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Relationship between external training load and match load in adult male professional soccer players: a Brazilian team case

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ABSTRACT
Purpose. To analyse the association between training external load [volume (TV) and intensity (TI)] and match external load intensity (MI) in professional male soccer players.
Methods. The sample comprised 16 soccer players from one professional soccer team in Rio de Janeiro (Brazil League Serie A). The inclusion criteria only considered microcycles with one game, including soccer players who played at least 60 min. Six microcycles were analysed. External load was monitored using a portable 5-Hz global positioning system during training and matches, and the following variables were analysed: TD – total distance travelled in match; D20 – distance travelled between 14 and 20 km/h; HIR – high-intensity running travelled > 20 km/h; NS – number of sprints > 24 km/h; ACC – number of accelerations > 3 m/s2; DC – number of decelerations < –3 m/s^2. Repeated-measures correlation coefficients were applied.
Results. A moderate negative correlation was found between DTTV and NSMI, and between NSTV with HIRMI, ACCMI, DCMI and D20MI, and a moderate positive correlation was found between D20TV and D20MI. A moderate negative correlation was found between DTTI and NSMI, between NSTI with HIRMI, DCMI and D20MI, and between ACCTI and ACCMI. A moderate positive correlation was found between NSTI and NSMI, and between D20TI with DTMI and D20MI. Lastly, a strong negative correlation was found between NSTI and ACCMI.
Conclusions. There are positive and negative correlations between external load variables of different magnitudes. This contribution addresses the limited evidence available on the correspondence between training and competition demands, adding new insights into load management in elite soccer.
Key words: football, match running performance, athletic performance, locomotor demands, displacement patterns

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Introduction

The quantification of load during training and matches in professional soccer has attracted considerable attention from both coaches and sport scientists [1]. Training load is commonly classified as internal or external [2, 3]. In team sports, external load (EL) is usually quantified through variables such as total distance covered, distances in specific speed zones, accelerations, and decelerations, with global positioning systems (GPS) widely used as a valid tool for this purpose [4–7]. Monitoring EL has become standard practice in soccer, as it assists coaches in planning microcycles, ensuring players reach match day in optimal condition [8–11], while also allowing verification of key training principles such as progressive overload, individualisation, and variation [12].

Previous studies have shown that match EL is influenced by several contextual factors, including match outcome, importance, location, opponent quality, travel demands, and competition type [4, 13–16]. Additionally, high-intensity actions (e.g., sprints, accelerations, decelerations) are particularly relevant, as they frequently precede decisive moments such as goals or assists [17, 18], and contribute to performance indicators like successful crosses, shots, and interceptions [19, 20]. Consequently, understanding how training EL influences match EL may be critical for planning and load management strategies.

While some evidence suggests associations between training and match EL (e.g., accelerations in training relate to accelerations in competition) [21–23], the number of studies addressing this link remains limited due to the variables analysed and the samples studied. Moreover, given that the periodisation of training loads is strongly influenced by the competition calendar, club management, and coaching strategies, most analyses are necessarily restricted to specific blocks of the season. Six microcycles within a single match were selected in this study to ensure comparability and homogeneity of competitive demands. To account for the non-independence of the data arising from repeated observations of the same players, a repeated measures correlation [24] was used. This represents an important gap, given that examining how training EL (volume and intensity) aligns with match EL in such microcycles could provide valuable insights for optimising microcycle programming in professional soccer. Therefore, the purpose of this study was to analyse the association between training external load (volume and intensity) and match external load in professional male soccer players, with the aim of providing coaches with evidence to optimise microcycle design and better align training with competitive demands.

Material and methods

Study design

This study is comparative and descriptive, applied research using performance analysis. The investigation was conducted with soccer players from the first-division team of the Brazilian championship. This study describes the performance data collected from GPS units during movement patterns common to professional soccer players during training and matches. Data collection came from Brazilian championship games from 2020 to 2021. All participants had undergone preseason training and had appropriate conditioning without injuries.

