Acute and transient match-related fatigue in university female footballers.

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Abstract

This study aimed to examine the acute fatigue response experienced by female footballers during and after match-play. Twenty university footballers completed three trials of a countermovement jump on a force platform pre- and post-match-play (35 observations). External loads were recorded during match play via global positioning systems (GPS) and heart rate (HR), respectively. Match-play loads were split into thirds and analysed via linear mixed model. Pre- and post- jump metrics (n=16) were analysed using a paired samples t-test. Significant decrements were observed between the first and final third for all metrics apart from accelerations ($p > 0.05$). Relative concentric peak force ($p = 0.035$) was significantly increased post-match. Whilst a reduction was observed for relative concentric mean power ($p = 0.034$). The remaining 14 metrics did not display any significant changes ($p > 0.05$). The stability of CMJ performance pre- to post-match alongside the reductions within match support the notion of transient fatigue. Moreover, coaches can use this data (i.e. transient fatigue) to inform tactics in **university female football** (e.g. substitutions) and conditioning regimes.

Key Words; female football, external load, countermovement jump, fatigue, internal load

Introduction

Football match-play is dynamic and comprises multi-directional intense actions that cause neuromuscular fatigue (Brownstein et al., 2017). Neuromuscular fatigue is defined as an exercise-induced reduction in force or power output (Place & Millet, 2020). Decrements in function can occur transiently (i.e. within match-play), acutely (i.e. within hours) and can be present >72 hours post exercise (Alba-Jiménez et al., 2022; Carling & Dupont, 2011). For example, Mohr et al. (2003) found declines in high-speed running (HSR) and sprint distance (SD) in the final 15-minutes of football match-play in male players. Similar declines in match running performance have been observed in female players between halves (Datson et al., 2017) and between peak 5-minute periods and the following 5-minutes (Ramos et al., 2017). Transient fatigue, match contextual factors and pacing strategies have all been proposed as potential explanations for these decrements in workload during match-play (Bangsbo et al., 2006; Krustrup et al., 2006; Novak et al., 2021). **In terms of transient fatigue, some of the purported mechanisms include increases in blood lactate and pH and depletion of energy stores (Krustrup et al., 2006). However, consensus on the mechanisms of transient fatigue has not been reached and sex specific differences have yet to be elucidated (Krustrup et al., 2022).** Understanding changes in external workload during a match could be important for practitioners as this might inform conditioning programmes and also influence tactical decisions (e.g. substitutions). To the authors knowledge, no study has investigated alterations in workload across match-play within sub-elite populations. Without this information, practitioners working with sub-elite populations are making decisions based on data from elite female or male populations. This is likely to be inappropriate as higher-level players have better developed physical qualities compared to sub-elite players which might lead to differing fatigue responses (Johnston et al., 2015).

The countermovement jump (CMJ) is one of the most widely used assessments within practice to objectively measure fatigue (Claudino et al., 2017; Fernandes et al., 2020; McMahon et al., 2018). Previous research has shown CMJ variables (i.e., jump height, impulse and mean force, power and velocity) to be valid and reliable (ICC > 0.80; CV 3.56-8.02%), meaning these are able to detect changes in function (Pérez-Castilla et al., 2021). Johnston and colleagues (2013), demonstrated reductions in CMJ peak power after rugby league competition in male players. Interestingly, CMJ peak force was maintained despite the reduction in CMJ peak power output, suggesting that velocity components could be more sensitive than force ones (Johnston et al., 2013). The preferential disruption of type 2 fibres would explain the maintenance of force through slower type 1 muscle fibres (Mclellan et al., 2011). Holistically, the literature shows CMJ outcome metrics such as jump height (JH), peak power and absolute and relative force to be sensitive to changes and therefore have the potential to quantify fatigue (Johnston et al., 2013). Moreover, the inclusion of time-based metrics (e.g. flight time: contraction time, eccentric duration and concentric duration) in CMJ testing can help elucidate if there are changes in jump strategy in the **presence** of fatigue (Cormack et al., 2008; Gathercole et al., 2015).

