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Minutes Played Should be Used for the Calculation of Session Rating of Perceived Exertion During Matches in NCAA Division I Women's Soccer

Original Research

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Abstract

Introduction: Monitoring Training Load in soccer is used to achieve the best individualized performance outcomes and to prevent injuries. However, there is no clear recommendation for which 'match duration' should be used in the calculation of match Session Rating of Perceived Exertion Training Load (sRPE-TL) in NCAA DI women's soccer. Therefore, the purpose of this study was to establish a duration standard to be used in the calculation of sRPE-TL in collegiate NCAA DI women's soccer matches. A secondary aim was to investigate whether multiple positions require the use of different durations for the calculation of sRPE-TL.

Methods: Seventeen athletes (means ± standard deviations: age 20 ± 1.1 yrs., height 170 ± 6.6 cm, weight 64.6 ± 7.0 kg) participated in this study. Repeated measures correlations were used to determine the relationship between the different sRPE-TL calculations and objective variables (e.g., GPS variables and HR-based variable). Data was analyzed using the rmcorr package in R Studio executing R. Alpha was set a-priori at $p \leq 0.05$.

Results: The s-RPE-TL using the four 'minutes played' durations ('minutes played only', 'warm-up added', 'halftime added', and 'warm-up and halftime added') were strongly correlated with TLS (r = .773, .776, .789, .786), total distance (r = .825, .813, .811, .798), number of sprints (r = .716, .717, .712, .711), HSD (r = .608, .615, .609, .612), and mechanical load (r = .738, .738, .734, .732). When separated by positions, the correlations between sRPE-TL and objective data were similar across all four 'minutes played' durations.

Conclusions: Any of the 'minutes played' durations should be used to calculate match sRPE-TL values for the entire team. Multiple positions do not require the use of different durations for the calculation of sRPE-TL which facilitates sRPE-TL comparisons across positions.

Key Words: Training Load, Collegiate, Periodization, Female, GPS

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Introduction

The current literature suggests that moderate to high training loads are necessary for positive training adaptations in physical fitness but can lead to increased fatigue, injury, or illness [1–3]. Additionally, when athletes do not have adequate recovery time there is an increased risk of injury and reduced physical performance [4–7]. For this reason, periodization schedules consider the recovery time required following training sessions and matches to potentially minimize injury risk and prevent the suggested attenuation of physical performance [8,9]. Thus, quantifying and monitoring training load are crucial to enable the coaching staff to follow the predetermined periodization schedule. The overall training load is a result of the combination of internal and external loads. The internal load reflects how the individual athlete responds physiologically and perceptually to a variety of external loads [10]. Understanding the interaction between internal and external loads enhances individual athlete management by improving the coach's ability to devise periodization schedules [11–15].

Session Rating of Perceived Exertion Training Load (sRPE-TL) is the most commonly used and inexpensive method to assess daily training load [16]. Initially proposed by Foster et al. [17], sRPE-TL is widely adopted in team sports [17,18]. It is calculated by multiplying the training duration, in minutes, by the athlete's Rating of Perceived Exertion (RPE) for the session using Borg's Category Ratio-10 RPE (Figure 1) scale. sRPE-TL is positively-correlated with internal and external training load variables in men's and women's soccer [10,14,19–22]. The subjective aspects of sRPE-TL may provide a global comprehension of how the athlete's body is responding to the acute and chronic training loads [22]. Despite the broad usage of sRPE-TL, there is currently not a clear recommendation for which duration should be used in the calculation of sRPE-TL during matches [21]. Further, the calculation of sRPE-TL may have to be adapted according to the level of competition and gender. Most reports in the literature assessed correlations between training load variables in male professional teams. However, there are major differences between professional and collegiate soccer matches. Currently, the NCAA collegiate soccer rules permit multiple substitutions with clock stoppage and the potential for overtime during playoffs. Conversely, professional soccer rules limit teams to five substitutions per match and the athletes are not permitted back in the match post substitution. Thus, athlete participation in collegiate soccer includes multiple smaller bouts of match play rather than the long continuous bouts observed in professional soccer. Finally, the duration of a NCAA Division I (DI) men's soccer match may last up to 162 minutes, depending on clock stoppage, injuries, overtime, number of substitutions, etc. [21].