Sample

A non-probabilistic sample for convenience was used. The sample comprised 16 outfield players from one professional soccer team in Rio de Janeiro (Brazil League Serie A) (body mass: 78 ± 7.6 kg; height: 1.81 ± 0.05 m; fatmass: 11 ± 3.7%). These soccer players competed in national and international representative championships once (90 min) per week. In addition, they regularly trained for two hours in technical and tactical aspects 4–7 times a week and one hour of physical preparation 2–3 times a week. The average duration of training sessions used for the study was 64 min.

Following approval and with the Institution's consent, the researchers contacted the volunteers (age > 18 years old) and informed them about the aims and procedures of the study. They signed an informed consent form to participate in the data collection. No modifications were made to participants' training, nutritional, or hydration status. They maintained a passive recovery time pattern of 24 h without training efforts between the games. The inclusion criteria only considered microcycles with one game, soccer players who played for at least 60 min of the game, trained on all days during the week before the match, and participated in at least 2 matches, while exclusion criteria concerned games with extra time, substituted players, and goalkeepers. Forty observations were used for the final analysis.

External load variables

External load variables were monitored during the training and match using a portable 5-Hz global positioning system (GPS) unit (Catapult®, Melbourne, AUS). The GPS unit was positioned via an elasticised shoulder harness to sit between the player's scapulae at the base of the cervical spine. The GPS unit was activated, and a GPS satellite lock was established for at least 15 min before the player took the field, per the manufacturer's recommendations. The recorded information was downloaded after each session using the Catapult Sprint software (Catapult Innovations®, Melbourne, AUS) for analysis (see Table 1 for a description of the variables). The mean number of satellites and the horizontal dilution of position were recorded during data collection. In addition, the volume and intensity of the match and training were analysed. The match intensity (MI) corresponded to the total load normalised to the minutes played. For the training volume (TV), the sum of the values during the days of the microcycle was analysed, and the intensity (TI) corresponded to the TV normalised by the minutes that the training sessions lasted. Six microcycles were analysed.

Statistical analysis

The normality of the variables was analysed using the Shapiro-Wilk test, where a normal distribution was assumed ($p > 0.05$) and by visualising histogram plots. Descriptive statistics were presented as the mean and standard deviation. A repeated measures correlation coefficient was used to analyse the relationship between variables with 95% confidence intervals. This approach accounts for the violation of the independence of observations assumption inherent in traditional correlation analyses [24]. Correlations coefficients were categorically classified as: 0.0 to 0.10 trivial; 0.11 to 0.39 weak; 0.40 to 0.69 moderate; 0.70 to 0.89 strong; and 0.90 to 1.00 very strong [25]. All statistics were calculated using RStudio with an alpha of 0.05.

Results

Table 2 describes the external load variables of training volume and intensity and match intensity.

Table 3 shows the repeated measures correlation coefficients, 95% *CI*s and p values between the training volume and match intensity variables. A moderate negative correlation was found between DT_{TV} and NS_{MI}, and between NS_{TV} with HIR_{MI}, ACC_{MI}, DC_{MI} and $D20_{MI}$, and positive moderate correlation was found between $D20_{TV}$ and $D20_{MI}$.

Table 4 contains the repeated measures correlation coefficients, 95% *CI*s and *p* values between the training intensity and match intensity variables. A negative moderate correlation was found between DT_{TI} and NS_{MI}, between NS_{TI} with HIR_{MI}, DC_{MI} and $D20_{MI}$, and be-

Table 1. Description of external load variables

Variable	Match intensity	Training volume	Training intensity	Description
Total distance (m)	TD_{MI}	TD_{TV}	TD_{TI}	total distance travelled in the match
Distance 20 km/h (m)	$D20_{MI}$	$D20_{TV}$	$D20_{TI}$	distance travelled between 14 and 20 km/h
High-intensity running (m)	HIR_{MI}	HIR_{TV}	HIR_{TI}	high-intensity running travelled > 20 km/h
Number of sprints (count)	NS_{MI}	NS_{TV}	NS_{TI}	number of sprints > 24 km/h
Accelerations (count)	ACC_{MI}	ACC_{TV}	ACC_{TI}	number of accelerations > 3 m/s^2
Decelerations (count)	DC_{MI}	DC_{TV}	DC_{TI}	number of decelerations < –3 m/s^2

