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Relationships Between Pre-Match Training Load Variables and Matchday Countermovement Jump Height in NCAA DI Women's Soccer

Original Research

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Abstract

Introduction: The purpose of this study was to assess the repeated measures correlations between the sums of training load (TL) variables preceding matchday and matchday countermovement jump (CMJ) height in NCAA Division I (DI) women's soccer athletes.

Methods: A total of 23 female soccer players (20 ± 1.2 years; 1.69 ± 0.06 m) participated in this study. Repeated measures correlations were used to determine the relationships between matchday CMJ height and TL variables.

Results: Matchday CMJ height showed very weak to weak negative relationships with the sums of the TL variables for the microcycle preceding the match: sRPE-TL (r = -0.184, p = 0.036), TD (r = -0.229, p = 0.008), TLS (r = -0.192, p = 0.028), HSD (r = -0.229, p = 0.008), ML (r = -0.204, p = 0.020), and number of sprints (r = -0.237, p = 0.006).

Conclusions: Although significant negative weak relationships were observed, the results suggest that the sums of TL variables preceding matchday may not be the most reliable indicators of matchday preparedness in collegiate DI women's soccer. Future research should aim to investigate other strategies to predict matchday readiness in collegiate women's soccer.

Key Words: Periodization, Neuromuscular, Fatigue, GPS, Athletes

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Introduction

Training load (TL) quantification and monitoring is used in collegiate athletics to help coaches and supporting staff to determine whether players are prepared for upcoming matches with the main goals being to maximize physical fitness and to minimize injury risk. Preparedness is dependent upon the athlete's fitness and neuromuscular status, which can change daily in response to the physical activities performed [1,2]. Acute fatigue (i.e., within hours following a match) is the result of the metabolic response to high TLs (i.e., high volume and intensity of physical work performed and the physiological responses to these workloads) while chronic fatigue is linked to the hormonal, metabolic, structural, and neuromuscular responses to accumulating TLs over time [3]. The athlete's ability to recover from fatigue-inducing events, such as training sessions and matches, is directly related to the athlete's fitness status. The current literature suggests that relative moderate to high TLs (absolute values of TL variables vary across genders and competition levels) are necessary for positive training adaptations in physical fitness but this can lead to increased risk of fatigue, injury, or illness [4–7]. Adequate recovery is crucial to avoid overuse injuries and a congested schedule can lead to increased risk of injuries during a soccer season [8–11]. Over a five-year period, the injury rates during practices and matches were ~6 and ~17, respectively, per 1,000 athlete exposure events (AEE) in collegiate NCAA women's soccer. Nearly four thousand injuries, from which 23.3% were noncontact and 17.6% were overuse injuries, were reported in over 450,330 AEE [12]. Further, Ehrmann et al. [13] reported that players performed higher meters per minute (matches and training) in the weeks preceding an injury when compared to their seasonal averages. Additionally, injuries may predispose athletes to future injuries as larger inter-limb asymmetries during bilateral CMJ tests have been reported in those with prior injuries [14]. Thus, the justification for an individualized periodization is increased in dynamic sports like soccer due to the high-intensity intermittent nature of the game and the high volume of external loads (i.e., physical work) during the competitive season.

The TL variables used during athlete monitoring can be divided into internal and external load variables. The internal load variables represent the athlete's physiological and perceptual responses to the activities while the external load variables objectively measure the physical work performed [7]. Popular internal load variables include session rating of perceived exertion TL (sRPE-TL) [15] and heart rate (HR)-based methods such as training impulse (TRIMP) [16]. Global Positioning System (GPS)-based variables such as total distance (TD) [17], high-speed distance (HSD) [18], number of accelerations [19], number of decelerations [20], and number of sprints [21] are widely incorporated as external load variables during athlete monitoring. TL variables may also provide valuable information regarding an athlete's fitness as coaches can observe improvements in total work performed and/ or in the internal response to similar workloads [22]. However, it is currently unknown whether TL monitoring variables can provide the coaching staff with the ability to determine an athlete's neuromuscular status on matchday.