Pustina et al. [21] attempted to establish a duration standard for the calculation of sRPE-TL in NCAA DI men's soccer by reporting the strength of the relationship between sRPE-TL and time-motion variables including Global Positioning System (GPS) and accelerometer-derived data. The authors suggested that 'only minutes played' should be used, as this duration showed the highest correlation coefficients [21]. However, Pustina et al. [21] used Person's *r* correlations to verify these relationships; thus, they did not account for the lack of independence in the data as each of the 20 athletes participated in ~15 matches. It is also possible that the relationships among training load variables differ between male and female collegiate soccer athletes. In a recent report, McFadden et al. [23] compared the internal and external training loads in male and female collegiate soccer. The authors presented evidence that total distance covered (TD) during matches does not differs between men's and women's collegiate soccer but men have higher high-speed running distance (HSD). Lastly, the calculation of sRPE-TL may also require position-adjusted duration standards due to the positional differences in physical demands during a match [19,24]. For example, in men's professional soccer, central defenders have been observed to have lower TD and lower running time during a match when compared to other positions [25,26].

Calculating sRPE-TL properly is crucial to ensure coaches can detect changes in performance, prevent overtraining, and reduce the risk of injuries [21]. Thus, further insight into the duration standard used to calculate sRPE-TL during NCAA DI women's soccer matches is needed to adequately prescribe individualized post-match activities. Therefore, the purpose of this study was to establish a duration standard to be used in the calculation of sRPE-TL in collegiate NCAA DI women's soccer matches. A secondary aim was to investigate whether the relationships among sRPE-TL and objectively-collected load variables differ across playing positions. The authors hypothesized that using 'minutes played only' to calculate sRPE-TL would show the strongest relationships to other internal and external load variables. Additionally, duration standards for the calculation of sRPE-TL would differ across playing positions due to the different functions performed during a match.

Scientific Methods

Participants

Seventeen NCAA DI women's soccer athletes older than 18 years of age were included in the study (See **Table 1** for participant's demographics). The dataset included 257 unique observations from n = 6 defenders, n = 7 midfielders, and n = 4 forwards (92, 100, and 66 observations each, respectively). Approval from the University of Mississippi's

Institutional Review Board was obtained and data was de-identified to perform this retrospective analysis. The team played a total of 20 matches (18 regular season and 2 post-season) during the 2019 season and the athletes included for the analysis played at least 10 matches during the season (regardless of minutes played during a match) as an attempt to minimize sample bias. However, full data were only available for 17 matches. Goalkeepers were excluded from this investigation due to the different nature of the physical demands experienced during a match when compared to any other field position.

Table 1. Participant Demographics (n=17).

Variables	Mean ± Standard Deviation	Minimum	Maximum
Age, years	20.0 ± 1.1	18.0	22.0
Height, cm	170.0 ± 6.6	157.0	178.0
Weight, kg	64.6 ± 7.0	53.1	77.1

Protocol

This study utilized archived monitoring data from an NCAA DI women's soccer team to perform a retrospective analysis. Athletes' training loads were quantified as part of the usual training load monitoring program utilized by a DI women's collegiate team during preseason and competition season in the fall of 2019. Athletes wore their assigned Polar Team Pro (Polar; Stamford, CT) wearable module, located on the chest, including a heart rate (HR) sensor, a GPS sensor, and an Inertial Measurement Unit (IMU) which consists of accelerometers, gyroscope, and magnetometer sensors [27]. Following each match, HR, GPS, and IMU data were uploaded into the Polar Team Pro cloud-based server for future off-line analysis. The Polar Team Pro system has showed a standard error of the estimate of 1.0% and coefficient of variation of 1.0% in the measurement of TD during team sport simulated movements [28].

The athletes' internal load measures selected for this examination were Polar's Training Load Score (TLS) and sRPE-TL. For the calculation of TLS, data from the Polar Team Pro HR monitor (Polar Electro; Kempele, Finland) were utilized. The Polar HR sensors have shown to be a valid HR measurement [29–31]. The Polar Team Pro system performed an automatic calculation of Polar's TLS, which is a HR-based modified version of training impulse previously proposed by Bannister in 1991 [27,32]. sRPE-TL was measured using a Borg's Category Ratio-10 RPE (Figure 1) scale with verbal and visual anchors approximately 10 minutes post-match at the conclusion of a cool-down [20]. The team's athletic trainer displayed the scale to each athlete and asked "what is your rate of perceived exertion for this match?" [20].

Rating of Perceived Exertion	
0	**Rest, Inactive**
1	**Really Easy**
2	**Easy**
3	**Moderate, Medium**
4	
5	**Difficult**
6	**Hard**
7	**Really Hard**
8	**Really, Really Hard**
9	**One of the Hardest Sessions**
10	**Maximum**

Figure 1. Borg's Category Ratio-10 RPE scale with verbal and visual anchors.

