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Quantification of in-season training load in Division I male collegiate soccer players

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ABSTRACT
The purpose of this study was to quantify any differences in training load (TL), as measured via Duration, Heart rate (HR) and Session-Rating of Perceived Exertion Load (S-RPE Load), in Division I male collegiate soccer players. Training sessions during the fall competitive season were categorized by the days away from the next competition [match day (MD) out] in 26 collegiate soccer players. All training sessions were monitored using HR transmitter technology. HR data was expressed as percent of total practice duration spent in zones (%HR_{Low} [≤ 69%], %HR_{Mod} [70-89%] and %HR_{High} [≥ 90%]). A significant, main effect finding was noted for Duration ($p < 0.01$), S-RPE Load ($p < 0.01$), %HR_{Low} ($p < 0.01$), %HR_{Mod} ($p < 0.01$), and %HR_{High} ($p < 0.01$) between MD out from competition. Post hoc analysis revealed MD-1 had the lowest TL across all MDs. Load on MD-3 was greatest for Duration (90.72 ± 23.78 min), S-RPE Load (1223.50 ± 393.60 au), and %HR_{High} (7.07 ± 9.87). The highest load for %HR_{Mod} was on MD-4 (35.52 ± 17.16 min), while %HR_{Low} was on MD-1 (74.45 ± 18.93 min). As MD approached, various trends, such as a bell-shaped curve (Duration, S-RPE Load, %HR_{High}) and a linear taper (%HR_{Mod}), were evident. Periodization trends in internal and external TL are evident within the microcycle lens where the focus of training is on recovery and preparation for the forthcoming match.

1. Introduction

In a team sport setting, daily training and weekly competitions result in variations in internal (physiological) and external (mechanical) training loads (TL) (Clarke et al., 2013; Malone et al., 2015; Manzi et al., 2010). During training, drills performed by the whole team require similar external load requirements, whereas the internal load response varies by individual (Azcárate et al., 2018; Foster, 2001; Impellizzeri et al., 2004). This indicates the importance in measuring both external and internal load placed on the individual athlete (Azcarate et al., 2018; Impellizzeri et al., 2004). Therefore, the measurement of TL is important for coaches, technical staff, strength and conditioning professionals, and medical personnel. This is particularly true as coaches and staff plan practices during the competitive season, to ensure that players are in peak physical condition to perform maximally during competition.

One of the most common, low-cost methods of estimating TL is session rating of perceived exertion (S-RPE). S-RPE provides a subjective measure following team training and competition (Foster et al., 2001). S-RPE Load, defined as training time multiplied by S-RPE, has been increasingly used to monitor training response and recovery across a variety of levels of competition, including professionally (Azcárate et al., 2018; Gaudino et al., 2015; Stevens et al., 2017). For example, S-RPE Load has been used in professional rugby to show a strong relationship to overall team injury. Importantly, the harder you train, based on S-RPE, the more likely you are to develop an injury (Gabbett et al., 2010). In a recent review on the relationship between internal and external training loads in team sports (i.e., football, Australian football, rugby & basketball), McLaren et al. (2018) found a large positive relationship between S-RPE and total distance (r = 0.79). Pustina et al. (2017) reported similar results in Division I male soccer players, between S-RPE Load

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and total distance (r = 0.81). S-RPE Load's popularity can be attributed to ease of use and low cost in quantifying individual player TL (Foster et al., 2001).

In addition to S-RPE, another common method to objectively quantify TL is the use of heart rate (HR) based methods. These methods have been studied across different sport domains including American football (Clarke et al., 2013), basketball (Manzi et al., 2010), and football (Impellizzeri et al., 2004; Stevens et al., 2017). Within American football (r = 0.69-0.91) and professional basketball (r = 0.69-0.85), similar relationships using various HR based methods and S-RPE Load have been reported (Clarke et al., 2013; Manzi et al., 2010). First developed by Banister (1991), training impulse is a method to quantify TL using HR and training duration. Variations have been formulated since then, providing additional versions to the original formula. In non-team sports such as running and swimming, strong links between HR methods and S-RPE were reported (Borresen et al., 2008; Wallace et al., 2009). Recently, HR based training protocols have been useful in determining the intensity of football matches. Sparks et al. (2017) showed moderate to large correlations between low intensity (r = 0.46) and moderate intensity (r = 0.25-0.57) velocity and HR zones in university level male soccer players. Verification of a relationship across these different sports with S-RPE Load has provided another reliable method for measuring TL.

