

Title of Article:

In-season internal and external training load quantification of an elite European soccer team

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Abstract

Elite soccer teams that participate in European competitions often have a difficult schedule, involving weeks in which they play up to three matches, which leads to acute and transient subjective, biochemical, metabolic and physical disturbances in players over the subsequent hours and days. Inadequate time recovery between matches can expose players to the risk of training and competing whilst not fully recovered. Controlling the level of effort and fatigue of players to reach higher performances during the matches is therefore critical. Therefore, the aim of the current study was to provide the first report of seasonal internal and external training load (TL) that included Hooper Index (HI) scores in elite soccer players during an in-season period. Sixteen elite soccer players were sampled, using global position system, session rating of perceived exertion (s-RPE) and HI scores during the daily training sessions throughout the 2015-2016 in-season period. Data were analysed across ten mesocycles (M: 1 to 10) and collected according to the number of days prior to a match. Total daily distance covered was higher at the start (M1 and M3) compared to the final mesocycle (M10) of the season. M1 (5589m) reached a greater distance than M5 (4473m) (ES = 9.33 [12.70, 5.95]) and M10 (4545m) (ES = 9.84 [13.39, 6.29]). M3 (5691m) reached a greater distance than M5 (ES = 9.07 [12.36, 5.78]), M7 (ES = 6.13 [8.48, 3.79]) and M10 (ES = 9.37 [12.76, 5.98]). High-speed running distance was greater in M1 (227m), than M5 (92m) (ES = 27.95 [37.68, 18.22]) and M10 (138m) (ES = 8.46 [11.55, 5.37]). Interestingly, the s-RPE response was higher in M1 (331au) in comparison to the last mesocycle (M10, 239au). HI showed minor variations across mesocycles and in days prior to the match. Every day prior to a match, all internal and external TL variables expressed significant lower values to other days prior to a match ($p < 0.01$). In general, there were no differences between player positions.

Conclusions: Our results reveal that despite the existence of some significant differences between mesocycles, there were minor changes across the in-season period for the internal and external TL variables used. Furthermore, it was observed that MD-1 presented a reduction of external TL (regardless of mesocycle) while internal TL variables did not have the same record during in-season match-day-minus.

Keywords: soccer training; internal load; external load; training load; periodization.

1 **Introduction**

2 Elite soccer teams that participate in European competitions have weekly schedules featuring up to
3 three-matches that can lead to increased levels of fatigue, and higher risk of illness and injury [1].
4 The knowledge of internal and external training load (TL) helps coaches to design an effective
5 individual and group training periodization in elite team sports [2-7] Djaoui et al., 2017; Jaspers et
6 al., 2016; Malone et al., 2015; 2017; Nédélec et al., 2012; Stevens et al., 2017). However, it is only
7 recently that some studies have described the in-season training periodization practices of elite
8 football teams in more detail, including a comparison of training days within weekly microcycles [4,
9 7-9]. As an example, Malone et al. [4] found that a lowering TL in the last training day immediately
10 before any given match differed from the other training days on several internal and external TL load
11 variables such as session rated perceived exertion (s-RPE), plus total distance and average speed,
12 respectively. In addition, some studies have shown limited variation through the in-season and have
13 suggested that training in elite soccer has a regular load pattern [4, 5, 10, 11].

14 Moreover, several authors [1, 10, 12, 13] have claimed that it is also very important to
15 monitor elite athletes' health to provide further information concerning the details of player fatigue,
16 stress, muscle soreness, need for recovery and sleep perception. These variables are commonly
17 associated with biochemical (physical and physiological) and biomechanical stress responses,
18 recognized as internal TL [13, 14]. On this issue, a valid and simple way to control internal TL is the
19 session rating of perceived exertion (s-RPE) which showed correlations to the heart frequency
20 training zones [15]. Furthermore, another way to quantify the level of fatigue, stress and delayed
21 onset muscle soreness (DOMS) and the quality of sleep is the Hooper Index [12].

22 However, the simultaneous use of s-RPE and Hooper Index (HI) is limited. In fact, very few
23 authors have studied the relationship between the use of the HI and s-RPE [10, 16]. Here, Clemente
24 et al. [10] found a correlation between s-RPE and HI levels, and negative correlations between s-
25 RPE and DOMS ($p = -0.156$), s-RPE and sleep ($p = -0.109$), s-RPE and fatigue ($p = -0.225$), ITL and
26 stress ($p = -0.188$) and ITL and HI ($p = -0.238$) in 2-game weeks. On the other hand, Haddad et al.
27 [16] failed to observe any association between HI and RPE. Therefore, further research is needed to
28 clarify this issue, specifically to validate these results during in-season. Subsequently, it is also
29 necessary to quantify the external TL that is associated with the total amount of workload performed
30 during training sessions and/or matches [13-14]. According to Halson [17] and Casamichana et al.
31 [18], one easy and practical way to control training response for each player (e.g. frequency, time,
32 total distance and distances of different exercise training intensity) is time-motion analysis by using
33 a global positioning system (GPS).

