



2019

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### Recommended Citation

Jason G. Ulmer, Grant R. Tomkinson, Sandra E. Short, et al.. "Test-retest reliability of TRIMP in collegiate ice hockey players" (2019). *Education, Health & Behavior Studies Faculty Publications*. 37.  
<https://commons.und.edu/ehb-fac/37>

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# Test-retest reliability of TRIMP in collegiate ice hockey players

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**ABSTRACT:** The utility of the heart rate derived variable TRaining IMPulse (TRIMP) for assessing internal training load in ice hockey players is not clear. Having a reliable measure of internal training load during on-ice training sessions would help coaches program exercise training. This study determined the reliability of TRIMP during on-ice training sessions in ice hockey players. Twelve Division I collegiate male ice hockey players (aged 18–23 years) had their heart rate (HR) data recorded during two on-ice practice sessions separated by two weeks. TRIMP and other descriptive HR variables were compared between sessions. TRIMP demonstrated moderate reliability during on-ice sessions. Systematic error, quantified as standardized change in means was negligible (−0.19); random error quantified as the percent typical error (%TE) was moderate (12.2%); and, test-retest correlation was very strong (0.75). TRIMP is suitable for quantifying training load during intermittent work in hockey athletes. The results from our study can be used to determine the threshold for meaningful change in TRIMP, which may aid in informing decisions by coaches and strength training staff regarding on-ice training session difficulty and composition.

**CITATION:** Ulmer JG, Tomkinson GR, Short S et al. Test-retest reliability of TRIMP in collegiate ice hockey players. *Biol Sport*. 2019;36(2):191–194.

Received: 2018-10-08; Reviewed: 2019-03-14; Re-submitted: 2019-03-21; Accepted: 2019-03-29; Published: 2019-04-25.

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**Key words:**

Internal training load

Training impulse

Heart rate

Reliability

Athletes

Sport

## INTRODUCTION

Ice hockey is a complex intermittent team sport. During competition, roughly 18% of actual playing time is spent performing high-intensity activity (e.g., fast forward skating, forward sprinting, fast backward skating), with the remainder spent performing low-intensity activity (e.g., slow forward skating, gliding, standing) [1]. The external work performed on-ice is predominately supported by anaerobic metabolism [2], however aerobic factors appear to be important for fatigue resistance [3, 4]. The development of ice hockey training programs is challenging as multiple components of fitness need to be addressed (e.g., speed, muscular strength, aerobic endurance, sport-specific skill) along with game tactics and team play. In-season, this is primarily accomplished during on-ice training sessions. Typical on-ice practice consists of a combination of systems drills, skill drills, battle drills and conditioning drills—making it difficult for coaches to quantify the external work performed—with the duration of each varying throughout the season. Furthermore, physical activity levels during on-ice practice differ between playing position and line status of the player. Coordinating the training load between on-ice and off-ice work adds to the complexity of the development of

training programs. Due to these unique demands, training load is difficult to quantify in ice hockey, especially during on-ice sessions.

Automated heart rate (HR) monitoring systems are currently being used by professional and collegiate ice hockey teams as a way of assessing an athlete's response to workload (i.e., internal load) in practice and game settings. The use of an objective measure of on-ice training load provides a scientific basis for changes in performance, assisting team coaches and strength and conditioning staff to better assess load-performance relationships with a view to optimizing future planning for practices and competitions. The HR derived variable TRaining IMPulse (TRIMP) has recently gained favor in team sport as a means to quantify sessional training load [5–9]. TRIMP is a measure of internal load that integrates time, intensity and a relative weighting of the intensity of exercise [10]. To our knowledge, the reliability of TRIMP has only been tested in a laboratory setting during steady-state and interval cycling [11] and has demonstrated moderate reliability (percent typical error [%TE]: 10.7–15.6). Furthermore, the reliability of TRIMP is not known for on-ice training sessions in hockey, which involve intermittent work comprising

variable work-rest intervals performed at a range of exercise intensities. Since these data are currently being used by professional and collegiate hockey teams, it would be useful for coaches, staff, and athletes to know the thresholds for real or meaningful change for these variables. The aim of this study was to evaluate the test-retest reliability of TRIMP during on-ice training sessions in Division I collegiate male ice hockey players. We hypothesized that TRIMP would demonstrate moderate reliability on ice.

