



Impact of Official Matches on Soccer Referees' Power Performance

by

Daniel Castillo¹, Javier Yanci¹, Jesús Cámara¹

The evaluation of match officials' neuromuscular performance is now an important consideration and the vertical jump test is considered suitable for assessing lower limb power, partly because it is directly related to refereeing. The aim of this study, therefore, was to determine the effect of soccer matches on match officials' vertical jump performance by assessing various biomechanical variables. Eighteen field referees (FRs) and 36 assistant referees (ARs) who officiated in 18 official matches participated in this study. Before the match, at half time and immediately after the match, officials performed two countermovement jumps. Flight phase time (FT), maximum force production (MF_{propulsion}), time to production of maximum force (TMF_{propulsion}), production of maximum power (MP), maximum landing force (MF_{landing}) and time to stabilization (TTS) were calculated for all jumps. There was a tendency for match officials' jumping performance to improve after matches than beforehand (FR: effect size (ES) = 0.19 ± 0.36, possibly trivial; AR: ES = 0.07 ± 0.17, likely trivial). There were also likely small and very likely moderate differences between FRs' MP in pre-match and half-time jumps (ES = 0.46 ± 0.47) and in their pre- and post-match jumps (ES = 0.71 ± 0.48). These results indicate that refereeing soccer matches does not reduce vertical jump performance; the subsequent neuromuscular fatigue is not sufficient to affect landing technique.

Key words: strength, biomechanics, competition, fatigue.

Introduction

Refereeing soccer matches is a very physically demanding task for field referees (FRs) and assistant referees (ARs). FRs have been shown to cover approximately 10–12 km during the course of matches with a mean heart rate (HR_{mean}) of 86% of their maximum heart rate (HR_{max}) (Mallo et al., 2009a) with 34% of the total distance being covered during high-intensity running (>13 km·h⁻¹) (Mallo et al., 2009a). The physical demands of soccer matches on FRs have been shown to be similar to, or even higher than the demands on players (Weston et al., 2007). ARs, however, have been shown to run 5–6 km during soccer matches with almost 20% of this distance being covered during high-intensity running (Krustrup et al., 2009) and a HR_{mean} of

77% of their HR_{max} (Mallo et al., 2009b).

A number of studies have shown that match officials perform a considerable amount of high-intensity running (Weston, 2014) and it is possible that they may experience fatigue during matches as a consequence. Fatigue has been shown to have a detrimental effect on physical performance (Weston, 2014): distance covered at high-intensity running and total distance covered were shorter during examined 15 min periods of the second half than in the first 15 min period of the first half. Accumulated match-related fatigue is determined by several factors, including running performance during the match (Weston et al., 2012), thus, in order to track development of fatigue directly, it is necessary to combine

¹ - Faculty of Education and Sport, University of the Basque Country, Vitoria-Gasteiz, Spain.

assessments of match running performance and the physiological impact of the match with performance tests before and after games (Krustrup et al., 2010). Although it is difficult to discern from match analysis data (Weston et al., 2012), some authors have attempted to infer how matches affect players' (Cortis et al., 2013; Povoas et al., 2014) and FRs' (Tessitore et al., 2007) fatigue levels from data on match-induced changes in vertical jump and sprint performance. However, to our knowledge only one study has investigated how soccer matches affect the physical performance of both FRs and ARs (Castillo et al., 2016).

