RELATIONSHIP BETWEEN EXTERNAL LOAD AND DIFFERENCES IN COUNTERMOVEMENT JUMP IN AN OFFICIAL MATCH OF PROFESSIONAL FEMALE SOCCER PLAYERS.

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The purpose of the present study was to correlate the external load of an official soccer match with the percent change in the countermovement jump (CMJ) variables (pre, immediately and 24 hours post [24h]). External load was analyzed through accelerometers and CMJ through force platforms. The main findings were the correlations very strong between the percentage of change in the CMJ variables and the external load between in jump height (JH) pre-post ($_1$) with acceleration distance between >2.79 m/s^2 (ACC4); JH pre-24h ($_2$) with distance 19 to 23 km/h, >23 km/h, distance at accelerations between 0 to 1.5 m/s^2, between 1.5 to 2 m/s^2; Jump time$_1$ with ACC4; peak power pre-post with distance at accelerations between 2 to 2.79 m/s^2; rate of force development braking (RFD$_{B1}$) with ACC4; rate of power development$_{1,2}$ with distance between 0.5 to 7 km/h. Our results suggest that the change in the vertical jump with countermovement is correlated with the external load performed during a match in professional female soccer players.

KEYWORDS: biomechanics, football, kinetic, fatigue, vertical jump, soccer match.

INTRODUCTION: Fatigue has a biphasic nature after exercise with a high amount of stretch-shortening cycle (SSC) actions (Komi, 2000) as are the actions in soccer (running, accelerating, and braking). These reductions in performance observed immediately after exercise are largely attributed to metabolic alterations (activation of group III/IV muscle afferents), which affect excitation-contraction coupling and reduced stretch reflex sensitivity, leading to a reduction in muscle stiffness and consequently force production (Komi, 2000). During the last time, the use of vertical jumps (VJ) to assess neuromuscular fatigue has increased (Balloch, 2018). The reasons for this are that since it involves a SSC which is manifested in most sport actions (Komi, 2000) and it is also an easy test to implement, does not produce fatigue and is non-invasive (Lombard et al., 2020). The major of studies not considering the external load or analyze VJ during match simulations or friendly match, where all participants must perform the same external load during the execution of the protocol (Lombard et al., 2020), but this does not adhere to the reality of a real match, which is interesting for trainers and researchers (Silva el al., 2013). All this to be able to control the loads so as not to overtrain the players and reduce the risk of injury (Carling et al., 2018), although it could also be useful to increase the training loads in the case of players who are recovered.
On the other hand, various studies that have analyzed vertical jump have only analyzed jump height (JH) (Silva et al., 2013), but it has a limitation, as athletes are able to maintain JH by altering movement strategies (Schmitz et al., 2014). Therefore, it has been recommended to observe other mechanical variables of jumping to analyze changes in movement strategies that could be related to changes in neuromuscular status (Gathercole et al., 2015) and for this

is necessary instruments how force platforms (Merino-Muñoz et al., 2020b). To our knowledge only two study has analyzed the relationship of external load and changes in the vertical jump following a soccer match in young players (de Hoyo et al., 2016; Beattie et al., 2021) but it only analyzed some variables of countermovement jump (CMJ). Therefore, our objective is to analyze the relationship between changes in vertical jump variables with countermovement and external load in an official match in adult female professional players in Chile and, as a secondary objective, to analyze the differences in different time moments.