In an attempt to establish a duration standard for the calculation of match sRPE-TL, the sRPE values reported by the athletes were multiplied by eight different 'match duration' definitions as performed by Pustina et al. [21]:

1. Minutes played only
2. Minutes played and warm-up
3. Minutes played and halftime
4. Minutes played including warm-up and halftime
5. Total match duration only
6. Total match duration and warm-up
7. Total match duration and halftime
8. Total match duration including warm-up and halftime

'Total match duration' was defined as the total amount of minutes from the initial kick-off to the final blow of the whistle. 'Minutes played' was defined as the total number of minutes the athlete participated in the match. The Polar Team Pro system includes a GPS sensor, allowing the researchers to access the position of the athlete during any given period during the match. This technology in combination with video recordings and match statistics were utilized to determine the exact number of minutes each athlete participated in the match including periods when the game clock was stopped. Figure 2 shows the duration of the various periods included in a soccer match. Overtime was only required if the second-half finished as a draw (e.g., 0 vs. 0, 1 vs. 1, 2 vs. 2, etc.). If a team scored a goal during overtime the match ended.

Figure 2. Duration, in minutes, of each period of a NCAA DI soccer match including overtime.

The athletes' external load variables selected for this retrospective analysis were TD, distance covered in different speed zones, accelerations, decelerations, and number of sprints. The number of sprints was a count variable for every moment the athlete reached a speed ≥ 15.0 km.h^{-1}. HSD was defined as the total distance travelled ≥ 15.0 km.h^{-1}. This retrospective analysis only included accelerations ≥ 2.0 m.s^{-2} and decelerations ≤ -2.0 m.s^{-2}. A 'mechanical load' was calculated by adding the number of accelerations and decelerations during a given period (e.g., 54 detected accelerations ≥ 2.0 m.s^{-2} and 35 decelerations ≤ -2.0 m.s^{-2} equal a mechanical load score of 89). External load data were collected from the beginning of the soccer-specific warm-up until the end of the match.

Statistical Analysis

The Shapiro-Wilk test of normality was utilized prior to data analysis to examine for normality of the data. A one-way analysis of variance (ANOVA) was utilized to compare the sRPE-TL values derived from calculations using eight different durations. The Levene's test was utilized to verify the assumption of homogeneity of variances. The relationships between the eight sRPE-TL values and other internal and external load variables (HR, GPS, and IMU variables) were analyzed through repeated measures correlations. This analysis was chosen to avoid violating the assumption of independence which would occur if multiple values from each athlete were considered independent from one another [33,34]. The magnitude or the strength of the associations were considered very weak if the repeated measures *r* values were between 0-0.19, weak if between 0.2-0.39, moderate if between 0.4-0.59, strong if between 0.6-0.79, and very strong if between 0.8-0.99. To address the secondary aim, athletes were grouped by playing positions (defenders, midfielders, and forwards) according to the team's official roster. Statistical analyses were performed using Statistics Package for the Social Sciences (version 28.0, SPSS Inc. Chicago, IL) and using the rmcorr package in R studio (version 2022.07.1, R Studio, Boston, MA, USA) executing R (version 4.2.1, University of California, Berkeley, CA, USA). Alpha was set a-priori at 0.05 as the statistical significance criterion. Data is presented as means ± standard deviations (SD).

Results

The means and standard deviations for all variables of interest are shown in Table 2. The Levene's test of homogeneity of variances was statistically significant ($p < 0.001$). Thus, the Brown-Forsythe test was used to assess whether the mean sRPE-TL's were different when using multiple durations in the calculations of the values. The Brown-Forsythe test was statistically significant suggesting that the mean sRPE-TL were different ($p < 0.001$). The Games-Howell test was used for pairwise post-hoc comparisons and showed that 'minutes played only' was statistically significantly lower than 'minutes played including warm-up and halftime' ($p = 0.041$) and all four sRPE-TL calculated using total match duration ($p = 0.015$ for 'match duration only'; $p < 0.001$ for the other three 'match durations'). This was expected as the sRPE-TL values are a product of the sRPE reported by the athlete and the duration used. It was important to show that these values were statistically different in order to justify the different relationship among the sRPE-TL variables and the objectively-collected training load variables. All repeated measures correlations between each of the eight sRPE-TL calculations showed statistically significant associations with all objective variables (Table 3). The repeated measures correlation between 'minutes played only' sRPE-TL and TD is shown in Figure 3 ($r = .825$ and $r^2 = .680$). Sixty-eight percent of the variance in sRPE-TL can be account for by TD. The 'minutes played only' sRPE-TL was statistically significantly ($p < 0.001$) correlated to TLS, TD, number of sprints, HSD, mechanical load (.773, .825, .716, .608, and .738, respectively). Descriptive statistics of training load variables with athletes separated by positions are presented in Table 4. The one-way ANOVA suggested that there were no significant differences among positions ($p < 0.05$). The nonsignificant differences observed by positions were potentially confounded by the small sample sizes, the large variability of the data due to differences in playing time, and the formation used. Lastly, Table 5 shows the repeated measures correlations among training load variables separated by positions. Overall, larger correlations were observed among the 'minutes played' sRPE-TL variables and the training load variables for the defenders and midfielders. However, the correlations between sRPE-TL and TLS in the forwards group seemed to be fairly consistent across sRPE-TL durations.

