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Lessons learned from low-cost athlete monitoring in lacrosse during a 12-week training cycle

OLIVIA SISSON, CAMDEN JOHNSTON, CATHERINE NOONAN, JENNIFER BUNN

Abstract

Introduction. **Monitoring athlete load is important for performance, but often includes expensive equipment.** Aim of Study. **The purpose of this study was to determine the feasibility of using heart rate (HR) monitors and session rating of perceived exertion (sRPE) to track training load for lacrosse athletes in practices and games and develop a load estimation during games.** Material and Methods. **Twelve Division I female lacrosse players wore chest straps and watches throughout 12-weeks of training sessions to measure cardiovascular load (CVL), and sRPE was collected after each session. Acute:chronic (A:C) training ratio was calculated using CVL and sRPE. Since athletes could not wear the HR monitor in regulated games, a multiplier was developed using HR data to estimate the CVL. Estimated CVL was compared to the actual CVL obtained during an exhibition game. Both sRPE and CVL were measured in arbitrary units (AU).** Results. **There was a moderate relationship between the CVL and sRPE load assessments (r = 0.445, p = 0.147). The mean A:C over the 12-week assessment period was 0.93 ± 0.17 AU and 1.13 ± 0.40 AU for CVL and sRPE load respectively, which is in the ideal range of A:C workload. The actual CVL (416.9 ± 100.6 AU) of an exhibition game compared poorly with CVL estimations using the game clock (227.2 ± 117.3 AU, r = 0.223, p = 0.565), running stopwatch (354.4 ± 145.7 AU, r = 0.195, p = 0.616), and running stopwatch excluding halftime (287.8 ± 147.0 AU, r = 0.195, p = 0.615).** Conclusions. **CVL and sRPE are feasible and cost-effective methods for monitoring training and A:C workload. CVL estimations for games were inaccurate, so sRPE should be used for low-cost game load assessment.**

KEYWORDS: session rating of perceived exertion, training load, workload, training impulse, monotony, strain.

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Corresponding author: bunnj@campbell.edu

Campbell University, Department of Physical Therapy, Buies Creek, North Carolina, USA

Introduction

Athlete monitoring has become a crucial part of preparing teams and individuals for competition. Monitoring training load (e.g. heart rate, distance, sprints) can assist coaches in assessing the athletes' adaptation to training and aid in determining amount of rest needed for recovery. Monitoring enables prediction and prevention of overtraining as well as individualization of practice for each of the athletes' needs [20]. The ability to quantify the demands on team sport athletes during competition and training gives information needed to monitor athletes more efficiently and effectively [5]. Athlete monitoring consists of providing information regarding physiological or internal load (e.g. heart rate, blood lactate, oxygen consumption, and ratings of perceived exertion) and/or external load (e.g. high-intensity distance, power output speed, acceleration, deceleration, jumping), and may include the use of specialized tools such as heart rate (HR) monitors, global positioning systems (GPS), gyroscopes, accelerometers, time-motion analyses, ratings of perceived exertion, and wellness surveys [4]. A recent publication comprised practical guidelines for athlete monitoring with equipment selection and methods of data use including: assessing monotony, strain, athletes' floor and ceiling, and the acute:chronic (A:C) ratio [23]. However, given budget constraints, athletic programs must find effective, low-cost tools to capture these data.

Using a HR monitor to assess physiological load is valid and reliable and has potential to be a sufficient athlete-monitoring tool [13, 14]. Use of HR-based training impulse (TRIMP) or a cardiovascular load score for each athlete using HR zones provides information to assist in training athletes. Unfortunately, wearing necessary equipment to obtain HR during games is not always possible. However, given an estimate of in-game training load, coaches can better prepare each athlete for the intensity competition requires. Session rating of perceived exertion (sRPE) is a subjective monitoring tool that coaches and trainers have used for years to understand how difficult athletes believe their training session to be [3, 7, 16, 20]. Obtaining a sRPE from an athlete may not always be an exactly representative of the internal load the athlete is experiencing, but sRPE is an interpretation of how athletes may feel throughout the training session. Even though RPEs are useful, athletes can mistreat the sRPE scores, which could potentially affect the training sessions to follow [4].

