Quantification of in-season training load relative to match load in professional Dutch Eredivisie football players

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Abstract

The aims of this study were (1) to quantify and compare the load of a professional football team’s training days and matches, and (2) to compare training of nonstarters the day after the match with regular training of starters and nonstarters. On-field training load during in-season training days (categorized as days before match day, i.e. MD minus) and three friendly matches were recorded using a Local Positioning Measurement (LPM) system. Mixed Linear Models showed lower load when training approached match day. Relative to match values (100%), training values for running (52–20%; MD-4–MD-1) and high-speed running (38–15%) were lower than for total distance (67–35%), and all considerably lower than match values. On average, medium and high accelerations and decelerations during training were more similar to match values (90–39%). Load during nonstarters training was lower than during regular training for almost all variables on MD-4 and several high-intensity variables on MD-3 and MD-2. The results highlight that acceleration and deceleration measures complement more commonly used external load variables based on distance and speed. Furthermore, nonstarters are potentially under loaded compared to starters, especially in terms of (high-speed) running.
Introduction

In team sports, the daily monitoring of training and match load can help coaches and practitioners to plan, structure, evaluate, and therewith optimize their training process (Borresen & Lambert, 2009). Recently, it has for example been reported that increased 1- to 2-weekly cumulative training loads and week-to-week changes in training load led to increased injury risks in Australian Football (Rogalski et al., 2013). The quantification of training and match load can therefore aid to decrease injuries and optimize performance in team sport athletes (Cummins, Orr, O’Connor, & West, 2013).

Due to the increased use of contemporary tracking technologies, professional clubs can now easily collect objective internal (physiological) and external (physical) load variables of players during both training and match play (Buchheit, Allen, et al., 2014). Several of these load variables have been linked to subjective ratings of perceived exertion (RPE) in football (Gaudino et al., 2015) and other team sports (Gallo, Cormack, Gabbett, Williams, & Lorenzen, 2015; Lovell, Sirotic, Impellizzeri, & Coutts, 2013). However, a combination of variables predicted RPE better than any variable alone in rugby (Lovell et al., 2013). This may indicate that multiple objective external and internal load variables should be included in order to accurately describe the physical and physiological demands of team sports in general and football in particular (Buchheit, Manouvrier, Cassirame, & Morin, 2015; Casamichana & Castellano, 2015).

Indeed, numerous studies have provided detailed information about the external load of elite football players during matches (see Sarmento et al. (2014) for a review), including acceleration and metabolic variables (Dalen et al., 2016; Ingebrigtsen et al., 2015; Osgnach et al., 2010; Russell et al., 2016; Varley & Aughey, 2013; Wehbe et al., 2014), since these variables have been considered both metabolically and mechanically relevant (Greig et al., 2006; Stevens et al., 2015). Only recently, however, several studies have described the in-season training periodization practices of elite football teams in detail, including a comparison of training days within weekly micro-cycles (Akenhead, Harley, & Tweddle, 2016; Anderson et al., 2016; Malone et al., 2015). Malone et al. (2015) found that only the last training before the match differed from the other training days on several internal and external load variables, but they did not include accelerations and metabolic power estimations because the accuracy of GPS measurements of high-intensity velocity changes is limited (Akenhead, French, Thompson, & Hayes, 2014; Buchheit, Al Haddad, et al., 2014). Nevertheless, Akenhead et al. (2016) used GPS and reported that when the training session was closer to match day distance covered while accelerating and decelerating followed a similar decrease as total distance and distance ran at high speeds. However, to date no study has described the number of accelerations and decelerations nor the metabolic demands of whole training sessions. Moreover, since training and match are usually measured with different tracking systems, no study so far has directly compared these demands between training sessions and matches. As a result, the load of training sessions relative to matches remains unclear.