34 Nowadays, researchers study the data collected during short training microcycles of 1-2-3
35 weeks [9-10, 13, 19], in mesocycles consisting of 4-10 weeks [20-22] and during longer training

36 periods of 3-4 months [18, 23] and 10-month periods [11]. However, most of these studies have
37 provided limited information regarding the TL, using only the duration and RPE without the
38 inclusion of other internal and external TL variables such as HI or data collected from GPS. In
39 addition, few studies [4-5, 10] have attempted to quantify TL with respect to changes between
40 mesocycles and microcycles (both overall and between player's positions) across an in-season.

41 Finally, the literature is somewhat inconclusive about establishing differences in TL for
42 player positions not only amongst training sessions but also during the in-season across a full
43 competitive season regarding training sessions, but there is information related to match-play data
44 that reveals some differences for player positions [4, 24]. Therefore, the purpose of this study was
45 twofold: a) quantify external TL in an elite professional European soccer team that played UEFA
46 competitions across ten months of the in-season 2015/16 and b) quantify the internal TL using s-
47 RPE and HI. For this purpose, we divided the in-season into ten months, following Morgan et al.
48 [11], and used the match day minus approach used by Malone et al. [4] for data analysis.
49 Additionally, we also compared player positions for both situations. We hypothesized that training
50 load is lower on training days closer to the next match and that the intensities and volume remain
51 constant throughout the competitive period.

52

53 **Materials and methods**

54 **Participants**

55 Nineteen elite soccer players with a mean \pm SD age, height and mass of 26.3 ± 4.3 years, 183.5 ± 6.6
56 cm and 78.5 ± 6.8 kg, respectively, participated in this study. The players belong to a team that
57 participated in UEFA competitions. The field positions of the players in the study consisted of four
58 central defenders (CD), four wide defenders (WD), four central midfielders (CM), four wide
59 midfielders (WM) and three strikers (ST). Inclusion criteria were regular participation in most of the
60 training sessions (80% of weekly training sessions); the completion of at least 60 minutes in one
61 match in the first half of the season and one match in the second half of the season. All participants
62 were familiarised with the training protocols prior to the investigation. The study was conducted
63 according to the requirements of the Declaration of Helsinki and was approved by the institution's
64 research ethics committee.

65

66 **Design**

67 TL data were collected over a 39-week period of competition during the 2015-2016 annual season.
68 The team used for data collection competed in four official competitions across the season, including
69 UEFA Champion league, the national league and two more national cups from their own country,

70 which often meant that the team played one, two or three matches per week. For the purposes of the
71 present study, all the sessions carried out as the main team sessions were considered. This refers to
72 training sessions in which both the starting and non-starting players trained together. In addition, all
73 data collected from matches for the period chosen were considered. Only data from training sessions
74 and matches were considered. Data from rehabilitation or additional training sessions of recuperation
75 were excluded. This study did not influence or alter the training sessions in any way. Training data
76 collection for this study was carried out at the soccer club's outdoor training pitches. Total minutes
77 of training sessions included warm-up, main phase and slow down phase plus stretching.
78 Compensation minutes of matches were included in the collected data, however this measure is not
79 revealed because the administration of the soccer club does not want to provide any information that
80 could identify the team in this study.

81

82 **Methodology**

83 The in-season phase was divided into 10 mesocycles or 10 months, respectively, as used by Morgans
84 et al. [11] and because the coaches and staff of the club work by months. Training data were also
85 analysed in relation to the number of days away from the competitive match fixture (i.e., match day
86 minus). In a week with only one match, the team typically trained five days a week (match day
87 [MD] minus [-]; MD-5; MD-4; MD-3; MD-2; MD-1), plus one day after the match (MD+1). This
88 approach was used by Malone et al. [4].

89

90 **External training load – training data**

91 A portable global positioning system (GPS) units (Viper pod 2, STATSports, Belfast, UK) was used
92 to monitor the physical activity of each player (external TL). This device provides position velocity
93 and distance data at 10 Hz frequency. Each player wore the device inside a custom-made vest
94 supplied by the manufacturer across the upper back between the left and right scapula. This position
95 allows the GPS antenna to be exposed for a clear satellite reception. All players wore the same GPS
96 device for each training session in order to avoid inter unit error [25]. Previously, some studies have
97 been able to provide valid and reliable estimates of instantaneous and constant velocity movements
98 during linear, multidirectional and soccer-specific activities by using this system [26, 27].

99 Following recommendations by Maddison & Ni Mhurchu [28], all devices were activated 30
100 minutes before data collection to allow the acquisition of satellite signals and synchronise the GPS
101 clock with the satellite's atomic clock. GPS data were then downloaded using the respective
102 software package (Viper PSA software, STATSports, Belfast, UK) and were clipped to involve the
103 main team session (i.e. the beginning of the warm up to the end of the last organised drill).

104 The metrics selected for the study were total duration of training session, total distance and
105 high speed distance (HSD, above 19Km/h).