Females have been shown to display greater resistance to fatigue in isometric and isotonic tasks (Ansdell et al., 2019; Temesi et al., 2015), thus it is plausible that females might have displayed reduced fatigue during/after football match-play. Keane et al. (2015) found decrements in CMJ performance after a repeated sprint protocol in collegiate female team sport athletes, though, there were no changes in knee extensor maximal voluntary contraction (MVC) similar to McLellan et al., (2011). These data are in contrast to Howatson and Milak (2009) who found decrements in MVC of the knee extensors for up to 48 hours in male collegiate team sport athletes. Taken together these results demonstrate differences in the fatigue responses between male and female athletes. There is a dearth of research into fatigue responses in female athletes, suggesting the information currently applied to female athletes is based off of male research and likely inappropriate. Historically, male research has been applied to female athletes with no consideration for sexual differences (Smith et al., 2022). As such, more research is needed to investigate fatigue responses of female athletes of differing performance levels. Indeed, only 6% of sport and exercise research includes female only participants (compared to 31% for males) (Cowley et al., 2021). It is important that females are benefitting from the same quality and quantity of sport and exercise research as males (Cowley et al., 2021). Therefore, the aim of this study was to quantify transient and acute fatigue response of female football players during and post football match-play. A secondary aim was to identify which metrics are able to detect fatigue within sub-elite female footballers. The current study hypothesized that evidence of transient fatigue would be present during match-play and that alterations would be observed in CMJ strategy metrics.

Methods

Participants

Twenty university female football players (age 20.0 ± 1.3, mass 64.9 ± 12.9 kg, stature 164.9 ± 6.6 cm) were recruited to take part in the study via convenience sampling. Match-play data was collected over 6 matches totalling 45 observations. Jump data was collected over five competitive fixtures totalling 18 participants and 35 observations. Participants had a minimum training age of 2 years in structured football training and were free from illness and injury. The participants **weekly schedule** consisted of two pitch-based training sessions ~90 minutes, two gym sessions ~60 minutes and a match. **The pitch and gym sessions were performed consecutively on a Monday and Friday, with matches played on Wednesday.** The average maximal aerobic speed (derived from a 1200m time trial) for the squad in which the participants were drawn was 3.41. Participants completed informed consent prior to taking part in the study and ethical approval was granted by the host institution ethics committee (ETHICS2021-02). Goalkeepers were not recruited to participate in the study due to differences in locomotion compared to outfield players.

Study design

A repeated-measures design was employed to assess the transient and acute fatigue response from football match-play in trained female footballers. Participants attended the host institutions sports academy prior to their competitive fixture. The participants completed a 10-minute standardised warm up including lower body muscle activation exercises followed by 3 sub-maximal CMJs and 3 maximal CMJs. Thereafter, participants performed 3 trials of a CMJ with a minimum of 15s rest in between each trial. Participants were then given a GPS unit and heart rate (HR) monitor to wear during their competitive fixture. After the match (~ 15 minutes) participants repeated the CMJ protocol. For participants data to be included in the study they had to complete the full match. Post match jump testing was not possible for one match which explains the disparity in matches contributing to each section of data.

Match Characteristics

The competitive matches were played at least 7 days apart and were home games played across one season. No matches were played with adverse weather conditions (i.e., snow, heavy rain, high winds), with an average temperature of 11.1°C. **Matches were played at a similar time in the afternoon, with start times between 1pm and 5pm.** The results were 4 wins (13-0, 2-1, 4-0, 3-1) and 2 losses (2-1, 4-3). Matches were played on natural (n=2) and synthetic (n=3) pitch surfaces with dimensions of 100m x 65m.

CMJ Procedures

Participants stood on the force platform with their knees and hips fully extended, feet approximately hip-width apart and with their hands on their hips. Participants were instructed to perform a countermovement to a comfortable self-selected depth before rapidly ascending with the aim of attaining maximal vertical displacement (Fernandes et al., 2020). Hands were kept on the hips, with no flexion of the knee or hip in flight (Fernandes et al., 2020; Pérez-Castilla et al., 2021). CMJ performance was measured using a force platform (ForceDecks, VALD Performance, Australia) the platform was positioned on the same surface throughout the study.