Therefore, the first aim of the present study was to quantify and compare the external and
internal load, including accelerations, decelerations and metabolic demands, of a professional football team’s typical training days and matches, measured with the same highly accurate Local Positioning Measurement (LPM) system. We hypothesized that training load is lower on training days closer to the next match. Furthermore, because training sessions usually include exercises played in relatively small areas, we hypothesize that, compared to matches, the values during training are higher for accelerations and decelerations compared to the traditional used total distance and distance ran at high speeds. Additionally, nonstarters that do not or just briefly play in the match often have an extra training session the day after the match, when starters have a recovery session. However, since the number of nonstarters is usually low, this may affect the organization and thereby the content and load of this extra session. Therefore, the second aim of this study was to compare these extra training sessions of nonstarters with regular training sessions of the whole team (starters and nonstarters). Since the extra nonstarters training offers a possibility to compensate in load for the missed match, we hypothesize that the training sessions of nonstarters have at least a similar load compared to regular training sessions.

**Methods**

**Participants**

Twenty-eight elite outfield football players of a Dutch Eredivisie team (mean ± SD: 22 ± 3 years, 182 ± 7 cm, 76 ± 7 kg) took part in this study. Players approved the use of training and match data for the purpose of the present study by written consent. The study was approved by the Ethics Committee Human Movement Sciences of the Vrije Universiteit Amsterdam.

**Design**

Training load data were collected for outfield players using a LPM system (specifications below) during the 2014–2015 in-season. Both pre-seasons (summer and winter) and training sessions during the FIFA International Match Calendar were excluded. Training sessions that were not on the home ground outdoor training pitches (104 × 65 m)—such as twenty sessions at the home stadium the day before a match and eight sessions before and after matches abroad—were not recorded. Two training sessions were not fully recorded due to technical issues with the monitoring system and therefore excluded from analysis. All remaining main team training sessions (regular training, including starters and nonstarters) and training sessions the day after the match (nonstarters training) were analysed. All training sessions included a warm-up and either combination of technical drills, passing drills, small and large sided games with or without goalkeepers, tactical games, finishing drills, and running drills for the whole team. Players that did not finish the whole training session were excluded. Match data (excluding
warm-up) was collected for two friendly matches (2 × 45 min) and one training match (2 × 30 min) using the same LPM system. Individual observations were included if players played at least 60 min. Match values were then recalculated to 90 min. Out of a total of 1029 individual training and match observations (median = 39.5; range = 3–55), 43 observations (4.2%) contained invalid time-motion data and 185 observations (18.0%) contained invalid heart rate data due to technical issues with equipment and therefore these data could not be included.

The team that took part in the study often played two matches per week due to participation in domestic cup and European competition. This irregular match schedule led to various types of micro-cycles with different numbers of (full) days between matches (12×2, 14×3, 2×4, 2×5, 9×6, 1×8 and 1×9). Consequently a ‘typical’ week (usually regarded as one match per week with six full days between matches) is difficult to define for top teams playing in multiple competitions. We therefore classified training sessions based on the number of days before match day (i.e. MD minus) (Malone et al., 2015). For example, MD-2 means that this session took place two days before match day.

The second day after the match was usually a day off for the team under investigation (except for the micro-cycle with two full days between matches). As a result, there were only two micro-cycles (8 and 9 full days) that contained regular training sessions that took place more than four days before the next match; these three training sessions were excluded from analysis. Regular training sessions (44 in total) were subsequently categorized as MD-4, MD-3, MD-2 and MD-1. Nonstarters training sessions (32 in total) were also categorized as MD-4, MD-3 and MD-2. Because there is a minimum of two full days between matches, the nonstarters training session—always the day after the match—will never take place on MD-1. In addition, for the nonstarters there were only two training sessions classified as MD-4. Therefore, also sessions that took place more than four days before the next match (8×MD-6 and 1×MD-8) where included in the nonstarters MD-4 category. All these sessions (MD-4, MD-6 and MD-8) where expected to have a similar (high) training load since, different from MD-3 and MD-2, there was no need to taper for the upcoming match.