## MATERIALS AND METHODS

### *Participants*

Twelve male Collegiate Division I ice hockey players (7 forwards, 5 defense, age  $20.3 \pm 1.0$  yrs, height  $182.6 \pm 5.1$  cm, mass  $87.9 \pm 6.8$  kg) completed two on-ice training sessions wearing HR monitoring equipment. Only males aged 18 years or older who were official team players were included as injured players or those who were prescribed an alternate training program were excluded. All testing procedures were approved by the University of North Dakota Institutional Review Board and written consent was obtained from all participants before the start of the study.

### *Study Design*

A repeated measures design was used. Athletes participated in two on-ice sessions occurring two weeks apart at the same time of day (1:45–2:30 pm). Training sessions were selected during the beginning portion of the in-season when the exercise intensity and duration were similar. Both on-ice training sessions had identical practice plans (containing the same drills) and occurred on a Thursday when the work load would be considered light to moderate as game days are Friday and Saturday. Intensity of training tasks was controlled by coaches' instructions, drill type and aided by the routine nature of Thursday practices. Athletes refrained from exercise training before on-ice sessions on testing days and were instructed to maintain normal dietary intake during the study period. HR data were recorded for each training session.

### *TRIMP Measurement*

For both the test and retest on-ice sessions, athletes were fitted with Firstbeat™ HR monitors (Firstbeat SPORT, Jyväskylä, Finland) before taking the ice. The athletes participated in a light to moderate ice hockey practice consisting of multiple repetitions of one warm-up drill (2 on 0 offensive shooting), two shooting and passing drills (2 on 0 with position-specific shooting), two system drills (2 vs 1 and 2 vs 3 mixed offense and defense) and one battle drill (5 vs 5). The following HR data were recorded: TRIMP, maximum HR, average HR, and percent time spent in each training zone (1–5). HR data were recorded from when all athletes were on-ice to when the final training drill was completed.

Firstbeat SPORT software (Firstbeat SPORT, Jyväskylä, Finland) was used to record and derive sessional HR data. TRIMP, a measure of total internal load (accumulated over the course of a training

session), was calculated using Banister's exponential HR scaling equation [10]:

$$TRIMP = \sum(D \times HR_r \times 0.64e^y)$$

where, D is the duration (min) at a particular heart rate,  $HR_r$  is the heart rate as a fraction of the heart rate reserve, and y is the  $HR_r$  multiplied by 1.92 (men) or 1.67 (women).

In addition, maximal and average HRs for each session were recorded along with time in each training zone. Training HR Zone 1 comprises heart rates ranging from 28–110 beats per minute (bpm); Zone 2 ranging from 111–144 bpm; Zone 3 ranging from 145–155 bpm; Zone 4 ranging from 156–167 bpm; and Zone 5 ranging from 168–240 bpm.

### *Statistical Analysis*

Test-retest reliability was quantified as the systematic error (bias), random (within-subject) error and test-retest correlation. A publicly available Microsoft Excel spreadsheet was used for all calculations [12]. Data normality was assessed and session descriptive statistics were presented as means and standard deviations. Systematic errors were quantified as the absolute and standardized changes in means (bias) between test and retest. Positive changes indicated larger retest measurements with standardized changes of 0.2, 0.5 and 0.8 used as thresholds for small, moderate and large [13]. Random errors were quantified as raw, percent and standardized typical errors (TE). Percent TEs of <10%, 10–15% and >15%, were used as thresholds for good, moderate and poor, with standardized TEs interpreted using the thresholds previously described for standardized changes [13]. Test-retest correlations were quantified as Intra-class Correlation Coefficients (ICC), with correlations of 0.1, 0.3, 0.5, 0.7, and 0.9 used as thresholds for weak, moderate, strong, very strong, and nearly perfect [14]. Ninety-five percent confidence intervals (95%CI) were reported for each variable.

