RELIABILITY OF TRIAXIAL ACCELEROMETRY FOR MEASURING LOAD IN MEN'S COLLEGIATE ICE HOCKEY

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ABSTRACT

Van Iterson, EH, Fitzgerald, JS, Dietz, CC, Snyder, EM, and Peterson, BJ. Reliability of triaxial accelerometry for measuring load in men's collegiate ice hockey. *J Strength Cond Res* 31(5): 1305–1312, 2017—Wearable microsensor technology incorporating triaxial accelerometry is used to quantify an index of mechanical stress associated with sport-specific movements termed PlayerLoad. The test-retest reliability of PlayerLoad in the environmental setting of ice hockey is unknown. The primary aim of this study was to quantify the test-retest reliability of PlayerLoad in ice hockey players during performance of tasks simulating game conditions. Division I collegiate male ice hockey players ($N = 8$) wore Catapult Optimeye S5 monitors during repeat performance of 9 ice hockey tasks simulating game conditions. Ordered ice hockey tasks during repeated bouts included acceleration (forward or backward), 60% top-speed, top-speed (forward or backward), repeated shift circuit, ice coasting, slap shot, and bench sitting. Coefficient of variation (CV), intraclass correlation coefficient (ICC), and minimum difference (MD) were used to assess PlayerLoad reliability. Test-retest CVs and ICCs of PlayerLoad were as follows: 8.6% and 0.54 for forward acceleration, 13.8% and 0.78 for backward acceleration, 2.2% and 0.96 for 60% top-speed, 7.5% and 0.79 for forward top-speed, 2.8% and 0.96 for backward top-speed, 26.6% and 0.95 for repeated shift test, 3.9% and 0.68 for slap shot, 3.7% and 0.98 for coasting, and 4.1% and 0.98 for bench sitting, respectively. Raw differences between bouts were not significant for ice hockey tasks ($p > 0.05$). For each task, between-bout raw differences were lower vs. MD: 0.06 vs. 0.35 (forward acceleration), 0.07 vs. 0.36 (backward acceleration), 0.00 vs. 0.06 (60% top-speed), 0.03 vs. 0.20 (forward top-speed), 0.02 vs. 0.09 (backward top-speed), 0.18 vs. 0.64 (repeated shift test), 0.02 vs. 0.10 (slap shot), 0.00 vs. 0.10 (coasting), and 0.01 vs. 0.11 (bench sitting), respectively. These data suggest that PlayerLoad demonstrates moderate-to-large test-retest reliability in the environmental setting of male Division I collegiate ice hockey. Without previously testing reliability, these data are important as PlayerLoad is routinely quantified in male collegiate ice hockey to assess on ice physical activity.

KEY WORDS activity monitor, wearable microsensor technology, mechanical stress, time-motion PlayerLoad, GPS, external load

INTRODUCTION

Accessibility to reliable and objective quantification of sport-based physical activity performed in the field setting is desirable for athletes, physiotherapist, and coaches alike. Importantly, when data of this nature can be routinely collected in a sport-specific environmental setting, information derived from these data is suggested to enhance the evaluation and understanding of physical activity patterns during this period (6,8,20). In particular, this has led to several lines of evidence, suggesting that availability to objective data from the field setting aids in optimizing the ratio between external load placed on the body and subsequent internal stress that accompanies physical training (8,10,11,20,23). Interpretation of this data, which can be quantified via wearable microsensor technology, is suggested to attenuate the potential for exacerbated training stress leading up to or during game competition (8,10,11,20,23). Accordingly, an accumulating body of research focusing on wearable microsensor technology provides support for the efficacy and value of objectively quantifying sport-based physical activity in athletic settings that includes, for example, basketball, soccer, rugby, and Australian Rules football (10,11,18,20,23).