Aim of Study

The purpose of this study was threefold: 1) to address the feasibility of using HR monitors and sRPE to track training load for lacrosse athletes in practices and games; 2) to evaluate monotony, strain, and A:C training loads; and 3) to develop a load score multiplier to estimate cardiovascular load during games. This information can provide practical use for coaches of any sport, sport scientists, and strength and conditioning coaches who are interested in athlete monitoring, but have budgetary constraints. Previous literature on athlete monitoring is useful, but practical guidelines and information for starting the process are often passed along only through word of mouth, and not as published data. Further, low-cost options for athlete monitoring are rarely discussed or published.

Material and Methods

Participants

Twelve Division I female lacrosse players, all starters for most games, participated in this project. Players were 20.6 ± 1.3 years old, and voluntarily completed university-approved documents prior to study participation. This study was conducted in accordance to the Declaration of Helsinki. Measurements were taken during 12 weeks of in-season training and included 93 training sessions. Training sessions included lacrosse team practices, conditioning, and strength training sessions.

Load assessment

Our budget did not allow for purchase of a "team system" to assess HR, thus athletes wore Polar RS300X HR monitor chest straps and watches (Kempele, Finland) throughout training. Each HR monitor was customized for each athletes' height, weight, and date of birth. Output from the HR monitor for each session included mean HR, session maximal HR (HRmax), and time spent in each of the five HR zones. Each zone was calculated using estimated HRmax for each athlete (zone 5: 90-100% HRmax; zone 4: 80-90% HRmax; zone 3: 70-80% HRmax; zone 2: 60-70% HRmax; zone 1: 50-60% HRmax). HRmax was estimated by subtracting the participant age from 220. Total session cardiovascular load (CVL) was calculated using time spent in each HR zone for the session as shown in Equation 1. This is a slight variation from the TRIMPzone method which does not include the mean HR for the session [6]. Other TRIMP methods [2] were not used because lacrosse is a sport of varying intensity, and we wanted to capture these oscillations. The output of the CVL calculation is in arbitrary units (AU). HR was assessed during all in-season team practices and strength and conditioning sessions, totaling 92 training sessions and one exhibition game.

Equation 1

$$\text{CVL} = (5 \times zone\ 5) + (4 \times zone\ 4) + (3 \times zone\ 3) + + (2 \times zone\ 2) + (1 \times zone\ 1) + \text{mean HR}$$

Within 30 minutes of practice cessation, sRPE was also obtained. A scale of 1-10 was used to evaluate sRPE, and each player was provided with instructions on how to evaluate sRPE. The sRPE was then multiplied by the total time for each training session to create an RPE load score in AU. Both CVL and sRPE were used to assess weekly monotony, strain, and A:C workload. A:C workload was calculated using the exponentially weighted moving average (EWMA) model [9, 11, 15]. Excel was used to calculate these ratios [18]. Monotony was calculated using the average load across a 7-day training period and dividing it by its standard deviation [7, 8]. The variable indicates training monotony, and values close to one indicate higher levels of variability. Strain was calculated by multiplying the weekly monotony score by the total training load for the week. This measure is sensitive to alterations in training load, and may be predictive of illness [14, 21]. High strain values indicate higher athlete loads [23].

Game CVL

The National Collegiate Athletics Association (NCAA) rules prohibited players from wearing watches that accompanied HR monitors during games, thus we elected to estimate player CVL during games based on CVL during off-season games and playing time. Players completed 10 off-season games while wearing the HR monitors, and coaches provided an estimation of play time per player. Idle HR was removed by subtracting the time the athlete was not playing from HR zones 1 and 2. The total CVL for the 10 games was calculated and divided by total number of minutes played, creating a CVL/minute multiplier. The team played an exhibition game just prior to the start of the season. Seven players wore the HR monitors during this game, and playtime for each player was tracked using both the game clock and a running stopwatch. Actual CVL was obtained using data/readings from the HR monitors. Estimated CVL was calculated by multiplying the CVL/minute multiplier and total time played using 1) the game clock, 2) the running stopwatch including halftime, and 3) the running stopwatch excluding halftime.

Statistical analyses

Means and standard deviations for training CVL, sRPE, monotony, strain, A:C ratio, actual game CVL, and estimated game CVL were calculated. Pearson correlations were conducted comparing the CVL and sRPE values of the players. Pearson correlations were conducted comparing the three CVL game estimations to the actual game CVL. All analyses were conducted in Microsoft Excel (Redmond, WA).

