Contextual Factors Influencing External and Internal Training Loads in Collegiate Men's Soccer

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Abstract

Curtis, RM, Huggins, RA, Benjamin, CL, Sekiguchi, Y, Adams, WM, Arent, SM, Jain, R, Miller, SJ, Walker, AJ, and Casa, DJ. Contextual factors influencing external and internal training loads in collegiate men's soccer. *J Strength Cond Res* 34(2): 374–381, 2020—This study investigated factors influencing training loads (TL) in collegiate men's soccer. Total distance, high-speed running distance (>14.4 km·h^{-1}), high-intensity heart-rate zone duration (HI HRZ, $>70\%$ heart rate relative to maximum), and session rating of perceived exertion were assessed daily from 107 male soccer players competing for 5 National Collegiate Athletics Association Division I teams. Differences between athlete role (starter and reserve), position (defender, midfielder, and forward), season phase (preseason, in-season, and postseason), days relative to match (MD-1 to MD-5+), days between matches (<4, 4–5, >5 days), previous match outcome (win, loss, and draw), and upcoming opponent relative ranking (weaker, trivial, and stronger) were examined. Mean differences (MD) and effect sizes (ESs) with 90% confidence intervals were reported. There were trivial and insignificant differences by player role, position, or upcoming opponent strength, and small-moderate increases in preseason TL compared with in-season (ES [range] = 0.4–0.9). TLs were lower for MD-1 and higher for MD-5+ (ES [range] = 0.4–1.3) when compared with MD-2-4. External loads (ES = -0.40 ± 0.20) were less after wins compared with losses. TLs are increased in the preseason, when training sessions occur greater than 5 days from a match and after losses. Contextualizing factors affecting TLs has implications for developing workload prescription and recovery strategies.

Key Words: GPS, player tracking, sports science, team sport, athlete monitoring

Introduction

Workload management has become commonplace as a strategy to promote positive biological adaptation, expediting recovery, optimizing performance, and reducing injury risk of elite and developing athletes (42). Accordingly, workload management involves the appropriate prescription, monitoring, and adjustment of both external (i.e., external stimulus applied irrespective of internal characteristics) and internal loads (i.e., individual response to an external stimulus) (1,23). Different from workload sustained in a match, training load (TL) is modifiable and can be structured to promote positive physiological adaptations and performance improvements (43). However, if the balance between workload and recovery is not managed properly, the athlete's ability to positively adapt is diminished, or worse, injury and illness risk is elevated (39,42). This provides strong rationale for coaches to track and manage training loads effectively.

The workload demands of soccer competition have been assessed in a host of populations including elite male (5,7,16), female (28), collegiate (15), and youth (11) athletes. Although previous studies have investigated TL in elite professional (3,21,30,35) and youth (44) soccer, collegiate-level training sessions are not well understood. With that, the structure of the collegiate soccer season is structurally different from other elite standard leagues (15). The short (i.e., ~15 weeks) and congested (i.e., 2–3 matches per week) match calendar in collegiate soccer presents a degree of complexity for coaches and practitioners to consider when attempting to manage loads and maximize player health and availability (9,29).

Suggested by Paul et al. (37), some approaches to quantifying workloads could be considered reductionist. That is, workload metrics are often investigated without regard to the many factors that influence them and thus fail to acknowledge the complexity of soccer workload demand. However, some have attempted to quantify TLs by considering a variety of factors such as season type (25,30,31), position (2,21,30,36), match location and match outcomes (10,36), and days relative to an upcoming match (2,30,36). Understanding the effect of various contextual factors on physical workloads is necessary for sport coaches and practitioners, where precise management of physiological stress-recovery balance becomes a critical tool for mitigating injury risk and maximizing player availability.

The effects of contextual factors on TL has exclusively been explored in professional soccer and largely with English Premiere League (EPL) players (2,3,21,30,36). Furthermore, most investigations have elected to quantify the effect of 1–2 factors on a larger number of TL metrics. Therefore, the purpose of this study was to examine 7 separate contextual factors' influence on both external and internal TLs in National Collegiate Athletics

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Association (NCAA) Division I men's soccer players. Specifically, we examine the influence of player role, position, season phase, days relative to match, days between match, previous match outcome, and opponent rank differential on TLs.

Methods

Experimental Approach to the Problem

Objective workload data were collected over the full collegiate soccer season (August–November) during the 2016 (1 team) and 2017 (4 teams) seasons. In the current investigation, one observation included aggregate workload data (e.g., total distance [TD] covered) for one player participating in one NCAA-sanctioned training session or match. Because the purpose of this investigation was to isolate the effects of contextual factors on training loads, match data (n = 1,902 observations) were excluded. A total of 4,224 (range: 43–71 per player) training observations were analyzed.