CMJ Data analysis

The sampling frequency of the force platform was 1,000Hz. The platform was zeroed and the participant was instructed to stand still on the platform for weighing. Following the weighing phase, the participants commenced the test. The initiation of movement was set to greater than 5 standard deviations of pre-takeoff analysis period to limit erroneous data that may occur from other start thresholds (Pérez-Castilla et al., 2022). Data was analysed using the ForceDecks software (version 2.0.8587) which automatically calculated the CMJ trials and

JH, movement duration, peak and mean force and power, impulse and velocity across the phases of the jump. The ForceDecks is deemed a reliable tool in the assessment of kinetic and kinematic variable during the CMJ (Merrigan et al., 2021).

External load

External load data was collected during each normal competitive fixture. The study utilised GPS technology **with a sampling rate of 10Hz** (Catapult Vector S7, Australia). The units were contained within a purpose made vest and were worn in between the scapulae. To quantify the external load experienced during match-play. The data collected shows the total distance (TD) players covered and the speeds at which they covered this distance, PlayerLoad (sum of the accelerations across all axes of the internal tri-axial accelerometer) and the number of accelerations (>3.0 m/s), decelerations (>3.0 m/s) performed. Speeds were operationally defined as standing and walking, 0-6.0km/h; jogging, 6.1-8.0kmh; low-intensity running 8.1-12km/h; moderate-intensity running 12.1-15.5km/h; high-intensity running 15.6-20.0km/h, sprinting >20.0km/h. These thresholds were based off of previous studies within sub-elite (i.e., collegiate) and youth (U17-U20) **female** populations (Ramos et al., 2017; Vescovi & Favero, 2014). During match-play an average number of satellites of 14.8 ± 1.2 and an average horizontal dilution of precision of 1 were observed. These values indicate an acceptable number of available satellites and signal accuracy (Malone et al., 2017).

Internal load

Internal load was collected via telemetric HR monitors (Polar H10, Finland), worn around the chest, with the sensor placed just below the sternum ensuring there was no interference with the participants natural movement. Absolute HR values were used and did not consider an individual’s maximum HR or heart rate reserve. The heart rate monitors connect to the GPS unit allowing the data to be extracted from the Catapult software (Catapult Openfield version 3.7.3 Build#79834).

GPS data analysis

The GPS data was downloaded and analysed on the manufacturers software. Each half was segmented into 15-minute periods for analysis (totaling 6 periods). This data was then imported into a custom excel spreadsheet (Microsoft, Redmond, USA) for further analysis.

Statistical analysis

Data was analysed using Jamovi version 2.3.28 (*The Jamovi Project,* 2018). For the period analysis, a linear mixed model (LMM) was used with period included as a fixed effect and player ID and opposition included as random effects. The assumptions of LMM analysis were checked and satisfied. Post hoc testing was used to calculate significance between periods using a Bonferroni correction. For the jump data, normality was assessed via the Shapiro-Wilk test and repeatedly found to be satisfied. Paired samples t-tests were used to determine the difference in means of pre and post-match CMJ data. The magnitudes of the differences between variables were calculated using standardised differences of effect size (ES; Cohen's d) with a 90% confidence interval (CI). To interpret the ES the Hopkins scale was used <0.2 = trivial; 0.2-0.59 = small; 0.6-1.19 = moderate, 1.2-1.99 = large and >2 very large (Batterham & Hopkins, 2006). Spearman correlations were also run to detect correlation between load markers and jump metrics which were significantly altered post match-play. Correlations were interpreted as trivial (0.00-0.09), small (0.10-0.29), moderate (0.30-0.49), large (0.50-0.69), very large (0.70-0.89), nearly perfect (0.90-0.99) or perfect (1.00) (Hopkins et al., 2009).