Results

Load assessment

The mean CVL was 367.5 ± 143.7 AU and the mean sRPE load was 1164.4 ± 524.9 AU. A Pearson correlation revealed a moderate relationship between the two load assessments ($r = 0.445$, $p = 0.147$), indicating that subjective and objective assessments of loading did not consistently agree. The mean monotony calculated was 5.24 ± 4.3 AU and 2.10 ± 0.33 AU for CVL and sRPE load respectively. The CVL monotony indicates very little variation in internal loading through the training period, but the sRPE shows much greater variation in subjective loading because the score is closer to 1.0. The players subjectively felt variation in the training throughout the season, despite the fact that their physiological load did not indicate this change. Mean strain was 1803.9 ± 1204.7 AU for CVL and 2449.9 ± 1290.7 AU for sRPE load. Strain is sensitive to training load, and high values (>2282 AU as assessed by sRPE) are linked with increased risk of injury and self-reported illness [7, 19]. While we were not privy to details related to illness and injury data, we can report that there was only one soft tissue injury during the season, and all starters and players coming from the bench retained their roles.

The mean A:C over the 12-week assessment period was 0.93 ± 0.17 AU and 1.13 ± 0.40 AU for CVL and sRPE load respectively. Both ratios are within the appropriate range to avoid undertraining and overtraining as indicated by Gabbett [9]. Data were collected while the team was in-season, so large alterations or increases in A:C workload were not ideal or recommended. Figure 1a shows the A:C for CVL over the course of the lacrosse season, and Figure 1b shows the A:C for sRPE load for the same time period. CVL and sRPE data were not collected during spring break, thus both figures show a void in the data during the assessment period. Further, sRPEs were not collected during the second-to-last week of the assessment period as shown in Figure 1b, so this week was removed from any analyses. CVL was more consistent during the assessment period with A:C workload occurring in the optimal zone of 0.8-1.5 [9]. However, sRPE showed greater variation in the A:C

Figure 1. Changes in a) CVL and A:C workload and b) sRPE load and A:C workload over the 12-week assessment period

Note: The dotted lines represent the zone of the optimal A:C training load zone to reduce risk of injury [9] workload throughout the assessment period. These variations were seen the week of 1/24/2018, where training was high due to the start of the season occurring within two weeks. The workload was fairly consistent with sRPE during February, but there were substantial drops in CVL in the same month. Further, CVL was consistent in both workload and A:C ratio from 3/24/2018 through the end of data collection, whereas sRPE had a tendency to increase during this time period. This difference in March and April may have been due to the approach of the end of the academic semester and ensuing projects and exams, which often affect sleep and well-being [1]. Thus, having both objective and subjective ratings of workload are useful to gauge athlete training and readiness for training and recovery.

Game CVL

Table 1 shows the mean ± SD for the actual game CVL and the three estimated game CVLs. None of the three methods used to estimate game CVL were significantly correlated with the actual CVL, and all tended to underestimate the CVL. Thus, these methods are likely invalid assessments for game CVL, and perhaps simply using a sRPE from the game would be more beneficial for tracking game load without the use of equipment during the game.

Table 1. Comparisons of the actual game CVL and the three methods of estimating CVL based on playing time

	Mean CVL (AU)	Correlation with actual CVL
Actual	416.9 ± 100.6	–
Game clock	227.2 ± 117.3	r = 0.223, p = 0.565
Running stopwatch including halftime	354.4 ± 145.7	r = 0.195, p = 0.616
Running stopwatch excluding halftime	287.8 ± 147.0	r = 0.195, p = 0.615

Note: CVL – cardiovascular load; AU – arbitrary units

Discussion

These data show that athlete monitoring through low-cost methods of chest strap HR monitors and sRPE is feasible, useful, and compliant with contemporary suggestions for athlete loading. From our experience in one year of athlete monitoring, we learned several lessons including: 1) how to make sense of internal load measures, but we would like to learn about more, 2) in-game assessment of load is best done either very simply or with high-tech equipment, 3) manpower is needed for appropriate data collection, and 4) consult a team of invested staff about the data. Expansion of each of these lessons is below.

Lesson #1

CVL and sRPEs are good, but more is better. CVL was useful for an assessment of internal loading and sRPE provided subjective assessments of load, but the two values did not always agree. Previous literature has indicated that using both external and internal load measures are necessary to provide a whole picture of athlete loading [21, 22]. Further, CVL and sRPE did not provide an idea of athlete readiness or recovery prior to any training session. So adding in wellness questions related to recovery, fatigue, and sleep would be useful to the coaches for decisions regarding load during training. This information would help to fill the gap between CVL and sRPE. Wellness questions could also be useful in conjunction with the A:C workload ratio. Comparing weekly changes between wellness scores and A:C ratios would provide coaches with information about athlete responses to changes in workload and perhaps help with detection of soft tissue problems and fatigue before overtraining, injury, or illness occurs.