Previous research has reported a variation in daily TL across different sport domains. Within American football (Canadian), where teams compete once a week, TL takes on a bell-shaped curve structure, representing a purposeful buildup and taper, with the highest TLs noted in the middle of the week and purposeful reductions in TLs the following days as the team prepares for the next match (Clarke et al., 2013). In professional basketball, a one match week saw clear tapering toward match day (MD). This trend of heavier TLs further out from competition was visible three days out from MD (656 ± 88 au) compared to one day out (222 ± 56 au). In a sport such as basketball, where multiple matches per week is common, weekly structure for training, recovery and days off commonly changes. While multi-match weeks present challenges for practice structure and player recovery, this study showed that total weekly TLs were less than 5% different than single-match weeks (Manzi et al., 2010). When solely looking at training days (i.e., excluding matches) the two-match week (1722 ± 229 au) had significantly less TL compared to a one-match week (2436 ± 233 au). Thus, indicating periodization strategies by the coaching staff, in order to provide proper training stimulus for the players. Therefore, quantifying TL can help structure more tailored training sessions to allow for proper recovery while ensuring adequate time is allotted for on-field strategy and skill acquisition in preparation for upcoming matches.

Like other team sports, football teams have shown similar tactical periodization on days out from competition. The current club season structure forces teams to compete in one to two-matches within a week due to domestic, league cup and continental competitions. As MD gets closer, findings of progressive tapering in TL have been reported (Kelly et al., 2020; Malone et al., 2015; Stevens et al., 2017). With only one match in a periodized microcycle, purposeful training stimuli can be applied to the athletes. In professional Dutch football, a clear tapering of time spent in > 90% HR max from MD-4 to MD-1 has been reported (Stevens et al., 2017). Additionally, Kelly et al. (2019) reported that S-RPE Load was progressively reduced by 70-90 au per day in the three training days before a match. Another study focusing on a full week periodization plan (MD-4: off day), noted that only the practice prior to competition showed reductions in TL, with no differences in TL noted between the MD-5, MD-3 and MD-2 training sessions (Malone et al., 2015). These findings may be attributed to differing coaching styles, or periodization plans, but it appears that a consistent finding across elite level football teams show MD-1 resulting in the lowest TL, with varying degrees of taper or planned midweek spike in S-RPE Load or HR response in training during a one-match per week microcycle.

While internal (S-RPE Load, HR Based) and external (Duration) methods have been used previously to quantify and compare TL at the international and collegiate soccer level (Pustina et al., 2017; Sparks et al., 2017), there is limited knowledge on MD variability regarding TLs in United States Division I collegiate soccer. In collegiate level soccer where matches are played within a condensed semester time frame, with multiple matches occurring each week, S-RPE Load and HR-based TL analysis may be beneficial in monitoring training throughout the competitive season. Therefore, the intent of this study was to quantify any differences in TL, as measured via Duration, HR and S-RPE, by MD out from competition in Division I male collegiate soccer players.

2. Methods

2.1. Participants

Twenty-six Division I male soccer players (mean ± SD: 20.4 ± 1.4 yr, 74.2 ± 6.7 kg, 180.7 ± 5.9 cm) were monitored across a 12 week Fall 2019 competitive regular season. The team competed in a total of 18 (13 non-conference, 5 conference) National Collegiate Athletic Association (NCAA) matches. Weekly training session quantity ranged from 4-6 sessions throughout the season with a range of zero to two matches in a seven-day microcycle.

All outfield players (9 Defenders, 9 Midfielders, 8 Forwards) were included for analysis. Players who were participating in individual, recovery, rehabilitation, or specific fitness sessions were excluded. Goalkeepers were excluded from analysis, due to the unique demands of their position and the increased potential of injury due to the monitor. The Institutional Review Board at Georgia Southern University approved the study, and all players consented to have their data analyzed for the study.

2.2. Apparatus

Each player was outfitted with an individualized HR monitor (Polar Team 2, Bethpage, NY) based on their demographics, and wore the same monitor throughout the season. Players were shown the RPE chart (Borg, 1962) prior to providing a value, and reported their value away from other players and coaches.