Results

Match GPS Data

Table 1 shows the values and 95% CI's for all metrics for each period of the match. Period 1 had the highest values which were greater than period 2 for TD (p = .004), metres per minute (m/min) (p = .002 and PlayerLoad (p < .001). There were no differences between period 2 and period 3 (P > .005). Period 1 was greater than period 3 for HSR (p = .017) and PlayerLoad (p = .032). In half two period 4 was still reduced compared with period 1 for TD (p = .003), PlayerLoad (p < .001) and m/min (p < .001) which was also lower than period 3 (p =

.016). Period 5 was lower than period 1 for m/min (*p* = .002) and PlayerLoad (*p* = .008). HSR and SD were greater than period 3 (*p* = .021) and 4 (*p* = .008) respectively. Period 6 was the lower than all other periods for TD (*p* < .001), m/min (*p* < .001) and PlayerLoad (*p* < .001). Decelerations and HSR was lower in period 6 compared to period 1 (*p* < .001), HSR was also reduced compared to period 2 (*p* = .038), 4 (*p* = .041) and 5 (*p* < .001). For accelerations demands were stable throughout each period (*p* > .005).

Match HR data

Table 1 displays the average HR values and 95% CI's for each period of the match. Average HR was stable with no differences between any period of the match (*p* > .005).

Table 1 about here.

Pre and post CMJ Data

The pre and post CMJ data are shown in Table 2. Only two of the 16 metrics showed significant differences pre-post match-play. Relative concentric peak force (t = -2.2, *p* = 0.035, d = 0.85) increased from pre-match values. Whereas relative concentric mean power (t = 2.2, *p* = 0.034, d = 0.62) showed significant decreases.

External load correlations

No significant correlations were observed between external load metrics and pre-post percentage changes for relative concentric peak force (*p* > 0.05) and relative concentric mean power (*p* > 0.05) (see Table 3).

Internal load correlations

No significant correlations were observed between average HR and pre-post percentage changes for relative concentric peak force (*p* > 0.05) and relative concentric mean power (*p* > 0.05) (see Table 3).

Table 2 about here.

Table 3 about here.

Discussion

The main purpose of this study was to quantify the transient and acute fatigue responses elicited from match-play in trained female footballers. The main findings are 1) university female footballers experience significant decreases in workload for each metric besides accelerations, 2) CMJ responses were unchanged post football match-play. These observations partly support our hypotheses that there would be evidence of transient fatigue during football match-play. However, CMJ performance post-match-play remained unchanged which rejects our hypothesis. The in-match decreases in running demands provide evidence of transient fatigue in **university female footballers.** The lack of change in CMJ performance post-match-play demonstrate that fatigue was dissipated due to its transient nature. Practically these data could support coaches with tactical in-game decision making (i.e. substitution timing) and could also inform conditioning programmes for university players.

Match thirds external load data

The current study showed decreases in TD, m/min, and PlayerLoad after the first period of match-play. There were also reductions in the final period of the match for every metric, beside acceleration. Mohr et al. (2008) found similar reductions in HSR between the first and second 15-minute periods of match-play and in the final period of the match in males. Mohr et al. (2008) suggested transient fatigue would explain these results. The causes of in-game transient fatigue could be owing to the accumulation of potassium, or reductions in energy stores (e.g. phosphocreatine, glucose) in the muscle causing reductions in force output (Krustrup et al., 2006). More practical explanations include athletes distributing their workload to conserve energy for different points in a match (i.e. pacing) (Abbiss & Laursen, 2008). Moreover, contextual factors such as formation or reaction to opposition could explain these alterations in workload (Novak et al., 2021). Whilst pacing and contextual factors cannot be ruled out as explanations, these factors would likely cause fluctuations in workload as opposed to decreasing with time. Additionally, the presence of transient fatigue has been observed elsewhere during football match-play (Carling & Dupont, 2011; Krustrup et al., 2006; Mohr et al., 2008; Ramos et al., 2017). Carling & Dupont, (2011) found physical performance declines after intense periods and in the final period of match-play in male players. With respect to decrements in workload in the final period of the match, metabolic mechanisms are proposed to be the main cause of transient fatigue with insufficient endogenous carbohydrate stores to support the intense activities associated with football match-play (Alghannam, 2012). Taken together these results provide a strong case for transient fatigue being the cause of these alterations in workload throughout match-play. Practically, fuelling strategies (e.g. carbohydrate-protein ingestion) (Highton et al., 2013) could be implemented alongside greater levels of conditioning to increase endogenous carbohydrate stores (Gibala & Mcgee, 2008) which could reduce fatigue. Furthermore, coaches could use this information to inform decision making such as substitution timing. Our data would suggest that substitutions at 75-minutes in **university female football** would be an appropriate time to counter workload reductions.