The metabolic and neuromuscular fatigue from soccer-based actions (i.e., sprinting, accelerating, decelerating, jumping, kicking, etc.) elicits decrements in an athlete's ability to generate force. On average, athletes have reduced neuromuscular performance following intense soccer-based activities, which highlights the need for monitoring neuromuscular status to ensure proper recovery [2]. Countermovement jumps (CMJ) have previously been utilized to assess neuromuscular fatigue and/ or preparedness in soccer [1,2,23,24]. CMJs can be quickly measured to allow practitioners to have daily or weekly assessments of neuromuscular status. Previous literature has extensively reported changes in CMJ metrics following high intensity soccer-related activities such as games, simulations, or trainings [1,2,23–25]. For example, Ishida et al. [2] observed reductions in CMJ height 12 hours following a collegiate NCAA DI women's soccer match. The authors also reported large negative correlations between TL variables (i.e., TD, r = -0.65; total player load, r = -0.58; HSD, r = -0.58; and sRPE-TL, r = -0.64) and the change/ reduction in weighted (i.e., 20kg) CMJ height 12 hours post-match [2]. However, the use of CMJ has not been explored in pre-match preparedness using multiday TL sum within soccer. Sanders et al. [26] aimed to identify factors contributing to neuromuscular fatigue in NCAA DI women's basketball players assessing TLs and whether weekly changes contributed to alterations in neuromuscular fatigue using CMJ. Minimal reductions in CMJ performance, when compared to the first week, were observed when 3-day average TLs were decreased [26]. Given the similarities between the sports, exploration of CMJs as a measure of preparedness in NCAA DI women's soccer is warranted.

Therefore, the purpose of this study was to assess the repeated measures correlation of matchday CMJ height and the sums of TL variables for the microcycle preceding matchday in NCAA Division I women's soccer athletes. The second aim was to assess these relationships using the 3-day sums of TL variables preceding matchday. The latter is similar to the protocol performed previously in Sanders et al. [26] when the 3-day average of TLs was utilized with NCAA DI collegiate basketball players. It was hypothesized that matchday CMJ height would show negative moderate correlations with the sums of TL variables during the 3 days or microcycle preceding matchday.

Scientific Methods

Participants
Twenty-three NCAA DI women's soccer players older than 18 years of age were included in the study (20 ± 1.2 years; 1.69 ± 0.06 m). The dataset included 152 unique observations from eight in-season microcycles. Approval from the university's Institutional Review Board was obtained and data was de-identified to perform this retrospective analysis. Goalkeepers were excluded from this investigation due to the different nature of the physical demands experienced during a match when compared to field positions.

Protocol
This retrospective analysis utilized archived TL monitoring data from the fall 2020. Players were assessed as part of an NCAA DI women's soccer team's standard TL monitoring procedures. The TL data was summed for the microcycle (i.e., from the first practice following a match until the day before the next matchday) and the three days before matchday. Players wore their assigned Polar Team Pro (Polar Electro, Kempele, Finland) wearable module, located on the chest, continuously during the training sessions. The modules include a 10 Hz GPS [27] unit, an Inertial Measurement Unit (IMU), and a HR monitor [27]. Following each training session, the data from the Polar Team Pro modules were uploaded into the Polar Team Pro cloud-based server for future off-line analysis. Recently, Huggins et al. [28], suggested that the Polar Team Pro system provides reliable measures of GPS variables. Additionally, Polar HR sensors have shown to be valid (r = 0.997 during high-intensity activities with ECG Holter) and reliable [29–31].

The internal load was measured using sRPE-TL for the perceptual response and Polar Training Load Score (TLS) for the physiological response. Session rating of perceived exertion (sRPE) was measured using a Borg's Category Ratio-10 RPE scale, with verbal and visual anchors, approximately 10 minutes following the end of the training session during a brief cool-down [32]. A supporting staff member displayed the scale to each player and asked "what is your rate of perceived exertion for this session?" [32]. Practice duration was recorded and the sRPE value was multiplied by the session duration in minutes. The final product was considered the sRPE-TL score in arbitrary units. The TLS is a variable provided in the Polar Team Pro software which considers the athlete's heart rate response, calorie consumption, mechanical impact, and the duration of the session [27].