Several situational and contextual factors with the potential to affect training session workloads were selected for analysis. To assess differences between player role within the team, athletes were deemed *starters* (n = 2,183 observations) if they competed in greater than 60% of the total match time and started in greater than 60% of the total matches in the season (3), and all other athletes were considered *reserves* (n = 2,041 observations). Players were additionally divided into position groups consisting of *defenders* (n = 1,497), *midfielders* (n = 1,557), and *forwards* (n = 901). To examine the effect of season phase, TLs during *preseason* (n = 1,083), *in-season* (n = 2,454), and *postseason* (n = 688) were considered, with postseason referring to the period directly following the in-season where conference and NCAA tournament play occurs. All 5 teams in this study participated in postseason tournament play. Individual TL sessions were additionally classified by days relative to an upcoming match (match day minus [MD−]). Data were analyzed for 1 (MD-1, n = 1,382), 2 (MD-2, n = 1,189), 3 (MD-3, n = 716), 4 (MD-4, n = 423), and 5 *or greater* (MD-5+, n = 514) days before a match. To examine the effect of the number of days between matches, TL sessions were grouped into levels of *less than* 4 days (<4 days, n = 648), 4–5 days (4–5 days, n = 1,609), and *greater than* 5 days (>5 days, n = 1,967). Previous match outcome was considered by grouping training sessions according to *win* (n = 1,598), *loss* (n = 1,762), or *draw* (n = 218). All training sessions following the previous match outcome were included in the analysis. The effect of upcoming opponent strength on TLs was assessed by classifying opponent final season rating percentage index relative to the reference teams' final season RPI. Final season RPI was acquired for each participating team retrospectively (17). Out of 206 nationally ranked NCAA Division I institutions, teams in this study finished the season with a national ranking of 59, 90, 100, 120, and 140. A rank differential metric was computed and a classification of *trivial* was given to opponents ranked within ±25 positions of the reference team. Opponents ranked more than 25 positions higher were considered *stronger*, whereas opponents ranked more than 25 positions lower were considered *weaker*.

Subjects

One-hundred seven NCAA Division I male collegiate soccer players (mean + *SD*: age, 20 ± 2 years; body mass, 77.4 ± 5.1 kg; height, 179.9 ± 6.5 cm; %body fat, 9.9 ± 2.4%; $\dot{V}O_2max$, 53.8 ± 4.1 ml·kg^{-1}·min^{-1}) from 5 different universities participated in this study. All subjects were medically cleared for physical activity by their respective university's sports medicine department and free of any debilitating musculoskeletal injuries or contraindicated medical conditions. Institutional review board (IRB) and ethics approval was obtained from all institutions, with primary oversight and coordination provided by the university of University of Connecticut (IRB Approval ID: H17-134). All subjects provided written informed consent before the season. When the subject was younger than 18 years of age, parental consent was also obtained.

Procedures

Heart rate (HR) and global positioning satellite (GPS) player tracking devices were used to capture external and internal loads during all training sessions and matches (Polar Team Pro; Polar Electro, Lake Success, NY). The 10-Hz GPS player tracking device has reported accuracy and reliability outdoors for 40 and 100 m TDs at 4 separate movement (i.e., walk, jog, run, and sprint) velocities (mean difference = −1.04 to −2.78 m; coefficient of variation = 1.17–3.16%) and during a team sport simulation circuit (mean difference = 0.23 m; CV = 0.96%) (22). Devices were attached to the body using a chest strap before the start of each practice. To reduce interunit error, players wore the same device for each training sessions (24). Players donned the player tracking device before the beginning of the session warm-up and wore it until the end of the last organized training activity. After each training session was completed, data were synced through the cloud to a Polar Electro server and subsequently exported to Microsoft excel spreadsheets (Microsoft Corporation, Redmond, WA) for analysis. External TL parameters selected as dependent variables in this analysis included TD (m) and high-speed running distance (HSR; >14.4 km·h^{-1}, m). For assessment of training session internal load, both physiological and perceptual methods were used. Objective internal load was assessed using a high-intensity HR zone (HI HRZ) consisting of total duration (minutes) above >70% HR relative to maximum (HRmax). This threshold was selected for a representation of match-specific cardiovascular loading as previous work has found collegiate men's soccer athletes average intensities of 78 ± 8% HRmax during matches (15). In addition, within 15 minutes after training session, athletes were asked "How hard was your session?" using a CR-10 scale for rating of each athlete's perceived exertion during the session (20). Session rating of perceived exertion (sRPE, a.u.) was calculated as the product of total session duration in minutes and rating of perceived exertion (RPE, a.u.) (20). Each athlete's maximum HR and estimated maximal oxygen uptake were assessed during their respective team's preseason fitness testing, which consisted of either a repeated sprint test (Yo-Yo intermittent recovery test (27) or 30-15 intermittent fitness test (14)) or graded incremental treadmill run to exhaustion through respirometry (TrueOne; Parvo Medics, Sandy, UT) (40). During the graded treadmill exercise test, a 2% grade was used and speed was increased every 2 minutes until exhaustion occurred. Speed was increased according to observed expiratory levels to ensure that the test duration was between 8 and 12 minutes in length, so as not to induce muscular fatigue.