Triaxial accelerometry is a well-recognized form of wearable microsensor technology that, when linked with gyroscopes to measure angular velocities and magnetometers to

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assess orientation, demonstrates the capacity to objectively quantify intermittent and multidirectional sport-related physical activity in mediolateral, vertical, and anteroposterior planes of motion (5,6,18). It follows, therefore, that early generation wearable microsensor technology incorporating triaxial accelerometry, gyroscopes, and magnetometers have developed the PlayerLoad index, which is suggested to quantify the integration of running (e.g., distance, speed) and non-running (e.g., change of direction, jumping) physical activity (5,6,18). In the field-based setting, PlayerLoad can be measured in indoor and outdoor environments, has low-user dependence, and, perhaps equally important, is suggested to quantify dynamic and cumulative external load associated with sport training and competition in a broad range of athletes (8,12,17,18,20).

Wearable microsensor technology that is used to quantify external load (e.g., PlayerLoad) has been tested for reliability in laboratory settings (1,5). However, to the best of our knowledge, limited investigations have evaluated the reliability of PlayerLoad in the sport-specific environmental setting (5). Thus, although studied across a broad range of sports, while being measured during training and competition scenarios to objectively evaluate athlete physical status (8,12,17,18,23), the reliability of PlayerLoad specific to ice hockey has not been previously tested. This is an important question to test as wearable microsensor technology used to measure PlayerLoad is currently and routinely used in the settings of professional and collegiate men's ice hockey.

The aim of this study was to evaluate the test-retest reliability of PlayerLoad using the most recent technology capable of measuring this parameter (Catapult Optimeye S5 monitor; Catapult Sports, Melbourne, Australia) in Division I collegiate male ice hockey players during performance of game-competition–simulated ice hockey tasks on their home ice arena.

METHODS

Experimental Approach to the Problem

To assess test-retest reliability of PlayerLoad in repeat performance of simulated game-specific ice hockey tasks, Division I collegiate male ice hockey players performed 9 ordered ice hockey tasks in one single bout, which were repeated in an identical manner for a second bout, with all testing occurring on a single study visit. In addition to being commonly performed during in-game and practice settings, the selected on-ice ice hockey tasks have been demonstrated as being valid for assessing ice hockey task performance (7,14,19). All testing occurred in the late afternoon, while beginning and ending earlier than the start of a pregame skate-around that precedes a typical evening collegiate ice hockey game.

Subjects

Eight Division I male collegiate ice hockey players volunteered to participate in this study ($n = 8$; defensemen = 4, forwards = 4; age = 21 ± 1 years, range = 20 to 22 years, height = 184 ± 2 cm, body mass index = 25 ± 0 $\text{kg}\cdot\text{m}^{-2}$). Potential participants were excluded if they played the position of goalie or had not skated over the previous 30 days because of previous or current injury. All aspects of this study were reviewed and approved by the University Institutional Review Board. Participants were informed of all risks and procedures and gave written informed consent before participation. Participants were given full knowledge. One researcher worked for the wearable microsensor technology manufacturer used to measure PlayerLoad in this study and, but he was not provided support from this company to conduct this study.

Procedures

Testing was performed during a break in the competitive season consisting of one study visit lasting approximately 1 hour at the University ice arena (Olympic standard ice sheet size: $100\cdot200$ feet). Participants wore all game-specific ice hockey equipment during testing. Participants were instructed to refrain from vigorous exercise 24 hours before testing and to refrain from caffeine, tobacco, and alcohol 12 hours before testing. Participants were instructed to consume the same meal they would eat before a game 2 hours before testing.

Participants were instructed to perform the standardized team warm-up that would normally be performed before in-season game competition. After warm-up, each participant completed 2 separate bouts of testing, with each bout and task being separated by 3 minutes of passive rest while sitting on the ice hockey bench.

Each bout consisted of 9 distinct ice hockey tasks that were performed in identical order for each participant. The following 9 ice hockey tasks were performed for bout 1 and repeated in identical order for bout 2: (a) forward acceleration, (b) backward acceleration, (c) forward top-speed, (d) backward top-speed, (e) ~60% top-speed (i.e., rate of perceived exertion at 12 on Borg's 6–20 scale (4)), (f) coasting, (g) repeated shift, (h) slap shot, and (i) bench sitting. All protocols were consistent with the literature, whereby the on-ice ice hockey tasks have been demonstrated as being valid for assessing ice hockey task performance (7,14,19).