Evaluation of match officials' neuromuscular performance is now considered important (Tessitore et al., 2007). The vertical jump is regarded as an appropriate test for evaluating power performance of the lower limbs, and has the benefit of being directly related to refereeing (Tessitore et al., 2007). Although some researchers have observed a significant decrease in soccer players' lower limb power as measured by the vertical jump test after a soccer match (Nedelec et al., 2014), other researchers have found that athletes show higher lower limb power after fatiguing tasks (Boullosa and Tuimil, 2009; Boullosa et al., 2011). A study of match officials concluded that soccer referees' jumping performance was similar before and after matches (Tessitore et al., 2007), yet only ten matches were analyzed. We were therefore interested in analyzing the influence of refereeing on vertical jump performance considering a greater number of matches. The decline in soccer players' power performance during the course of matches has already been analyzed, mainly from data including jump height and flight time values (Cortis et al., 2013; Edholm et al., 2014; Nedelec et al., 2014), although some studies have assessed the impact force during the landing phase in players of team sports (Oliver et al., 2008; Thorlund et al., 2009). Nevertheless, there has been no study examining the effect of soccer games on biomechanical variables characterizing the vertical jump performance of both FRs and ARs.

The aim of this study was, therefore, to determine the effect of soccer matches on the vertical jump performance of FRs and ARs by measuring various biomechanical variables of

jumping performance.

Methods

Participants

Fifty-four match officials (age, 29.5 ± 8.6 years; body height, 175.9 ± 5.6 cm; body mass, 74.2 ± 8.5 kg; BMI, 24.0 ± 2.6 kg·m⁻²) who officiated 18 official soccer matches in the Spanish National Division during the 2014/2015 season participated in this study after giving their informed consent. All participants had at least ten years of refereeing experience and six year experience of refereeing at this level; they trained at least three times a week. Participants were classified as FRs ($n = 18$, 27.2 ± 5.7 years; 177.8 ± 6.7 cm; 74.1 ± 8.1 kg; 23.4 ± 2.3 kg·m⁻²) or ARs ($n = 36$, 30.6 ± 9.5 years; 174.9 ± 4.8 cm; 74.3 ± 8.8 kg; 24.3 ± 2.7 kg·m⁻²). This investigation was performed in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the University of the Basque Country (UPV/EHU); it also met the ethical standards for Sport and Exercise Science Research (Harriss and Atkinson, 2013).

Procedures

The effects of official soccer matches on jump performance were evaluated (Figure 1). Match officials undertook a standardized 15 min warm-up consisting of 7 min of slow jogging followed by progressive sprints and jumps. Before the match (pre-match), at half time (half time) and immediately after the match (post-match), officials performed two countermovement jumps. The participants' internal load (heart rate) was measured with heart rate monitors and their external load with global positioning systems (GPS) during the first and second half of the matches.

Power performance evaluation

Participants performed the vertical countermovement jump (CMJ) test on a force plate sampling at 500 Hz (Quattro Jump™, Kistler, Winterthur, Switzerland). Two maximal jumps separated by a rest of approximately 10 s (Gorostiaga et al., 2009) were performed on three occasions (pre-match, half-time, post-match) as described in a previous study (Castillo et al., 2016). The highest jump result at each time point was used for further analysis. We recorded several variables during the propulsion and landing phases (Figure 2). Flight phase time (FT) was also recorded. The maximum force

production ($MF_{propulsion}$), the time to the production of maximum force ($TMF_{propulsion}$) and the production of maximum power (MP) were obtained during the propulsion phase (Dal Pupo et al., 2012; McLellan et al., 2011; Stone et al., 2003). Data on maximum force production, corresponding to the second peak in the vertical ground reaction force ($MF_{landing}$), and the time to stabilization (TTS) were obtained during the landing phase (Camara et al., 2011; Rojano et al., 2010; Seegmiller and McCaw, 2003). The TTS was determined during the landing phase and was measured as the time from the first contact of the feet with the ground to the time when the vertical ground reaction force (VGRF) reached and remained within 5% of the subjects' body mass (Camara et al., 2011).

Internal match load

The officials' HR was recorded continuously during the matches (Polar Team System™, Kempele, Finland) as a series of average 5 s running values. The HR was not recorded during the 15 min rest period between halves. HR_{max} was taken as the maximum value exhibited during match play (Costa et al., 2013). HR responses were grouped into five intensity categories: (a) 50–60% of HR_{max} ; (b) 61–70% of HR_{max} ; (c) 71–80% of HR_{max} ; (d) 81–90% of HR_{max} ; (e) 91–100% of HR_{max} (Costa et al., 2013; Edwards, 1993).