Our data showed no changes in average HR in any period across the match, which is in contrast to previous work. Young et al. (2018) found reductions in average HR commensurate with workload between halves in elite U21 hurlers. This could be expected as greater activation of the parasympathetic nervous system and reduced activation of the sympathetic nervous system leads to a decrease in cardiac output in line with workload demands (White & Raven, 2014). The lack of reduction of average HR in line with reductions in workload may further support the transient fatigue hypothesis suggesting that internal load was similar however, mechanical output was impaired.

CMJ acute fatigue responses

Limited research investigated the acute fatigue effects of match-play in elite female footballers (Andersson et al., 2008). Andersson and colleagues (2008) found a 4% decrease in JH immediately post match-play but did not report any other force-time metrics. Although this result suggests a fatigue response, the inclusion of only a single outcome variable (i.e. jump height) fails to account for alterations in jump strategy which could contextualise these results further.

Relative concentric mean power was the only metric to demonstrate a significant reduction after match-play in our study. Female jump strategies are more biased towards the concentric phase (i.e. a shallower more reactive countermovement) (Walsh et al., 2007), which could explain why our changes were biased to the concentric phase. A reduction in concentric mean power in isolation could suggest that an acute fatigue response was elicited via match-play. However, relative concentric peak force increased, which could suggest that match-play elicited a post activation performance enhancement (PAPE) response. The opposing changes in peak force and mean power could be suggestive of differing responses to match-play. For example, this suggests that peak force production was unaffected from match-play however, mean power was reduced due to the time component of this metric. That is, peak force is a single point within a CMJ, whereas mean power considers the whole concentric phase. As Gathercole and colleagues (2015) suggested, increases in durations could be suggestive of altered movement strategy suggesting a fatigue response that is not captured in other CMJ metrics. Although not significant, both concentric and eccentric duration demonstrated a small increase which could contribute to the decrease in mean power.

Despite external load data suggesting transient fatigue, this fatigue had dissipated before the post-match CMJs. No correlations were observed between percentage changes in CMJ variables and match-play external loads. In females, Scott et al., (2020) found no relationship between running distance at higher speed thresholds and self-reported measures of fatigue. However, in males a relationship between external load during match-play and fatigue appears apparent (Hader et al., 2019; Rowell et al., 2017). Females demonstrate a high number of fatigue resistant type 1 fibres, compared to the more fatigable type 2 fibres (Roepstorff et al., 2006). Additionally, female vastus lateralis muscles display high capillarization (compared to males) which works to reduce fatigue and improve recovery (Senefeld et al., 2018). This is particularly pertinent given that females display greater knee dominance due to higher quadricep activation (Dadfar et al., 2021). Therefore, the recovery of the vastus lateralis muscle could explain why post-match CMJ performance was unaltered in our study.

Our study had some limitations that should be considered. The profile of matches included within the study did not include any draws, the games that were studied were all definitive i.e., win or loss. **The differing profiles of these games such as a heavy win and losses may have had some effect on the results, however this is representative of competition.** Another limitation is that post-match jump testing occurred at ~15-minutes, this could have led to fatigue responses being dissipated. Future research could investigate technical, tactical data to determine if technical actions such as passes or tackles also decrease in line with physical outcomes.