The external load variables utilized were total distance covered (TD), distanced covered at high-speed (< 15.0 km.h−1; HSD), mechanical load (ML), and number of sprints. The number of sprints was calculated as a sum of every moment the player reached a speed ≥ 15.0 km.h−1. HSD was defined as the total distance traveled ≥ 15.0 km.h−1. The ML was defined as the sum of all accelerations ≥ 2.0 $m.s^{-2}$ and decelerations ≤ -2.0 $m.s^{-2}$ (e.g., 32 detected accelerations ≥ 2.0 $m.s^{-2}$ and 49 decelerations ≤ -2.0 $m.s^{-2}$ equal a mechanical load score of 81). All objective data from the Polar Pro System were collected from the beginning of the warm-up until the end of the session.

CMJs were assessed approximately ~1 hour prior to eight in-season competitive matches. The athletes performed standardized pre-assessment warm-ups which included 10 bodyweight squats and 10 bodyweight squat-jumps. Immediately following, three successive maximal CMJs were measured using a contact mat (Just Jump System, Probotics, Huntsville, AL, USA). The athletes were instructed to keep their hands placed at their hips throughout the CMJ movement to prevent the influence of the arm swing in the lower body fatigue assessment. The two highest jumps were averaged and used as the CMJ height in the analyses.

Statistical Analysis
All training load variables were summed for the microcycle and the 3 days preceding matchday. The within-subjects' relationships between matchday CMJ height and the sums of training load variables preceding matchday were analyzed through repeated measures correlations 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). This analysis was chosen to avoid violating the assumption of independence as suggested previously [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 0.8-1. McMahon et al. [35] suggested that the Just Jump System overestimates jump height when compared to a force platform. However, both measures showed excellent relationship (r = 0.998). Thus, a correction equation based on the linear regression was provided to be used with jump heights measured with the contact mat. Corrected CMJ height values were calculated using the correction equation: corrected jump height = (0.8747 x measured jump height) – 0.0666 [35]. 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 presented in **Table 1**. The results from the repeated measures correlations are presented in **Table 2**. Nonsignificant very weak positive relationships (i.e., higher sums of TL variables lead to higher matchday CMJ height values) were observed between matchday CMJ height with the 3-day sums of the training load variables (except sRPE-TL) preceding the match: TD (r = 0.143, p = 0.103, 95% CI = -0.031, 0.309), TLS (r = 0.147, p = 0.093, 95% CI = -0.026, 0.313), HSD (r = 0.108, p = 0.219, 95% CI = -0.066, 0.277), ML (r = 0.112, p = 0.202, 95% CI = -0.0623, 0.281), and number of sprints (r = 0.104, p = 0.235, 95% CI = -0.070, 0.273). A significant weak positive correlation was observed between matchday CMJ height and sRPE-TL (r = 0.177,

p = 0.043, 95% CI = 0.004, 0.340). Significant very weak to weak negative (i.e., lower sums of TL variables lead to higher matchday CMJ height values) within-subjects correlations were observed between matchday CMJ height with the sums of the training load variables for the microcycle preceding the match: sRPE-TL (r = -0.184, p = 0.036, 95% CI = -0.348, -0.010), TD (r = -0.229, p = 0.008, 95% CI = -0.388, -0.058; **Figure 1**), TLS (r = -0.192, p = 0.028, 95% CI = -0.355, -0.019), HSD (r = -0.229, p = 0.008, 95% CI = -0.389, -0.058), ML (r = -0.204, p = 0.020, 95% CI = -0.365, -0.031), and number of sprints (r = -0.237, p = 0.006, 95% CI = -0.395, -0.066; **Figure 2**).