Statistical Analyses

Descriptive statistics are presented as mean and *SD*. Multilevel mixed-effects models were used to assess differences between fixed contextual factors. Mixed modelling was used for its ability to cope with unbalanced and repeated-measures data (13). To account for individual and team differences, a multilevel random intercept was set with players nested within their respective team. For all fixed factors (i.e., role, position, season phase, days relative to match, days between match, previous match outcome, and opponent rank differential), pairwise differences were assessed post hoc using Tukey's HSD. Alpha level was set at $p \leq 0.05$. Differences were divided by square root of the sum of the intercept and residual variance components in the model to determine a standardized effect size (ES) for each difference between categorical fixed factor. Effect size and confidence intervals (ES ± 90% CI) were calculated to quantify the magnitude of pairwise differences. Effect size was interpreted according to the following thresholds: <0.2 = trivial, 0.2–0.6 = small, 0.7–1.1 = moderate, 1.2–2.0 = large, and >2.0 = very large (6). Statistical analyses were conducted in R Studio (Version 3.2.5, R Core Team).

Results

Table 1 displays average TL descriptive data for each contextual factor and is presented as mean (*SD*). Starters accumulated 79.2 ± 18.8% of the total match minutes, started in 81.6 ± 22.1% of the total matches, equating to 15 ± 4 starts during the season. Reserves accumulated 19.6 ± 19.8% of the total match minutes, started in 16.8 ± 21.4% of the total matches, equating to 3 ± 4 starts during the season.

Figure 1 and Figure 2 display class level comparisons for the effect of contextual factors on external TLs (i.e., TD and HSR) and internal TLs (i.e., HI HRZ and sRPE), respectively. Results indicated that there were no significant differences in TD, HSR, or sRPE between starters and reserves during training, but a small reduction in starter HI HRZ duration (MD = −4.35 minutes, ES = −0.43 ± 0.23). There were no significant differences in TD, HSR, sRPE, or HI HRZ between playing positions.

Average preseason TLs were greater when compared with in-season for both external (TD, MD = +651 m, ES = 0.48 ± 0.24; HSR, MD = +157 m, ES = 0.48 ± 0.24) and internal measures (HI HRZ, MD = +3.6 minutes, ES = 0.36 ± 0.25; sRPE, MD = +164au, ES = 0.85 ± 0.41). There was a trivial decrease in TD (MD = −238.33, ES = −0.18 ± 0.11) and small increase in training HSR (MD = +101 m, ES = 0.28 ± 0.13) during post-season compared with in-season training sessions; however, internal workloads were unchanged between these phases.

There were mostly moderate to large reductions in external and internal workloads for MD-1 compared with all other days relative to a match (ES [range] = 0.64–1.82). Similarly, there were small increases in TD (ES [range] = 0.42–0.55), small to moderate increases in HSR and HI HRZ (ES [range] = 0.41–0.75), and moderate to large increases in sRPE (ES [range] = 0.75–1.61) for MD-5+ compared with MD-2, MD-3 and MD-4.

There were moderately lower external and internal TLs for <4 days between matches compared with 4–5 days and >5 days (ES [range] = 0.62–0.1.15). Differences between 4 and 5 days between matches and >5 days between matches were either insignificant (HI HRZ) or trivial-small (TD, ES = 0.16 ± 0.08; HSR, ES = 0.20 ± 0.07; sRPE, ES = 0.55 ± 0.17).

Table 1

Descriptive statistics for total distance (TD), high-speed running distance (HSR), high-intensity heart-rate duration (HI HRZ), and session RPE (sRPE).*†

	mean ± *SD*, TD (m)	HSR (m)	HI HRZ (minutes)	sRPE (au)
Role				
Starter	4,387 (1,867)	537 (484)	30 (18)	407 (247)
Reserve	4,505 (1,942)	560 (485)	36 (20)	431 (261)
Position				
Defender	4,556 (1,929)	534 (451)	33 (20)	386 (242)
Midfielder	4,624 (1,982)	614 (494)	35 (20)	452 (262)
Forward	4,268 (1,769)	569 (516)	30 (18)	422 (256)
Season phase				
Preseason	5,150 (1,861)	560 (501)	41 (20)	611 (263)
In-season	4,209 (1,798)	554 (471)	31 (18)	385 (219)
Postseason	4,197 (2,078)	531 (485)	31 (19)	420 (286)
Days relative to match				
MD-1	3,608 (1,284)	388 (342)	24 (14)	322 (199)
MD-2	4,766 (1,719)	603 (434)	36 (17)	459 (236)
MD-3	4,660 (2,299)	618 (599)	38 (23)	440 (290)
MD-4	4,902 (2,164)	576 (472)	41 (22)	537 (308)
MD-5+	5,304 (2,079)	736 (616)	40 (20)	546 (209)
Days between match				
<4 days	3,320 (1,280)	333 (286)	24 (15)	297 (184)
4–5 days	4,476 (1,785)	571 (514)	33 (18)	443 (228)
>5 days	4,798 (2,030)	602 (492)	37 (20)	456 (284)
Previous match outcome				
Win	4,105 (1,925)	468 (429)	31 (20)	371 (257)
Loss	4,480 (1,872)	583 (542)	32 (18)	438 (250)
Draw	4,494 (1,621)	519 (347)	31 (16)	404 (251)
Opponent rank				
Stronger	4,626 (1,796)	506 (467)	34 (20)	504 (223)
Trivial	4,202 (1,967)	577 (576)	32 (19)	386 (236)
Weaker	4,267 (1,967)	628 (448)	34 (20)	412 (280)

*au = arbitrary unit.

