Short Communication

Establishing a duration standard for the calculation of session rating of perceived exertion in NCAA division I men's soccer

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Objectives: The purpose of this study was to determine the best predictor of training and/or match load using session RPE.

Design and Methods: 20 NCAA DI male soccer players participated in the study during the 2014 and 2015 competitive seasons. Players completed 15.20 ± 1.05 matches for a total of 304 individual data points and 29.90 ± 1.89. training sessions for a total of 598 individual data points. GPS variables (total distance, High-intensity running distance, and Player load) were analyzed with session RPE using Pearson product-moment correlations. To evaluate various methods of session RPE, "match duration" was recorded using eight different definitions: total match duration including warm-up and half-time, total match duration and warm-up, total match duration and half-time, total match duration only, minutes played including warm-up and half-time, minutes played and warm-up, minutes played and half-time, and minutes played only. A one-way ANOVA with repeated measures was used to determine if differences existed between the eight session RPE calculations.

Results: Results from the ANOVA showed that all session RPE measures were significantly different from one another ($P < 0.05$). Very large correlations were reported between session RPE calculated using minutes played and total distance (0.81), while session RPE calculated using match duration showed less magnitude (0.57).

Conclusions: Minutes played should be used to calculate session RPE as it was found to most closely reflect the actual workloads incurred during competitive matches.

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Key words: monitoring ■ training load ■ rating of perceived exertion

INTRODUCTION

"Optimizing training first involves quantifying what the athlete is currently doing[1]." One of the most common methods for quantifying training load is the session rating of perceived exertion (RPE) method.[2] Session RPE is calculated by multiplying the athletes rating on a 10-point scale by the duration of the training session. Much of the evidence regarding the validity of session RPE as a tool to monitor soccer performance has been provided via relationships with summated heart rate scores as criterion measures.[3-5] Although there is a large aerobic component to soccer[6], heart rate in itself may not be the most meaningful indicator of training load for such an intermittent-type sport[7]. Thus, additional methods may be required to assess session RPE as a global estimate of training load during soccer training.[4,5,8]

A Global Positioning System (GPS) is a space-based navigation system that provides location and time information[9]. GPS technology has improved over the last several years[9] and evidence indicates that GPS data can provide a viable estimate of external training loads imposed on athletes in team sports.[10-12] In order to improve measurements of change-of-direction and contact activities, GPS units have been equipped with additional gyroscope and triaxial accelerometer technology.[13] The information provided from GPS is much more objective compared to session RPE. However, few studies have observed the relationship between session RPE and external loads measured using GPS technology.[3, 8] These studies have reported significant correlations between session RPE and both GPS and accelerometer derived variables ($r = 0.71$-0.84; $P < 0.01$).

One potential problem with the session RPE method is in how one calculates the duration of a competitive match. A National Collegiate Athletic Association Division I men's soccer can span an entire period of 162 minutes. One must decide if they will include the warm-up, half-time, cool-down, or any stoppages that may occur in their session RPE calculation. Using an entire period of 162 minutes to calculate a session RPE would potentially overestimate match load. This overestimation of match load may cause coaches to wrongly prescribe post-match recovery and training. The use of frequent player substitutions is a common strategy at this level, creating situations where many players do not play the entire match. It is logical to assume that the most accurate measure of duration will reflect the amount of time that the player was in the match. An accurate session RPE calculation during matches is required to supply information concerning post-match recovery and training strategies. In addition session RPE can be

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used to provide a more logical explanation for changes in performance[14], prevent over training[15], and potentially reduce injury[16].

Therefore, the purpose of this study was to determine the relationship between measures of session RPE and GPS variables during NCAA Division I men's competitive soccer matches. An Analysis of Variance was used to compare the eight duration measurements that were used to calculate session RPE. These 8 session RPE match loads were compared with GPS and accelerometry-based external training load scores. The authors hypothesized that using minutes played instead of total session duration would produce higher correlations with external training load variables measured using wearable GPS and accelerometer technology.