Data collection and data analysis

Players’ physical activity of training and test matches was measured with a LPM system (version 05.91T; Inmotiotec GmbH, Regau, Austria). LPM data sampled at 31 Hz or higher were filtered (integrated ‘weighted Gaussian average’ filter set at 85%; speed frame interval set at 50 ms) using Inmotio software (version 3.7.0.152; Inmotiotec GmbH, Regau, Austria). Recently, the LPM system showed acceptable accuracy for measures of speed and average acceleration and deceleration for intermittent activities (Stevens et al., 2014). Integrated metabolic power calculation, based on the algorithm of di Prampero et al. (2005), which was extended by Osgnach et al. (2010) for use in team sports, was employed to estimate metabolic power and therewith energy expenditure. Adjustable terrain factor (KT) and energy cost of constant running on flat terrain (in J·kg⁻¹·m⁻¹) were set at 1.05 and 4.0 respectively (Sassi et al., 2011; Stevens et al., 2015).
Variables selected for analysis were training duration (min), total distance (m), estimated energy expenditure (kJ·kg\(^{-1}\)), running (14.4–19.8 km·h\(^{-1}\)) distance (m), high-speed running (> 19.8 km·h\(^{-1}\)) distance (m) and distance (m) producing high power (> 20 W·kg\(^{-1}\)), in which high power is assumed to reflect mainly anaerobic activities (Osgnach et al., 2010). Additionally, the number of medium (1.5–3.0 m·s\(^{-2}\)) and high (> 3.0 m·s\(^{-2}\)) acceleration, and medium (−1.5 to −3.0 m·s\(^{-2}\)) and high (< −3.0 m·s\(^{-2}\)) decelerations were selected for analysis. Acceleration thresholds were close to those suggested by Johnston et al. (2014). Accelerations and decelerations had to last at least 0.5 s (Dalen et al., 2016). Furthermore, accelerations were only included when they resulted in velocities above 2.78 m·s\(^{-1}\) (= 10.0 km·h\(^{-1}\)) during the acceleration phase, whereas decelerations were only included when they started above and ended below a velocity of 2.78 m·s\(^{-1}\). These velocity thresholds were applied to only include real accelerations and decelerations of intense full-body movements, and therewith to exclude ‘fake’ accelerations that were solely the result of upper-body movements, as checked visually from video footage. Heart rate was measured using LPM-integrated Polar Wearlink\® technology (Polar Electro Oy, Kempele, Finland). The highest heart rate measured during either Yo-Yo IR2 tests, training sessions or test matches was designated as the player’s maximum heart rate (HR\(_{\text{max}}\)). Finally, time spent above 90%HR\(_{\text{max}}\), generally accepted as an average threshold needed to maintain and improve aerobic endurance in elite team sport athletes (Hoff et al., 2002; Owen, Wong del, McKenna, & Dellal, 2011), was included as a measure of internal (cardiovascular) load.

Statistics

Linear mixed modelling (MLwiN, version 2.22) (Goldstein, 2003) was used for data analysis as this statistical technique can easily deal with unbalanced designs, repeated measures and missing data. To examine inter-day differences of regular training sessions and matches, a 3-level linear mixed model was used. Single training sessions were clustered within MD minus (i.e. days before the next match) and the observations of MD minus were clustered within players. MD minus was entered to the linear mixed model as a categorical independent variable in order to estimate the difference in the outcomes between the different days before the match. To examine differences between regular training and nonstarters training sessions three similar 3-level linear mixed models were used (separate models for MD-4, MD-3 and MD-2), but in this case training mode (regular vs nonstarters training) was entered as independent variable to the model. Significance was set at \(P < .05\).