Table 2. Means and standard deviations for variables of interest per match (n=17).

Variables		Mean ± Standard Deviation
sRPE-TL Minutes Played, A.U.		
	Minutes Played	438.7 ± 234.7
	Warm-Up Added	600.8 ± 254.5
	Halftime Added	566.2 ± 251.0
	Halftime & Warm-Up Added	728.4 ± 271.7#
sRPE-TL Match Duration, A.U.		
	Match Duration	682.6 ± 112.1#
	Warm-Up Added	845.1 ± 138.3#
	Halftime Added	810.2 ± 134.2#
	Halftime & Warm-Up Added	972.6 ± 160.4#
TLS, A.U.		263 ± 91.3
Total Distance, m		8981 ± 2951
Number of Sprints		77 ± 26.9
HSD, m		982 ± 387.6
Mechanical Load, A.U.		140 ± 41.8
Reported RPE		6.4 ± 1.0
Minutes Played Duration, min		67.7 ± 31.1
Total Match Duration, min		106.7 ± 0.7
Warm-Up Duration, min		25.5 ± 0.2
Halftime Duration, min		19.9 ± 0.3

# Indicates statistically significantly higher than "Minutes Played" at the 0.05 level. Values correspond to the team average per match when including each athlete's mean for each variable of interest for all matches.

Table 3. Repeated measures correlations between the various sRPE-TL calculations and objective variables during competitive matches.

Variables		TLS	Total Distance	Number of Sprints	HSD	Mechanical Load
sRPE-TL Minutes Played						
	Minutes Played	.773*	.825*	.716*	.608*	.738*
	Warm-Up Added	.776*	.813*	.717*	.615*	.738*
	Halftime Added	.789*	.811*	.712*	.609*	.734*
	Halftime & Warm-Up Added	.786*	.798*	.711*	.612*	.732*
sRPE-TL Match Duration						
	Match Duration	.704*	.587*	.567*	.492*	.588*
	Warm-Up Added	.703*	.600*	.581*	.507*	.599*
	Halftime Added	.703*	.586*	.564*	.491*	.584*
	Halftime & Warm-Up Added	.705*	.599*	.577*	.506*	.596*

* Indicates a significant correlation at the p < 0.01 level.

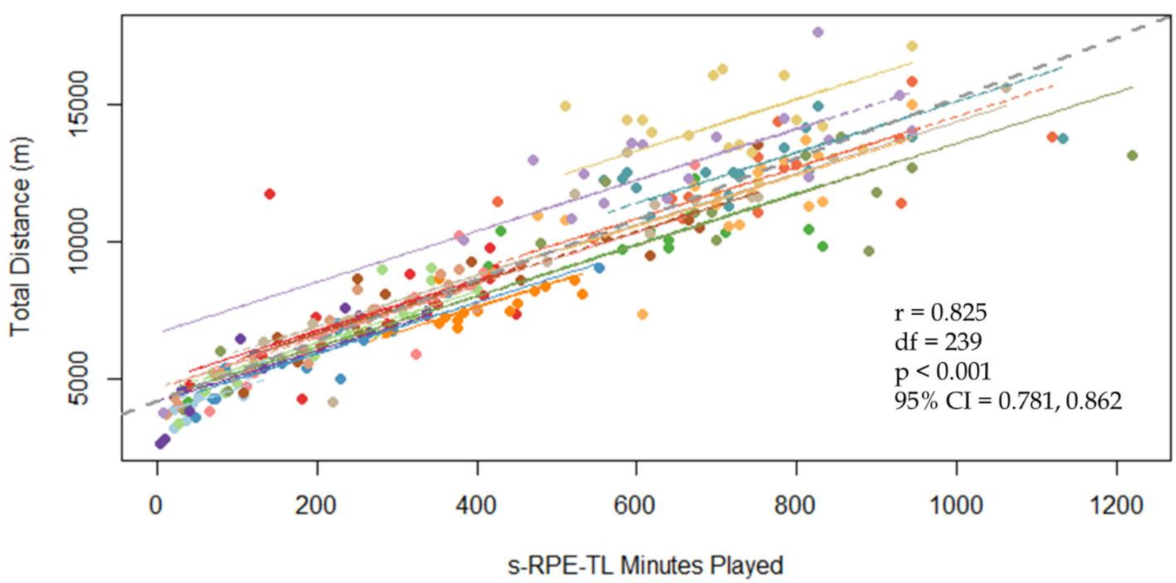

Figure 3. Repeated measures correlation between sRPE-TL ‘Minutes Played Only’ and TD. Each participant’s data corresponding regression line are shown in a different color. The grey dashed line corresponds to the overall regression slope of a simple linear regression.