106

107 **Internal training load – training data**

108 Approximately 30 min before each training session, each player was asked to rate the perception of
109 the quantity of fatigue, stress and DOMS and quality of sleep of the night that preceded the
110 evaluation. The Hooper index scale of 1–7 was used, in which 1 is very, very low and 7 is very, very
111 high (for stress, fatigue and DOMS levels) and 1 is very, very bad and 7 is very, very good (for sleep
112 quality). The Hooper Index is the summation of the four subjective ratings [12].

113 Thirty minutes following the end of each training session, players were asked to provide an
114 RPE rating, 0-10 scale [29]. Players were prompted for their RPE individually using a custom-
115 designed application on a portable computer tablet. The player selected their RPE rating by touching
116 the respective score on the tablet, which was then automatically saved under the player's profile.
117 This method helped minimise factors that may influence a player's RPE rating, such as peer pressure
118 and replicating other player's ratings [30]. Each individual RPE value was multiplied by the session
119 duration to generate a session-RPE (s-RPE) value [21, 31, 32].

120

121 **Statistical Analysis**

122 Data were analysed using SPSS version 22.0 (SPSS Inc., Chicago, IL) for Windows statistical
123 software package. Initially, descriptive statistics were used to describe and characterize the sample.
124 Shapiro-Wilk and the Levene tests were used to assumption normality and homoscedasticity,
125 respectively. ANOVA was used with repeated measures with Bonferroni post hoc, once variables
126 obtained normal distribution (Shapiro-Wilk>0.05), to compare 10 mesocycles and to compare days
127 away from the competitive match fixture. Results were significant in the interaction ($p \leq 0.05$). The
128 effect-size (ES) statistic was calculated to determine the magnitude of effects by standardizing the
129 coefficients according to the appropriate between-subjects standard deviation and was assessed using
130 the following criteria: <0.2 = trivial, 0.2 to 0.6 = small effect, 0.6 to 1.2 = moderate effect, 1.2 to 2.0
131 = large effect and >2.0 = very large [33]. The associations between s-RPE and HI scores were tested
132 with Spearman correlation. Data are represented as mean \pm SD.

133

134 **Results**

135 **In-Season Mesocycle Analysis (table 1)**

136 For the duration of training sessions, M1 had more minutes than other mesocycles, especially M4
137 (ES = 6.77 [9.11, 4.44]), M5 (ES =9.64 [13.12, 6.16]), M6 (ES = 6.64 [9.14, 4.14]) which decreased,

138 then increased some minutes to M7 and then decreased to M8 (ES = 6.17 [8.52, 3.82]), to M9 (ES =
139 5.83 [8.09, 3.59]) and to M10 (ES = 6.89 [9.47, 4.31]). M5 was the lowest, especially compared to
140 M7 (ES = 5.72 [3.51, 7.93]) M8 (ES = 5.74 [3.53, 7.96]) and M10 (ES = 5.03 [3.03, 7.02]). There
141 were no differences between player positions during the season (fig 1). For external load, total
142 distance tended to decrease during the season. M1 and M3 saw a greater distance reached. M1
143 reached a greater distance than M5 (ES = 9.33 [12.70, 5.95]) and M10 (ES = 9.84 [13.39, 6.29]). M3
144 reached a greater distance than M5 (ES = 9.07 [12.36, 5.78]), M7 (ES = 6.13 [8.48, 3.79]) and M10
145 (ES = 9.37 [12.76, 5.98]). There were significant differences between player positions only in M1
146 for WD vs WM (ES = 4.87 [6.82, 2.92]), CM vs WM (ES = 5.07 [7.09, 3.06]) (fig 1); Average speed
147 had few variations during the season. M3 reached the highest average speed while M10 reached the
148 lowest (ES = 7.15 [9.81, 4.49]); high-speed running distance was higher in M1, especially compared
149 to M5 (ES = 27.95 [37.68, 18.22]), which was the mesocycle with the lowest high-speed running,
150 compared to M6 (ES = 5.89 [8.15, 3.63]), M7 (ES = 12.65 [17.15, 8.16]), M8 (ES = 6.31 [8.71,
151 3.92]), M9 (ES = 7.27 [9.97, 4.57]) and M10 (ES = 8.46 [11.55, 5.37]). There were significant
152 differences between player positions only in M1 for CD vs WD (ES = 5.01 [3.02, 7.00]). For internal
153 load, s-RPE was higher in M1, especially compared to M5 (ES = 5.17 [7.21, 3.13]) and M8 (ES =
154 3.87 [5.53, 2.21]), with a tendency to decrease until the end of the season to M10 (ES = 3.81 [5.46,
155 2.17]). There were no differences between player positions during the season (fig 1). HI had fewer
156 variations during the season, reaching the highest value in M5 and the lowest value in M10 (ES =
157 3.47 [5.03, 1.92]). There were no significant differences between player positions.

158 There were associations between HI scores and s-RPE, HI scores and external TL variables,
159 and S-RPE and external TL variables, but few correlations were found: stress and total distance in
160 M2 (-6.34, $p < 0.01$); fatigue and s-RPE in M9 (0.589, $p < 0.05$); DOMS and s-RPE in M9 (0.487,
161 $p < 0.05$); fatigue and s-RPE in M11 (0.469, $p < 0.05$); and HI total score and total distance in M11
162 (0.489, $p < 0.05$).