Nine Ice Hockey Tasks

Forward and backward accelerations were measured by having participants sprint skate with stick in their native hand and stick blade in contact with ice from a stationary start a total of 17.68 m (i.e., from blue line to blue line).

Forward top-speed, backward top-speed, 60% top-speed, and coasting were measured separately from one another using the same 17.68 m distance that was used during acceleration testing. The start of each test began with skating one complete lap around the rink, whereby each test began upon reaching the official start line (i.e., the first blue line). Upon reaching the start line, specific to the ice hockey task being performed, participants either skated as fast as possible (i.e., forward or backward top-speed), skated at ~60% of top-speed (i.e., rate of perceived exertion at 12 on Borg's

6–20 scale (4)), or coasted until reaching the second blue line (i.e., traveled 17.68 m).

The final tests that were performed included repeated shift, slap shot, and bench sitting. The repeated shift protocol was standardized as described previously (19). For slap shot testing, participants were instructed to shoot the puck toward a standard hockey goal with maximum effort. Participants shot from a standing position while being positioned a standardized distance of 17.68 m from the goal (i.e., nearest blue line to goal). For the final test, participants were instructed to sit on the bench for a period of 20 seconds. During bench sitting, participants were asked to remain seated upright with stick in hand in a vertical position with blade on the ground.

Each participant completed all ice hockey tasks in identical order on the same day for both bouts.

Video

High-definition video was recorded for each participant during all testing (Sony HDR-PJ440; Sony Inc., Tokyo, Japan). Because 1 frame per second is equivalent to 2 Hz, we captured video at a true 50 frames per second, which is a frame rate that can be readily input to a monitor while allowing adequate syncing capabilities with the 100-Hz Catapult Optimeye S5 monitor data. The videographer was positioned at center ice, and all recording occurred at approximately 13 m from the ice (i.e., ~half way up the bleachers) using a tripod at 1.8 m in height.

Timing System

We used a TC Speed Trap-II wireless timing system (Gill Athletics, Champaign, IL) to measure the start and end of all on-ice hockey tasks. The photo cells for timing gates at the start and finish line (i.e., directly over the center of the respective blue line) were placed approximately at the waist level of participants to ensure the body crossing the line tripped the laser timer. For repeated shift circuit testing, we placed timing gates on the face-off circle, blue line, and center line (19). Because all on-ice skate testing required the stick to be in hand, we asked participants to keep the stick-blade touching the ice to prevent premature tripping of timing gates.

PlayerLoad

Use of a single Catapult Optimeye S5 monitor ($96 \cdot 52 \cdot 13$ mm^3 dimensions) to measure PlayerLoad measured in arbitrary units (AU) in all participants was performed in strict compliance with the manufacturer guidelines. The same monitor was firmly placed between the scapulae of each participant in a monitor-specific Catapult branded neoprene vest undergarment (Catapult Sports, Melbourne, Australia) that each participant had fitted before testing.

The fifth-generation microprocessor of the Catapult Optimeye S5 monitor is used to quantify PlayerLoad microsensor data in the indoor environment through integration of 100-Hz 2–16g triaxial accelerometry (quantifies linear motion in all directions–acceleration or deceleration) with triaxial gyroscopes (samples at 200–2,000° per second to measure body angular motion and rotation) and 100 Hz triaxial magnetometers (measures direction and orientation of body position). The triaxial gyroscope and magnetometer functions are necessary in the aggregation of data from each specific axis in the mediolateral, vertical, and anteroposterior planes of motion to quantify PlayerLoad during dynamic multi-plane body movement. PlayerLoad is equal to quotient of the square root of the sum of the squared instantaneous rates of change in all acceleration planes over 100 (1,5,6,18). Microsensor data in this study were downloaded to the unit via 2-GB internal flash memory while using a USB port used to upload data for post-processing. Quantification of PlayerLoad during repeated high-intensity exercise efforts during both laboratory and sport settings have been conducted using previous generations of this technology (1,5).