†Data are presented as mean (*SD*). Congestion refers to the number of matches completed in the previous 7 days.

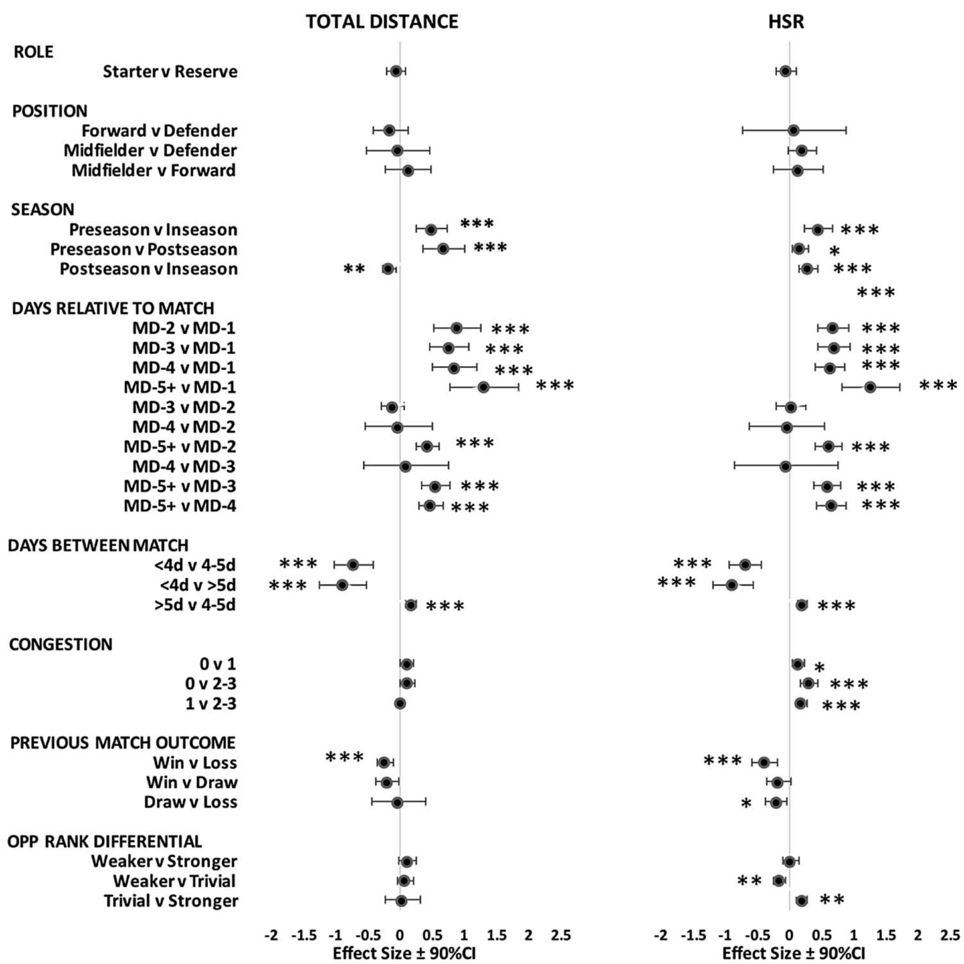

Figure 1. Factor class comparisons for external load metrics of total distance (TD) and high-speed running distance (HSR) expressed as effect size (ES) ± 90% CI. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. MD− = match day minus; W = win; L = loss; OPP = opponent; CI = confidence interval.

There was evidence of a small effect of previous match outcome on external but not internal TLs. Training session TD (MD = −327 m, ES = −0.24 ± 0.09) and HSR (MD = −143 m, ES = −0.40 ± 0.20) were less after wins compared with sessions after a loss. There were no significant differences seen between win or loss and previous match outcome of draw. Differences in training session loads between various upcoming opponent strengths were also trivial and insignificant.

Discussion

We found differences in both external and internal TL by season phase, days relative to match, days between match, and previous match outcome. Equally noteworthy, there were mostly insignificant differences in average TLs when the athlete's role, position, and upcoming opponent relative ranking were considered. Taken together, these findings have implications for management of athlete preparation and recovery throughout the course of a competitive soccer season.

Limited attention has been paid to quantifying differences in average TLs between starter and reserve players in soccer, despite important implications match exposure has on player workload management. This is particularly relevant in the current cohort where reserves received only 1/5 of total match exposure throughout the competitive season. Anderson et al. found significantly higher accumulated TD for reserves during training but no differences between player roles when total accumulated TD over the whole season (i.e., training + match workloads) was considered (3). Although in the current study we report average values instead of seasonal accumulated values, we found no differences in external loading (i.e., TD and HSR) by starting status. We did find a small but significant difference in HI HRZ (ES = 0.43 ± 23), with starters averaging less high-intensity HR minutes compared with reserves. These findings of higher physiological but not physical loading may suggest a potential discrepancy in efficiency (i.e., external:internal load) for reserves compared with starters. It is inherent that reserves will receive less match-specific loading and therefore may be lacking in physical capacity maintenance during the season when compared with their counterparts receiving match time. On the contrary, these results may simply be indicative of a role selection bias, whereby starters receive greater match time due to their greater physical capacity. In either scenario, these findings may support reports of increased levels of aerobic fitness in players receiving more match time (41).