163 *Insert table 1*

164 *Insert fig 1*

165 Fig 1 - TL data for duration, s-RPE, total distance and HSD in respect to mesocycles between
166 positions.

167 Abbreviations: (A) duration; (B) s-RPE; (C) total distance; (D) HSD; (CD), central defenders; (WD),
168 wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. a denotes
169 significant difference in CD versus WD, (b) denotes significant difference in WD versus WM, (c)
170 denotes significant difference in WD versus ST, (d) denotes significant difference CM versus WM,
171 all $P < 0.05$.

172

173 **In-Season Match-Day-Minus Training Comparison (table 2)**

174 For duration of training sessions, MD-5 was higher than MD-4 (ES = 4.44 [6.27, 2.62]), MD-3 (ES
175 = 5.69 [7.90, 3.49]), MD-2 (ES = 6.49 [8.94, 4.03]) and MD+1 (ES = 42.61 [57.4, 27.81]), with the
176 exception of MD-1 (ES = -6.34 [-3.94, -8.75]). MD-4 (ES = -4.44 [-6.27, -2.62]), (ES = 42.61 [57.4,
177 27.81]), MD-3 (ES = -13.14 [-8.48, -17.79]), (ES = 37.33 [50.31, 24.36]) and MD-2 (ES = -18.24 [-
178 11.85, -24.64]) (ES = 43.92 [59.17, 28.67]) were higher than MD-1 and MD+1, respectively. MD-1
179 was the highest and MD+1 was the lowest (ES = 61.40 [82.70, 40.10]). No differences were found
180 between players positions (fig 1). For external load, total distance was higher in MD-5 than MD-4
181 (10.73 [14.58, 6.86]), MD-3 (8.88 [12.11, 5.65]), MD-2 (16.06 [21.71, 10.41]), MD-1 (30.47 [41.07,
182 19.87]) and MD+1 (16.23 [21.93, 10.52]). MD-4 was higher than MD-2 (6.31[8.70, 3.91]), MD-1
183 (28.24 [38.07, 18.40]) and MD+1 (9.09 [12.39, 5.79]). MD-3 was also higher than MD-2 (9.30
184 [12.67, 5.93]), MD-1 (17.51 [23.66, 11.37]) and MD+1 (10.80 [14.67, 6.93]). MD-2 was higher than
185 MD-1 (32.04 [43.18, 20.89]) and MD+1 (6.03 [8.34, 3.73]), and MD+1 was higher than MD-1 (7.42
186 [4.67, 10.17]). There were significant differences in MD-2 between WD vs ST (5.13 [9.19, 1.07])
187 and CM vs ST (5.01 [9.01, 1.02]). Average speed was higher in MD-5 than MD-4 (6.01 [8.29,
188 4.71]), MD-3 (3.81 [5.45, 2.16]), MD-2 (9.20 [12.54, 5.87]), MD-1 (24.36 [32.86, 15.86]) and
189 MD+1 (-12.69 [-8.19, -17.20]). MD-4 was higher than MD-2 (6.37 [8.79, -3.96]), MD-1 (41.11
190 [55.39, 26.83]) and MD+1(-14.05 [-9.09, -19.02]). MD-3 was also higher than MD-2 (10.56 [14.35,
191 6.77]), MD-1 (46.36 [58.42, 28.31]) and MD+1(-13.63 [-8.80, -18.45]). MD-2 was higher than MD-
192 1 (45.96 [61.92, 30.01]) and MD+1 (-14.63 [-9.47, -19.80]), and MD+1 was higher than MD-1
193 (17.44 [11.32, 25.56]). No differences were found between player positions (fig 2); high-speed
194 running distance was higher in MD-5 than MD-2 (4.22 [5.98, 2.46]), MD-1 (10.75 [14.61, 6.90]) and
195 MD+1 (7.05 [9.67, 4.42]). MD-4 was higher than MD-2 (2.33 [4.01, 1.06]), MD-1 (14.49 [19.60,
196 9.37]), MD+1 (7.71 [10.55, -0.86]). MD-3 was also higher than MD-2 (2.35 [3.62, 1.08]), MD-1
197 (14.04 [19.00, 9.08]) and MD+1 (6.41 [8.85, 3.99]). MD-2 was higher than MD-1 (13.37 [18.11,
198 8.64]), MD+1 (4.89 [6.85, 2.94]) and MD+1 was higher than MD-1 (3.44 [1.89, 4.98]). In MD-3
199 there were significant differences between player positions (fig 2) for CB vs WD (4.94 [1.01, 8.89]).
200 In MD-2 there were significant differences between player positions CD vs WD (7.81 [2.05, 13.57]),
201 CD vs WM (5.74 [1.31, 10.17]) and WD vs ST (6.02 [10.62, 1.41]). In MD-1 there were significant
202 differences between player positions CD vs WD (4.93 [0.99, 8.86]) and WD vs ST (5.03 [1.03,
203 9.04]). For internal load, s-RPE was higher in MD-3 than MD-2 (2.81 [4.19, 1.42]), MD-1 (6.20
204 [8.56, 3.84]) and MD+1 (17.08 [23.08, 11.08]). MD-5 was higher than MD-1 (5.42 [7.54, 3.30]) and
205 MD+1 (15.47 [20.92, 10.02]). MD-4 was higher than MD-2 (2.45 [3.75, 1.15]), MD-1 (5.74 [7.95,
206 3.52]) and MD+1 (9.77 [13.30, 6.25]). No differences were found between player position (fig 1). HI
207 had few variations during the MD minus with the exception of MD+1, which were higher than MD-