Table 1. Means and standard deviations of variables of interest (n = 23)

	Microcycle		3-day	
	Mean	SD	Mean	SD
CMJ Height, cm	45	4.9	45	4.9
Corrected CMJ Height, cm	39	4.3	39	4.3
sRPE-TL, A.U.	1,421	711.2	713	245.3
TD, m	17,197	6,062.2	10,629	3,010.0
Number of Sprints, count	146	72.6	83	32.6
TLS, A.U.	491	217.1	283	106.0
HSD, m	1,615	900.1	959	418.8
ML, count	435	172.9	252	83.9

SD = standard deviation, CMJ = countermovement jump, cm = centimeter, sRPE-TL = session rating of perceived exertion training load, A.U. = arbitrary units, TD = total distance, m = meters, TLS = training load score, HSD = high-speed distance, ML = mechanical load; Corrected CMJ Height = (0.8747 x measured jump height) – 0.0666.

Table 2. Repeated Measures Correlations between matchday CMJ height and training load variables

	Microcycle Training Load Variables					
	sRPE-TL	TD	TLS	HSD	ML	Number of Sprints
r	-0.184	-0.229	-0.192	-0.229	-0.204	-0.237
95% CI - Lower Limit	-0.348	-0.388	-0.355	-0.389	-0.365	-0.395
95% CI - Upper Limit	-0.010	-0.058	-0.019	-0.058	-0.031	-0.066
df	128	128	128	128	128	128
p-value	0.036	0.008	0.028	0.008	0.020	0.006

	3-day Training Load Variables					
	sRPE-TL	TD	TLS	HSD	ML	Number of Sprints
r	0.177	0.143	0.148	0.108	0.112	0.105
95% CI - Lower Limit	0.004	-0.031	-0.026	-0.066	-0.062	-0.070
95% CI - Upper Limit	0.340	0.309	0.313	0.277	0.281	0.273
df	128	128	128	128	128	128
p-value	0.044	0.104	0.093	0.220	0.203	0.236

CMJ = countermovement jump, sRPE-TL = session rating of perceived exertion training load, TD = total distance, TLS = training load score, HSD = high-speed distance, ML = mechanical load.

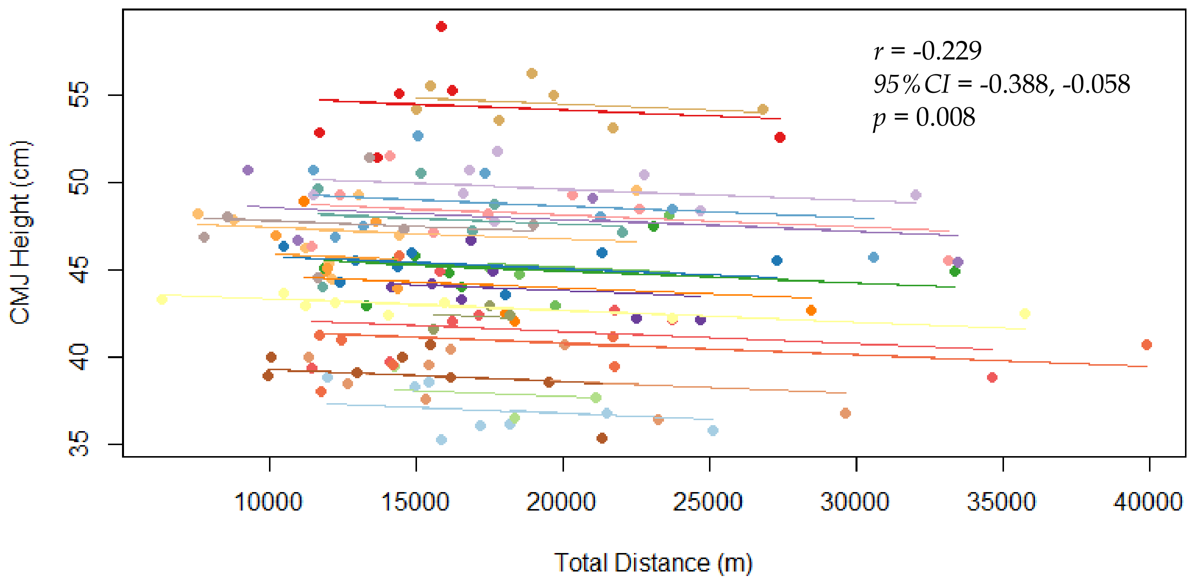

Figure 1. Repeated measures correlation between matchday CMJ height and the sum of TD for the microcycle preceding matchday. Each participant's corresponding regression line is shown in a different color.