Catapult Sprint software (Sprint 5.1.7 Catapult Sports, Melbourne, Australia) was used for proprietary postprocessing of data. Data were cropped using the video and gate time data to establish the start and end points of each ice hockey task with omission of pretest and posttest resting data. This was done to ensure that analyses only included PlayerLoad accumulated during each ice hockey task.

Statistical Analyses

Parametric data are presented as mean ± standard deviation (*SD*) where appropriate. There are no previous studies examining PlayerLoad in the setting of the current experimental design in male Division I collegiate ice hockey players to guide statistical considerations. Therefore, a priori power and standardized differences (i.e., effects size) analyses suggested that the sample number needed to detect large differences (effects size ≥ 0.8) if present at a power ≥ 0.80 between repeated ice hockey tasks was met with the present sample size (9). The assumption of data normality was met as computed using D'Agostino and Pearson normality testing. Mixed model repeated-measures analysis of variance testing was used to quantify differences between bouts across performance of ice hockey tasks (variance associated with differences in position played was accounted for by setting player position as a random effect). Main effects were set as bout and ice hockey task while including a bout-by-ice hockey task interaction. Post-hoc testing using a Bonferroni correction was applied in the event of a significant F-test statistic to assess pairwise differences.

Coefficient of variation (CV) and intraclass correlation coefficient (ICC) analyses with 95% confidence limits (CL), in addition to typical error (TE) and minimum difference (MD), were parameters used to assess test-retest reliability of total PlayerLoad for each ice hockey task. Standard calculation of CV for sums of the sample or individually for bouts 1 or 2 were performed as $(SD \cdot \text{mean}^{-1}) \cdot 100$. Calculation of CV between bouts was calculated in the following steps adapted from the methods of Bland and Altman (3): first, within-subject variance was calculated, $s = (\text{bout } 1 - \text{bout } 2)^2 \cdot 2^{-1}$;

Table 1. PlayerLoad stratified by ice hockey task.*†

Variable	All	Bout 1	Bout 2	Δ	*d*	*p*
F.accl	1.56 ± 0.20	1.53 ± 0.20	1.59 ± 0.20	0.06 ± 0.07	0.29	0.37
B.accl	0.95 ± 0.20	0.99 ± 0.25	0.92 ± 0.25	0.07 ± 0.07	0.45	0.37
F.TS	0.85 ± 0.16	0.86 ± 0.14	0.84 ± 0.14	0.03 ± 0.04	0.21	0.52
B.TS	0.48 ± 0.16	0.47 ± 0.14	0.49 ± 0.14	0.02 ± 0.02	0.41	0.24
60%.TS	0.33 ± 0.08	0.34 ± 0.08	0.33 ± 0.08	0.00 ± 0.01	0.63	0.76
SS	0.47 ± 0.04	0.48 ± 0.06	0.46 ± 0.06	0.02 ± 0.02	0.38	0.28
RS	6.06 ± 0.84	5.97 ± 0.88	6.16 ± 0.88	0.18 ± 0.12	0.58	0.18
IC	0.36 ± 0.32	0.36 ± 0.23	0.36 ± 0.23	0.00 ± 0.02	0.00	0.99
BS	0.41 ± 0.36	0.41 ± 0.25	0.41 ± 0.25	0.01 ± 0.02	0.00	0.70

*Δ = raw mean difference between bouts 1 and 2; *d* = standardized differences between bouts (effect size); *p* = value determined from the *F*-statistic from the repeated-measures analysis of variance; F.accl = forward acceleration; B.accl = backward acceleration; F.TS = forward top speed; B.TS = backward top speed; 60%.TS = 60% top speed; SS = slap shot; RS = repeated shift; IC = ice coasting; BS = bench sitting.