Results

Inter-day differences of regular training

Descriptive data (mean ± SD) of match, regular training and nonstarters training are presented in Table 4.1. Figure 4.1 presents the results of the mixed linear model analysis; it shows estimated
## Table 4.1. Descriptive statistics of training load variables of match, regular training, and nonstarters training (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Match</th>
<th>MD-4 (91/72)</th>
<th>MD-3 (143/131)</th>
<th>MD-2 (231/210)</th>
<th>MD-1 (253/215)</th>
<th>MD-4 (67/54)</th>
<th>MD-3 (86/65)</th>
<th>MD-2 (78/64)</th>
</tr>
</thead>
<tbody>
<tr>
<td># sessions</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>14</td>
<td>15</td>
<td>11</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td># players per session</td>
<td></td>
<td>18 ± 6</td>
<td>19 ± 2</td>
<td>19 ± 3</td>
<td>18 ± 2</td>
<td>8 ± 3</td>
<td>8 ± 3</td>
<td>10 ± 2</td>
</tr>
<tr>
<td>N total (time-motion/HR)</td>
<td>38 (37/33)</td>
<td>92 (91/72)</td>
<td>152 (143/131)</td>
<td>242 (231/210)</td>
<td>257 (253/215)</td>
<td>69 (67/54)</td>
<td>88 (86/65)</td>
<td>78 (78/64)</td>
</tr>
<tr>
<td>Duration (min)</td>
<td>90 ± 0*</td>
<td>88 ± 11</td>
<td>82 ± 7</td>
<td>77 ± 12</td>
<td>59 ± 7</td>
<td>85 ± 13</td>
<td>82 ± 8</td>
<td>82 ± 11</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>10927 ± 619</td>
<td>7267 ± 913</td>
<td>6120 ± 1188</td>
<td>5219 ± 881</td>
<td>3848 ± 454</td>
<td>6022 ± 993</td>
<td>5775 ± 986</td>
<td>5455 ± 825</td>
</tr>
<tr>
<td>EE (kJ·kg⁻¹)</td>
<td>58 ± 3</td>
<td>40 ± 6</td>
<td>33 ± 6</td>
<td>29 ± 5</td>
<td>21 ± 2</td>
<td>33 ± 5</td>
<td>32 ± 4</td>
<td>30 ± 4</td>
</tr>
<tr>
<td>Time &gt; 90%HRmax (min)</td>
<td>22 ± 18</td>
<td>17 ± 10</td>
<td>4 ± 6</td>
<td>4 ± 5</td>
<td>3 ± 4</td>
<td>9 ± 9</td>
<td>6 ± 6</td>
<td>4 ± 4</td>
</tr>
<tr>
<td>RUN (m)</td>
<td>1614 ± 320</td>
<td>834 ± 169</td>
<td>692 ± 219</td>
<td>510 ± 156</td>
<td>328 ± 101</td>
<td>372 ± 137</td>
<td>349 ± 129</td>
<td>383 ± 148</td>
</tr>
<tr>
<td>HSR (m)</td>
<td>738 ± 244</td>
<td>249 ± 85</td>
<td>281 ± 134</td>
<td>175 ± 108</td>
<td>106 ± 53</td>
<td>291 ± 267</td>
<td>105 ± 115</td>
<td>75 ± 47</td>
</tr>
<tr>
<td># medium ACC</td>
<td>165 ± 25</td>
<td>131 ± 31</td>
<td>82 ± 25</td>
<td>81 ± 21</td>
<td>55 ± 13</td>
<td>88 ± 19</td>
<td>79 ± 18</td>
<td>84 ± 15</td>
</tr>
<tr>
<td># high ACC</td>
<td>61 ± 14</td>
<td>66 ± 18</td>
<td>44 ± 13</td>
<td>45 ± 15</td>
<td>26 ± 8</td>
<td>38 ± 12</td>
<td>35 ± 12</td>
<td>40 ± 14</td>
</tr>
<tr>
<td># medium DEC</td>
<td>111 ± 19</td>
<td>98 ± 23</td>
<td>64 ± 18</td>
<td>65 ± 17</td>
<td>44 ± 10</td>
<td>69 ± 15</td>
<td>65 ± 15</td>
<td>67 ± 14</td>
</tr>
<tr>
<td># high DEC</td>
<td>58 ± 14</td>
<td>49 ± 16</td>
<td>30 ± 11</td>
<td>29 ± 11</td>
<td>23 ± 8</td>
<td>26 ± 11</td>
<td>27 ± 11</td>
<td>27 ± 8</td>
</tr>
<tr>
<td>HP (m)</td>
<td>2472 ± 315</td>
<td>1363 ± 266</td>
<td>1066 ± 335</td>
<td>854 ± 242</td>
<td>565 ± 124</td>
<td>951 ± 297</td>
<td>750 ± 181</td>
<td>741 ± 173</td>
</tr>
</tbody>
</table>