Another aspect of the "more is better" lesson is the addition of funding to purchase wearable technology that includes GPS and accelerometry, as well as updated HR assessment. The information we gathered sparked the interest of the sport coaches, strength and conditioning coaches, players, and athletic trainers enough to indicate the need for more information. This was integral to the "buy-in" of the coaches and players as a whole for use of the data. This step-wise process gave interested parties an introduction to athlete monitoring and its use.

Lesson #2

Assessing in-game loads should be done with either high-tech equipment or no-tech equipment. Wearable technology is useful for data collection, but each sport has unique rules regarding permitted equipment. The watches that accompanied our HR monitors were not allowed during NCAA-sanctioned games. We attempted to use CVLs from non-sanctioned games in conjunction with on-field play time to estimate in-game CVL, but the game CVL estimates were not accurate when tested in an exhibition game. Thus, for a budget-friendly method of collecting load, we suggest simply using sRPE after the game and using game time as the multiplier to achieve load in AU. This method of collection has been supported for accuracy and reliability in previous literature [8, 10, 12, 17, 18]. More expensive systems are preferable as they employ equipment that is worn underneath sports uniforms, adhering to NCAA rules, and they provide more accurate readings of CVL. Attempting to estimate HR or other metrics, either internal or external, during a game may be futile because of variability in play time, sleep, nutrition, opponent, and team strategy.

Lesson #3

Data collection takes a team and logistical decisions. We started data collection with a humble 12 HR monitors, an undergraduate intern, and a faculty member. The three lacrosse coaches provided guidance regarding logistical decisions for collection of the HR and sRPE data. An early mistake that we made was assuming that the athletes would follow the initial directions for wearing and turning on the HR monitors, and because of this error we had to wade through a lot of bad data. To remedy this, we placed instructions for wear of the devices in each players' locker and provided regular verbal reminders about turning them on and off appropriately. This extra work did prove to be beneficial in getting better data. Additionally, getting good data is dependent upon regular data upload and proper maintenance of the equipment, thus we chose to upload data almost daily so that if there was a problem we could quickly remedy it. We also checked and changed the batteries of the devices regularly.

For sRPE, the coaches collected the numbers manually each day. In hindsight, having the coaches collect this information could have skewed these numbers, and this collection was rather tedious. Moving forward, we would suggest using tools that are readily available for input of data like this. There are free smart-device applications available (e.g., Athlete Data, Quantum Sports Analytics, AthleteMonitoring App, PM Reporter Pro) that help to collect sRPE, wellness questions, sleep information, and nutritional information. While these apps are useful, they are often not customizable, so we recommend exploring a variety of applications before choosing the one that best meets your needs. Consulting with the athletes, managers, coaches, athletic trainers, and other support staff may also be useful in making the selection.

Lesson #4

Data evaluation takes a different team. Interpreting and acting upon the data can be overwhelming for coaches and sports scientists. Data evaluation should begin with observation and description of trends, including by individual, by position, and for the whole team. In our initial analysis, only a sports scientist and the lacrosse coaches evaluated the data, but more minds were needed. The goal should be to make the data transparent for all stakeholders – from the sports scientist to the coaches, athletic trainers, strength and conditioning coaches, and any other support staff. Each group offers unique insight because each will evaluate the data from their own perspective. Players may also offer a unique perspective of their data. Coaches typically evaluated the data by position and for the whole team in order to make decisions about practice loads and intensities. Athletes and coaches benefited from the knowledge of the CVL in preparation for competitions by paying attention to the loads they encountered within practices and games. This gave coaches an opportunity to prevent overtraining and gave athletes adequate recovery time throughout the season. Athletic trainers and strength and conditioning coaches can use the information to make decisions about return to play for injured athletes. Specifically, comparing the CVL and sRPE loads of healthy athletes to injured athletes provided another metric in the decision-making process regarding exercise and rehabilitation prescription.