Table 4. Means and standard deviations per match for variables of interest separated by position.

Variables		Defenders (n=6)	Midfielders (n=7)	Forwards (n=4)
sRPE-TL Minutes Played, A.U.				
	Minutes Played	503.2 ± 189.5	399.2 ± 289.1	411.0 ± 232.1
	Warm-Up Added	666.9 ± 204.2	554.0 ± 316.6	583.8 ± 247.2
	Halftime Added	632.2 ± 201.2	520.1 ± 312.6	548.0 ± 243.0
	Halftime & Warm-Up Added	795.9 ± 216.0	674.9 ± 340.9	720.7 ± 259.9
sRPE-TL Match Duration, A.U.				
	Match Duration	689.5 ± 69.8	650.2 ± 139.2	729.1 ± 121.3
	Warm-Up Added	853.4 ± 85.7	805.2 ± 171.8	902.2 ± 150.2
	Halftime Added	818.6 ± 82.3	771.0 ± 167.6	866.0 ± 143.9
	Halftime & Warm-Up Added	982.5 ± 98.1	972.6 ± 200.2	1039.1 ± 172.8
TLS, A.U.		265 ± 38.7	262 ± 129.8	262 ± 90.9
Total Distance, m		9252 ± 1961	8985 ± 4013	8621 ± 2741
Number of Sprints		73 ± 16.4	80 ± 33.3	75 ± 33.7
HSD, m		949 ± 277.5	1010 ± 447.1	983 ± 518.8
Mechanical Load, A.U.		140 ± 30.0	140 ± 49.9	139 ± 53.5

Values correspond to the position average per match when including each athlete's mean for each variable of interest for all matches.

Table 5. Repeated measures correlations between the various sRPE-TL calculations and objective variables separated by playing positions during competitive matches.

		Minutes Played				Match Duration			
		Minutes Played	Warm-Up Added	Halftime Added	Halftime & Warm-Up Added	Match Duration	Warm-Up Added	Halftime Added	Halftime & Warm-Up Added
Defenders	TLS	0.847*	0.841*	0.851*	0.842*	0.710*	0.714*	0.705*	0.711*
	TD	0.883*	0.867*	0.869*	0.853*	0.635*	0.647*	0.627*	0.641*
	Sprints	0.791*	0.785*	0.791*	0.783*	0.630*	0.640*	0.626*	0.637*
	HSD	0.735*	0.733*	0.744*	0.739*	0.609*	0.618*	0.612*	0.621*
	ML	0.803*	0.801*	0.803*	0.799*	0.655*	0.666*	0.649*	0.662*
Midfielders	TLS	0.714*	0.728*	0.731*	0.738*	0.685*	0.688*	0.685*	0.690*
	TD	0.803*	0.791*	0.787*	0.777*	0.568*	0.581*	0.574*	0.586*
	Sprints	0.671*	0.677*	0.660*	0.665*	0.527*	0.543*	0.524*	0.540*
	HSD	0.532*	0.551*	0.525*	0.540*	0.437*	0.460*	0.433*	0.455*
	ML	0.693*	0.693*	0.679*	0.679*	0.533*	0.545*	0.530*	0.543*
Forwards	TLS	0.752*	0.751*	0.791*	0.781*	0.752*	0.736*	0.762*	0.750*
	TD	0.660*	0.664*	0.656*	0.658*	0.547*	0.559*	0.549*	0.561*
	Sprints	0.663*	0.674*	0.656*	0.664*	0.563*	0.577*	0.559*	0.574*
	HSD	0.541*	0.537*	0.530*	0.526*	0.415*	0.425*	0.417*	0.426*
	ML	0.667*	0.666*	0.662*	0.659*	0.556*	0.562*	0.556*	0.563*

* Indicates a significant correlation at the $p < 0.01$ level.

Discussion

The primary finding of this study was that TD showed stronger correlations with sRPE-TL than any other objective variable collected. The largest correlation observed was between 'minutes played' sRPE-TL and TD, where $r = .825$ and $r^2 = .680$. Thus, 68% of the variance in sRPE-TL can be explained by TD. However, all four 'minutes played' durations ('minutes played only', 'warm-up added', 'halftime added', and 'warm-up and halftime added') showed to be strongly or very strongly correlated ($r \geq 0.6$) with internal and external load variables (Table 3). When separated by playing positions, a combination of different metrics may provide a better picture. Overall, TD and TLS showed the strongest correlations with sRPE-TL when compared to the other variables. For example, the midfielders TD showed the strongest correlations with sRPE-TL, while for the forwards TLS had the strongest correlations with sRPE-TL (Table 5). Given the importance of sRPE-TL for the quantification and monitoring of internal training load in sports, establishing a duration standard for its calculation during collegiate matches is crucial for appropriate training prescription pre and post matches.

