early, or unit malfunction), this data was excluded from analysis. This resulted in 389 individual match loads and 508 individual practice loads collected. Time on ice data, recorded and published by official league timekeepers (KHL), was reported for 57 matches. As before, if a player did not complete the full match (was injured, or other removal), this data was excluded from analysis.

Subjects

14 elite male ice hockey players were included in this analysis of microsensor and time on ice data, and the anthropometric data can be seen in Table 1.

Due to unique positional demands, goalkeepers were excluded from all analysis. All players took part in at least 5 competitive matches and 10 practices in the KHL during the 2019-20 season. The study was reviewed and approved by an ethics panel at University of Gloucestershire, United Kingdom, and written consent was given by all participants.

Procedures

All players wore a triaxial accelerometer, gyroscope, and magnetometer (Catapult Vector T6; Catapult Sports, Melbourne, Australia) positioned between the shoulder blades on the upper back, as recommended by the manufacturer guidelines. Data was recorded at a sampling frequency of 100 Hz and downloaded from each device using the manufacturer's software and firmware (Catapult Openfield, version 1.15.3, Melbourne, Australia; firmware version 4.2). This study was approved by an ethics panel at the University of Gloucestershire, and abides by the Declaration of Helsinki.

Statistical Analysis

A database of identified metrics (PL, OIL, SL, EE and HFS) for every player in each training and competitive session was created in Excel (Microsoft Corp, Redmond, WA), and the statistical package IBM SPSS Statistics v.27 (IBM Corp., Armonk, N.Y., USA) was used to calculate normal distribution of data, which was confirmed via the Shapiro–Wilk test, and homogeneity of variance, which was confirmed with Levenes test. This allowed for the use of parametric methods of analysis. Independent sample *t* tests were performed to show the difference between defense and forwards during training and competition sessions, with the alpha level of significance set at ≤ 0.05.

Time on Ice values were collected from the official KHL website (14) and were collated in Excel. The statistical assumptions for parametric analysis were met, and subsequently an independent sample t-test was performed to explore the differences between positions.

RESULTS

External Workload (total metrics)

Descriptive statistics for match and practice external workload total metrics can be found in Table 2. Forwards had a significantly greater total OIL ($p<0.05$) and total EE ($p<0.01$) than defenders during matches, whereas defenders had a significantly greater total PL ($p<0.05$). There were no significant differences between positions in matches for total SL or total HFS. In practices, forwards had a significantly greater total PL ($p<0.05$), OIL ($p<0.01$), SL ($p<0.05$) and EE ($p<0.05$) than defenders. There were no significant differences between positions for total HFS.

For both forwards and defenders, match play produced significantly higher values than practices in all metrics ($p<0.05$).

External Workload (relative metrics)

Descriptive statistics for match and practice relative workloads can be found in Table 3. In matches, forwards had a significantly greater OIL/min ($p<0.01$) and EE/min ($p<0.01$) than defenders, whereas defenders had a significantly greater PL/

Table 1. Anthropometric data for subjects

	n	Age (yrs)	Height (cm)	Body Mass (kg)
Defenders	5	27.2 ± 2.8	182.2 ± 6.7	93.2 ± 4.8
Forwards	9	29.9 ± 3.0	183.7 ± 5.3	90.7 ± 6.9

Table 2. Absolute external workload metrics by position and conditions

Position (Condition)	Total PlayerLoad mean ± SD	Total On Ice Load mean ± SD	Total Skating Load mean ± SD	Total Explosive Efforts mean ± SD	Total High Force Strides mean ± SD
Forwards (Matches)	249.0 ± 48.2*#	166.3 ± 39.0*#	1992.9 ± 421.8#	40.9 ± 26.2*#	236.6 ± 79.1#
Forwards (Practice)	214.3 ± 70.1*	129.2 ± 48.8*	1563.0 ± 580.0*	30.9 ± 21.2*	158.0 ± 92.0
Defenders (Matches)	260.3 ± 47.9#	155.2 ± 40.6#	2045.0 ± 364.3#	27.0 ± 12.7#	245.1 ± 56.8
Defenders (Practice)	198.6 ± 70.2	110.4 ± 48.0	1452.8 ± 533.9	22.6 ± 12.7	152.7 ± 72.8

** Significantly different (p<0.05) between positions for condition*

 # Significantly different (p<0.05) between conditions for position

Table 3. Relative external workload metrics by position and conditions

Position (Condition)	PL/min mean ± SD	OIL/min mean ± SD	SL/min mean ± SD	EE/min mean ± SD
Forwards (Matches)	2.42 ± 0.43*#	1.62 ± 0.36*	4.72 ± 0.62*	0.007 ± 0.004*
Forwards (Practice)	2.66 ± 0.39*	1.59 ± 0.34*	4.80 ± 0.58*	0.006 ± 0.003*
Defenders (Matches)	2.52 ± 0.42	1.50 ± 0.37	5.47 ± 0.50	0.004 ± 0.002#
Defenders (Practice)	2.58 ± 0.53	1.42 ± 0.44	5.56 ± 0.79	0.005 ± 0.003