METHODS

This study used a descriptive correlational design. Session RPE, a widely used subjective indicator of internal training load, was recorded after each session. In addition, players' training and competitive match activities were quantified using GPS technology. The relationships between the session RPE during and commonly used GPS and accelerometer-based external training load quantification methods were used to examine the criterion validity of session RPE calculated using minutes played and total match definitions.

This study involved retrospective analysis of archived monitoring data from a NCAA Division I men's soccer team. Data were collected as a normal part of the team's monitoring program during the fall 2014 and 2015 competitive seasons. In order to be included in the study, athletes had to meet the following inclusion criteria: play in at least 12 matches and complete at least 25 training sessions in one full season. If players played more than 14 matches and 30 training sessions, their most recent training sessions were used for analysis. This allowed early season sessions to serve as a familiarization period. In order to avoid sample bias, each player completed a similar number of matches and training sessions. In addition, the cutoffs were selected to maximize the number of players involved in the study. Overall, 20 (means ± standard deviations for: age 21.5 ± 1.3 y, height 177.6 ± 6.5 cm, body mass 74.3 ± 5.9 kg) out of a total of 32 eligible field players met the inclusion criteria for the study. Goalkeepers were excluded from this study. Players completed 15.20 ± 1.05 matches for a total of 304 individual data points and 29.90 ± 1.89 training sessions for a total of 598 individual data points. Retrospective analysis of athlete monitoring data was approved by the university institutional review board.

Data Collection Procedures

The players' external load was monitored and quantified by means of portable GPS devices (MinimaxX, v.4.0, Catapult Innovations, Soresby, Australia) operating at a sampling frequency of 10 Hz and incorporating a 100 Hz triaxial accelerometer. Each player wore a special harness that enabled this device to be fitted to the upper part of his back. The GPS devices were activated 15 minutes before the start of each training session, in accordance with the manufacturer's instructions. Training session GPS data collection included field training only. These sessions varied, but generally consisted of a 10-minute dynamic warm-up, 10-15 minute passing pattern, and about 30-70 minutes of small-sided-games and drills. The small-sided-games and drills were prescribed based on sets and reps. For example: 6 versus 6 for four 5-minute periods. Data were discarded during between-drill recovery periods, and when players were not involved in drills. During matches, GPS data was recorded during the warm-up and match play (warm-up, first half, second half, and optional overtime periods). Data were discarded from half-time rest periods and when players were on the bench. At the conclusion of the training session or match, raw data were downloaded to a personal computer and analyzed using the software package Logan Plus v.5.1 (Catapult Innovations, Soresby, Victoria, Australia 2014). The software allowed the user to select time periods that players were involved in drills, and exclude time periods when players were not involved. This was done in 'live mode' during the sessions, but could be further edited after the session was completed. The device has been reported to be both reliable and valid in previous studies.[10,12]

The team completed four to seven sessions per week, with a mean of 75.1 ± 23.5 minutes played per match and training session duration of 68.5 ± 17.3 minutes. All of the observed training sessions were designed by the team's head coach and sport scientist. During recovery periods, the players were allowed to drink fluids as needed. After training sessions and matches players consumed Muscle Milk® Collegiate Formula, a protein and carbohydrate drink. They were also told to eat a high carbohydrate meal shortly after training and continued to consume a high carbohydrate diet throughout the entire season.

GPS and accelerometer data collection included: total distance, high-intensity running distance (HODO), and Player load. HODO was defined as the total distance traveled above 14.4 km·hr-1[17]. Player load is a vector quantity developed by the manufacturer and is expressed in arbitrary units. To calculate Player load, the square root of the sum of squared instantaneous rates of change in the three planes of motion are taken:

$$Player\ Load = \sqrt{((aca_{t=i+1} - aca_{t=1})^2 + (act_{t=i+1} - act_{t=1})^2 + (acv_{t=i+1} - acv_{t=1})^2)}/100$$

where *aca* is the acceleration in the anteroposterior axis, *act* is the acceleration in the transverse axis, *acv* is the acceleration in the vertical axis, *i* is the current time, and *t* is time.