Several studies have investigated positional TL profiles in professional soccer cohorts (2,21,30,36), although to the best of our knowledge, no such work exists in collegiate populations.

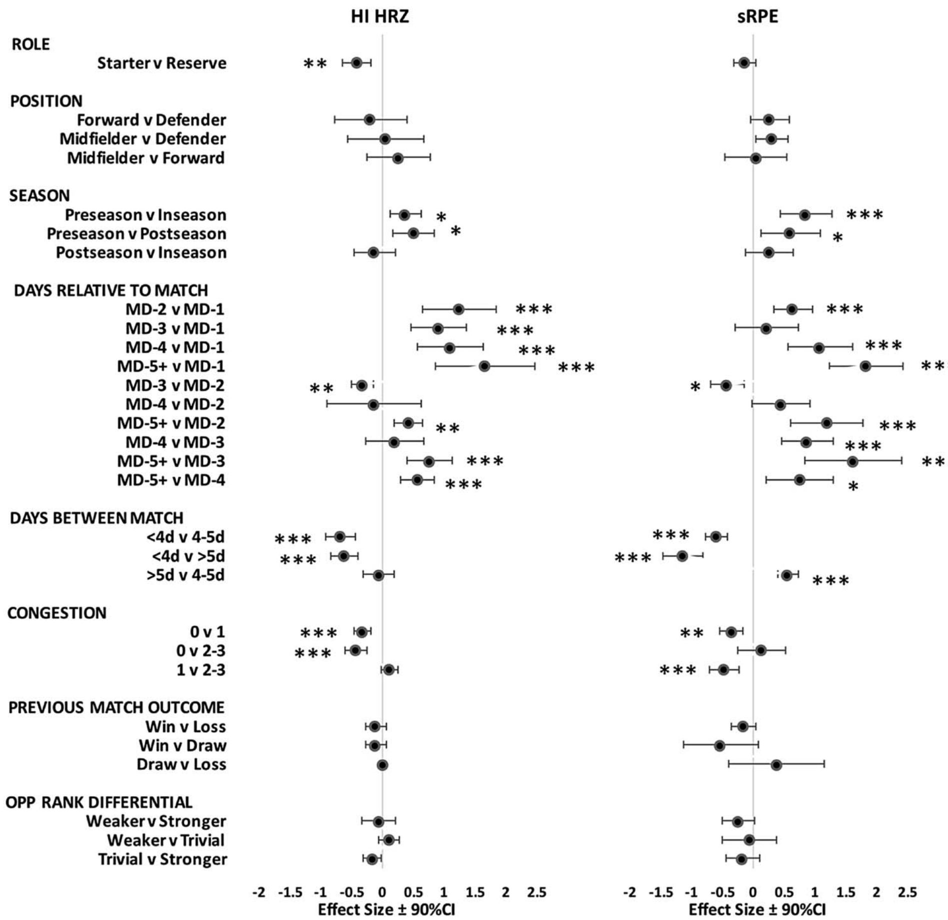

Figure 2. Factor class comparisons for internal load metrics of session RPE (sRPE) and high-intensity heart-rate zone minutes (HI HRZ) expressed as effect size (ES) ± 90% CI. **p* < 0.05; ***p* < 0.01; ****p* < 0.001. MD− = match day minus; W = win; L = loss; OPP = opponent; CI = confidence interval.

Efforts to identify factors affecting the training demands of soccer have focused mostly on the interaction of position and days relative to a match (30,36) or match congestion (2). Previous investigations on EPL players have found defenders to have the highest HRs relative to maximum of all positions (30) and center midfielders to accumulate significantly more TD during training than all other positions except forwards (21). These observations suggest that internal workloads may be higher and external workloads lower for defenders compared with midfielders and forwards. However, we found no differences in average external or internal TLs between positions in collegiate men's soccer. This is important to note because previous literature has shown that several differences exist between positions for external and internal workloads in both collegiate and professional matches (15,18). The lack of difference noted by position in collegiate soccer training, but not matches, could indicate a lack of position-specific preparation strategies used at the collegiate level. However, given the wealth of differences in the way the game is played in NCAA collegiate soccer (e.g., substitutions, clock stoppages, and seasonal structure), this conclusion is deficient without investigating the effectiveness of current positional preparation strategies used.