External match load

Match officials were equipped with GPS devices (MinimaxX v4.0, Catapult Innovations™, Melbourne, Australia) operating at a sampling frequency of 10 Hz. The data on mean total distance covered, and mean distance and percentage of total distance covered at high-intensity velocity ($>13 \text{ km}\cdot\text{h}^{-1}$) (Mallo et al., 2008) are presented separately for each half.

Statistical analysis

Descriptive results are presented as means \pm standard deviation (SD). We opted to use effect sizes (ES) with the uncertainty of the estimates shown as 90% confidence intervals (CI) to quantify the magnitude of the differences between bilateral vertical jump measures at the various time points (pre-match, half-time, post-match). Results were calculated separately for FRs and ARs (Hopkins et al., 2009). We used the parallel groups controlled trial with adjustment for a predictor to analyze pre-rest-post match play

differences between FRs and ARs. ESs were classified as trivial (<0.2), small (0.2 to 0.6), moderate (0.6 to 1.2), large (1.2 to 2.0), very large (2.0 to 4.0) or extremely large (>4.0) (Hopkins et al., 2009). These changes were then qualified via probabilistic terms and assigned using the following scale: 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; $>99.5\%$, most likely (Hopkins et al., 2009). Inference was classified as unclear if the 90% confidence limits (CLs) overlapped the thresholds for the smallest worthwhile positive and negative effects (Hopkins et al., 2009). Mean differences, CIs, ESs and magnitude-based inferences were calculated using a custom-made spreadsheet (Hopkins et al., 2009).

Results

FRs spent approximately 90% (40 min) and 84% (37 min) of their refereeing time in HR zones above 80% of their HR_{max} in the first and second halves of matches, respectively (Table 1). ARs spent 52% (24 min) and 48% (21 min) of their refereeing time at above 80% of their HR_{max} in the first and second halves, respectively. FRs covered a total distance of $9989.1 \pm 454.8 \text{ m}$, including $2872.8 \pm 422.4 \text{ m}$ (28.8%) at high-intensity velocity ($>13 \text{ km}\cdot\text{h}^{-1}$), whereas ARs covered $5146.5 \pm 544.75 \text{ m}$ with approximately 14% of the total distance ($771.4 \pm 170.8 \text{ m}$) at high-intensity velocity.

Table 2 shows the pre-match, half time and post-match values of the considered jumping variables. Likely small and likely moderate changes were found in $MF_{propulsion}$ in FRs from pre-match to half-time and from pre- to post-match, respectively (Table 3). Also, likely small and very likely moderate changes were found in MP in FRs from pre-match to half time and from pre- to post-match, respectively. However, a likely trivial change was found in ARs from half time to post-match play in $MF_{propulsion}$.

Table 4 presents the pre-match, half-time and post-match values of the considered jumping variables and the changes during the course of the match between FRs and ARs. A very likely and moderate difference was found in MP from pre-match to post-match ($ES = -1.03 \pm 0.52$; 0/1/99) between FRs and ARs. Although a likely and small magnitude difference was found in FT from pre-match to rest-match ($ES = -0.36 \pm 0.39$; 1/22/77), a possibly and small magnitude

difference was found after the match. The effects for all remaining measures between FRs and ARs

were possibly and unclear.