## RESULTS

Overall, TRIMP demonstrated moderate reliability during on-ice sessions. Systematic error was negligible (standardized change:  $-0.19$ ); random error was moderate (TE: percent, 12.2%; standardized, 0.63); and, test-retest correlation was very strong (ICC: 0.75) (Table 1). Other descriptive HR measures during on-ice sessions are presented in Table 1.

## DISCUSSION

Our data indicate that TRIMP demonstrates moderate reliability in collegiate ice hockey athletes and therefore coaches, practitioners and scientists can use this variable to detect moderate changes in internal loads during on-ice practices and games. Descriptive data for maximum HR, average HR and time in HR zones indicated that on-ice sessions were highly comparable.

TRIMP measures have been used in various individual and team

sports to measure internal load [5–9] and have demonstrated moderate reliability in the laboratory [11]. Our results in hockey athletes are consistent with those reported during steady-state and interval cycling at 30–70% maximum work rate (%TE: 10.7–15.6) [11]. The moderate test-retest reliability (%TE: 12.2) indicated that TRIMP is suitable for quantifying training load during intermittent on-ice work comprising variable work-rest intervals performed at a range of exercise intensities, in ice hockey athletes. The standardized TE (0.63) suggests that TRIMP is capable of detecting moderate changes in training load during on-ice sessions, which make up the vast majority of in-season training sessions and pose the biggest challenge to assessing training load.

The unique demands of ice hockey and the difficulty it creates in exercise programming [15, 16], underscores the need for objective measures of training load, such as TRIMP, to assist the assessment of athletes' physiological response to workload. After normative data are established for a typical in-season microcycle (weekly training and matches), our reliability data can be used to establish thresholds for real or meaningful change. Therefore, the practitioner can be more confident when evaluating the data to determine whether real (error-free) change had occurred and the magnitude of such a change. To determine if real or meaningful changes in training load have occurred during a particular session, coaches can multiply the %TE provided in this study by 1.5–2.0 [14]. For example, to calculate a threshold for TRIMP one can multiply the percent TE (12.2%) by 1.5 to de-

termine the percent change in TRIMP needed to indicate (error-free) real change. The resultant product (18.3%) can be multiplied by the TRIMP athlete-specific norm (e.g., 70 AU), which yields 12.8 AU. Lastly, 12.8 AU can then be added to the TRIMP norm to determine the upper threshold for real change. Using this method, coaches can have roughly 84% confidence that real change occurred if the TRIMP value is greater than the upper threshold [14].

Thresholds for meaningful change should improve the utility of TRIMP to inform decisions regarding on-ice training session difficulty and composition. This may help the coach better align the intended training load of the session to the actual training load administered, and these data can be easily passed on to strength and conditioning staff to inform off-ice programming. Thresholds for TRIMP may also be useful for evaluating an athlete's response to a given workload to gain insight into their training status or to set thresholds for specific athletes due to overtraining concerns or return to play after injury [17]. TRIMP may be used alone, or in combination with other measures of internal load (e.g., sessional ratings of perceived exertion) and external load (e.g., accelerometer-derived load) to best describe sessional training load [18]. Within-session monitoring of TRIMP may also increase an athlete's perception of involvement in, or sense of ownership over, their training program [17].