Table 2. Description of match and training external load

M_I		T_V		T_I	
variable	mean ± *SD*	variable	mean ± *SD*	variable	mean ± *SD*
TD (m/min)	98.7 ± 11.3	TD (m)	22,396 ± 3603	TD (m/min)	65.8 ± 5.88
NS (#/min)	0.56 ± 0.16	NS (#)	97.2 ± 31.6	NS (#/min)	0.29 ± 0.11
HIR (m/min)	8.69 ± 2.77	HIR (m)	1368 ± 349	HIR (m/min)	4.02 ± 0.8
ACC (#/ min)	0.77 ± 0.28	ACC (#)	233 ± 84.5	ACC (#/min)	0.69 ± 0.25
DC (#/ min)	0.66 ± 0.2	DC (#)	161 ± 59.5	DC (#/min)	0.47 ± 0.16
D20 (m/ min)	15.2 ± 4.25	D20 (m)	2578 ± 697	D20 (m/ min)	7.58 ± 1.62

counts, M_I – match intensity, T_V – training volume, T_I – training intensity, TD – total distance travelled in a match
D20 – distance travelled between 14 and 20 km/h, HIR – high-intensity running travelled > 20 km/h
NS – number of sprints > 24 km/h, ACC – number of accelerations > 3 m/s^2, DC – number of decelerations < –3 m/s^2

Table 3. Repeated measures correlation coefficients (RMCC) between match intensity and training volume external load

Variable		DT_{MI}	NS_{MI}	HIR_{MI}	ACC_{MI}	DC_{MI}	$D20_{MI}$
DT_{TV}	RMCC	0.23	**–0.45**	0.08	0.14	–0.14	0.29
	p-value	0.40	**0.08**	0.76	0.62	0.61	0.27
	LL 95% *CI*	–0.30	**–0.77**	–0.43	–0.39	–0.59	–0.24
	UL 95% *CI*	0.65	**0.05**	0.56	0.59	0.39	0.69
NS_{TV}	RMCC *r*	–0.33	0.43	**–0.60**	**–0.61**	**–0.62**	**–0.53**
	p-value	0.21	0.10	0.01	0.01	0.01	0.04
	LL 95% *CI*	–0.71	–0.09	**–0.84**	**–0.85**	**–0.85**	**–0.81**
	UL 95% *CI*	0.19	0.76	**–0.15**	**–0.16**	**–0.18**	**–0.04**
DAI_{TV}	RMCC r	0.34	–0.31	0.18	–0.01	–0.17	0.43
	p-value	0.20	0.24	0.51	0.96	0.53	0.10
	LL 95% *CI*	–0.19	–0.70	–0.35	–0.51	–0.61	–0.09
	UL 95% *CI*	0.71	0.22	0.62	0.49	0.36	0.76
ACC_{TV}	RMCC *r*	0.03	0.09	–0.13	–0.20	–0.32	–0.10
	p-value	0.90	0.74	0.62	0.46	0.23	0.71
	LL 95% *CI*	–0.47	–0.43	–0.59	–0.63	–0.70	–0.57
	UL 95% *CI*	0.52	0.56	0.39	0.33	0.21	0.42
DC_{TV}	RMCC *r*	–0.01	–0.16	–0.17	–0.19	–0.39	–0.07
	p-value	0.96	0.56	0.52	0.49	0.13	0.81
	LL 95% *CI*	–0.51	–0.61	–0.62	–0.62	–0.74	–0.54
	UL 95% *CI*	0.49	0.37	0.35	0.34	0.13	0.44
$D20_{TV}$	RMCC *r*	0.47	–0.45	0.17	0.06	–0.09	**0.55**
	p-value	0.07	0.08	0.52	0.82	0.73	**0.03**
	LL 95% *CI*	–0.03	–0.78	–0.35	–0.45	–0.56	**0.07**
	UL 95% *CI*	0.78	0.05	0.62	0.54	0.42	**0.82**

CI – confidence interval, LL – lower limit, UL – upper limit, TV – training volume, MI – match intensity, TD – total distance travelled in a match, D20 – distance travelled between 14 and 20 km/h, HIR – high-intensity running travelled > 20 km/h, NS – number of sprints over 24 km/h, ACC – number of accelerations > 3 m/s^2, DC – number of decelerations < –3 m/s^2
Bold values mean $p < 0.05$.