2.3. Procedure

All data collection was done on the field the team was participating on that day. Upon arrival to practice, players were provided their monitor ~15 minutes prior to training. All training sessions included warm-ups and coaching staff organized drills. The duration of training was measured from the point the team was organized by the coaching staff to initiate warm-up, until the final drill was concluded, and players were allowed to leave the training facility. Any player activity before or after these timepoints was excluded from the duration of each session. Within 15 minutes following the end of training, players returned the monitors and reported an RPE number on the intensity of the session.

HR monitors were used to measure practice time spent in three specific training zones (Low [≤ 69%], Moderate [70-89%] and High [≥ 90%]) determined based on the estimated HRmax of each player. The HR zones refer to the time spent in each zone divided by the total time of each training session. They are expressed as percent of total practice duration (%HR_{Low}, %HR_{Mod}, %HR_{High}). Training time spent in each zone was compared to total training time to ensure proper breakdown was provided. RPE Load was calculated as S-RPE multiplied by training duration (Foster et al., 2001) for each training session and used for analysis.

Training sessions were categorized based on their proximity away from matches (i.e., MD minus) (Malone et al., 2015; Stevens et al., 2017). The sessions were broken down into 4 days or more prior (MD-4), 3 days prior (MD-3), 2 days prior (MD-2), and 1 day prior (MD-1) to MD. Within microcycles where two matches took place (i.e., Tuesday & Saturday), the Monday session was categorized at MD-1, and Wednesday, Thursday and Friday sessions were categorized as MD-3, MD-2 and MD-1, respectively. Reasoning for this is to provide congruent proximity from competition between all 12 weeks of the season.

2.4. Statistical Approach

Data IBM SPSS Version 25.0 (SPSS, Inc., Chicago, IL) was used for all analysis. All data is reported as means ± SD. Shapiro-Wilks test was used to assess normality of the distribution of data. A one-way ANOVA was used to compare MDs in proximity to competition. In the event of a significant main effect, post-hoc Bonferroni analysis was conducted on all findings. Significance was set at $p < 0.05$. Practical significance was assessed using Cohen's d effect size (ES) statistics with the Hopkins' scale of magnitude. The scale utilized for all practical significance was < 0.20 for trivial, 0.20 - < 0.60 for small, 0.60 - < 1.20 for moderate, 1.20 - < 2.00 for large, and ≥ 2.00 for very large (Hopkins, 2009).

3. Results

Data was collected on 26 players over 42 practices during the season. Seventeen practices for MD-1, 11 for MD-2, 7 for MD-3, and 7 for MD-4 were included in analysis. One player was omitted from analysis due to a season ending injury during preseason. Descriptive data (mean ± SD) for Duration, S-RPE load, %HR_{Low}, %HR_{Mod}, %HR_{High} for each MD out are presented, with a traditional bell-shaped curve reference, in Figure 1.

3.1. Duration

A significant, main effect finding was noted for Duration between MD out ($F(3,774) = 133.92$, $p < 0.01$). Post hoc analyses revealed that MD-1 was significantly shorter in Duration than MD-2 (-30.36 ± 1.83 min [mean difference ± standard error], $p < 0.01$, $d = 1.64$), MD-3 (-33.66 ± 2.18 min, $p < 0.01$, $d = 1.63$), and MD-4 (-23.68 ± 2.02 min, $p < 0.01$, $d = 1.17$). Practice Duration on MD-4 was significantly less than MD-2 (-6.68 ± 2.17 min, $p < 0.05$, $d = 0.31$) and MD-3 (-9.98 ± 2.47 min, $p < 0.01$, $d = 0.43$). No differences were seen between MD-2 and MD-3 ($p = 0.93$, $d = 0.15$).

3.2. S-RPE Load

A significant, main effect finding was noted for S-RPE Load between MD out ($F(3,754) = 142.28$, $p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in S-RPE Load than MD-2 (-475.53 ± 30.48 au, $p < 0.01$, $d = 1.73$), MD-3 (-632.04 ± 36.30 au, $p < 0.01$, $d = 1.99$), and MD-4 (-412.07 ± 34.22 au, $p < 0.01$, $d = 1.12$). S-RPE Load on MD-3 was significantly greater than MD-2 (156.51 ± 38.59 au, $p < 0.01$, $d = 0.44$) and MD-4 (219.98 ± 41.61 au, $p < 0.01$, $d = 0.51$). No differences were seen between MD-2 and MD-4 ($p = 0.50$, $d = 0.16$).