Notes: * match values have been recalculated to 90 min; mean ± SD values are based on all included samples, including repeated measures of individual players; Note that the nonstarters MD-4 training also includes training sessions with more than 4 days to the next match. Abbreviations: MD-4 = training session 4 days before Match Day (MD); HR = heart rate; EE = estimated energy expenditure; RUN = running (>14.4–19.8 km·h⁻¹); HSR = high-speed running (>19.8 km·h⁻¹); ACC = accelerations (medium: 1.5–3.0 m·s⁻²; high: >3.0 m·s⁻²); DEC = decelerations (medium: -15 to -3.0 m·s⁻²; high: <-3.0 m·s⁻²); HP = high power (>20 W·kg⁻¹).
training load variables of each regular training day expressed as a percentage of estimated match values. Match was significantly different from all training days for all variables, except duration, which was not significantly different between match and MD-4. In general, training load variables declined when match day approached (MD-4 > MD-3 > MD-2 > MD-1).

Figure 4.1. Estimated training load variables of typical training days expressed as a percentage of estimated match values.

Notes: Values above the horizontal line represent the estimated full match values for each variable (= 100%); Error bars of training days indicate 95% confidence interval of the mean difference between each estimated training day and estimated match, expressed as a relative match value. Error bars of the match indicate 95% confidence interval of the estimated match value, expressed as a relative match value. Abbreviations: MD-4 = training session four days before Match Day (MD); EE = estimated energy expenditure; HR = heart rate; RUN = running (14.4–19.8 km·h⁻¹); HSR = high-speed running (> 19.8 km·h⁻¹); ACC = accelerations (medium: 1.5–3.0 m·s⁻²; high: > 3.0 m·s⁻²); DEC = decelerations (medium: -1.5 to -3.0 m·s⁻²; high: < -3.0 m·s⁻²); HP = high power (> 20 W·kg⁻¹).

Estimated match and training session means are different from each other (P < .05) unless indicated by: a = not different from match, b = not different from MD-4, c = not different from MD-3, d = not different from MD-2, e = not different from MD-1.
Relative to match values (100%), training values for total distance were between 67 and 35% (range MD-4 to MD-1; Fig. 4.1). Lower values were found for running (52–20%) and especially high-speed running (38–15%). On average, medium and high accelerations and decelerations during training were more similar to match values (90–39%). Figure 4.2 shows the estimated cumulative load per variable during a typical week consisting of a recovery training (not recorded), a day off, four consecutive training days and a match. All values were expressed as the number of matches equalling this load. As can be seen, the total weekly load (including training sessions and match) was higher for acceleration variables (3.1–3.9 matches) compared to running (2.5 matches) and high-speed running (2.1 matches).

Figure 4.2. Estimated cumulative weekly training load of a typical week with one match and four subsequent training sessions (MD-4, MD-3, MD-2, MD-1) expressed as number of matches per variable.

Notes: a typical week with one match was considered to be a week with a recovery training (day after the match; not recorded), a day off, four subsequent training sessions (MD-4, MD-3, MD-2 and MD-1) and a match. Abbreviations: MD-4 = training session four days before Match Day (MD); EE = estimated energy expenditure; HR = heart rate; RUN = running (14.4–19.8 km·h⁻¹); HSR = high-speed running (> 19.8 km·h⁻¹); ACC = accelerations (medium: 1.5–3.0 m·s⁻²; high: > 3.0 m·s⁻²); DEC = decelerations (medium: -1.5 to -3.0 m·s⁻²; high: < -3.0 m·s⁻²); HP = high power (> 20 W·kg⁻¹).