Table 1
Internal and external match demands registered during soccer matches on field and assistant soccer referees

| | Field Referees | | Assistant Referees | |
|---|---|---|---|---|
| | 1 st half Mean \pm SD (% of the total) | 2 nd half Mean \pm SD (% of the total) | 1 st half Mean \pm SD (% of the total) | 2 nd half Mean \pm SD (% of the total) |
| 50-60% HR _{max} (min) | 0.0 \pm 0.1 (1.1%) | 0.0 \pm 0.1 (0.0%) | 1.2 \pm 2.4 (2.6%) | 1.9 \pm 3.1 (3.9%) |
| 61-70% HR _{max} (min) | 0.4 \pm 0.9 (0.9%) | 1.2 \pm 2.2 (2.5%) | 6.0 \pm 4.9 (13.4%) | 8.3 \pm 5.1 (17.1%) |
| 71-80% HR _{max} (min) | 3.5 \pm 3.4 (7.8%) | 6.4 \pm 5.3 (13.3%) | 14.2 \pm 4.1 (31.2%) | 16.6 \pm 4.7 (34.4%) |
| 81-90% HR _{max} (min) | 18.2 \pm 6.7 (40.4%) | 20.9 \pm 4.6 (43.3%) | 15.8 \pm 4.9 (34.9%) | 15.1 \pm 4.9 (31.4%) |
| 91-100% HR _{max} (min) | 22.8 \pm 8.3 (50.6%) | 19.7 \pm 8.7 (40.7%) | 8.0 \pm 5.2 (17.6%) | 6.3 \pm 4.4 (13.2%) |
| Total distance (m) | 4983.7 \pm 444.0 | 5005.4 \pm 465.5 | 2546.5 \pm 537.9 | 2600.0 \pm 551.6 |
| Distance at high intensity velocity (m) | 1437.2 \pm 393.6 (28.8%) | 1435.6 \pm 451.1 (28.7%) | 365.4 \pm 173.8 (14.3%) | 406.0 \pm 167.8 (15.6%) |

HR_{max}, maximum heart rate; SD, standard deviation

Table 2
Pre-, half time and post-match jump performance variables during soccer matches on field and assistant soccer referees

| Variables | Referees | Pre-match (mean \pm SD) | Half time (mean \pm SD) | Post-match (mean \pm SD) |
|-------------------------------|-----------|------------------------------|------------------------------|-------------------------------|
| MF _{propulsion} (N) | Field | 1743.63 \pm 154.48 | 1860.62 \pm 320.26 | 1790.13 \pm 173.77 |
| | Assistant | 1731.19 \pm 258.21 | 1827.66 \pm 335.05 | 1804.61 \pm 304.32 |
| TMF _{propulsion} (s) | Field | 0.63 \pm 0.23 | 0.74 \pm 0.36 | 0.74 \pm 0.28 |
| | Assistant | 0.65 \pm 0.22 | 0.72 \pm 0.29 | 0.63 \pm 0.19 |
| MP (W) | Field | 3443.38 \pm 869.36 | 3951.27 \pm 1030.09 | 4019.56 \pm 792.23 |
| | Assistant | 3467.04 \pm 726.41 | 3612.93 \pm 635.17 | 3558.86 \pm 758.33 |
| FT (s) | Field | 0.50 \pm 0.05 | 0.52 \pm 0.07 | 0.51 \pm 0.06 |
| | Assistant | 0.48 \pm 0.05 | 0.47 \pm 0.07 | 0.48 \pm 0.06 |
| MF _{landing} (N) | Field | 4370.29 \pm 1347.51 | 5253.89 \pm 2040.08 | 4210.35 \pm 1062.51 |
| | Assistant | 4688.57 \pm 1425.20 | 4932.84 \pm 1941.42 | 4633.97 \pm 1450.99 |
| TTS (s) | Field | 0.66 \pm 0.18 | 0.75 \pm 0.40 | 0.62 \pm 0.11 |
| | Assistant | 0.68 \pm 0.33 | 0.71 \pm 0.25 | 0.67 \pm 0.26 |

SD, standard deviation; MF_{propulsion}, maximum force on the propulsion phase;
TMF, time to production maximum force; MP, maximum power;
FT, flight time; MF_{landing}, maximum force on the landing phase; TTS, time to stabilization.