208 5 (7.43 [10.18, 4.67]), MD-4 (6.60 [9.08, 4.11]), MD-3 (6.60 [9.08, 4.11]), MD-2 (6.29 [8.68, 3.90])
209 and MD-1 (6.90 [9.49, 4.32]). No differences were found between player positions (fig 2).

210

211 *Insert table 2*

212 *Insert fig 2*

213 Fig 2 - TL data for duration, s-RPE, total distance and HSD in respect to days before a competitive
214 match between positions.

215 Abbreviations: A) duration; (B) s-RPE; (C) total distance; (D) HSD; (CD), central defenders; (WD),
216 wide defenders; (CM), central midfielders; (WM), wide midfielders; (ST), strikers. (a) denotes
217 significant difference in CD versus WD, (b) denotes.

218

219 **Discussion**

220 The purpose of the present study was to quantify the internal and external TL carried out by an elite
221 soccer team during the in-season (10 mesocycles).

222

223 **In-season mesocycle analysis**

224 For external TL variables, it was observed that the players covered a greater total distance at the start
225 (M1 and M3) compared to the final mesocycle (M10) of the in-season, with an estimated difference
226 of 1044m and 1146m, respectively. The higher distances covered at the beginning of the in-season
227 may be due to the coaches still having some emphasis on physical conditioning immediately after
228 the pre-season. In addition, the lower values in distance covered for M10 could be associated with
229 the in-season ending and consequently a reduction in external TL.

230 According to Impellizzeri et al. [21] and Alexiou & Coutts [23], the competitive matches
231 represent the greatest TL that soccer players typically experience. In addition, Malone et al. [4] and
232 Los Arcos et al. [34] reported that total distance values were significantly higher at the start of the
233 annual in-season compared to the final stage 1304 (434 – 2174) m, ES = 0.84 (0.28 – 1.39) and (ES
234 = from – 0.56 to -1.20), respectively. These previous data corroborate our results because it was
235 possible to observe higher values in M1 compared to M10, although M5 had the lowest values for
236 total distance (table 1).

237 The present data suggest that in-season variability in TL is very limited and only minor
238 decrements in TL across the in-season might occur. Apparently, this TL maintenance during the in-
239 season could be associated with the importance of the recovery activities after the matches and the
240 decisions made to reduce TL until the next match [35]. Furthermore, elite European soccer teams
241 training programmes remain constant during all mesocycles of the in-season and corroborate the

242 suggestion made by Malone et al. [4] because there is a need to win matches that does not allow the
243 reaching of a specific peak for strength and conditioning.

244 The average total distance covered was 5111m (4473-5691m) which was similar to the
245 5181m value reported by Malone et al. [4] and slightly higher than those reported by Gaudino et al.
246 [20] (3618-4133m). However, both the distances covered in the present study and in Gaudino et al.
247 [20] study fell short in comparison to those reported by Owen et al. [19] (6871m) because their study
248 only included data from training sessions. This means that the study conducted by Owen et al. [19]
249 reported higher distances covered even with lower training sessions. In terms of high-speed distance,
250 the values (average 118m) fall within the range of that of Gaudino et al. [20] (88–137m) across
251 different positions.

252 The results indicate that TL variables demonstrated limited relevant variation between player
253 positions (see fig 1 and 2). Competitive matches have been quantified as the most demanding session
254 (i.e. greatest TL) of the week [7, 24, 34, 36]. For instance, Di Salvo et al. [37] reported that CM
255 generally cover more distances compared to other positions during competitive matches. This result
256 corroborates the current results because CM (5502m) covered more total distance than CD (5052m),
257 WD (5388m), WM (4918m) or ST (4694m), but without statistical significance. In addition, when
258 we compared the distance covered in high-speed running zones (zones 4+5) during in-season
259 mesocycle analysis to positions played, a significant difference was found between positions only for
260 M1 when comparing CD vs WD and WD vs WM. There was no other difference between player
261 positions in all mesocycles (fig 1). These results suggest that the WD (212.7m) and WM (186,8m)
262 positions resulted in higher effort (>19km/h) during training when compared to all other positions
263 (CD=112.2, CM=164.1, ST=116.1m). Further, every position saw similar efforts at low speed
264 distance (CD=4563.7; WD=4724.5, CM=4767.8, WM=4340.4, ST=4233.3m) which is in opposition
265 to other studies [24, 37, 38].