As expected, our study found substantial differences in TL by season phase. From a training perspective, the preseason period focuses on rebuilding physical capacities that may have been lost over the offseason, whereas the in-season training programs focus primarily on maintaining physical capacities developed during the preseason (25,38). Our study corroborates the findings of Jeong et al. (25) who found internal workloads (i.e., %HRmax) were significantly higher during preseason vs. in-season training periods in Korean professional soccer players. In addition to intensified physiological loading during the preseason, we found greater amounts of TD and HSR in the preseason compared with the in-season period. As expected, the preseason period in collegiate soccer demands higher physical and physiological workloads and work rates than other times of the season. These results present important considerations for strength and conditioning coaches because higher preseason workloads have been associated with increased injury incidence and proportion (26). Noya Salces et al. (34) found that injury incidence was highest for Spanish professional soccer players during preseason training (6-weeks) and generally decreased throughout the in-season period ($p < 0.05$). This latter point has important implications on the primary purpose of the preseason period, to rebuild physical capacities (38), as Eliakim et al. (19) showed that increases in aerobic fitness ($\dot{V}O_2max$) of Israeli professional soccer players were significantly lower for players who sustained an injury during the 6-week preseason (0.9 ± 5.5%) compared with those who did not (10.4 ± 6.5%, $p < 0.05$). Although to the best of our knowledge no studies exist examining the effect of a very short preseason period on injury rate, the negative effect of intensified preseason training on injury and aerobic fitness development seen in professional soccer may be compounded by the relatively short (~2 weeks) period the NCAA allows for the college soccer preseason. Furthermore, coaches should consider that physiological adaptations and improvement in aspects of fitness made during the short preseason period will likely not be realized until much later into the in-season period after competition play has begun. Coaches and athletes should consider preemptive measures (e.g., increased off-season development) to ensure fitness is appropriately addressed before and during the preseason period and balance intensified preseason loads with adequate recovery to reduce injury risk. Our investigation also compared postseason TL with both preseason and in-season periods, which has not been documented in previous literature. Postseason periods are primarily concerned with maximizing readiness and peaking (38). Our results indicate that decreases in postseason HSR compared with the in-season period occurred. This finding may reflect collegiate teams' effort at peaking and tendency to decrease high-speed loading so as to minimize muscle tissue breakdown and soreness (33) and promoting optimal readiness and recovery. By contrast, these reductions may reflect fatigue and reduced capacity for HSR subsequent to the congested NCAA soccer calendar.

Analysis of the effect of days relative to a match revealed differences between MD-1 and all other relative days for TD, HSR, HI HRZ, and sRPE during training. These findings are consistent with others who have investigated EPL soccer training loads and found TL reductions are confined primarily to the day before a match (30,36). Also noteworthy, we found no differences in TL metrics 2–4 days before a match. In comparison to previous works, Owen et al. (36) found 3 days before a match demonstrated the highest TLs of all training days relative to a match (1–4 days), with loads progressively decreasing from day 3 rather than an abrupt decrease on day 1. Similarly, Anderson et al. (2) found TLs progressively decreased from 3 days out, but only during 1-match week schedules and not with 2 or 3-match weekly schedules. Our results were more consistent with an investigation by Malone et al. (30) on EPL players who found no differences in TLs between 2 and 4 days before a match. Our results suggest collegiate periodization strategies are limited to TL reductions 1 day before a match, which may be a potential area of change for NCAA sport and strength and conditioning coaches. With TLs being elevated 2 days removed from a match, concerns regarding the full recovery of NCAA players is warranted, given that 3 days is considered an essential recovery period for normalizing physical performance, indicators or fatigue, and inflammation from extensive physical stress, as seen in physical demanding training or match play (4,33). It is, however, relevant to consider that NCAA soccer teams average 1 match approximately every 4 days (15), with some matches occurring with as little as 2 days of recovery, thereby limiting the available time for adequate periodization of TLs. Our study did observe substantial increases in external loading when practices were held at least 5 days before compared with 1–4 days before a match, suggesting TLs were elevated when more days were allotted between games. Overall, the current congestion and variability seen within NCAA match scheduling does present challenges for appropriate periodization of TLs. The integration of individualized monitoring of training stress and recovery to optimize match readiness is warranted.

It had been previously observed that physical loading during matches is greater against similarly ranked opponents in both male and female soccer, which is attributed to a greater perceived chance of winning (12). In this light, it might be expected that training loads would be altered in preparation for opposition level. Previous investigations examining the effect of opposition level on match (12) and training (10) workloads have come in the form of ranking the opposition according to their season-end league position. However, our study took a novel approach in that instead of using an absolute ranking we computed and classified the opposition relative to the reference team. In comparison with earlier literature, Brito et al. found weekly TLs were highest when facing moderately ranked opposition compared to strong or weak opposition. By contrast, our study did not find upcoming opposition level to be a factor affecting training loads. These findings could speak to differing training structures and programming between academy and collegiate leagues or to the short and congested NCAA collegiate soccer season, where substantial importance is placed on every match. These results may additionally be explained by the unique opposition ranking strategies used in the current study. Further studies should investigate the effect of real-time opposition ranking on training characteristics.