Table 3
*Pre-, half time and post-match jump performance variables along
 with effect statistics and qualitative inferences in field and assistants*

| Variables | Referees | Pre match-Half time | | Half time-Post match | | Pre-Post match | |
|----------------------------------|-----------|-----------------------|---|-----------------------|---|-----------------------|---|
| | | ES (mean \pm CL) | Change score (% mean \pm SD); MBI; Rating | ES (mean \pm CL) | Change score (% mean \pm SD); MBI; Rating | ES (mean \pm CL) | Change score (% mean \pm SD); MBI; Rating |
| MF _{propulsion} (N) | Field | 0.40 \pm 0.52 | 5.1 \pm 7.8; Likely Small; 75/22/3 | -0.24 \pm 0.66 | -2.6 \pm 10.3; Unclear; 12/33/55 | 0.36 \pm 0.50 | 3.5 \pm 5.0; Possibly Small; 70/26/4 |
| | Assistant | 0.30 \pm 0.17 | 4.9 \pm 2.9; Likely Small; 85/15/0 | -0.11 \pm 0.10 | -1.7 \pm 1.9; Likely Trivial; 0/93/7 | 0.25 \pm 0.18 | 3.9 \pm 3.1; Possibly Small; 69/31/0 |
| TMF _{propulsion} (s) | Field | 0.28 \pm 0.38 | 9.6 \pm 16.0; Possibly Small; 64/34/2 | 0.02 \pm 0.41 | 3.6 \pm 17.4; Unclear; 22/60/18 | 0.40 \pm 0.43 | 15.6 \pm 14.9; Likely Small; 79/20/1 |
| | Assistant | 0.36 \pm 0.42 | 13.3 \pm 15.5; Possibly Small; 73/25/2 | -0.44 \pm 0.41 | -12.7 \pm 14.0; Likely Small; 0/16/84 | -0.09 \pm 0.31 | -2.1 \pm 9.5; Unclear; 6/66/28 |
| MP (W) | Field | 0.46 \pm 0.47 | 13.8 \pm 17.1; Likely Small; 83/16/1 | -0.10 \pm 0.41 | -1.6 \pm 12.8; Unclear; 11/55/34 | 0.71 \pm 0.48 | 20.3 \pm 14.7; Very Likely Moderate; 96/4/0 |
| | Assistant | 0.18 \pm 0.30 | 4.0 \pm 5.1; Possibly Trivial; 45/53/2 | -0.09 \pm 0.24 | -2.3 \pm 4.7; Likely Trivial; 3/75/22 | 0.12 \pm 0.29 | 2.2 \pm 5.9; Possibly Trivial; 32/64/4 |
| FT (s) | Field | 0.29 \pm 0.27 | 3.4 \pm 3.4; Possibly Small; 73/27/0 | -0.16 \pm 0.19 | -2.2 \pm 2.7; Possibly Trivial; 0/66/37 | 0.19 \pm 0.36 | 2.0 \pm 4.6; Possibly Trivial; 47/49/4 |
| | Assistant | 0.12 \pm 0.12 | 1.4 \pm 1.5; Likely Trivial; 13/87/0 | -0.04 \pm 0.14 | -0.6 \pm 1.9/ Very Likely Trivial; 0/96/4 | 0.07 \pm 0.17 | 0.6 \pm 2.0; Likely Trivial; 11/88/1 |
| MF _{landing} (N) | Field | 0.46 \pm 0.59 | 17.3 \pm 19.9; Likely Small; 78/19/3 | -0.52 \pm 0.54 | -14.2 \pm 16.5; Likely Small; 1/15/85 | 0.01 \pm 0.39 | 1.7 \pm 12.1; Unclear; 20/62/18 |
| | Assistant | 0.15 \pm 0.32 | 3.2 \pm 12.0; Possibly Trivial; 39/57/4 | -0.20 \pm 0.26 | -5.3 \pm 8.7; Possibly Small; 1/50/49 | -0.04 \pm 0.29 | -1.5 \pm 10.2; Unclear; 8/74/18 |
| TTS (s) | Field | 0.41 \pm 0.75 | 13.8 \pm 31.5; Unclear; 70/22/8 | -0.24 \pm 0.41 | -8.9 \pm 18.6; Possibly Small; 4/39/57 | -0.16 \pm 0.82 | -0.8 \pm 21.3; Unclear; 22/32/46 |
| | Assistant | 4.0 \pm 16.2 | 0.01 \pm 0.38; Possibly Trivial; 20/63/17 | -0.26 \pm 0.45 | -9.6 \pm 15.1; Possibly Small; 4/36/60 | -0.10 \pm 0.43 | -1.0 \pm 16.3; Unclear; 12/53/35 |