Table 4. Repeated measures correlation coefficients (RMCC) between match and training intensity external load

Variable		DT_{MI}	NS_{MI}	HIR_{MI}	ACC_{MI}	DC_{MI}	$D20_{MI}$
DT_{TI}	RMCC	0.22	**–0.51**	–0.17	–0.30	–0.25	0.25
	p-value	0.39	**0.04**	0.52	0.25	0.35	0.35
	LL 95% *CI*	–0.30	**–0.80**	–0.62	–0.69	–0.67	–0.28
	UL 95% *CI*	0.65	–0.02	0.35	0.23	0.28	0.66
NS_{TI}	RMCC	–0.33	**0.59**	**–0.59**	**–0.70**	**–0.51**	**–0.56**
	p-value	0.20	**0.02**	**0.02**	**<0.01**	**0.04**	0.02
	LL 95% *CI*	–0.71	**0.14**	**–0.84**	**–0.89**	**–0.80**	**–0.83**
	UL 95% *CI*	0.19	**0.84**	**–0.13**	**–0.32**	**–0.02**	–0.09
HIR_{TI}	RMCC	0.38	–0.21	0.11	–0.23	–0.21	0.44
	p-value	0.15	0.45	0.69	0.38	0.43	0.09
	LL 95% *CI*	–0.14	–0.64	–0.41	–0.65	–0.64	–0.08
	UL 95% *CI*	0.74	0.32	0.57	0.30	0.32	0.77
ACC_{TI}	RMCC	–0.09	0.42	–0.28	**–0.52**	–0.31	–0.31
	p-value	0.73	0.11	0.30	**0.04**	0.24	0.24
	LL 95% *CI*	–0.56	–0.10	–0.68	**–0.81**	–0.70	–0.70
	UL 95% *CI*	0.42	0.76	0.25	**–0.03**	0.22	0.22
DC_{TI}	RMCC	–0.12	0.05	–0.30	–0.44	–0.45	–0.23
	p-value	0.67	0.86	0.25	0.09	0.08	0.40
	LL 95% *CI*	–0.58	–0.46	–0.69	–0.77	–0.77	–0.65
	UL 95% *CI*	0.40	0.53	0.23	0.07	0.06	0.30
$D20_{TI}$	RMCC	**0.52**	–0.30	0.08	–0.24	–0.09	0.55
	p-value	**0.04**	0.26	0.76	0.37	0.75	**0.03**
	LL 95% *CI*	**0.03**	–0.69	–0.43	–0.66	–0.56	**0.07**
	UL 95% *CI*	**0.81**	0.43	0.56	0.29	0.43	**0.82**

CI – confidence interval, LL – lower limit, UL – upper limit, TI – training intensity, MI – match intensity, TD – total distance travelled in a match, D20 – distance travelled between 14 and 20 km/h, HIR – high-intensity running travelled > 20 km/h, NS – number of sprints over 24 km/h, ACC – number of accelerations > 3 m/s^2, DC – number of decelerations < –3 m/s^2
Bold values mean $p < 0.05$.

tween ACC_{TI} and ACC_{MI}. A positive moderate correlation was found between NS_{TI} and NS_{MI}, and between $D20_{TI}$ with DT_{MI} and $D20_{MI}$. Lastly, a strong negative correlation was found between NS_{TI} and ACC_{MI}.

Discussion

The purpose of the present study was to analyse the association between external training load (volume and intensity) and match load intensity in adult male professional players using GPS during one season in a Brazilian team. The main findings in relation to training volume were moderate to strong negative correlations between NS_{TV} with HIR_{MI}, ACC_{MI}, DC_{MI} and $D20_{MI}$, between DT_{TV} and NS_{MI}, and a moderate positive correlation between $D20_{TV}$ and $D20_{MI}$. In relation to training intensity, there were positive moderate correlations between $D20_{TI}$ and $D20_{MI}$, and between NS_{TI} and NS_{MI}, negative moderate correlations between NS_{TI} with HIR_{MI}, DC_{MI} and $D20_{MI}$, and a negative strong correlation between NS_{TI} and ACC_{MI}.