** Significantly different (p<0.05) between positions for condition*
 # Significantly different (p<0.05) between conditions for position

Table 4. Time on Ice statistics by position

Position	Mean TOI (mins) ± SD	Lowest av. TOI (mins)	Highest av. TOI (mins)
Defence	16.9 ± 3.49*	12.8	21.8
Forward	14.8 ± 3.00	8.8	18.5

** Significantly different (p<0.01) between positions*

min ($p<0.05$) and SL/min ($p<0.05$) than forwards. In practices, forwards had a significantly greater PL/ min ($p<0.05$), OIL/min ($p<0.01$) and EE/min ($p<0.01$) than defenders, whereas defenders had a significantly greater SL/min ($p<0.05$) than forwards. Considering matches against practices, forwards had significantly lower PL/min ($p<0.05$) in match. There were no significant differences between matches and practices for OIL/min, EE/min and SL/min. For defenders, practices produced a significantly higher EE/min ($p<0.05$) than matches, whereas all other variables showed no significant difference.

Time on Ice

Descriptive statistics for mean positional match time on ice (TOI) can be found in Table 4. The range for each position is also presented for context. Defenders had a statistically significant greater time on ice than forwards ($p<0.01$).

DISCUSSION

This is one of the first studies to investigate the match and practice load characteristics of elite male ice hockey players. The aim was to describe positional differences in TOI and external workload for practices and matches in elite male ice hockey.

In total load terms, in practices, forwards had a significantly greater PL, OIL, SL and total number of EE than defenders. This supports the findings of Douglas et al (8) in elite female participation, who found who found forwards to have significantly higher practice values for PL and EE. In matches, forwards had significantly greater total EE, supporting the work of Douglas et al (8), and significantly greater total OIL, which is contrast to the work of Allard et al (1). In the Allard et al (1) study, OIL was reported at 149 ± 38 au for all groups, which is lower than in the current study (forwards: 166.3 ± 39.0 au; defenders: 155.2 ±

40.6 au). Although not statistically significant, graphical interpretation of the Allard et al (1) paper reveals that defenders had the lowest mean OIL. Defenders had a significantly higher in-match PL in the current study, which contradicts the findings of Douglas et al (8). In an attempt to understand why this difference has occurred, it is prudent to consider the respective team ability. In the Douglas et al (8) study, the participating female team were highly successful, dominating most opponents. It is logical to suggest that in such matches, forwards will have higher workloads. In the current study, the participating male team did not have a lot of success, losing the majority of matches during the season. As such, it is logical in that situation that there was a greater load demand placed on the defenders over the course of the season.

The current study found that relative load demands varied by position. In practices, forwards had statistically higher PL/min and EE/min than defenders, which supports the findings of Douglas et al (8) in the study of elite female ice hockey players. This paper also found that in practice, forwards had significantly higher OIL/min whereas defenders had a higher SL/min. To the authors knowledge, this is the first paper to report OIL/min and EE/min values for elite male players in practices. In matches, we found defenders had a significantly higher PL/min than forwards, which is in contrast to the findings of Douglas et al (8). This paper also found defenders had significantly higher SL/min than forwards, and a significantly lower OIL/min and EE/min. The lower OIL/min values for defenders are in line with the findings of Allard et al (1) in a study of sub-elite male ice hockey players.

Traditionally, PL and OIL have been considered to be strongly related, as OIL is calculated in the same way as PL, minus the lowest threshold band of activity; OIL excludes movements below 0.3m.s^{-2} to exclude non-game related movement, including slow gliding, standing still, and resting on the bench (1). However, this study produced confounding results surrounding PL and OIL. In matches, defenders had a significantly higher PL than defenders, but forwards had a significantly higher OIL. This could in part be explained by the fact that defenders spend more time in lower activity actions during a match. Jackson et al (12) found that defenders spent 58.7% of a match performing forwards and backwards gliding and standing still, compared to 50.1% for forwards.