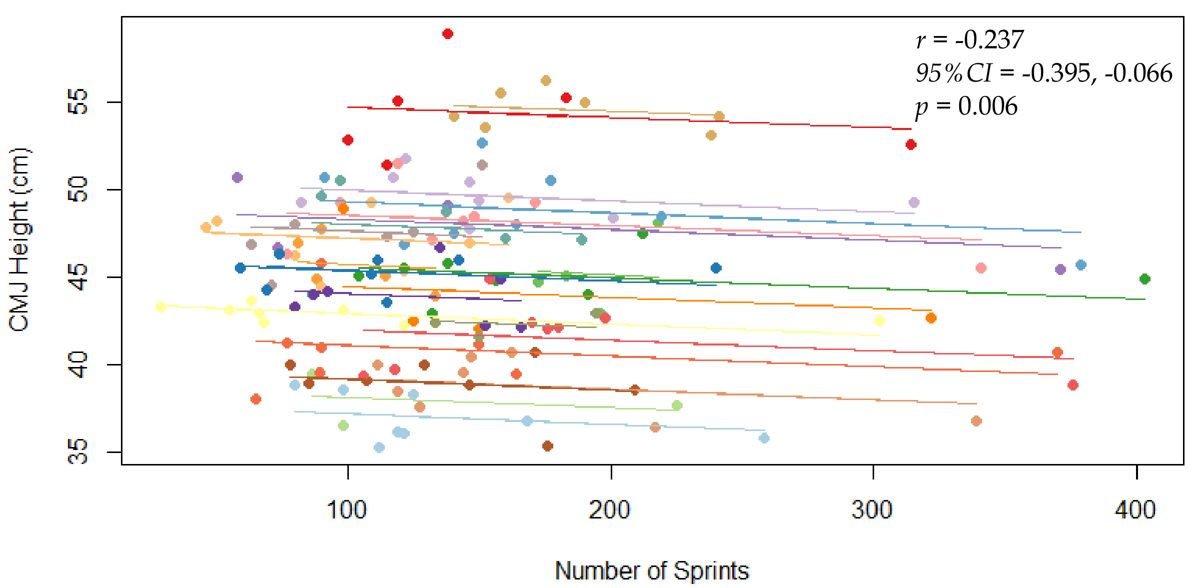

Figure 2. Repeated measures correlation between matchday CMJ height and the total number of sprints for the microcycle preceding matchday. Each participant's corresponding regression line is shown in a different color.

Discussion

This investigation aimed to evaluate the relationships between matchday CMJ height and the sums of internal and external TL variables for the microcycle and for the three days preceding the match in NCAA DI women's soccer players. It was hypothesized that matchday CMJ height would show negative moderate correlations with the sums of TL variables during the 3 days and microcycle preceding matchday. However, the results presented here suggest that the sums of training load variables for the microcycle are only weakly or very weakly negatively (i.e., lower sums of TL variables lead to higher matchday CMJ height values) correlated to CMJ height during matchday (Table 2, Figure 1, and Figure 2) and thus, does not appear to predict much of the variance in CMJ height. For example, the relationship between CMJ height and HSD was weak and HSD only explained 5.6% of the variance in CMJ height (r = -0.237, r^2 = 0.056, p = 0.006). Although partially significant, the results suggest that the sums of training load variables preceding matchday may not be adequate indicators of matchday preparedness in collegiate DI women's soccer.

According to the author's knowledge, this was the first investigation to correlate internal and external load variables with matchday CMJ height in collegiate women's soccer. The rationale for the current investigation's hypotheses relied on the expected variability in the fatigue responses from periodized TLs imposed by the coaching staff throughout the season. Recent investigations have focused on using CMJ metrics to quantify neuromuscular fatigue following matches compared to pre-match values [1,2,24,25]. Given the high rate of injuries in collegiate soccer [12] and its relationship with increased TLs [8–11] and increased acute:chronic workload ratio (ACWR) [36], allowing adequate recovery may potentially minimize injury risk. The goal of the current investigation was to evaluate whether CMJ performance was linked to the prior week's acute TLs and subsequently to propose a new TL monitoring strategy. However, given the results, the use of acute TLs to predict matchday readiness are not recommended.