†Data are represented as mean ± *SD* for raw data in arbitrary units (AU). Bout 1, *N* = 8; bout 2, *N* = 8; all = mean of combined bouts 1 and 2.

second, we calculated, $s^2 \cdot \text{mean}^{-1}$; finally, we calculated, CV = $\sqrt{s^2 \cdot \text{mean}^{-2}}$. Test-retest CVs were interpreted in this study from 0 to 100%, with the goal CV being set at 0–10% between test bouts, values >10–20% reflecting moderate reliability, and >20% modest to poor reliability between bouts (21).

Calculation of ICC was performed using covariance parameter estimates from analysis of variance models computed as, variance$\cdot$(variance + residual)$^{-1}$ (2,22). Test-retest ICCs were interpreted from 0.00 to 0.99, with values: <0.1 = trivial, 0.1–0.39 = modest, 0.4–0.59 = moderate, 0.60–0.75 = large, >0.75 = very large, and 0.99 representing perfect consistency between bouts (2,22).

Typical error for each ice hockey task was calculated as the *SD* of the differences between bouts divided by $\sqrt{2}$ (22). As part of the interpretation of TE, MD was calculated as, TE$\cdot 1.96 \cdot \sqrt{2}$ (22). Accordingly, any change in PlayerLoad for a given ice hockey task from bouts 1 to 2 (either above or below bout 1 measurements) greater than or equal to the MD, needed to occur to suggest a real change occurred in PlayerLoad between bouts as opposed to random measurement error (22).

Standardized differences (i.e., effect sizes) between means of the 2 bouts for each ice hockey task were calculated as, $d = (\text{bout } 1_{\text{mean}} - \text{bout } 2_{\text{mean}}) \cdot SD^{-1}$ (9). Interpretation of effect sizes was described using the

Table 2. Test-retest reliability stratified by ice hockey task.*†

Variable	CV (%)	ICC	TE (AU)	MD (AU)
F.accl	8.6 (7.4 to 9.8)	0.54 (−0.19 to 0.89)	0.13 (0.09–0.27)	0.35
B.accl	13.8 (7.8 to 19.8)	0.78 (0.23 to 0.95)	0.14 (0.09–0.28)	0.36
F.TS	7.5 (6.7 to 8.3)	0.79 (0.25 to 0.95)	0.08 (0.05–0.16)	0.20
B.TS	2.8 (2.7 to 2.9)	0.96 (0.83 to 0.99)	0.04 (0.02–0.07)	0.09
60%.TS	2.2 (2.2 to 2.2)	0.96 (0.81 to 0.99)	0.02 (0.02–0.05)	0.06
SS	3.9 (3.8 to 4.0)	0.68 (0.02 to 0.93)	0.04 (0.03–0.08)	0.10
RS	26.6 (−43.4 to 96.6)	0.95 (0.76 to 0.99)	0.25 (0.16–0.50)	0.64
IC	3.7 (3.6 to 3.8)	0.98 (0.90 to 0.99)	0.04 (0.03–0.08)	0.10
BS	4.1 (4.0 to 4.2)	0.98 (0.90 to 0.99)	0.04 (0.03–0.09)	0.11

*CV = coefficient of variation; ICC = intraclass correlation coefficient; TE = typical error; AU = arbitrary units; MD = minimum difference; F.accl = forward acceleration; B.accl = backward acceleration; F.TS = forward top speed; B.TS = backward top speed; 60%.TS = 60% top speed; SS = slap shot; RS = repeated shift; IC = ice coasting; BS = bench sitting.

†Bout 1, *N* = 8; bout 2, *N* = 8. In parentheses are 95% confidence limits.