In conclusion, this study aimed to quantify the acute fatigue responses elicited from match-play in trained female football players. Alterations were found in external load variables (e.g., TD, MPM, HSR, SD Decelerations and PlayerLoad) across the course of match-play particularly after the highest demand third and in the final third of the match. This finding could be suggestive of transient fatigue or tactical alterations and could be used to inform decision making around tactical factors (i.e. substitutions) to negate these decreases in external load variables in **university female players**. Post-match increases were observed for concentric peak force whilst concentric mean power declined. Taken holistically, the in-match decrements in running performance alongside the lack of changes in CMJ post, support the notion of transient fatigue in university female football. Practically, coaches could use this information to inform decision making around substitution timing. For example, coaches may make substitutions around 75-minutes as our data suggests transient fatigue may alter running performance in this timepoint.

Disclosure Statement

The authors report no conflicts of interest.

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Figures and Tables

Table 1. *Match-play differences between period.*

	Half one			Half two		
	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
TD (m)	1453 ± 39.2 95% CI [1371, 1533]	1346 ± 39.1 95% CI [1266, 1426] †	1392 ± 39.1 95% CI [1312, 1472]	1343 ± 38.8 95% CI [1263, 1423] *	1389 ± 38.7 95% CI [1310, 1469]	1197 ± 38.7 95% CI [1118, 1277] †
m/min (m)	91.3 ± 2.59 95% CI [85.9, 96.7]	84.5 ± 2.58 95% CI [79.1, 89.9] †	87.3 ± 2.58 95% CI [81.9, 92.7]	81.5 ± 2.57 95% CI [76.1, 86.8] *, ^	84.4 ± 2.57 95% CI [79.1, 89.8] *	72.9 ± 2.57 95% CI [67.6, 78.3] †
HSR (m)	140.0 ± 16.4 95% CI [104.6, 175]	116.6 ± 16.4 95% CI [81.3, 152]	112.6 ± 16.4 95% CI [77.3, 148] *	116.2 ± 16.4 95% CI [80.9, 152]	139.1 ± 16.3 95% CI [103.9, 174] ^	91.7 ± 16.3 95% CI [56.4, 127] *, #, ≠, ¥
SD (m)	48.2 ± 11.7 95% CI [22.7, 73.6]	40.7 ± 11.7 95% CI [15.3, 66.2]	43.6 ± 11.7 95% CI [18.2, 69.1]	32.3 ± 11.7 95% CI [6.88, 57.7]	52.9 ± 11.6 95% CI [27.5, 78.3] ≠	32.4 ± 11.6 95% CI [7.0, 57.8] ¥
PlayerLoad (au)	145.0 ± 6.14 95% CI [132, 157]	129.0 ± 6.13 95% CI [117, 142] †	133.0 ± 6.13 95% CI [121, 146] *	128.0 ± 6.10 95% CI [116, 141] *	132.0 ± 6.09 95% CI [120, 145] *	114.0 ± 6.09 95% CI [101, 126] †

Accelerations	1.03 ± 0.28 95% CI [0.47, 1.59]	1.02 ± 0.27 95% CI [0.46, 1.58]	0.89 ± 0.27 95% CI [0.33, 1.45]	0.90 ± 0.27 95% CI [0.34, 1.46]	1.32 ± 0.27 95% CI [0.76, 1.88]	0.77 ± 0.27 95% CI [0.21, 1.32]
Decelerations	3.12 ± 0.45 95% CI [2.22, 4.04]	2.57 ± 0.45 95% CI [1.66, 3.47]	2.12 ± 0.45 95% CI [1.22, 3.03]	2.29 ± 0.44 95% CI [1.39, 3.19]	2.50 ± 0.44 95% CI [1.60, 3.40]	1.54 ± 0.44 95% CI [0.64, 2.44] *****
Average HR (bpm)	173.0 ± 5.68 95% CI [161, 184]	175.0 ± 5.64 95% CI [163, 186]	170.0 ± 5.64 95% CI [159, 182]	161.0 ± 5.60 95% CI [150, 173]	165.0 ± 5.57 95% CI [153, 176]	161.0 ± 5.57 95% CI [150, 172]

Note: estimated marginal mean ± standard error and 95% confidence interval, † significantly different to all prior periods, * significantly different to period 1, # significantly different to period 2, ^ significantly different to period 3, ≠ significantly different to period 4, ¥ significantly different to period 5.