Regular training versus nonstarters training

Nonstarters training on the day after the match showed significantly lower values on MD-4 than regular training on MD-4 for almost all training load variables, while training duration was not significantly different (Fig. 4.3). Considerably lower values were found for nonstarters training compared to regular training for total distance (mean difference ± 95% CI = -17 ± 5%), energy expenditure (-18 ± 5%), but especially time spent above 90%HR_max (-52 ± 35%), running (-55 ± 13%), medium (-33 ± 9%) and high (-42 ± 12%) accelerations, medium (-29 ± 8%) and high...
Figure 4.3. Estimated training load variables of regular and nonstarters training days expressed as a percentage of estimated match values.

Notes: values above the horizontal line represent the estimated full match values for each variable (= 100%); Note that the nonstarters MD-4 training also includes training sessions with more than 4 days to the next match. Abbreviations: regular = regular training session; nonstart = nonstarters training session one day after Match Day (MD); MD-4 = training session four days before MD; EE = estimated energy expenditure; HR = heart rate; RUN = running (14.4–19.8 km·h⁻¹); HSR = high-speed running (> 19.8 km·h⁻¹); ACC = accelerations (medium: 1.5–3.0 m·s⁻²; high: > 3.0 m·s⁻²); DEC = decelerations (medium: -1.5 to -3.0 m·s⁻²; high: < -3.0 m·s⁻²); HP = high power (> 20 W·kg⁻¹).

Regular and nonstarters training are different from each other when indicated by * (P < .05) or ** (P < .001).
(-46 ± 15%) decelerations, and high power (-30 ± 9%). Lower values for nonstarters training compared to regular training were also found on MD-3 and MD-2, for running (-49 ± 14% and -25 ± 10%, respectively), high-speed running (-62 ± 32% and -57 ± 33%), high accelerations (-20 ± 10% and -10 ± 9%) and high power (-30 ± 10% and -13 ± 8%). Figure 4.4A shows that nonstarters have on average a lower estimated total load than starters during a typical week with one match, especially on running (-31%), high-speed running (-29%), high power (-24%), and time above 90%HRmax (-30%). During weeks with two matches a week nonstarters show even less total load, with for time above 90%HRmax, running distance and high-speed running distance on average less than a full match (Fig. 4.4B).

Figure 4.4. Estimated cumulative weekly load for starters and nonstarters during a typical week with one match (A) and two matches (B) expressed as number of matches per variable.

Notes: a typical week with one match (A) was considered to be a week starting with a recovery training for the starters (not recorded) and a nonstarters training session for the nonstarters (MD+1), followed by a day off, four subsequent training sessions (MD-4, MD-3, MD-2 and MD-1) and a match (only for starters). A typical week with two matches (B) consisted of two recovery sessions (only for starters) or two MD+1 sessions (only for nonstarters), two MD-1 sessions, two matches (only for starters) and a day off.
Discussion

In the present study we objectively quantified and compared the load of an elite football team's typical training days and matches. Consistent with our hypothesis, training load in general decreased when match day approached. Furthermore, as expected, the number of medium and high accelerations and decelerations during training were in general closer to whole match values than total distance, running and high-speed running. This highlights the importance of quantifying accelerations and decelerations in addition to the more traditional external load variables. Moreover, in this study we compared training sessions of nonstarters (the day after the match) with regular training sessions of the whole team (starters and nonstarters). In contrast to our hypothesis, the nonstarters training showed in general lower values than regular training, especially on MD-4, contributing to a lower weekly total load for nonstarters than starters.

Several studies involving English Premier League teams have also found that during a typical week—six full days between matches—the last day before the match (MD-1) has usually the lowest load (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015). However, whereas our study showed the highest training load on the first training of the week (MD-4), both Akenhead et al. (2016) and Anderson et al. (2016) showed the highest training load for the second training of the week (MD-4 and MD-3, respectively). Malone et al. (2015) found no differences in training load between the first three training sessions of the week. Altogether these results indicate that differences exist in the distribution of training load between high-level football teams, especially in the middle (MD-5, MD-4, MD-3) of a full training week.