3.3. %HR_{Low}

A significant, main effect finding was noted for %HR_{Low} between MD out ($F(3,709) = 31.45$, $p < 0.01$). Post hoc analyses revealed that MD-1 spent significantly more time in %HR_{Low} than MD-2 (9.04 ± 1.87 %, $p < 0.01$, $d = 0.46$), MD-3 (16.43 ± 2.17 %, $p < 0.01$, $d = 0.87$), and MD-4 (17.17 ± 2.13 %, $p < 0.01$, $d = 0.83$). %HR_{Low} on MD-2 was significantly higher than MD-3 (7.40 ± 2.32 %, $p < 0.01$, $d = 0.38$) and MD-4 (8.13 ± 2.29 %, $p < 0.01$, $d = 0.38$). No differences were seen between MD-3 and MD-4 ($p = 1.00$, $d = 0.04$).

3.4. %HR_{Mod}

A significant, main effect finding was noted for %HR_{Mod} between MD out ($F(3,709) = 30.88$, $p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in %HR_{Mod} than MD-2 (-5.67 ± 1.42 %, $p < 0.01$, $d = 0.38$), MD-3 (-12.25 ± 1.64 %, $p < 0.01$, $d = 0.85$), and MD-4 (-13.03 ± 1.62 %, $p < 0.01$, $d = 0.80$). %HR_{Mod} on MD-2 was significantly lower than MD-3 (-6.58 ± 1.76 %, $p < 0.01$, $d = 0.47$) and MD-4 (-7.36 ± 1.73 %, $p < 0.01$, $d = 0.47$). No differences were seen between MD-3 and MD-4 ($p = 1.00$, $d = 0.05$).

3.5. %HR_{High}

A significant, main effect finding was noted for %HR_{High} between MD out ($F(3,700) = 17.24$, $p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in %HR_{High} than MD-2 (-1.78 ± 0.64 %, $p < 0.01$, $d = 0.34$), MD-3 (-5.02 ± 0.73 %, $p < 0.01$, $d = 0.65$), and MD-4 (-3.02 ± 0.72 %, $p < 0.01$, $d = 0.47$). %HR_{High}