TABLE 3. Absolute vs. minimum differences across ice hockey tasks.*†

	F.accl	B.accl	F.TS	B.TS	60%.TS	SS	RS	IC	BS
F.accl		0.54 ± 0.24	0.66 ± 0.017	1.06 ± 0.20	1.19 ± 0.13	1.05 ± 0.14	4.45 ± 0.77	1.16 ± 0.29	1.11 ± 0.32
MD		0.47	0.34	0.38	0.25	0.27	1.51	0.57	0.62
B.accl			0.21 ± 0.17	0.52 ± 0.31	0.65 ± 0.27	0.51 ± 0.26	4.99 ± 0.63	0.62 ± 0.31	0.57 ± 0.23
MD			0.23	0.50	0.52	0.49	1.23	0.60	0.46
F.TS				0.40 ± 0.12	0.53 ± 0.12	0.38 ± 0.16	5.11 ± 0.76	0.50 ± 0.31	0.45 ± 0.27
MD				0.23	0.23	0.32	1.50	0.47	0.43
B.TS					0.13 ± 0.10	0.13 ± 0.08	5.51 ± 0.84	0.27 ± 0.17	0.29 ± 0.11
MD					0.16	0.15	1.62	0.32	0.22
60%.TS						0.14 ± 0.09	5.64 ± 0.83	0.03 ± 0.24	0.08 ± 0.28
MD						0.17	1.62	0.46	0.55
SS							5.49 ± 0.83	5.61 ± 0.88	0.22 ± 0.12
MD							1.63	1.73	0.23
RS								5.61 ± 0.88	5.56 ± 0.81
MD								1.73	1.59
IC									0.19 ± 0.14
MD									0.28
BS									
MD									

*F.accl = forward acceleration; B.accl = backward acceleration; F.TS = forward top speed; B.TS = backward top speed; 60%.TS = 60% top speed; SS = slap shot; RS = repeated shift; IC = ice coasting; BS = bench sitting.

†Data in non-shaded rows for ice hockey tasks are presented as mean ± *SD* in arbitrary units (AU) for raw differences in PlayerLoad between respective ice hockey tasks, row vs. column. Data in indented rows are minimum differences (MD) in PlayerLoad AU between respective ice hockey tasks, row vs. column. Raw values higher than MD suggest real worthwhile differences in PlayerLoad between ice hockey tasks.

following criteria: 0.0 = trivial; 0.2 = small; 0.6 = moderate; 1.0 = large; and ≥2.0 = very large (9). The alpha was set at 0.05 to determine 2-tailed statistical significance for all outcomes. All computations were made using SAS, v.9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Total Recording Period PlayerLoad and Time

Test-retest reliability for PlayerLoad of total recording periods of bout 1 (92.2 AU) and bout 2 (92.4 AU) were 8.6% (95% CL, 8.3–8.9) and 0.99 (95% CL, 0.99–0.99) for CV and ICC, respectively. The absolute difference in total PlayerLoad between bouts was 0.2 AU, whereas TE was 0.08 AU (95% CL, 0.06–0.16) and MD was 0.22 AU. Similarly, test-retest reliability of total time taken to perform all ice hockey tasks in bout 1 (732 seconds) and bout 2 (732 seconds) were 3.9% (95% CL, 3.9–4.0) and 0.99 (95% CL, 0.99–0.99) for CV and ICC, respectively. The absolute difference in total time between bouts was 0.2 seconds, whereas TE was 0.11 seconds (95% CL, 0.07–0.22) and MD was 0.30 seconds.

PlayerLoad Stratified by Ice Hockey Task

Mean PlayerLoad stratified into bout and ice hockey task is presented in Table 1. There was no interaction effect between bout and ice hockey task ($F_{(8,63)} = 0.66$, $p = 0.72$) (Table 1). There was no main effect for bout ($F_{(1,63)} = 0.96$, $p = 0.33$) (Table 1). We observed a main effect for ice hockey task ($F_{(8,63)} = 11.61$, $p < 0.01$) (Table 1). Trivial-to-small standardized differences between bouts for each ice hockey task were consistent with negligible absolute (Δ) differences (Table 1).