266 Regarding internal TL, the s-RPE response was higher in M1 (331au) in comparison to the
267 last mesocycle (M10, 239au) which is in line with data from external TL total distance and HSD
268 variables. However, it was found that in the middle of the season (M5) there was a lower response
269 (208au) for this parameter. This finding could be associated with some interruption for TL carried
270 out during training sessions due to the Christmas period and with an increase in the number of
271 matches played in M5 (6 matches). In general, there were no differences between player positions
272 (see fig 1). Therefore, it appears that there is no marked variation in internal TL across 10
273 mesocycles during the in-season. Some studies [4, 5, 10, 11] have also reported the limited relevant
274 variation in TL across the in-season. This seems to suggest that professional soccer daily training
275 practices follow a regular load pattern because they are linked to higher congestive periods of
276 matches. Furthermore, the importance of the recovery activities following matches and the decisions

277 made to reduce TL between matches to prevent fatigue during this period can also play an important
278 role in this constant TL [35].

279 Moreover, the data provides relevant information to quantify internal TL, measured by s-RPE
280 during microcycles and mesocycles. This may provide relevant information to establish guidelines
281 for soccer training periodization. The average of s-RPE during microcycles TL was 254.8au (range
282 33-342au). These values are lower than those reported by Scott et al. [22] (297au: range 38-936au),
283 but similar to Jeong et al. [39] study: 174-365au. for elite soccer players. The difference between our
284 study and the experiment conducted by Jeong et al. [39] could be attributed to the fact that they used
285 a sample of Korean professional players rather than top elite European soccer athletes that competed
286 in European competitions. The s-RPE values were also lower than the 462au of semi-professional
287 soccer players reported by Casamichana & Castellano [18]. Another explanation for the lower values
288 could be related to the amount of matches during each week and amongst mesocycles. It should be
289 reemphasised that we studied a top-class elite professional European soccer team. The range of s-
290 RPE for mesocycles of the in-season was 208-331au. Overall it would appear that in comparison to
291 top elite soccer players, the internal TL employed by our study falls within the boundaries of what
292 has been previously observed [18, 22, 39].

293 Haddad et al. [16] suggested that s-RPE is not sensitive to the subjective perception of
294 fatigue, DOMS or stress levels [16]. In contrast, however, Clemente et al. [10] stated that s-RPE
295 could be a reliable tool to quantify the internal TL and therefore could be a good indicator for
296 coaches and for practical applications in team sports training. Data presented in the current
297 experiment seems to corroborate this statement, indicating that s-RPE can be an effective tool to
298 measure training intensity in elite European soccer teams. On this subject, some studies have stated
299 that RPE may be a physiological and volatile construct that could be different according to the
300 cognitive focus of the player [40-42]. Nevertheless, Renfree et al. [43] reported that RPE can be
301 dissociated from the physiological process through a variety of psychological mechanisms.
302 Therefore, RPE could be an oversimplification of the psychophysiological perceived exertion and a
303 non-conclusive measure for capturing a wide range of sensations experience [40, 41, 43]. Another
304 major point is that RPE was collected 30 min after the end of each training session and it would be
305 pertinent to check if there is some variation during the training session, as contended by Ferraz et al.
306 [41]. These arguments may justify the fact that there were no differences in s-RPE between training
307 days as well as the absence of a relationship with the external TL results.

308 Comparing player positions, there were no differences for HI scores; this was not supported
309 by Clemente et al. [10] although their study was based on data from one vs two-matches week ($p <$
310 0.05). To the best of our knowledge, this is the first study to analyse HI scores during an entire in-
311 season. Clemente et al. [10] showed that central defenders (12.46 ± 2.54) and wide midfielder (12.42

312 ± 3.44) had higher values of HI scores than strikers (12.18 ± 4.84) and wide defenders ($12.16 \pm$
313 3.04). Centre midfielders had the lowest HI scores (10.34 ± 3.87). Despite these, the authors found
314 several significant differences between positions but, in general, these values were small. A possible
315 explanation for these non-consensual results could be associated with the differences in soccer TL.

316 In soccer training, due to the extensive use of small-sided matches and the different physical
317 (e.g. running) requirements associated with each position [37, 44, 45], training demands can be
318 markedly different between individuals [13, 46, 47]. This hypothetical difference in TL could be
319 amplified considering that only 11 players can start each official match, and therefore a considerable
320 number of players per team are not exposed to the TL of the match.

321 As suggested by Clemente et al. [10] study, we also correlated HI scores with s-RPE and
322 external TL variables, and some correlations could be observed: stress and total distance in M2 ($-$
323 6.34 , $p < 0.01$); fatigue and s-RPE in M9 (0.589 , $p < 0.05$); DOMS and s-RPE in M9 (0.487 , $p < 0.05$);
324 fatigue and s-RPE in M11 (0.469 , $p < 0.05$); and HI total score and total distance in M11 (0.489 ,
325 $p < 0.05$). These results are not in line with the literature, which suggests non-significant correlations
326 ($r = 0.20$) between s-RPE and perceived quality of sleep (from the Hooper questionnaire) [10, 48].
327 However, Thorpe et al. [49] reported associations between s-RPE and perceived fatigue, but not with
328 perceived quality of sleep. It is important to note that this last study analysed data for short periods
329 of training (microcycles). Therefore, since our study also comprised longer periods of training, we
330 can assume that this could have influenced the current results.