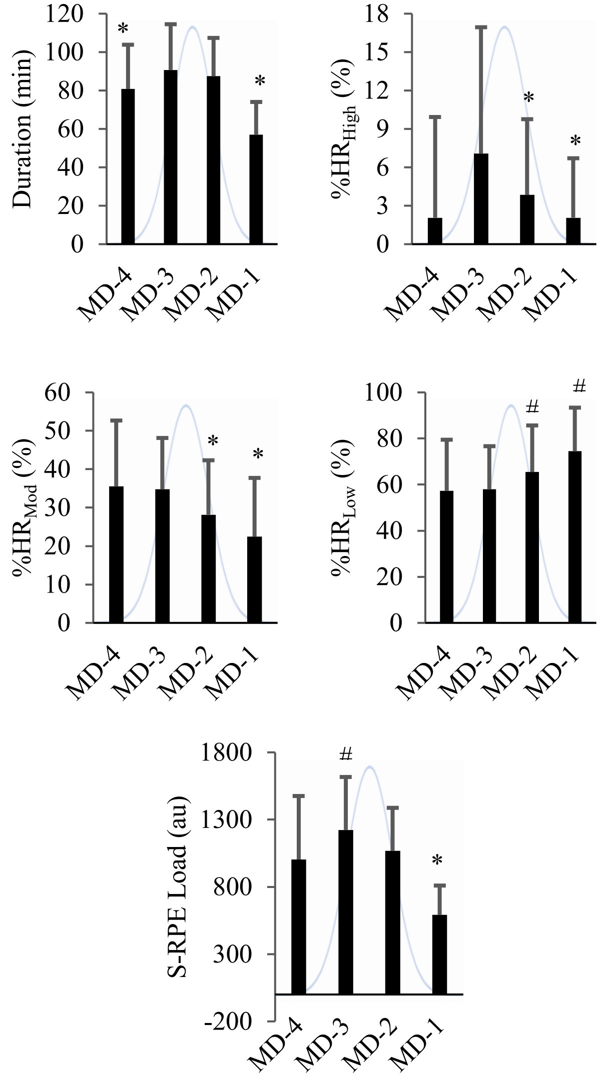

Figure 1: Means and standard deviations of total practice time (Duration), average percentage of time spent in each heart rate zone (%HRhigh: ≥ 85% HRmax, %HRmod: 65-84% HRmax, %HRlow: ≤ 64% HRmax), and Session rating of perceived exertion load (S-RPE Load), separated by days out from match (MD). Traditional bell-shaped curve is provided as visual reference to traditional models. *Note:* *Denotes day significantly ($p < 0.01$) lower than other days. #Denotes day significantly ($p < 0.01$) higher than other days.

on MD-2 was significantly lower than MD-3 (-3.24 ± 0.79 %, $p < 0.01$, $d = 0.40$). No differences were seen in MD-4 compared to MD-2 ($p = 0.67$, $d = 0.18$) and MD-3 ($p = 0.13$, $d = 0.23$).

4. Discussion

The aim of the present study was to quantify internal and external indicators of TL in accordance with MD out from competition within a Division I male competitive soccer season. The findings of the present study provide a novel insight into the weekly training periodization of a high level American collegiate team. As previously seen, TL generally decreased as the match approached (Akenhead & Nassis, 2016; Kelly et al., 2020; Stevens et al., 2017). The same trend was observed within the novel results. MD-1 recorded the lowest values for Duration, S-RPE Load, %HR$_{High}$, and %HR$_{Mod}$, while %H$_{Low}$ was greatest on this day. These findings provide insight into the coaching methodology with the emphasis on a lighter session on the last training day prior to competition, allowing players to have adequate recovery time.

In the current study, MD-3 (second day of training in each microcycle) was greatest for Duration, S-RPE Load, %HR$_{High}$. A common strategy among coaches is to place higher loads further away from competition. The current results showed an 18.00%

increase in S-RPE Load from MD-4 to MD-3, followed by an incremental reduction from MD-3 to MD-2 (12.87%) and MD-1 (47.57%). This coincides with results by Akenhead et al. (2016) that reported the highest S-RPE Load on the second day of the training week (MD-4) in elite level professional English football. Whereas Manzi et al. (2010) reported elite level European basketball athletes performed the highest S-RPE Load on the first training day of the week (MD-5). Malone et al. (2015) reported no differences in TL performed by athletes during the first three training sessions of the week in the English Premier League. The current study results resemble a bell-shaped curve which has been previously reported in various sport athletes where S-RPE Load increased after the first session of the week (Clarke et al., 2013; Los Arcos et al., 2017). This may be due to coaches being conscious of the proximity of the first session of the training week to the previous match and allowing for an initial lighter session to help build up to the planned hardest session of the week.

From MD-3 until MD, numerous studies across professional football and basketball all reported a gradual decline in S-RPE Load (Akenhead & Nassis, 2016; Kelly et al., 2020; Manzi et al., 2010) with a large drop in TL from MD-2 to MD-1. For example, Manzi et al. (2010) and Akenhead et al. (2016) observed a 51.84% and 27.81% reduction in S-RPE Load, respectively. Both representing the largest drop in load across the training week. The current study's 47.5% decrease in TL on the final training session before competition demonstrates the importance for recovery the 24 hours prior to competition. Additionally, Stevens et al. (2017) and Clemente et al. (2019) reported the same trend with total distance covered in a training session. This uniform reduction in player load indicates purposeful planning by coaches, and technical staff to prepare players for competition.