Reliability of PlayerLoad Stratified by Ice Hockey Task

Test-retest reliability of PlayerLoad across separate ice hockey tasks consistently demonstrated moderate-to-large reliability (Table 2). The CV for each ice hockey task fell within the range of 0–10% (good strength) for 7 of 9 ice hockey tasks, with backward acceleration and repeated shift tasks moderately falling outside of this range. Stronger than CV, the ICC for each ice hockey task was >0.75 (very large) for 8 of 9 ice hockey tasks with forward acceleration still falling within the range of 0.4–0.59 (moderate). Finally, compared with absolute mean differences for each ice hockey task from bout 1 to bout 2 illustrated in Table 1, MD levels in Table 2 were larger.

Absolute vs. Minimum Differences in PlayerLoad Across Ice Hockey Tasks

Illustrated in Table 3 are between-ice hockey task differences in PlayerLoad in both absolute and MD terms for bout 1. Real differences between 2 ice hockey tasks (e.g., forward vs. backward acceleration) are shown by higher absolute differences compared with MD values shown in shaded rows in Table 3. Although absolute differences in PlayerLoad between ice hockey tasks within bout 1 were generally higher than MD PlayerLoad values, there were few cases where this did not occur, such as ice coasting vs. bench sitting. Patterns shown for differences in PlayerLoad between absolute vs. MD values for bout 1 were mirrored for bout 2.

DISCUSSION

The present study aimed to assess the test-retest reliability of the Catapult Optimeye S5 monitor for the quantification of PlayerLoad specific to environmental field testing of tasks native to ice hockey in male Division I collegiate ice hockey players. These data suggest that measurement of PlayerLoad during performance of ice hockey tasks simulating game competition consistently shows moderate-to-large reliability in this sample of collegiate ice hockey players. Moreover, reliability parameters such as TE and MD (22), which are used to set thresholds to detect real worthwhile differences, suggest that PlayerLoad values are distinctly different from one another based on any of the 9 ice hockey tasks tested in this study. In contrast, CV, ICC, TE, and MD values for each ice hockey task suggest between-bout differences in PlayerLoad are not real differences, rather suggesting that these differences are likely attributable to random measurement error associated with this microsensor technology platform.

Strong reliability is an attractive feature of wearable microsensor technology, which has been implemented in environmental settings (e.g., team sports) to continually track unique body movements, and in several instances has been suggested to indicate levels of mechanical stress associated with physical training (6,10,11,13,18). Previous to this study, others demonstrate that the foundation of PlayerLoad, which is triaxial accelerometry, can be used to measure both the frequency and the magnitude of movement in the major planes of movement that are common to athletic activities during training and competition across a range of sport settings (1,5,6,16,18). However, to the best of our knowledge, limited studies have tested the reliability of PlayerLoad across the range of sport-specific environmental field settings (1,5). Nevertheless, observations from laboratory-based study in addition to field-based study (e.g., Australian rules football matches) suggest that PlayerLoad demonstrates favorable reliability in both laboratory and field conditions (1,5). With this, we support, and also extend this body of evidence, in demonstrating similar moderate-to-large levels of PlayerLoad reliability in the environmental setting of ice hockey using the Catapult Optimeye S5 monitor technology platform.

Although the need to quantify PlayerLoad that is specific to a given athletic task may vary depending on the setting (e.g., practice vs. competition) or sport, the present observations, which are underscored by reliability indices (e.g., TE and MD), suggest that PlayerLoad in male collegiate ice hockey players may distinctly differ based on a given ice hockey task. This unique extractable PlayerLoad information is valuable for the purposes of evaluating how much external load may be associated with select ice hockey tasks tested in this study, which are tasks that are commonly performed in practice and game competition settings. Reliably measuring PlayerLoad specific to ice hockey tasks is useful for the purposes of categorically tracking PlayerLoad over the full course of a training and competition ice hockey season.