Lastly, the sports scientist can inform and explain the data, leaving decisions about practice, training, and rehab to the appropriate staff members. This method worked well for the team because the coaches and supporting staff – who have a financial stake in the success of the team – were informed and had the necessary tools to make evidence-based decisions. This team approach enabled collaboration and spurred new ideas for future research.

Conclusions

Sports scientists, coaches, and athletic trainers do not have to expend a large budget to obtain load information, but should employ low-cost technology to easily obtain sRPE values and other subjective data. Having a systematic process for data collection and a team for help with collection and interpretation are key for success to implement the information to improve team performance. These simple methods of data collection for athlete monitoring are useful to assess athlete load, monotony, and strain, but only provide internal loading information. Nonetheless, sRPE and CVL data can be used to predict injury and overtraining risk when utilized in combination with A:C training load assessments [8, 9].

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References

1. Ahrber K, Dresler M, Niedermaier S, Steiger A, Genzel L. The interaction between sleep quality and academic performance. J Psychiatr Res. 2012; 46(12): 1618-1622.
2. Banister EW, Calvert TW, Savage MV, Bach T. A systems model of training for athletic perofmrance. Austr J Sports Med Exer Sci. 1975; 7: 57-61.
3. Borg G. Borg's Perceived Exertion and Pain Scales. Champaign, IL: Human Kinetics; 1998.
4. Bourdon PC, Cardinale M, Murray A, Gastin P, Kellmann M, Varley MC, et al. Monitoring athlete training loads: Consensus statement. Int J Sports Physiol Perform. 2017; 12(2): S2161-S2170.
5. Cardinale M, Varley MC. Wearble training-monitoring technology: Applications, challenges, and opportunities. Int J Sports Physiol Perform. 2017; 12(2): S255-S262.
6. Edwards S. The Heart Rate Monitor Book. Sacramento, CA: Feet Fleet Press; 1993.
7. Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc. 1998; 30(7): 1164-1168.
8. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, et al. A new approach to monitoring exercise training. J Strength Cond Res. 2007; 15(1): 109-115.
9. Gabbett TJ. The training-injury prevention paradox: Should athletes be training smarter or harder? Br J Sports Med. 2016; 50(5): 273-280.
10. Herman L, Foster C, Maher MA, Mikat RP, Porcari JP. Validity and reliability of the session RPE method for monitoring exercise training intensity. South African J Sports Med. 2006; 18: 14-17.
11. Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute:chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. Br J Sports Med. 2016; 50(4): 231-236.
12. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. Med Sci Sports Exerc. 2004; 36(6): 1042-1047.
13. Malone S, Collins K. Relationship between individualized training impulse and aerobic fitness measures in hurling players across a training period. J Strength Cond Res. 2016; 30(11): 3140-3145.
14. Manzi V, Iellamo F, Impellizzeri F, D'Ottavio S, Castagna C. Relation between individualized training impulses and performance in distance runners. Med Sci Sports Exerc. 2009; 41(11): 2090-2096.
15. Murray NB, Gabbett TJ, Townshend AD, Hulin BT, McLellan CP. Individual and combined effects of acute and chronic running loads on injury risk in elite Australian footballers. Scand J Med Sci Sports. 2017; 27(9): 990-998.
16. Scott BR, Lockie RG, Knight TJ, Clkark AC, Janse de Jonge XA. A comparison of methods to quantify the in-season training load of professional soccer players. Int J Sports Physiol Perform. 2013; 8(2): 195-202.
17. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. J Strength Cond Res. 2013; 27(1): 270-276.
18. Sullivan A. Exponentially weighted moving average calculator. 2018; available from: https://adam-sullivan.com/.
19. Thornton HR, Delaney JA, Duthie GM, Scott BR, Chives WJ, Sanctuary CE, et al. Predicting self-reported illness for professional team-sport athletes. Int J Sports Physiol Perform. 2016; 11(4): 543-550.
20. Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. J Strength Cond Res. 2009; 23(1): 33-38.
21. Weaving D, Jones B, Marshall P, Till K, Abt G. Multiple measures are needed to quantify training loads in professional rugby league. Int J Sports Med. 2017; 38(1): 735-740.
22. Weaving D, Marshall P, Earle K, Nevill A, Abt G. Combining internal- and external-training-load measures in professional rugby league. Int J Sports Physiol Perform. 2014; 9(6): 905-912.
23. Wing C. Monitoring athlete load: Data collection methods and practical recommendations. Strength Cond J. 2018; 40(4): 26-39.