331

332 **In-season match-day-minus training comparison**

333 In the present study, we also investigated the TL pattern in respect to number of days prior to a
334 match during the in-season phase.

335 For external TL, our data provided the following pattern by decreasing values from until
336 MD-1: MD-5 > MD-4 < MD-3 > MD-2 > MD-1 for total distance and average speed, MD-5 > MD-4
337 > MD-3 > MD-2 > MD-1 for HSD (table 2). Our results are in line with elite English Premier
338 League players for total distance and average speed, remaining similar across all days except for
339 MD-1 in which the load was significantly reduced [4].

340 We also observed a noticeable consistent variation in external TL, total distance covered, in MD-1
341 when the load was significantly reduced in comparison with the rest of the training days. Our data
342 corroborates with some studies [4, 8, 49].

343 Finally, MD+1 revealed significant result despite the limited training duration (~20 min). The
344 average speed and HSD has higher values than all other match days minus. One argument that can
345 justify these results could be the high-intensity applied by the coach (which was not controlled in
346 this study). Another explanation is related to the context, competitive schedule and the objectives

347 defined for TL management, once MD+1 had little duration (20min). Another possible justification
348 could be associated with a training session of recuperation with lower load for starters and a
349 “normal” training session for non-starters.

350 When we compared HSD (above 19Km/h) during in-season match-day-minus by positions, a
351 significant difference was found between positions when comparing WD vs ST and CD vs WD, CD
352 vs WM in MD-2 in MD-2. In addition, when we compared total distance covered, a significant
353 difference could be observed between CD (149m) vs WD (295m) in MD-3, CD (103m) vs WD
354 (289m) in MD-2 and CD (49m) vs WD (111m) in MD-1; CD (103m) vs WM (240m), WD (289m)
355 vs ST (134m) in MD-2; and also WD (111m) vs ST (43m) in MD-1 (fig 2). These results are in line
356 with other studies [24, 37-38] that reported that CM players have consistently been found to cover
357 more distance in general while WM players cover more distances at high-intensity running speed.

358 Regarding match days, Reilly & Thomas [50] and Rienzi et al. [51] stated that higher
359 distances are covered by midfield players (11.5km); however, Bangsbo [52] reported that elite
360 defenders and strikers covered approximately the same distance (10-10.5km). This may be due to the
361 nature and role of the position inside the team, as well as coaching strategy and/or game plan.
362 During training sessions, the coach or the conditioning staff may find it advantageous to model
363 training to elicit similar effort or experience the same training load regardless of position.

364

365 For internal TL, s-RPE data presented a non-perfect pattern by decreasing values from until
366 MD-1: MD-5 < MD-4 < MD-3 > MD-2 > MD-1 for s-RPE (table 2), but none between player
367 positions (fig 2). We also observed a noticeable consistent variation in s-RPE on MD-1 in elite
368 soccer players, when the load was significantly reduced in comparison with the rest of the training
369 days [4, 8, 49]. In addition, the data presented by s-RPE is associated with external TL variation.

370 Furthermore, HI scores revealed no variation in days prior to the match. These results are in
371 line with those reported by Haddad et al. [16], where it was suggested that fatigue, stress, DOMS
372 and sleep are not major contributors of perceived exertion during traditional soccer training without
373 excessive TL. Our results also do not support Hooper and Mackinnon [12] study because self-
374 reported ranking of well-being does not allow the provision of efficient mean of monitoring internal
375 TL.

376 In opposition to the results presented for external in MD+1, internal TL, s-RPE has a lower
377 value than all other match days (33.6 au) but HI has a higher value than all other match days (15au)
378 (table 1). These results are associated with an accumulative high-intensity training session between
379 MD-5 and MD-2

380

381 **Practical Applications and Limitations**

382 This study provides useful information relating to the TL employed by an elite European soccer
383 team that played in a European Competition. It provides further evidence of the value of using the
384 combination of different measures of TL to fully evaluate the patterns observed across the in-season.
385 For coaches and practitioners, the study generates reference values for elite players which can be
386 considered when planning training sessions. However, it is important to remember that the in-season
387 match-day-minus training comparison was analysed by mean values and microcycles/weeks (7-day
388 period) of the in-season have different patterns, as mentioned before. Another limitation is related to
389 the numerous true data points missing across the 39-week data collection period due to several
390 external factors beyond our control (e.g. technical issues with equipment, player injuries, and player
391 transfers).

392

393 **Conclusions**

394 In summary, we provide the first report across 10 mesocycles of an in-season that included HI scores
395 and s-RPE to measure internal TL plus distances covered at different intensities measured by GPS,
396 in elite soccer players that played European competitions. Our results reveal that although there are
397 some significant differences between mesocycles, there was minor variation across the season for the
398 internal and external TL variables used. In addition, it was observed that MD-1 presented a reduction
399 of external TL during in-season match-day-minus training comparison (regardless of mesocycle)
400 (i.e. reduction of total distance; five different training intensity zones) and internal TL (s-RPE).
401 However, the internal TL variable, HI did not change, except for MD+1. This study also provided
402 ranges of values for different external and internal variables that can be used for other elite teams.