This study is not without limitations. The results are generalizable to only male collegiate hockey athletes. The small sample size reduces the confidence in the precision of our reliability estimates, but

**TABLE 1.** Results of the reliability analysis of HR variables during on-ice sessions (n=12).

Measurement	Test mean (SD)	Retest mean (SD)	Bias (95%CI)	Standardized Bias (95%CI)	TE (95%CI)	Percent TE (95%CI)	Standardized TE (95%CI)	ICC (95%CI)
TRIMP (AU)	70.3 (16.4)	67.7 (15.1)	-2.6 (-10.2, 5.0)	-0.19 (-0.76, 0.38)	8.4 (5.9, 14.3)	12.2 (8.5, 20.7)	0.63 (0.45, 1.08)	0.75 (0.34, 0.92)
Maximum HR (%)	87.1 (3.7)	88.0 (3.6)	0.9 (-1.2, 3.1)	0.42 (-0.60, 1.40)	2.9 (2.2, 4.5)	3.3 (2.5, 5.1)	1.34 (1.00, 2.10)	0.39 (-0.10, 0.73)
Average HR (%)	69.9 (5.2)	69.6 (4.8)	-0.3 (-2.9, 2.3)	-0.08 (-0.71, 0.55)	2.9 (2.0, 4.9)	4.2 (2.9, 7.0)	0.70 (0.50, 1.19)	0.71 (0.26, 0.91)
Time in HR zone 1 (min)	8.2 (5.2)	7.7 (4.1)	-0.4 (-3.4, 2.5)	-0.13 (-1.01, 0.75)	3.3 (2.3, 5.6)	41.5 (28.9, 70.4)	0.98 (0.69, 1.66)	0.55 (0.00, 0.85)
Time in HR zone 2 (min)	12.1 (2.7)	11.8 (2.5)	-0.2 (-2.1, 1.6)	-0.15 (-1.33, 1.02)	2.1 (1.5, 3.5)	17.6 (12.5, 29.3)	1.31 (0.93, 2.22)	0.40 (-0.19, 0.78)
Time in HR zone 3 (min)	16.2 (4.9)	16.1 (5.5)	-0.2 (-2.0, 1.7)	-0.03 (-0.42, 0.36)	2.1 (1.5, 3.5)	13.0 (9.3, 21.6)	0.43 (0.31, 0.74)	0.87 (0.61, 0.96)
Time in HR zone 4 (min)	9.7 (6.9)	8.5 (6.4)	-1.2 (-6.0, 3.5)	-0.30 (-1.48, 0.88)	5.3 (3.8, 9.0)	58.2 (41.2, 98.9)	1.31 (0.93, 2.22)	0.40 (-0.19, 0.78)
Time in HR zone 5 (min)	0.6 (1.5)	0.1 (0.2)	-0.5 (-1.4, 0.5)	ICC=0	1.1 (0.8, 1.8)	367 (267, 600)	ICC=0	0.00 (-0.56, 0.55)

Note: AU=Arbitrary Units; HR=heart rate; ICC=Intraclass correlation coefficient; TE=Typical error; TRIMP=TRaining IMPulse.

does not systematically bias them. It is likely that additional error can be attributed to differences in the execution of the on-ice practice sessions, inflating the TE. However, every effort was made to select identical sessions and our descriptive HR information confirms that we were successful in doing so. Our testing sessions enhance the ecological validity of our data due to assessing actual on-ice practices rather than lab-based simulations. Differences in athlete preparedness prior to testing sessions may have contributed to the TE [19]; however, we excluded athletes participating in modified programming, conducted testing sessions at the same point in the weekly microcycle and instructed athletes to refrain from exercise training before testing sessions. We evaluated reliability during light to moderate practices, future research should examine if reliability is altered during sessions involving more time spent performing high intensity exercise with differing practice content. Lastly, it should be

noted that additional factors may influence HR beyond an athlete's response to workload (e.g., emotions, elevated core body temperature) [20].

In conclusion, our data indicate that TRIMP is suitable for quantifying moderate changes in training load during on-ice sessions in hockey athletes. Using these data, a coaching staff may be better able to assess the difficulty of training sessions and adjust training to better meet the individual needs of team sport athletes, which may increase the likelihood of maintaining a highly-trained state without overtraining.

**Acknowledgements:** The authors thank the athletes who volunteered in this study. The authors have no conflicts of interest or external funding sources to disclose.

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