Observations from studies examining the efficacy of wearable microsensor technology for various types of physical activity tracking suggest that measurement of a range of body movements at differing intensities can be used effectively in a variety of athletic and nonathletic settings (1,5,6,15,18). Stratified PlayerLoad (external load) recording has been demonstrated to show the capacity to differentiate field position played and game vs. practice competition in Australian football or basketball (6,18), which is consistent with the variable within bout patterns of PlayerLoad across ice hockey tasks demonstrated in this study. We illustrate that the PlayerLoad parameter is capable of reliably reflecting ice hockey task movements that involve forward, backward, or static patterns, in addition to high, medium, or low effort intensities in the setting of male collegiate ice hockey. These data are consistent with, while also extending observations of Barrett et al. (1), who demonstrate that there are unique relationships between treadmill speed and vector planes comprising PlayerLoad. Thus, this study demonstrates that both the between- and the within-bout reliability of PlayerLoad via Catapult Optimeye S5 monitoring during environmental field testing of ice hockey tasks extends the limited but promising continuum of reliability testing of PlayerLoad in both laboratory and field settings (1,5).

The strengths of this study should be considered in parallel with the limitations. Although we performed a priori power calculations suggesting an appropriate sample size for testing the aim of this study, this sample of ice hockey players was not that of the entire team and all came from a single institution, which is considered a top collegiate ice hockey program in the United States. Moreover, the overall high training level of Division I ice hockey players may have influenced these data because this level of ice hockey player may demonstrate a more consistent set of ice hockey skills that may be more reproducible compared with ice hockey players of a lower-tiered collegiate team. However, despite this consideration for potential skill level discrepancy between collegiate ice hockey divisions, we would not expect that between- and within-bout reliability of PlayerLoad to differ in other populations of collegiate ice hockey players because these players commonly perform similar patterns of skill execution during practice and game play. Additionally, we did not include a criterion measurement technique to provide a secondary method for quantifying and comparing external load during ice hockey task performance. Therefore, construct validity of the Catapult Optimeye S5 monitor to accurately quantify external load via the PlayerLoad index associated with performance of the present ice hockey tasks cannot be elucidated from these data. Nevertheless, although not previously tested in ice hockey, earlier generations of this wearable microsensor technology used to quantify PlayerLoad as a surrogate for external load have been tested while suggesting that this index is indeed related to the accumulation of external load associated with participation in sport-based physical activity (1,5,8,20).

These data suggest that the PlayerLoad parameter commonly used to estimate external load during sport-based physical activity demonstrates test-retest reliability in the specific environmental setting of male Division I collegiate ice hockey. The present observations are consistent with the current line of study testing PlayerLoad in both the sport and laboratory settings (1,5,6,12,18). However, we extend this body of evidence into the sport of ice hockey, which is recognized to currently use this wearable microsensor technology platform to quantify PlayerLoad for the purposes of objectively monitoring physical activity while occurring in the absence of evidence supporting the reliability of repeat measurements of PlayerLoad for these purposes. Thus, this study provides preliminary supporting evidence suggesting that coaches, trainers, and athletes can reliably quantify PlayerLoad across a spectrum of game-specific ice hockey tasks in male Division I collegiate ice hockey players in the field environment setting.

Practical Applications

These data suggest that PlayerLoad can be routinely and reliably assessed in the sport-specific setting of male collegiate ice hockey. This is an important next step in wearable microsensor technology aimed for use in ice hockey because it has been previously suggested that PlayerLoad in the setting of other sports may be used, for example, to indicate injury, track sport–specific activity patterns, and objectively compare physical activity across player positions in game and competition settings (5,8,12,18,23). The observations from this study demonstrate that the Catapult Optimeye S5 monitor can be used for rapid and reliable quantification of on-ice PlayerLoad in a closed-roof ice hockey arena. In this manner, and perhaps being used in a similar capacity as demonstrated in other sports (6,8,12,20,23), constant repeat monitoring of on-ice PlayerLoad can be used to track relative changes in training session external load while providing invariable information for managing accumulated fatigue throughout the competition season. With this technology and index of external load, coaches and sport-scientists should be expected to be able to establish reliable objective patterns of PlayerLoad directly associated with ice hockey–specific movements, including, but not limited to acceleration, top speed, shooting, and repeated shift timing during practice and competition. This is important as PlayerLoad and, hence, external load are suggested to be inherently coupled with mechanical stress on the body associated with sport-based physical movements.

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