The results disagree with previous literature. Clemente et al. [23] found weak correlations between D20, HIR, ACC, and DC of training volume (TV) with match volume (MV). However, they only analysed this association between the same variable at both times (i.e., D20 from training with D20 from match). Unlike ours, their correlations were lower, which could be due to the number of days in each microcycle analysed (3 to 5 days of training vs. 4 to 6 in our study). Also, they did not analyse the match intensity load. The study by Silva et al. [22] analysed the relationship between TV and training intensity (TI) with match intensity (MI) and presented positive weak-to-moderate correlations. Unique similar correlations were found between HIR_{TV} and HIR_{TI} with HIR_{MI}, and Guerrero-Calderón et al. [21] found that TV could predict MV at distances greater than 14 km/h and 24 km/h. However, the statistical approach used was different, which may explain the differences in our results, mainly the negative correlations. The studies mentioned used Pearson's correlation coefficients using repeated subjects (dependent measures), except for the study by Guerrero-Calderón et al. [21], which used linear mixed models, which have the advantage of modelling subjects as random intercepts, however Guerrero-Calderón et al. [21] mention that the inter-dependency of the observations could not be fully overcome.

Concerning the moderate to strong correlations found, they correspond to the association between the same variable in both moments; this agrees with Silva et al. [22], where their stronger correlation was between the same variables. This could be explained by several factors, such as the tactical work carried out in the microcycle in order to carry out similar actions depending on the next rival, and also to the position of the players, assuming that the technical-tactical drills in training were similar to the match demands in each game position [21], explaining that the player had training load demands similar to the match load, following the specificity the training principle [12].

The negative correlations can be explained by the fatigue effect or contextual factors in the games. According to previous studies, reducing the training volume while maintaining intensity could positively affect the volume of high-intensity running during the match. This training volume is quantified through an external load [21] or with the duration of the training and the number of weekly workouts [26], which runs into controversy with our results. Guerrero-Calderón et al. [21] also found correlations between TD_{TV}. These affects negatively the match EL, where they mention that contextual factors, such as opponent quality, playing position, match result, tournament type, among others, could be affecting these results, but mainly the match load, due to its multifactorial and complex nature [14, 15, 27, 28].

Limitations and future research

The present study has limitations in the low sample and the number of microcycles analysed, reducing the statistical power and generating considerable uncertainty in statistical parameters (large confidence intervals). On the other hand, the GPS sampling rate (5 Hz) might not be as accurate with some actions as linear sprints [29]. Lastly, the non-probabilistic sample and the result are not necessarily generalisable. Future research should continue to analyse these relationships in other populations, such as young and female players, analyse microcycles with more than one match (congested) and consider contextual factors that can affect match external load, such as opponent quality and match importance.

Practical application

With this information, physical trainers can plan their weekly trainings based on a previous analysis of the upcoming competition, which could impose known factors. Also, depending on positioning roles, training drills should align with the demands required by the technical team, for example, more attacking advances (sprints) by the fullbacks or, for teams that press high up the pitch, more high-intensity running by their midfielders and forwards. Also, monitoring EL is important for the rehabilitation phases, and a lack or deficit of a specific match EL necessitate prescribing exercises with demands like those needed by the player or technical team to meet the physical demands required. Another application based on our results is to apply caution with the number of sprints performed in the training because this seems to decrease the intensity (metric divided by minutes) of other important external load variables.

However, it should be noted that this application must be taken with caution so that the player arrives in optimal condition for the match (as little as possible fatigue), not assuming a purely linear relationship, where non-linear curves have been found between cumulative and acute training load and match load [30].

Conclusions

This study aimed to examine the relationship between external training load and external match load in professional soccer microcycles, including a competitive match. It found positive and negative correlations between external load variables. This contribution addresses the limited evidence available on the correspondence between training and competition demands, adding new insights into load management in elite soccer. Despite these advances, the study is limited to a single team and context. Practically, the results provide coaches and practitioners with evidence to better align training design with competitive requirements, ultimately optimising player performance and recovery.

Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Universidade Federal do Rio de Janeiro (approval No.: 13846919.8.0000.5257).

Informed consent

Informed consent was obtained from all individuals included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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