Although this investigation presents a novel study of contextual factors affecting collegiate men's soccer workloads, this study is not without limitations. These results may be biased toward the coaching philosophies and tactical formations of the teams investigated (8). Furthermore, miscellaneous activities such as drink and training breaks were not controlled for in this analysis, which may have varied between teams depending on facility locations and potentially led to overestimation in accumulated TD. Our study used preseason fitness tests to establish maximal HR values for each athlete, which may not account for changes in maximum HR over the complete season due to increases or decreases in aerobic fitness. Due to the multisite nature of this investigation, standardization of preseason fitness testing across institutions was not achieved. Although both laboratory and field testing of cardiorespiratory fitness are common among elite soccer teams, there are inherent dissimilarities between continuous graded treadmill and intermittent run testing protocols used in this investigation. In addition, validation of maximal oxygen uptake and maximal HR measures has not been assessed in collegiate male soccer athletes for the Yo-Yo intermittent recovery test and 30-15 intermittent fitness test. However, maximal HR attained during field-based intermittent recovery testing has shown to not differ from values obtained during maximal treadmill run testing in soccer players (32). Currently, there is no consensus regarding classification of starter and reserve soccer players when investigating multiple matches over an entire competitive season. Similar to prior research with professional soccer players (3), which categorized players by starting status based on the proportion of matches started throughout the season (>60% of matches started), we classified player roles by the combination of total matches started and total seasonal match minutes. This was necessary to account for the frequent substitution strategies often used in NCAA collegiate soccer, whereby a player may not start the match but still receive substantial playing time. In addition, the positional classifications in the current investigation are limited because match running performance has been found to differ based on more detailed subdivision of forwards, midfielders, and defenders (e.g., center vs. wide) in professional soccer (8) and collegiate soccer (15).

This investigation provides a unique perspective of factors influencing TL in competitive soccer athletes. Our results indicate collegiate TLs are primarily affected by season phase, days relative to a match, days between a match, and previous match outcome. Of note, no difference in TLs was found for factors of player role, position, and opposition rank level. Further work exploring interactions between factors affecting training loads in competitive soccer (e.g., player role and position) is warranted.

Practical Applications

Personnel managing seasonal and individual training prescription and recovery practices should account for increased volume and intensity in the preseason, substantially higher workloads when training sessions occur greater than 5 days from a match, and increased external loading after losses vs. wins. In addition, event periodization strategies in collegiate men's soccer are limited to substantial decreases in workloads the day directly preceding a match. Coaches and practitioners should be aware that future works investigating the effect of the NCAA collegiate soccer structure on player workloads and wellness are needed and that comparisons between collegiate and other standards of play should be done with caution due to the unique season structure used at the NCAA collegiate soccer level.