*ES, effect size; CL, confidence limits; MBI, magnitude based inference;
 MF_{propulsion}, maximum force on the propulsion phase; TMF, time to production maximum force;
 MP, maximum power; FT, flight time; MF_{landing}, maximum force on the landing phase;
 TTS, time to stabilization.*

Table 4
Pre-, half time and post-match jump performance variables along with effect statistics and qualitative inferences for the within- and between-groups comparisons

| Variables | Referees | Pre match-Half time | | Half time-Post match | | Pre-Post match | |
|---------------------------------|-----------|---------------------|-----------------------------|----------------------|------------------------------|-------------------|------------------------------------|
| | | ES (mean ± CL) | MBI; Rating | ES (mean ± CL) | MBI; Rating | ES (mean ± CL) | MBI; Rating |
| MF _{propulsion} (N) | Field | 0.04 ± 0.69 | Unclear; 34/39/28 | -0.17 ± 0.57 | Unclear; 13/41/46 | -0.22 ± 0.40 | Possibly Small; 4/42/54 |
| | Assistant | | | | | | |
| TMF _{propulsion} (s) | Field | -0.09 ± 0.79 | Unclear; 27/33/40 | -0.30 ± 0.65 | Unclear; 10/30/60 | -0.60 ± 0.69 | Likely Moderate; 3/13/84 |
| | Assistant | | | | | | |
| MP (W) | Field | -0.42 ± 0.81 | Unclear; 10/22/68 | -0.26 ± 0.49 | Unclear; 6/35/59 | -1.03 ± 0.52 | Very Likely Moderate; 0/1/99 |
| | Assistant | | | | | | |
| FT (s) | Field | -0.36 ± 0.39 | Likely Small; 1/22/77 | 0.02 ± 0.18 | Likely Trivial; 5/92/3 | -0.20 ± 0.95 | Unclear; 23/27/50 |
| | Assistant | | | | | | |
| MF _{landing} (N) | Field | -0.34 ± 1.00 | Unclear; 18/22/60 | 0.15 ± 0.63 | Unclear; 44/39/17 | -0.15 ± 0.47 | Unclear; 11/47/42 |
| | Assistant | | | | | | |
| TTS (s) | Field | -0.36 ± 1.09 | Unclear; 19/21/60 | -0.10 ± 0.67 | Unclear; 22/38/40 | 0.06 ± 0.70 | Unclear; 37/37/26 |
| | Assistant | | | | | | |

ES, effect size; CL, confidence limits; MBI, magnitude based inference; MF_{propulsion}, maximum force on the propulsion phase; TMF, time to production maximum force; MP, maximum power; FT, flight time; MF_{landing}, maximum force on the landing phase; TTS, time to stabilization.