It has been proposed that CMJ height is not as sensitive comparatively to CMJ metrics derived from force plates [1,37]. Potentially, had the use of alternative metrics (e.g., peak power, peak force, eccentric impulse, concentric impulse, bilateral asymmetries, etc. [1,2,24]) been examined utilizing the current investigation's design, relationships could have been observed. In elite female rugby athletes, Gathercole et al. [37] observed reductions in CMJ flight time, but not in CMJ height following weeks with increases in training load. It is possible that the estimated jump heights from flight time are not as sensitive to detect subtle fatigue-induced differences [37]. Thusly, direct measures of CMJ height (i.e., 3D motion capture systems or Vertec) may show to be more sensitive to detect neuromuscular fatigue [37]. However, jump mats are more easily accessible (i.e., low cost) and convenient when assessing CMJ's of an entire team in condensed time periods. Future investigations should aim to incorporate the use of force plate CMJ metrics to predict match external load performance, potentially providing the coaching staff a pre-match indication of athlete readiness.

Current scientific literature has explored the ACWR which is calculated by dividing the acute (one week) and chronic (four weeks) workloads. In youth women's soccer, increases in the acute TLs in relation to the chronic TLs have been associated with increased incident of injuries (OR = 1.59, p = 0.033) [36]. In professional men's soccer, Malone et al. [38] have concluded that players who had in-season ACWR between 1.0 and 1.25 were at lower risk of injury compared to the reference group (OR = 0.68, p = 0.006). However, the association between ACWR and injuries has not been observed in a number studies and thusly, should be interpreted with caution [39,40]. In the context of the current study, measures which include the chronic TLs like ACWR could have provided a different perspective into the relationship between TLs and matchday CMJ height. It is possible that CMJ height could be greater influenced by the interaction between acute and chronic TLs, through large increases or decreases in acute load when compared to chronic load, rather than the absolute acute loads. Perhaps, chronic loads may directly influence the magnitude of acute metabolic fatigue in response to high-intensity activities. However, the current investigation aimed to address the influence of acute TLs on matchday CMJ height.

Limitations

The microcycles during this season were controlled by the coaching staff and there were differences in the number of training sessions. For example, one match previously scheduled for a Sunday had to be postponed to the following Tuesday due to inclement weather, adjusting subsequent training. However, the variability in the length of the microcycles was partially addressed by including the 3-day sums of TLs in the analysis. In addition, these differences increase the applicability of the current investigation as collegiate soccer seasons are often impacted by challenges with the logistics or weather. This study was conducted during the fall 2020 season which, due to COVID-19, limited the number of matches to only one match per week and only eight per season. This provided a unique opportunity to explore the TLs from controlled training sessions with only one match per week. In a typical NCAA DI soccer season (i.e., any year except 2020), the weekly TLs would likely include larger variability due to multiple matches per week.

Lastly, it has been proposed that the Just Jump System is a reliable measure but overestimates CMJ height [35]. However, in this examination, we were interested in the relationships among variables, which are not affected by linear transformations to any of the variables. For this reason, though corrected CMJ height values were provided in **Table 1**, these differences were not extensively discussed in this manuscript.

Conclusions

Significant very weak to weak negative repeated measures correlations were observed between matchday CMJ height with the sums of the training load variables for the microcycle preceding the match. Although significant, the results suggest that the sums of TL variables preceding matchday may not be reliable indicators of matchday preparedness in collegiate DI women's soccer. Alternative methods including force plate variables, such as peak force, eccentric impulse, concentric impulse, and bilateral asymmetries should be explored instead of simply utilizing CMJ height. Future research should aim to address other strategies to predict matchday preparedness in collegiate women's soccer in order to enhance training periodization to better prepare the athletes for competition.

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