These findings are partially in agreement with Pustina et al. [21] where the authors suggested the use of 'only minutes played' (Pearson's *r* between sRPE-TL 'minutes played' with: TD = .808, Player Load = .785, HSD = .570) for the calculation of sRPE-TL in male collegiate soccer during matches. However, the authors did not utilize a statistical test which accounts for the lack of independence between matches in the dataset. For this reason, the current investigation utilized the repeated measures correlations to assess the within-subjects' relationships between sRPE-TL and other objective internal and external training load variables. Therefore, when calculating sRPE-TL for the entire team, the results reported here suggest the potential use of any of the four durations based on 'minutes played'. This is of particular interest to soccer coaches and strength and conditioning staff who currently calculate sRPE-TL using total match duration or a standard, pre-set, estimated duration such as 120 minutes (i.e., estimating a 30-minute warm-up followed by a 90-minute match). It is important to consider that when using rmcorr, the minutes played per athlete alone was statistically significantly ($p < 0.001$) correlated to TLS, TD, number of sprints, HSD, mechanical load (rmcorr r = .785, .894, .752, .650, .750; respectively). Thus, minutes played alone could potentially provide valuable information to coaches and practitioners about an athlete's match load.

Due to the suggested positional differences in physical demands, we investigated whether the team's staff may potentially need to adjust their calculations based on position in order to accurately assess internal training load [19,24,35]. A recent investigation by Ishida et al. [35], aimed to verify how competition phase and athlete position affect the relationship between internal and external training loads. The authors concluded that athlete position affects the relationship between internal and external training loads during collegiate women's soccer matches [35]. In the current study, TD was strongly positively correlated with sRPE-TL using 'minutes played' in the defender group. This may represent that TD is a better indicator of physical performance for this position. Interestingly, the TD in the defender's group was not lower than the other positions as previously reported in the literature [25,26,36]. Plausibly, the results for the defenders were influenced by the different formations employed by each team in the previous literature, which may require defenders to cover larger or smaller areas of the field. When playing in a 3-5-2 formation, the defenders are responsible for covering a larger area, which may have contributed to the augmentation of the TD of the defenders. In modern soccer, when using this formation, the wing-backs are likely to cover more TD and HSD as the coach may choose to defend in the 5-3-2 and attack in a 3-5-2. Thus, requiring the wing-backs to participate in the defensive part of the game just as much as in the offensive portion, which increases the need to transition across large areas of the field. However, the 3-5-2 formation was not included in the previous observations because it is not the most commonly utilized formation in professional men's soccer. Overall, the most popular formations in soccer are 4-4-2 and 4-3-3. In modern soccer, the use of formations like 4-2-3-1, 3-5-2, and 3-4-3 has increased. Bradley et al. [37] have suggested that defenders have a higher TD when the team is playing in a 4-4-2 than when playing in a 4-3-3 or 4-5-1, which indicates that playing formation can play a role in the physical performance of defenders [37]. Further, Barros et al. [36] also suggested midfielders, on average, have higher TD compared to central defenders and forwards during professional men's soccer matches.

In a meta-analysis including multiple team sports (Rugby, Soccer, Basketball, etc.), McLaren et al. [19] suggested sRPE-TL has a "possibly very large" relationship with TD, "likely large" with accelerometer-derived load and impact, and "likely moderate" with HSD. Comparatively in the current investigation, the rmcorr correlation coefficient was ≥ 0.8 for the correlation between the 'minutes played only' sRPE-TL calculations with TD. Potentially suggesting that TD can be utilized as the primary indicator of female collegiate soccer match exertion. The correlation coefficients between the 'minutes played' sRPE-TL calculations with TLS, number of sprints, HSD, and mechanical load were >0.6. Although these variables are also strongly ($r \geq 0.6$) correlated to all 'minutes played' sRPE-TL, the correlation coefficients are not as high as observed in TD. This potentially suggests that TLS, number of sprints, HSD, and mechanical load are of secondary importance when assessing the training load of collegiate women's soccer athletes.

However, number of sprints and HSD could possibly aid in the analysis of individual athletes to provide better insight into the high-intensity actions performed during the match. Lastly, the magnitude of the associations between TLS and all 'minutes played' sRPE-TL calculations were between 0.7-0.8. Interestingly, sRPE-TL is more strongly associated with TD, an external load variable, than with TLS, an internal load variable, which is in agreement with Scott et al. [22]. The authors attributed these lower correlations between sRPE-TL and TLS to the intermittent nature of soccer [22]. Potentially suggesting sRPE-TL is not as sensitive as HR-based methods to detect training load of high-intensity activities interspersed with extensive active recovery periods (i.e. low-to-moderate intensity lower the perception of effort) [22].