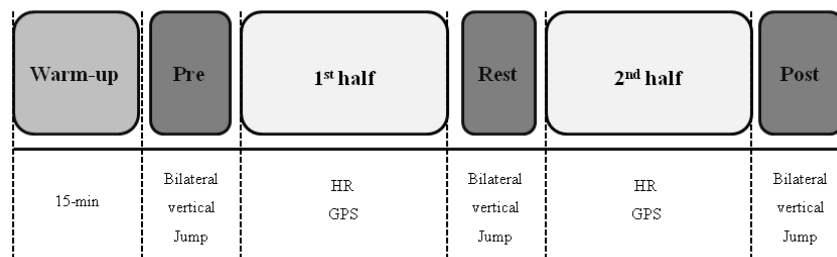


Figure 1
Temporal sequence of the fitness performances and measures obtained during each soccer match

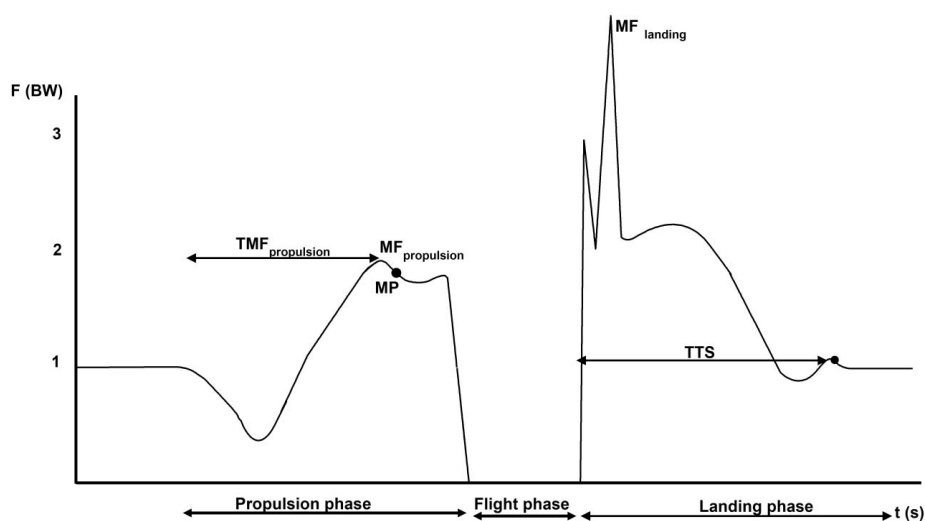


Figure 2

Jump variables during the propulsion and landing phases

MF_{propulsion}, maximum force on the propulsion phase; TMF, time to production maximum force; MP, maximum power; MF_{landing}, maximum force on the landing phase; TTS, time to stabilization.

Discussion

The aim of this study was to determine the effect of soccer matches on the vertical jump performance of FRs and ARs by measuring various biomechanical variables of jumping performance. Although some researchers have analyzed changes in performance following team sports matches (Cortis et al., 2011, 2013; Nedelec et al., 2014; Povoas et al., 2014), there has been only one study assessing how official soccer matches affect vertical jump performance of FRs (Tessitore et al., 2007). To our knowledge this is the first study to analyze how official matches affect officials' performance in the propulsion and landing phases of the vertical jump.

Vertical jump performance, particularly in the countermovement jump, is influenced by force during the propulsion phase, which is determined by lower limb muscle power (McLellan et al., 2011; Peterson et al., 2006). It is crucial that those officiating at higher levels are able to maintain adequate performance in relevant, sport-specific activities such as vertical acceleration (jumping

power) throughout a match (Tessitore et al., 2007). Our study demonstrates that FRs' vertical jump performance (i.e. MF_{propulsion}, TMF_{propulsion}, MP and FT) was similar before and after matches (Tables 2 and 3). This finding is in line with the results obtained in a previous investigation of match-induced changes in vertical jump performance in regional FRs (Tessitore et al., 2007). However, although soccer players and FRs cover a similar total distance during Football Association Premier League matches (Weston et al., 2011), it was shown that matches produce a significant decrement in soccer players' vertical jump performance (Cortis et al., 2013; Nedelec et al., 2014), whereas they did not have a detrimental effect on jumping performance of match officials (Tessitore et al., 2007). This difference could be attributed to players performing at a higher intensity than match officials during short bursts of activity. In addition, soccer players perform specific actions such as passes, shots, jumps and tackles (Barnes et al., 2014; Bradley et al., 2009). The results may also be influenced by the fact that soccer players cover a greater distance during

high-intensity running than FRs. In this study, we did not observe any evidence of fatigue in match officials; in fact, there was a tendency for improved jumping performance after matches (Tables 2 and 3). Similar performance boosts following fatiguing tasks have also been reported in other athletes and they have been attributed to post-activation potentiation effect (Boullosa and Tuimil, 2009; Boullosa et al., 2011).