To fairly compare our data with other studies that assessed in-season training load of full sessions in top-level leagues of professional football (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013), we used the averages of the four training days in our study. Average training duration (77 min), total distance (5614 m), running (591 m) and high-speed running (203 m) were high in the range of, or even somewhat higher than, other teams demonstrated (65–76 min, 3898–5667 m, 220–412 m, and 41–205 m, respectively) (Akenhead et al., 2016; Anderson et al., 2016; Malone et al., 2015; Scott et al., 2013).

To date, as far as we are aware, no other studies have reported the number of accelerations or decelerations or metabolic power variables during full training sessions. Time spent above 90%HRmax during training encompassed 8% (28 min) of total weekly training time, which is comparable to the 7% (21 min per week) found by Akenhead et al. (2016). However, the time spent above 90%HRmax in our study was rather low on MD-3, MD-2 and MD-1 (3–4 min) compared to MD-4 (17 min) and match (23 min), assuming limited aerobic conditioning on the last three days preceding the match. Therefore it appears that during in-season, when players have to peak frequently in competition (1–2 times a week), matches actually form the most important physiological stimulus. There seems only time for extra physiological conditioning during the middle of full-week micro-cycles, since the other days are too close to the match and therefore
would most likely either hinder physiological adaptations or cause pre-match fatigue (Issurin, 2010).

The average total distance covered during the matches in our study (10927 m) reflected that of top-level leagues in Europe and Australia (range 10063–11230 m) (Bradley et al., 2013; Bradley et al., 2010; Dalen et al., 2016; Ingebrigtsen et al., 2015; Manzi, Impellizzeri, & Castagna, 2014; Osgnach et al., 2010; Wehbe et al., 2014). Also running (14.4–19.8 km·h⁻¹) distance and high-speed running (> 19.8 km·h⁻¹) distance were within the range of the same top-level leagues (1614 vs 1612–1758 and 738 vs 646–1061 m, respectively). While the estimated energy expenditure of matches in our study (~58 kJ·kg⁻¹ above resting) was close to the values reported for the Italian Serie A (60–61 kJ·kg⁻¹) (Manzi et al., 2014; Osgnach et al., 2010), distance at high power was somewhat lower (2480 vs 2712–2839 m). Nevertheless, the above comparisons show that the matches in the present study are representative for matches in top-level leagues.

It is difficult to compare our acceleration data of the matches with literature, since there currently is little consensus regarding the use of acceleration thresholds in team sports (Johnston et al., 2014). Whereas our study showed the total number of accelerations and decelerations above 1.5 m·s⁻² (226 and 169, respectively) and 3.0 m·s⁻² (61 and 58), other studies that considered matches in elite leagues (Bradley et al., 2010; Dalen et al., 2016; Ingebrigtsen et al., 2015; Russell et al., 2016; Varley & Aughey, 2013; Wehbe et al., 2014) used absolute thresholds of 0.5, 2.0, 2.5, 2.78, 3.0, and 4.0 m·s⁻². It is important to realize that even if there was agreement, comparison between acceleration variables measured with different tracking systems (and system versions) would be difficult (Buchheit, Allen, et al., 2014). We believe that the thresholds used in our study, which are close to those proposed by Johnston et al. (2014), led to meaningful (whole body) accelerations and decelerations for data collected with the LPM system.

The usefulness of metabolic power variables estimated using time-motion data has recently been a topic of debate (Buchheit et al., 2015; Osgnach, Paolini, Roberti, Vettor, & di Prampero, 2016). We acknowledge that care should be taken using both estimated energy expenditure as well as the (arbitrarily chosen) distance producing high power (> 20 W·kg⁻¹) as measures for external load, especially when applied at an individual level (Stevens, de Ruiter, Beek, & Savelbergh, 2016). Currently, energy expenditure is underestimated, even when measured with an highly accurate LPM system, and most likely even more when using GPS (Stevens et al., 2015). Moreover, although energy expenditure would potentially be a better indicator of overall workload than distance covered (Polglaze et al., 2016), in the present study estimated energy expenditure provided very similar information as total distance covered during training (Pearson's correlation = 0.99).