Table 2. *Jump metric values pre- and post-match play.*

Metric Name	Time Point	Mean ± SD	CV %	Percentage Change	Effect Size [95% CI]
Jump Height **(cm)**	Pre	27.1 ± 2.4	8.9	-4.1	-0.50 [0.03, 0.98]
	Post	26.0 ± 1.9			
Peak Power / BM **(W/kg)**	Pre	42.7 ± 1.7	3.9	-0.2	-0.71 [0.22, 1.18]
	Post	42.6 ± 1.7			
Concentric Duration **(ms)**	Pre	293.2 ± 25.3	8.6	2.3	-0.24 [-0.70, 0.24]
	Post	299.9 ± 31.3			
Concentric Impulse **(Ns)**	Pre	149.0 ± 5.0	3.4	-1.9	-0.56 [0.08, 1.03]
	Post	146.2 ± 5.0			
Concentric Mean Power / BM **(W/kg)**	Pre	**22.1 ± 1.3**	**5.9**	**-3.6**	**-0.62 [0.13, 1.09]**
	Post	**21.3 ± 1.3**			
Concentric Peak Force / BM **(N/kg)**	Pre	**21.5 ± 0.6**	**2.6**	**2.8**	**0.85 [-1.33, -0.35]**
	Post	**22.1 ± 0.8**			
Contraction Time **(ms)**	Pre	805.1 ± 104.2	12.9	-8.2	-0.20 [-0.27, 0.67]
	Post	783.8 ± 107.9			
Concentric Peak Velocity **(ms)**	Pre	2.3 ± 0.1	3.2	1.3	0.38 [-0.10, 0.84]
	Post	2.4 ± 0.1			
Eccentric Braking Impulse **(Ns)**	Pre	24.8 ± 6.3	25.2	-7.3	-0.31 [-0.16, 0.78]
	Post	23.0 ± 5.2			
Eccentric Deceleration Impulse **(Ns)**	Pre	46.9 ± 10.0	21.6	-6.8	-0.37 [-0.11, 0.84]
	Post	43.7 ± 7.0			
Eccentric Duration **(ms)**	Pre	512.1 ± 108.1	21.1	-5.5	-0.67 [0.18, 1.14]
	Post	483.9 ± 110.1			
Eccentric Mean Power / BM **(W/kg)**	Pre	4.0 ± 0.8	19	-5.0	-0.30 [-0.17, 0.77]
	Post	3.8 ± 0.5			
Eccentric Peak Force / BM **(N/kg)**	Pre	18.3 ± 1.6	8.9	-1.6	-0.21 [-0.27, 0.67]
	Post	18.0 ± 1.3			
	Pre	-0.7 ± -0.2	20.3	-4.1	-0.23 [-0.24, 0.70]

Eccentric Peak Velocity **(m/s)**	Post	-0.7 ± 0.1			
RSI-Modified **(m/s)**	Pre	0.4 ± 0.1	19.5	1.0	0.03 [-0.44, 0.50]
	Post	0.4 ± 0.1			
Vertical Velocity at Take-off **(m/s)**	Pre	2.3 ± 0.1	3.5	-2.1	-0.63 [0.15, 1.11]
	Post	2.2 ± 0.1			

Note: CV%, coefficient of variation percentage. Metrics in bold are those comparisons which are significantly different (*P* < 0.05).

Table 3. *Jump metric correlations to external load variables.*

		TD	PlayerLoad	m/min	HSR	SD	Decelerations	Accelerations	Average HR
Concentric Peak Force / BM	*r*	-.057	-.112	-.023	-.058	.012	-.094	-.011	.043
	P	.746	.520	.896	.741	.944	.593	.948	.806
Concentric Mean Power / BM	*r*	-.007	.031	-.107	-.059	-.090	-.156	-.139	-.166
	P	.970	.858	.539	.734	.605	.370	.425	.339

Note: r, Spearman correlation coefficient.