Training duration throughout the match week also portrayed similar trends as S-RPE Load. Conversely, in the Spanish La Liga and the Dutch Eredivisie leagues, Martin-Garcia et al. (2018) and Stevens et al. (2017) respectively, observed a progressive tapering from MD-4 (77 ± 9 min; 88 ± 11 min, respectively) toward MD-1 (61 ± 12 min; 59 ± 7 min, respectively). The findings of the current study portray closer trends based on duration with Martin-Garcia et al. (2018) due to the similar bell-shaped curve seen from an increase in duration from MD-4 to MD-3 (+10 min) followed by a progressive decrease toward MD. Additionally, these two European teams and the current study observed the largest drop in average training duration from MD-2 (La Liga: 80 ± 10 min, Dutch Eredivisie: 77 ± 12 min, Division I collegiate: 87.41 ± 19.95 min) to MD-1 (La Liga: 61 ± 12 min, Dutch Eredivisie: 59 ± 7min, Division I collegiate: 57.06 ± 16.98 min). Interestingly, the collegiate team in the current study showed a similar large effect (d = 1.64) from MD-2 to MD-1 compared to the Professional La Liga (d = 1.70) and Dutch Eredivisie (d = 1.83) teams. Thus, as noted with S-RPE Load, this may be a result of the importance coaches' place in allowing players time to recover prior to a match.

$\%HR_{High}$ zone in the current study was reported to be the lowest for MD-1 (2.05%). Stevens et al. (2017) reported the lowest values for MD-1 for time spent in 90-100% of HR_{Max} (5.08%). Additionally, Akenhead and Nassis (2016) reported 5% of training on MD-1 at 90% or greater of HR_{Max}. In the present study, during their fall season the team played two matches in seven out of 14 regular season weeks. With the intense nature of matches, along with their condensed schedule, the need for eliciting heart rate responses in the $\%HR_{High}$ zone may not be a priority for coaches. Therefore, the focus may shift to technical and tactical drills on MD-1, with an emphasis on allowing proper recovery.

$\%HR_{Mod}$ was lowest on MD-1 that followed a linear tapering in time spent in this zone from MD-4. Coutinho et al. (2015) observed a similar HR response in elite Portuguese football players of a similar age (u19) to the athletes in the current study. They found that time spent in the 85-89.5% HR_{max} zone was highest in the first session of the week followed by a slight decrease as MD approached. Interestingly, the average time spent in the 75-84.9% zone during the midweek training sessions increased after the first session of the week and then decreased in the pre match training session. In contrast to the present study, it is hard to compare the mid-week training sessions because they combined all sessions, except the first and last of the week, into one average time across the different HR zones. However, these findings do show similar trends in a slow taper towards MD in the moderate percentage zone (70-89.9%). As opposed to all other TL indicators, $\%HR_{Low}$ shows a progressive increase during the training week. MD-1 held the greatest amount of time followed by MD-2. Coutinho et al. (2015) reported the same trend with the pre match training sessions spending the most time in <75% of HR max compared to midweek and start of the week training sessions.

It should be noted that while this study reviewed the HR and S-RPE Load responses of an entire team during a competitive season, athletes were not separated by playing status for analyses. It is possible that as the season progresses, differentiation in TL would exist between starters and nonstarters, as coaches potentially provide starters with more rest throughout the training week. Future research should consider investigating the nature of playing status as a covariate to the MD out performance variables.

In summary, the present study quantified TL within a Division I male soccer team during the fall 2019 competitive season. MD-1 represented the lowest load throughout the training week, providing potential insight into the technical staff's emphasis on recovery one day preceding competition. For Duration, S-RPE Load, $\%HR_{High}$, a bell-shaped trend in TL presented itself, which may signify the focus on recovery on MD-4 following the previous match. Whereas $\%HR_{Mod}$ showed a linear taper, while $\%HR_{Low}$ reported a linear trend of increased time as MD approached. Further research is still needed to better understand the TLs encountered by collegiate level soccer players and the different methodologies by coaching staffs to account for the short and condensed competitive schedule. The current findings provide insight into daily changes in TL leading up to competition during a competitive season to hopefully provide a deeper understanding into what is necessary to recover and prepare players for upcoming competition. The current results demonstrated a systematic reduction in daily TL in the days of training leading to the next competition with the lowest TL the day before competition. Due to the condensed nature of a collegiate season (17 matches in 91 total days), it is important for athletes to properly recover prior to the subsequent match. Additionally, with the goal to increase the athletic potential of the student athletes, proper periodization of highly intense sessions needs to be carefully placed within a training cycle to avoid maladaptation.

Conflict of Interest

The authors declare no conflict of interests.

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