Limitations

Like many collegiate soccer teams, the team utilized in this retrospective analysis changed formations multiple times during the season. The team played with a 3-5-2 formation for the majority of the fixtures, but formations were often adjusted late in matches depending on scenario. To date, no data has been reported to suggest how frequently teams use certain formations. Further, the team utilized in this investigation played six matches with overtime during the 2019 season. Possibly increasing the overall number of minutes played and altering how athletes perceived exertion in each match. Finally, this study included only one collegiate team which may have influenced the results related to positional differences as the sample size of each position was relatively small. Thus, future research should look to encourage collaboration among teams.

Conclusions

The current investigation's results could assist in the calculation of sRPE-TL by coaches and practitioners in the collegiate setting. Thus, leading to a more accurate representation of the physical demands experienced by each athlete during a match. Strong to very strong associations were seen between sRPE-TL calculated using any of the four 'minutes played' durations and TLS, TD, HSD, number of sprints, and mechanical load. Overall, 'minutes played only' may provide superior match sRPE-TL values to be used when calculating weekly sRPE-TL, as it only incorporates physical activity time and shows strong correlations to objective variables. The current investigation suggests that adjusting sRPE-TL duration by position may be a potential alternative to further assist coaches to determine post-match activities. However, this may be formation and competition level dependent. The results provided here give further indication of the importance of sRPE-TL in monitoring training load in soccer as a global perspective for match training load.

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Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. Gabbett TJ. The training—injury prevention paradox: should athletes be training smarter *and* harder? *Br J Sports Med.* 2016;50(5):273-280. doi:10.1136/bjsports-2015-095788
2. Schwellnus M, Soligard T, Alonso JM, et al. How much is too much? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *Br J Sports Med.* 2016;50(17):1043-1052. doi:10.1136/bjsports-2016-096572
3. Soligard T, Schwellnus M, Alonso JM, et al. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med.* 2016;50(17):1030-1041. doi:10.1136/bjsports-2016-096581
4. Bengtsson H, Ekstrand J, Hägglund M. Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med.* 2013;47(12):743-747.
5. Dellal A, Lago-Peñas C, Rey E, Chamari K, Orhant E. The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *Br J Sports Med.* 2015;49(6):390-394. doi:10.1136/bjsports-2012-091290

6. Ekstrand J, Hägglund M, Kristenson K, Magnusson H, Waldén M. Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med*. 2013;47(12):732-737.
7. Rollo I, Impellizzeri FM, Zago M, Iaia FM. Effects of 1 versus 2 games a week on physical and subjective scores of subelite soccer players. *International Journal of Sports Physiology and Performance*. 2014;9(3):425-431.
8. Brownstein CG, Dent JP, Parker P, et al. Etiology and recovery of neuromuscular fatigue following competitive soccer match-play. *Frontiers in physiology*. 2017;8:831.
9. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in Soccer: Part I – Post-Match Fatigue and Time Course of Recovery. *Sports Medicine*. 2012;42(12):997-1015. doi:10.2165/11635270-000000000-00000
10. McLaren SJ, Macpherson TW, Coutts AJ, Hurst C, Spears IR, Weston M. The relationships between internal and external measures of training load and intensity in team sports: a meta-analysis. *Sports Medicine*. 2018;48(3):641-658.
11. Bartlett JD, O'Connor F, Pitchford N, Torres-Ronda L, Robertson SJ. Relationships Between Internal and External Training Load in Team-Sport Athletes: Evidence for an Individualized Approach. *International Journal of Sports Physiology and Performance*. 2017;12(2):230-234. doi:10.1123/ijspp.2015-0791
12. Burgess DJ. The Research Doesn't Always Apply: Practical Solutions to Evidence-Based Training-Load Monitoring in Elite Team Sports. *International Journal of Sports Physiology and Performance*. 2017;12(s2):S2-S2-141. doi:10.1123/ijspp.2016-0608
13. Castillo D, Weston M, McLaren SJ, Cámara J, Yanci J. Relationships Between Internal and External Match-Load Indicators in Soccer Match Officials. *International Journal of Sports Physiology and Performance*. 2017;12(7):922-927. doi:10.1123/ijspp.2016-0392
14. Scott T, 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. *The Journal of Strength & Conditioning Research*. 2013;27(1):270-276. doi:10.1519/JSC.0b013e3182541d2e
15. Taylor KL, Weston M, Batterham AM. Evaluating Intervention Fidelity: An Example from a High-Intensity Interval Training Study. *PLoS One*. 2015;10(4). doi:10.1371/journal.pone.0125166
16. Alexiou H, Coutts AJ. A comparison of methods used for quantifying internal training load in women soccer players. *International journal of sports physiology and performance*. 2008;3(3):320-330.
17. Foster C, Hector L, Welsh R, Schrager M, Green M, Snyder A. Effects of specific versus cross-training on running performance. *Europ J Appl Physiol*. 1995;70(4):367-372. doi:10.1007/BF00865035
18. Borresen J, Lambert MI. Quantifying Training Load: A Comparison of Subjective and Objective Methods. *International Journal of Sports Physiology and Performance*. 2008;3(1):16-30. doi:10.1123/ijspp.3.1.16
19. Barrett S, McLaren S, Spears I, Ward P, Weston M. The influence of playing position and contextual factors on soccer players' match differential ratings of perceived exertion: a preliminary investigation. *Sports*. 2018;6(1):13.
20. Foster C, Florhaug J, Franklin J, et al. A new approach to monitoring exercise training. *The Journal of Strength & Conditioning Research*. 2001;15(1):109-115.
21. Pustina AA, Sato K, Liu C, et al. Establishing a duration standard for the calculation of session rating of perceived exertion in NCAA division I men's soccer. *Journal of Trainology*. 2017;6(1):26-30.
22. Scott B, Lockie RG, Knight TJ, Clark AC, de Jonge XAJ. A comparison of methods to quantify the in-season training load of professional soccer players. *International journal of sports physiology and performance*. 2013;8(2):195-202.
23. McFadden BA, Walker AJ, Bozzini BN, Sanders DJ, Arent SM. Comparison of internal and external training loads in male and female collegiate soccer players during practices vs. games. *The Journal of Strength & Conditioning Research*. 2020;34(4):969-974.
24. Gregson W, Drust B, Atkinson G, Salvo VD. Match-to-match variability of high-speed activities in premier league soccer. *International journal of sports medicine*. 2010;31(04):237-242.
25. Bloomfield J, Polman R, O'Donoghue P. Physical demands of different positions in FA Premier League soccer. *Journal of sports science & medicine*. 2007;6(1):63.
26. Di Salvo V, Baron R, Tschan H, Calderon Montero F, Bachl N, Pigozzi F. Performance Characteristics According to Playing Position in Elite Soccer. *Int J Sports Med*. 2007;28(3):222-227. doi:10.1055/s-2006-924294
27. Peltonen J, Tuulari E. Polar Team Pro - Portable player tracking system to Increase team performance and prevent injuries. *Polar R&D, Research and Technology*. Published online October 2018.