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References

1. Akubat I, Barrett S, Abt G. Integrating the internal and external training loads in soccer. *Int J Sports Physiol Perform* 9: 457–462, 2014.
2. Anderson L, Orme P, Di Michele R, et al. Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: Implications for carbohydrate periodisation. *J Sports Sci* 34: 1250–1259, 2016.
3. Anderson L, Orme P, Michele RD, et al. Quantification of seasonal-long physical load in soccer players with different starting status from the English Premier League: Implications for maintaining squad physical fitness. *Int J Sports Physiol Perform* 11: 1038–1046, 2016.
4. Andersson H, Raastad T, Nilsson J, et al. Neuromuscular fatigue and recovery in elite female soccer: Effects of active recovery. *Med Sci Sports Exerc* 40: 372–380, 2008.
5. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci* 24: 665–674, 2006.
6. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform* 1: 50–57, 2006.
7. Bradley PS, Sheldon W, Wooster B, et al. High-intensity running in English FA Premier League soccer matches. *J Sports Sci* 27: 159–168, 2009.
8. 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. *J Sports Sci* 29: 821–830, 2011.
9. Brink MS, Visscher C, Arends S, et al. Monitoring stress and recovery: New insights for the prevention of injuries and illnesses in elite youth soccer players. *Br J Sports Med* 44: 809–815, 2010.
10. Brito J, Hertzog M, Nassis GP. Do match-related contextual variables influence training load in highly trained soccer players? *J Strength Cond Res* 30: 393–399, 2016.
11. Castagna C, D'Ottavio S, Abt G. Activity profile of young soccer players during actual match play. *J Strength Cond Res* 17: 775–780, 2003.
12. Castellano J, Blanco-Villaseñor A, Alvarez D. Contextual variables and time-motion analysis in soccer. *Int J Sports Med* 32: 415–421, 2011.
13. Cnaan A, Laird NM, Slasor P. Using the general linear mixed model to analyse unbalanced repeated measures and longitudinal data. *Stat Med* 16: 2349–2380, 1997.
14. Čović N, Jelešković E, Alić H, et al. Reliability, validity and usefulness of 30–15 intermittent fitness test in female soccer players. *Front Physiol* 7: 510, 2016.
15. Curtis RM, Huggins RA, Looney DP, et al. Match demands of National Collegiate Athletic Association Division I Men's soccer. *J Strength Cond Res* 32: 2907–2917, 2018.
16. Dellal A, Chamari K, Wong DP, et al. Comparison of physical and technical performance in European Soccer match-play: FA Premier League and La Liga. *Eur J Sport Sci* 11: 51–59, 2011.
17. *DI Men's College Soccer Rankings—NCAA Men's Soccer RPI*: NCAA.-com; 2013. Available at: http://www.ncaa.com/rankings/soccer-men/d1. Accessed July 20, 2018.
18. Di Salvo V, Baron R, Tschan H, et al. Performance characteristics according to playing position in elite soccer. *Int J Sports Med* 28: 222–227, 2007.
19. Eliakim E, Doron O, Meckel Y, Nemet D, Eliakim A. Pre-season fitness level and injury rate in professional soccer—A prospective study. *Sports Med Int Open* 2: E84–E90, 2018.
20. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109–115, 2001.
21. Gaudino P, Iaia FM, Alberti G, et al. Monitoring training in elite soccer players: Systematic bias between running speed and metabolic power data. *Int J Sports Med* 34: 963–968, 2013.
22. Giersch GEW, Huggins RA, Benjamin CL, et al. Validity and reliability of a shirt-based integrated GPS sensor: 2759 Board #42 June 1 2:00 PM–3:30 PM. *Med Sci Sports Exerc* 50: 673–673, 2018.
23. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med* 44: 139–147, 2014.
24. Jennings D, Cormack S, Coutts AJ, Boyd L, Aughey RJ. The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *Int J Sports Physiol Perform* 5: 328–341, 2010.
25. Jeong TS, Reilly T, Morton J, Bae SW, Drust B. Quantification of the physiological loading of one week of "pre-season" and one week of "in-season" training in professional soccer players. *J Sports Sci* 29: 1161–1166, 2011.
26. Jones CM, Griffiths PC, Mellalieu SD. Training load and fatigue marker associations with injury and illness: A systematic review of longitudinal studies. *Sports Med* 47: 943–974, 2017.
27. Krustrup P, Mohr M, Amstrup T, et al. The yo-yo intermittent recovery test: Physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697–705, 2003.
28. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: Importance of training status. *Med Sci Sports Exerc* 37: 1242–1248, 2005.
29. Laux P, Krumm B, Diers M, Flor H. Recovery-stress balance and injury risk in professional football players: A prospective study. *J Sports Sci* 33: 2140–2148, 2015.
30. Malone JJ, Di Michele R, Morgans R, et al. Seasonal training-load quantification in elite English premier league soccer players. *Int J Sports Physiol Perform* 10: 489–497, 2015.
31. Manzi V, Bovenzi A, Franco Impellizzeri M, Carminati I, Castagna C. Individual training-load and aerobic-fitness variables in premiership soccer players during the precompetitive season. *J Strength Cond Res* 27: 631–636, 2013.
32. Metaxas TI, Koutlianos NA, Kouidi EJ, Deligiannis AP. Comparative study of field and laboratory tests for the evaluation of aerobic capacity in soccer players. *J Strength Cond Res* 19: 79–84, 2005.
33. Nédélec M, McCall A, Carling C, et al. Recovery in soccer: part I—Post-match fatigue and time course of recovery. *Sports Med* 42: 997–1015, 2012.
34. Noya Salces J, Gomez-Carmona PM, Moliner-Urdiales D, Gracia-Marco L, Sillero-Quintana M. An examination of injuries in Spanish Professional Soccer League. *J Sports Med Phys Fitness* 54: 765–771, 2014.
35. Owen AL, Wong DP, Dunlop G, et al. High-intensity training and salivary immunoglobulin a responses in professional top-level soccer players: Effect of training intensity. *J Strength Cond Res* 30: 2460–2469, 2016.
36. Owen AL, Lago-Peñas C, Gómez MÁ, Mendes B, Dellal A. Analysis of a training mesocycle and positional quantification in elite European soccer players. *Int J Sports Sci Coach* 12: 665–676, 2017.
37. Paul DJ, Bradley PS, Nassis GP. Factors affecting match running performance of elite soccer players: Shedding some light on the complexity. *Int J Sports Physiol Perform* 10: 516–519, 2015.
38. Reilly T. The training process. In: *The Science of Training—Soccer: A Scientific Approach to Developing Strength, Speed and Endurance*. London, United Kingdom: Routledge, 2007. pp. 1–18.

39. 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* 50: 1043–1052, 2016.
40. Shephard RJ, Allen C, Benade AJ, et al. The maximum oxygen intake. An International reference standard of cardiorespiratory fitness. *Bull World Health Organ* 38: 757–764, 1968.
41. Silva JR, Magalhães JF, Ascensão AA, et al. Individual match playing time during the season affects fitness-related parameters of male professional soccer players. *J Strength Cond Res* 25: 2729–2739, 2011.
42. 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* 50: 1030–1041, 2016.
43. Windt J, Gabbett TJ. How do training and competition workloads relate to injury? The workload-injury aetiology model. *Br J Sports Med* 51: 428–435, 2017.
44. Wrigley R, Drust B, Stratton G, Scott M, Gregson W. Quantification of the typical weekly in-season training load in elite junior soccer players. *J Sports Sci* 30: 1573–1580, 2012.