METHODS: Five adult female professional players were evaluated during an official match (age = 27.2 ±6.1 years, body mass = 59.4 ±3.4 kg, height = 1.62 ±0.5 m). Assessments were performed before the match (pre), immediately after the match (post) and 24 hours later (24h). The external load was collected through PlayerMaker accelerometers, which are placed in the soccer shoes (Waldron et al., 2021). The 90 minutes of play plus the complementary time were considered in the analysis. The variables chosen for the analysis are: Total distance (m) [TD]; distance (m) between 0.5 to 7 km/h [D7], between 7 to 13 km/h [D13], between 13 to 19 km/h [D19], between 19 to 23 km/h [D23]; >23 km/h [HSR]; distance (m) at accelerations between 0 to 1.5 m/s^2 [ACC1], between 1.5 to 2 m/s^2 [ACC2], between 2 to 2.79 m/s^2 [ACC3], >2.79 m/s^2 [ACC4]; distance (m) at decelerations between 0 to 1.5 m/s^2 [DCC1]; between 1.5 to 2 m/s^2 [DCC2]; between 2 to 2.79 m/s^2 [DCC3]; >2.79 m/s^2 [DCC4]. Countermovement jump (CMJ) was performed on two PASCO PS-2142 platforms with a sampling frequency of 1000 hertz and the players performed 3 attempts with 1 minute pause in between the average of the 3 attempts was analyzed. The players were instructed to descend and up as fast as possible and to seek the highest possible height. Before each measurement, a standardized warm-up was performed consisting of dynamic joint mobility for 2 minutes, 2 minutes of jogging and 1 minute of high intensity actions such as accelerations, braking and jumping. A 5-minute rest was given after the warm-up. The variables chosen for the analysis are: jump height (m) [JH] through flight time; jump time (s) [JT]; peak force (N/kg) [PF]; peak power (W/kg) [PP]; rate of force development yielding and braking (N/s/kg) [RFD]; T time (s); rate of power development (W/s/kg) [RPD] (Cohen et al., 2020).
Statistical analysis was performed in SPSS version 25. Data will be presented as mean and standard deviation. The difference between moments was analyzed through the ANOVA test for repeated measures with a post-hoc analysis of Bonferroni and effect sizes were reported as eta partial squared (η^2p). The correlation between the percentage change (Merino-Muñoz et al., 2020a) in CMJ variables and external match load was analyzed through Spearman's Rho test (rs). Correlations were classified as: 0.0 to 0.10 trivial; 0.11 to 0.39 weak; 0.40 to 0.69 moderate; 0.70 to 0.89 strong; and 0.90 to 1.00 very strong. The alpha was 0.05.

RESULTS: Differences (table 1) were found in peak force between pre and post (η^2p=0.701), in PP between post and 24h (η^2p=0.717) and RFD_B (η^2p=0.534) but not in post-hoc analysis. Correlations (table 2) between percent change in CMJ variables and external load are in Table 2. Very strong correlations were found between JH_1 with ACC4; JH_2 with D23, HSR, ACC1 and DCC2; JT_1 with ACC4; PP_1 with ACC3; RFD_{B1} with ACC4; RPD_1 and RPD_2 with D7.

Table 1: Description of variables and differences between moments.

	Pre		Post		24h				
CMJ variables	**M**	**±SD**	**M**	**±SD**	**M**	**±SD**	**F**	**p**	**η^2p**
JH (m)	0.27	0.04	0.29	0.02	0.27	0.04	1.926	0.208	0.325
JT (s)	0.74	0.10	0.75	0.13	0.75	0.07	0.120	0.889	0.029
PF (N/kg)	22.8	1.35	**21.9***	1.23	21.40	1.19	9.394	**0.008**	0.701
PP (W/kg)	41.4	4.0	44.0	2.1	**38.5****	3.2	10.12	**0.010**	0.717
RFD_Y (N/s/kg)	61.5	23.9	60.8	24.3	64.7	17.4	0.232	0.798	0.055
RFD_B (N/s/kg)	78.5	17.1	65.6	21.6	63.3	14.4	4.585	**0.047**	0.534
RPD (W/s/kg)	201.4	37.2	215.8	38.3	**184.0***	33.4	8.196	**0.012**	0.672

* difference with Pre; ** difference with Post; M mean; SD standard deviation; time; $_Y$ yielding; $_B$ braking; for description variables see methods.

Table2: Correlations between external match load and percent change in countermovement jumping variables.