The internal training load was assessed using the session RPE 10-point scale with verbal anchors [2]. Approximately ten minutes after the conclusion of each session, a sport scientist asked each player "how do you rate the overall difficulty of this session?". Although Foster et al.[2] recommends a 30-minute time period before the recording of sRPE, subject availability did not always allow for this methodology. There is evidence that this time period has little effect on RPE selection.[18,19] RPEwas multiplied by the duration of the session according to Foster et al.[2]. Training session duration was recorded individually from the beginning of the training session (including warm-up and recovery periods) to the end of the session (excluding cool-down period). In order to determine the association between GPS and match session RPE, "match duration" was recorded using eight different definitions: total match duration including warm-up and halftime, total match duration and warm-up, total match duration and halftime, total match duration only, minutes played including warm-up and halftime, minutes played and warm-up, minutes played and halftime, and minutes played only. Minutes played was defined as the total number of minutes that the player was in the game. Minutes played was recorded during matches using Stat Crew v1.13 (Stat Crew Software, Inc. Cincinnati, Ohio).

Data and Statistical Analysis

Descriptive results are presented as means ± standard deviations. A one-way analysis of variance with repeated measures was used to determine if there were differences between the eight session RPE calculations during matches. The relationships between the various session RPE and GPS-based training loads were analyzed using Pearson's product-moment correlation coefficients. The magnitude of the relationships was described as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$), and perfect ($r = 1$).[20] Linear regression analysis was used with the GPS variables as the criterion and session RPE estimates as the predictor. All of the statistical analyses were performed using Statistics Package for the Social Sciences (version 22.0, SPSS Inc. Chicago, IL) for Windows. Statistical significance was set at $P < 0.05$.

RESULTS

Means and standard deviations for training and matches are shown in Tables 1a and 1b. Significant differences were found between all eight session RPE calculations during matches $F(7, 133) = 886.761$, $p < 0.001$. Training session RPE correlation coefficients were 0.804, 0.812, and 0.726 for total distance, Player load, and HODO, respectively. Match correlations were very large for session RPE calculations that used minutes played and large for total session variables as shown in Table 2. Standard error of estimates for each variable are presented in Table 3.

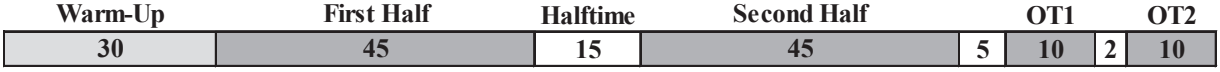

Figure 1 Distribution of durations (minutes) for a National Collegiate Athletic Association soccer match with overtime periods (OT).

Table 1a Means and standard deviations of measured variables during training and matches.

	Training	Matches
Variables	Mean ± SD	Mean ± SD
RPE (AU)	2.6 ± 1.2	6.2 ± 1.6
Time (min.)	68.8 ± 17.3	75.1 ± 23.5
Session RPE (AU)	387.9 ± 153.5	487.4 ± 227.3
Total Distance (m)	3556.7 ± 1464.9	11341.35 ± 2966.1
Player load (AU)	429.2 ± 330.5	1138 ± 298.1
HODO (m)	193.0 ± 119.7	1897.1 ± 654.2

Table 1b Means and standard deviations for calculated session RPEs during matches.

Session RPE		Mean ± SD
Minutes Played		
	Minutes Played	487.4 ± 227.3*
	Halftime Added	580.6 ± 247.6*
	Warm-Up Added	673.8 ± 268.5*
	Halftime & Warm-Up Added	766.9 ± 289.8*
Match Duration		
	Total Match Duration	599.0 ± 191.4*
	Halftime Added	692.1 ± 212.9*
	Warm-Up Added	785.3 ± 234.7*
	Halftime & Warm-Up Added	878.4 ± 256.9*

* Indicates significant difference at the p = 0.05 level.

Table 2 Correlations between the various session RPE calculations and GPS variables during competitive matches.