403

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417 **Formal analysis:** RO, JB.
418 **Funding acquisition:** DM, RF, MCM.
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428

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578

Table 1. Training Load Data during the ten mesocycles for squad average, Mean ± SD

Mesocycle (number of matches)	Duration (min)	Total Distance (m)	Average speed (m/min)	HSD (m)	s-RPE (au)	HI (au)
M1 (4)	81.6±1.1 ^{c, d, e, g, h, i}	5589.1±100.1 ^{d, i}	68.6±1.1	227.0±13.7 ^{d, e, f, g, h, i}	331.9±21.6 ^{d, g, i}	11.9±0.8
M2 (5)	78.4±1.6 ^{d, i}	5248.2±156.2 ^{b, i}	66.8±0.9 ^b	192.3±17.0 ^{d, g}	287.3±22.6 ^d	12.1±0.8
M3 (4)	77.4±1.9 ^d	5691.4±132.1 ^{d, f, i}	74.0±1.7 ⁱ	181.9±18.9 ^d	298.4±33.2	11.7±0.7
M4 (5)	72.3±1.6	5111.4±173.9	70.7±2.2	152.2±15.4 ^d	256.9±26.6	12.6±0.7
M5 (6)	63.6±2.4 ^{f, g, i}	4473.5±136.4 ^{e, f}	71.0±2.1 ⁱ	92.3±6.6 ^{e, f, g}	208.6±25.9	13.0±0.7 ⁱ
M6 (8)	71.7±1.8	5231.8±123.0 ⁱ	73.2±1.7 ⁱ	162.9±15.3	250.5±22.1	11.4±0.9
M7 (5)	75.5±1.7	5041.9±70.5 ⁱ	67.2±1.9	133.6±10.3	247.8±20.4	11.6±1.1
M8 (4)	74.5±1.2	5149.5±112.5 ⁱ	69.3±1.3 ⁱ	157.8±15.4	239.8±25.8	10.6±0.8
M9 (7)	72.9±1.8	5026.7±204.1	69.0±2.1 ⁱ	144.8±15.9	240.8±25.5	10.8±0.8
M10 (4)	73.3±1.3	4545.4±111.7	62.2±1.6	138.5±14.7	239.3±26.7	10.2±0.9

579 M= mesocycle (1, 2, 3, etc.); min= minutes; m=meters; HSD = high-speed running distance; s-RPE= session rating of perceived
 580 effort; HI = Hooper index; au=arbitrary units. a denotes difference from M2, b denotes difference from M3, c denotes difference from
 581 M4, d denotes difference from M5, e denotes difference from M6, f denotes difference from M7, g denotes difference from M8, h
 582 denotes difference from M9, i denotes difference from M10, all P < 0.05

583

584

Table 2. Training Load Data during the MD minus for squad average, Mean ± SD

MD	Duration (min)	Total Distance (m)	Average speed (m/min)	HSD (m)	s-RPE (au)	HI (au)
MD-5	80.2±1.3 ^{b, c, d, e}	7482.0±173.1 ^{a, b, c, d, e}	94.1±3.0 ^{a, c, d, e}	274.8±26.0 ^{c, d, e}	331.7±27.0 ^{d, e}	10.2±0.7 ^e
MD-4	74.2±1.4 ^{d, e}	5943.9±105.4 ^{c, d, e}	80.4±1.2 ^{c, d, e}	249.3±16.3 ^{c, d, e}	334.4±25.8 ^{c, d, e}	11.1±0.6 ^e
MD-3	72.8±1.3 ^{d, e}	6205.6±106.4 ^{c, d, e}	85.3±1.3 ^{c, d, e}	219.7±13.7 ^{c, d, e}	342.4±25.3 ^{d, e}	11.1±0.6 ^e
MD-2	73.2±0.8 ^{d, e}	5404.7±59.2 ^{d, e}	73.9±0.8 ^{d, e}	190.4±11.1 ^{d, e}	274.3±23.2 ^{d, e}	11.3±0.6 ^e
MD-1	86.1±0.2 ^e	3564.7±55.6 ^e	41.4±0.6 ^e	72.4±5.7 ^e	212.3±15.5 ^e	10.9±0.6 ^e
MD+1	20.4±1.5	4576.7±184.8	243.8±16.4	117.8±17.8	33.6±3.7	15.4±0.7

MD-=matchday minus (5, 4, 3, 2, 1); MD+1= matchday plus 1; min= minutes; m=meters; HSD = high-speed running distance; s-RPE= session rating of perceived effort; HI = Hooper index; au=arbitrary units. a denotes difference from MD-4, b denotes difference from MD-3, c denotes difference from MD-2, d denotes difference from MD-1, e denotes difference from MD+1, all P < 0.01.

585