It can be very valuable to express training load data against the match reference, since this facilitates the interpretation of the data, and hence the training prescription as well as the communication between practitioners, coaches and players. As far as we know, this is the first study that directly compares professional football players’ training load to match load measured with the same accurate tracking system. We acknowledge that, because we could
only use data of test matches played on the home training ground, the match sample size is rather small. However, 37 individual samples were still used to estimate external load variables. Nevertheless, match activity based on samples of less than 90 min that are extrapolated to 90 min could possibly overestimate full match activity. However, when we extrapolate 60-min match samples to 90 min and compare those to the measured data in studies that divided their 90-min data in 15-min bins (Akenhead et al., 2013; Bradley et al., 2009; Mohr et al., 2003; Russell et al., 2016) we see that extrapolation leads to an overestimation of complete match data of about 4% for measures of total distance, high-speed running distance and acceleration and deceleration. Moreover, in our study, the inclusion of these 22 samples of less than 90 min led to values for the internal and external load variables that were only about 2% higher (ranging from -0.1% for running to 4.6% for medium deceleration) compared to our samples (N=15) of complete (90 min) matches. Therefore, data from the literature as well as from the present study indicate that potential inaccuracies caused by the extrapolation were small and certainly do not affect our main outcomes and conclusions.

To facilitate the interpretation of training and match data, we also believe that it is preferable to use the number of accelerations rather than distance covered in a corresponding acceleration zone, particularly because these two variables provide rather similar information, as in our study (Pearson’s correlation = 0.88–0.92). Since the beginning of the 2015–2016 seasons FIFA allows the use of electronic tracking of players during official matches. Future research should focus on a comparison of acceleration demands between training sessions and official matches measured with the same tracking system. Also position-specific profiles should be taken into account, although the implications of these differences for training prescription are as of yet unclear (Carling, 2013).

In the present study, we also compared nonstarters training sessions with regular training sessions. Although we realize that the outcomes might be highly specific for the team under investigation, we believe that the finding that load in these nonstarter sessions was generally lower than regular training load is important as it highlights the general risk for under-loading nonstarters. During a typical week with one match nonstarters showed on average a lower total load than starters (up to ~30% less for running and high-speed running), even though we did not include the starters’ match warm-up and (low-intensity) recovery session. Interestingly, compared to starters, nonstarters spent significantly greater time above 90%HR_{max} on MD-3, while several external load variables were lower. One might speculate that the smaller number of players in the nonstarters training (~9 vs ~18 in regular training) induces an increase of ball touches, dribbles (Owen et al., 2011) and duels (Owen, Wong, Paul, & Della, 2014). This could increase the internal load due to a higher need for coordination (ball control) and static strength (duels), not reflected by the external load variables that mainly quantify the players’ locomotion. Altogether, there is clearly a challenge to sufficiently load nonstarters within a football-specific context, especially on (high-speed) running.
Practical implications

The data presented in this study highlights the importance of including accelerations and decelerations as external load measures, since they provide additional information to more commonly used variables. In football practice we advise to choose and report on only a few variables (3–6) to keep communication simple and effective. These variables should include at least a measure of cardiovascular load, distance ran at high speed and total number of intense accelerations in order to sufficiently describe the high-intensity demands of professional football (Gaudino et al., 2015). Estimations of energy expenditure could be useful for nutritionist advising on energy intake, but the values estimated based on metabolic power should be seen as a minimum since these values currently are underestimated. Coaches and practitioners should be aware of the potential risk of under loading nonstarters. They could offer additional physical loading, preferably in a football-specific context, for example by increasing the number of players during the nonstarters training, organizing additional test matches or by letting nonstarters play in matches of a lower team. Train harder with a nonstarter, especially in terms of running and high-speed running.

Conclusions

• MD-4 showed the highest training load, including acceleration and metabolic variables, after which training load gradually decreased when match day approached.

• Relative to match values, acceleration load during training was in general higher than total distance covered and distance ran at high speeds.

• Acceleration load on the most intense training day (MD-4) was close to match load.

• Nonstarters training showed in general a lower load than regular training, especially on MD-4, contributing to a considerably lower total weekly load for nonstarters compared to starters.