Over the duration of 57 matches in the Russian elite league, defenders averaged 16.9 (± 3.5) minutes on ice, which was statistically greater than forwards, who averaged 14.8 (± 3.0) minutes of actual playing time. This is not a surprise, considering how hockey team game rosters are constructed (three pairs of defensemen and four sets of forwards). It is logical that defenders would accumulate greater ice time as there as less of them in the rotation of players. These values are slightly lower than values first reported by Green et al (11), in a study using time-motion analysis to analyze ice time in university varsity players. This seminal work reported forwards accumulating around 20.7 minutes of ice time, and defenders accumulating around 28.0 minutes of ice time. It should be noted that Green et al's work was conducted over 45 years prior to the current study, and it is possible that evolution of the game has occurred during this time, which may account for the difference in values. Furthermore, the difference in playing level (university vs elite professional) may also contribute to the discrepancy. Ice time was not spread equally throughout the positional groups. 10% of defenders played at least 1 standard deviation (SD) above the mean on ice time, and 20% of defenders played at least 1SD below the mean on ice time. A similar pattern was found with forwards. 22% of forwards played at least 1SD above the mean ice time, and 17% of forwards played at least 1SD below the average ice time. This offers support to show that players do not receive equal ice time, instead being dictated by the coach to meet the tactics of the game. Whilst mean match ice time varied considerably in both groups (defenders: 12.8 – 21.8 minutes; forwards: 8.8 – 18.5 minutes), small and consistent standard deviations within players (defenders: 2.4 – 2.6; forwards: 1.5 – 2.6) show that the individual players ice time remained consistent throughout the season.

Calculating relative match and practice metrics is an important part of data collection for strength and conditioning coaches or sports scientists. Having knowledge of total workload helps to understand the volume of work a player has completed, but relative metrics add an additional level of understanding by describing the intensity of the completed work. This additional information is required for accurately planning practices to meet match demands. Whilst the majority of published studies (6, 8, 18, 19) in ice hockey have used 'real-world' activity duration (actual match duration plus in-match stoppages), one study (1) used individual player time on ice values to determine relative measures. In reality, both methods have merits and concerns. Utilizing a 'time on ice' approach gives a true reflection of each individual during a match. However, to apply this method to team practices would require each individual's contribution to each drill to be closely monitored, which would be extremely time consuming, and most likely unachievable in an applied setting. In contrast, taking a 'real-world' approach lowers the relative intensity of lower minute players in comparison to higher minute players. However, practices mimic match demands in so much as players will perform a drill with a subsequent period of rest, as they would complete a shift on the ice before returning to the bench to rest in a match. With this in mind, the authors urge practitioners utilizing external workload monitoring to carefully consider the method they use to produce relative metrics.

One outcome of this study highlights the different methods of calculating relative metric calculations. Further analysis and presentation of relative metric calculations for matches and practices could serve to provide a more accurate understanding of workload demands in elite ice hockey, leading to enhanced periodization and preparation strategies.

All of the current published literature in ice hockey, and the majority of literature investigating external workload in team sports, has concentrated on using singular metrics to assess the volume (i.e. PL) and intensity (i.e. PL/min) of workload. However, there is an argument in recent literature that a combination of metrics should be used to determine a more accurate representation of external load. In a systematic review of training load indicators in professional soccer (football), Jaspers et al., (13) concluded that future research should give consideration to the combination of metrics to determine training load (13). In soccer, this approach was first investigated by Owen and colleagues (21). In the study, the authors combined the GPS metrics of total distance, high speed running distance, sprint distance, and the sum of high intensity efforts (21) and found that this multi-modal analysis of load metrics provided a more holistic representation of training load than the individual metrics, due to significant training load variations in both load and intensity when assessed across microcycles (21). Whilst this type of research has currently only been performed in soccer, there is reason to believe it may be relevant to ice hockey, where players undertake high intensity intermittent skating, frequent changes of direction, physical contacts, static periods of exertion (for example, two players battling for puck position on the boards), and multiple rolling substitutions, which raises doubts on the ability of one sole metric to accurately encompass the external load placed on players during matches and practices. Supporting this, Allard et al (1) suggest that to understand the external load of ice hockey matches, external load should be quantified using a combination of metrics assessing the number and amplitude of skating strides, accelerations, changes in direction, collisions, and various key actions.

The results of the current study offer support to the current literatures recommendations for the use of external load monitoring in hockey. Thoroughly documenting the external load demands of matches and practices can provide the coaching staff with information to ensure that practice plans are being assessed and modified to equal match requirements to enhance the athlete preparation process. External load demands of elite male ice hockey are position specific, and it is evident that players accumulate more load in matches than practice. This information can be used to improve training session demand, by incorporating position-specific drills which replicate match intensity, resulting in optimized preparation.

PRACTICAL APPLICATIONS

This study has outlined practice and match workload characteristics for elite men's ice hockey players. It has produced some novel results from a population not previously reported in the literature, which can be used as reference for a coach or sports scientist in planning and monitoring on-ice load to optimize player performance. It has also challenged the use of previously reported metrics and leaves the coach with considerations for metric selection in their own practice. Finally, it confirms that time on ice alone should not be considered as an accurate measure of external workload, which could influence individual conditioning strategies during the season.

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CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure.

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