We did not measure blood lactate levels; however, it had been reported that match officials and soccer players at the same competitive level had similar blood lactate levels when samples were taken 1-2 min after the end of each half (Stølen et al., 2005), and the values were rather low at certain periods during matches (i.e. 4.8 and 5.1 mmol/L at the end of the first and second halves, respectively) (Krustrup et al., 2001) compared with lactate levels at exhaustion following high-intensity exercise (Bangsbo et al., 2006). This suggests that although soccer players experience temporary impairment of neuromuscular performance during some high-intensity periods of the game that is associated with high lactate concentrations (i.e. 12 mmol/L) (Bangsbo et al., 2007) and muscle acidosis (Krustrup et al., 2004), the low blood lactate values observed at the end of each half do not seem to be related with soccer referees' vertical jump performance. It appears that most players and match officials experience fatigue towards the end of the game what is confirmed by less high intensity running during the last 15 min of the game (Weston et al., 2011). However, the mechanisms underlying reduced performance at the end of a soccer game are still unclear (Bangsbo et al., 2006), although glycogen depletion in some muscle fibers, dehydration and hyperthermia have been suggested as possible explanations for the decline in neuromuscular performance (Bangsbo et al., 2007).

The majority of studies of pre-post-match changes have not considered the landing phase in soccer and refereeing (Cortis et al., 2013; Nedelec et al., 2014; Tessitore et al., 2007) and this is the first analysis of the impact of matches on landing variables in match officials. Analysis of the landing phase might improve our understanding of the mechanisms underlying vertical jump performance and is therefore of potential interest to conditioning coaches. We found that there was

no increase in MF_{landing} at the end of the first or second half compared with pre-match performance. Hard landings can result in considerable stress to the joints of the lower limbs (Bressel and Cronin, 2005; Dufek and Bates, 1991), but our results suggest that refereeing is not likely to result in overuse injuries due to increases in MF_{landing} . Likewise, we did not observe any increase in TTS at half-time or post-match. This indicates that refereeing does not induce sufficient neuromuscular fatigue to impair landing performance. Match officials perform 1,268 activity changes and many of them are consecutive, thus the preservation of landing time may help to ensure that the next action is performed optimally.

The main limitation of this study is that we did not differentiate between soccer referees of different categories in terms of their competitive levels. In addition, we only assessed bilateral jump performance, while soccer-specific activities are typically unilateral. Future research should investigate differences between elite professional soccer players and referees who officiate at the same level with respect to bilateral and unilateral vertical jump performance (i.e. propulsion, flight and landing phases).

Conclusion

A soccer match has a similar effect on field and assistant referees in terms of most vertical jump variables (propulsion and landing phases). Soccer matches are not stressful enough to induce a decrement in vertical jump performance. We also did not observe any changes in the biomechanical variables of landing technique, indicating that neuromuscular fatigue was not sufficient to modify these variables. As we found no evidence that match-related fatigue had an adverse effect on the biomechanical variables of vertical jump performance in match officials, and given that the match officials who participated in our study trained at least three times per week, we can conclude that three days of neuromuscular training per week is sufficient to ensure that referees can sustain their neuromuscular performance throughout a competitive match.

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Corresponding author:

Daniel Castillo

Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Lasarte, 71, 01007. Vitoria-Gasteiz, Spain.

Telephone: 945 01 35 65

E-mail: daniel.castillo@ehu.es