28. Huggins RA, Giersch GEW, Belval LN, et al. The Validity and Reliability of Global Positioning System Units for Measuring Distance and Velocity During Linear and Team Sport Simulated Movements. *The Journal of Strength & Conditioning Research*. 2020;34(11):3070-3077. doi:10.1519/JSC.0000000000003787
29. Gilgen-Ammann R, Schweizer T, Wyss T. RR interval signal quality of a heart rate monitor and an ECG Holter at rest and during exercise. *Eur J Appl Physiol*. 2019;119(7):1525-1532. doi:10.1007/s00421-019-04142-5
30. Goodie JL, Larkin KT, Schauss S. Validation of the Polar Heart Rate Monitor for Assessing Heart Rate During Physical and Mental Stress. *Journal of Psychophysiology*. 2000;14(3):159-164. doi:10.1027//0269-8803.14.3.159
31. Weippert M, Kumar M, Kreuzfeld S, Arndt D, Rieger A, Stoll R. Comparison of three mobile devices for measuring R–R intervals and heart rate variability: Polar S810i, Suunto t6 and an ambulatory ECG system. *Eur J Appl Physiol*. 2010;109(4):779-786. doi:10.1007/s00421-010-1415-9
32. Banister EW. *Modeling Elite Athletic Performance*. (Green H, McDougal J, Wegner H, eds.). Human Kinectics; 1991.
33. Bland JM, Altman DG. Statistics notes: Calculating correlation coefficients with repeated observations: Part 1--correlation within subjects. *BMJ*. 1995;310(6977):446-446. doi:10.1136/bmj.310.6977.446
34. Bakdash JZ, Marusich LR. Repeated Measures Correlation. *Front Psychol*. 2017;8:456. doi:10.3389/fpsyg.2017.00456
35. Ishida A, Travis SK, Draper G, White JB, Stone MH. Player Position Affects Relationship Between Internal and External Training Loads During Division I Collegiate Female Soccer Season. *Journal of Strength and Conditioning Research*. 2022;36(2):513-517.
36. Barros RML, Misuta MS, Menezes RP, et al. Analysis of the Distances Covered by First Division Brazilian Soccer Players Obtained with an Automatic Tracking Method. *J Sports Sci Med*. 2007;6(2):233-242.
37. Bradley PS, Carling C, Archer D, et al. The effect of playing formation on high-intensity running and technical profiles in English FA Premier League soccer matches. *Journal of Sports Sciences*. 2011;29(8):821-830. doi:10.1080/02640414.2011.561868