Session RPE		Total Distance	Player Load	HODO
Minutes Played				
	Minutes Played	.808**	.785**	.570**
	Halftime Added	.796**	.774**	.567**
	Warm-Up Added	.785**	.763**	.563**
	Halftime & Warm-Up Added	.774**	.752**	.559**
Match Duration				
	Total Match Duration	.566**	.547**	.477**
	Halftime Added	.573**	.554**	.479**
	Warm-Up Added	.578**	.559**	.481**
	Halftime & Warm-Up Added	.581**	.562**	.482**

* Indicates a significant correlation at the p = 0.05 level.
** Indicates a significant correlation at the p = 0.01 level.

Table 3 Standard error of estimate with Session RPE as the predictor.

		SEE		
Session RPE		Total Distance (m)	Player Load (au)	HODO (m)
Minutes Played				
	Minutes Played	1751	185	538
	Halftime Added	1797	189	540
	Warm-Up Added	1840	193	542
	Halftime & Warm-Up Added	1880	197	543
Gametime				
	Total Gametime	2449	250	576
	Halftime Added	2435	249	575
	Warm-Up Added	2425	248	575
	Halftime & Warm-Up Added	2419	247	574

DISCUSSION

The purpose of this study was to determine the relationship between measures of session RPE and GPS during during NCAA Division I men's competitive soccer matches. The results support the use of minutes played as the best indicator of duration, as it was found to be more associated with GPS variables measured during competitive matches.

Another interesting finding from this study was that incorporating warm-up periods were found to decrease the magnitude of correlation between minutes played session RPE and GPS variables despite the fact that warm-up was included in GPS data analysis. These findings suggest that the warm-up may be perceived as much less strenuous than in-match activities. During the pre-match warm-up routine, players generally covered approximately 1600m, very little of which is at a HODO pace. The warm-up consisted of about 10 minutes of dynamic movement preparation, 10 minutes of possession in a 10m x 5m grid, and some shooting or defensive shifting exercises.

GPS data was discarded during halftime periods, which was reflected by the reduced correlation coefficients when halftime periods were included in the minutes played session RPE calculations. In contrast, relationships became slightly stronger when halftime duration was added to total match duration. This stronger relationship to training load that was not quantified via GPS indicates that match duration may not be a good measure for session RPE calculation.

The results of this study showed that the session RPE method was significantly ($p < 0.01$) correlated with all indicators of external load during training and matches (Table 2). HODO had the lowest relationship among the GPS variables with session RPE during training ($r = 0.726$ and matches ($r = 0.559 – 0.570$). This suggests that session RPE may be less effective at representing soccer activities that are composed of more high intensity movements, which has been shown to result in session RPE underestimating training load.[8]

As shown in Table 1b, session RPE values can almost dou-

ble depending on how one defines the duration of a competitive match. When quantifying training or match load, it is important for the practitioner to be able to use session RPE to quantify both training and matches. The relationships between session RPE and total distance during training (r = 0.804) and matches that use minutes played (r = 0.808) suggests that these methods have a similar relationship with total distance. These relationships were reduced when the total duration of the match was used to calculate session RPE (r = 0.566), and this may cause an overestimation of training load. Likewise, similar results were observed between session RPE and both Player load and HODO. Thus, if sport scientists can more precisely monitor match loads using estimates that are similar to training estimates, then a better idea of actual overall training load can result. As a result, they should be able to more precisely plan training, prevent overtraining, and enhance overall athlete performance.

Previous research examining the relationship between session RPE and external training loads during training has reported large to very large relationships. Similar to the results of the present study, Scott et al.[8] reported session RPE to be highly correlated with total distance (r = 0.80), Player load (r = 0.84), and HODO (r = 0.65) in professional soccer players. In addition, Casamichana et al.[3] examined the relationship between session RPE and total distance (r = 0.76) and Player load (r = 0.74). It appears that total distance, HODO, and Player load may be viable indicators of training load in NCAA Division I soccer players. Additionally, session RPE may be used as a global indicator of exercise intensity.

CONCLUSION

The very large correlations reported in this study provide evidence for considering session RPE as a global indicator of individual training response in soccer training and competitive matches. Due to the large correlation coefficients observed with GPS variables, we suggest that minutes played serve as the "duration" when calculating session RPE. This may allow coaches to determine post-match recovery and training strategies, that more accurately reflect fatigue levels produced by competitive matches.

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