ELV	JH_1	JH_2	JT_1	JT_2	PF_1	PF_2	PP_1	PP_2	RFD_{Y1}	RFD_{Y2}	RFD_{B1}	RFD_{B2}	RPD_1	RPD_2
TD	-0.20	0.80	0.20	0.20	-0.40	0.10	-0.50	0.50	-0.40	-0.20	-0.20	-0.20	-0.20	-0.20
D7	0.50	0.10	-0.50	0.10	-0.30	-0.30	0.70	0.60	0.80	-0.10	0.50	-0.10	**0.90***	**.900***
D13	-0.20	0.70	0.20	0.00	0.10	0.40	-0.60	0.20	-0.60	0.00	-0.20	0.00	-0.50	-0.50
D19	-0.40	0.60	0.40	-0.40	0.30	0.70	-0.70	-0.10	-0.50	0.40	-0.40	0.40	-0.60	-0.60
D23	0.00	**0.90***	0.00	-0.60	0.30	0.80	-0.20	0.40	0.20	0.60	0.00	0.60	0.10	0.10
HSR	-0.10	**0.90***	0.10	-0.10	-0.30	0.30	-0.30	0.60	0.00	0.10	-0.10	0.10	0.10	0.10
ACC1	0.10	**0.90***	-0.10	0.10	0.00	0.30	-0.30	0.60	-0.30	-0.10	0.10	-0.10	-0.10	-0.10
ACC2	-0.60	0.60	0.60	-0.60	0.00	0.70	-0.70	-0.10	-0.20	0.60	-0.60	0.60	-0.40	-0.40
ACC3	-0.70	0.50	0.70	-0.30	-0.10	0.50	**-0.90***	-0.20	-0.60	0.30	-0.70	0.30	-0.70	-0.70
ACC4	**-0.90***	-0.10	**0.90***	-0.50	-0.30	0.30	-0.70	-0.60	-0.20	0.50	**-0.90***	0.50	-0.50	-0.50
DCC1	-0.60	0.60	0.60	-0.60	0.00	0.70	-0.70	-0.10	-0.20	0.60	-0.60	0.60	-0.40	-0.40
DCC2	0.00	**0.90***	0.00	-0.60	0.30	0.80	-0.20	0.40	0.20	0.60	0.00	0.60	0.10	0.10
DCC3	-0.20	0.80	0.20	0.20	-0.40	0.10	-0.50	0.50	-0.40	-0.20	-0.20	-0.20	-0.20	-0.20
DCC4	-0.21	0.87	0.21	-0.31	-0.21	0.46	-0.36	0.46	0.05	0.31	-0.21	0.31	0.05	0.05

* $p<0.05$; EXV external load variables $_1$ percent change between pre and post; $_2$ percent change between pre and 24; for description variables see methods.

DISCUSSION: The main findings were the correlations ($p<0.05$) between the percentage of change in the CMJ variables and the external load very strong between JH_1 with ACC4; JH_2 with D23, HSR, ACC1 and DCC2; JT_1 with ACC4; PP_1 with ACC3; RFD_{B1} with ACC4; RPD_1 and RPD_2 with D7. On the other hand, differences were found in PF between pre and post, in PP between post and 24h and RFD_B.

First, in relation to the differences found, different results have been found in the literature. One study analyzed changes in JH after a football match in female football players and found a decrease in JH immediately post and at 69 hr post (Andersson et al., 2008), unlike ours, a larger number of players from different positions were used which may have affected the analysis. Silva et al., (2013) found increases in the amount of cortisol, myoglobin, creatin kinase, C-reactive protein at 24 hours post-match and found a decrease in JH, which could explain the decrease in other CMJ variables such as PP which has a relationship with JH (Barker et al., 2018). There were also changes in RFD_B, a variable that could also be related to the increase in creatine kinase due to muscle damage produced by the match load, mainly by eccentric actions (Cohen et al., 2020; de Hoyo et al., 2016). Cohen et al., (2020) analyzed the differences in CMJ variables following a repeated sprint protocol with brake in 3 and 20 meters and found difference in the changes suffered by the groups immediately post and 48 hours later in RFD_B, unlike the group that performed the same protocol without brakes, which did not suffer any change in this variable.

Regarding the correlations between external loading and changes in the mechanical variables of the CMJ. de Hoyo et al., (2016), found correlations between the number of decelerations and the change in the average strength of the eccentric phase pre and post-match. Which is consistent with our findings where differences in CMJ variables correlated with the external load performed. Beattie et al., (2021) found correlations with other vertical jump variables, but unlike us, it was assessed 24 hrs pre and 48 hrs post, which could be affected by the biphasic nature of fatigue in conjunction with the external loading performed by the athletes. In a recent systematic review and meta-analysis (Hader et al., 2019), it was found that distances over 19 km/h correlated with changes in PP immediately post and 24 hrs. In our study PP had differences between post and 24 hrs, but not with pre and did not correlate with distances over 19km/h, which may be due to differences in the external loads analyzed in the studies.

CONCLUSION: Through our results suggest that the change in the vertical jump with countermovement is correlated with the external load performed during a match in professional female players. An individual analysis is also necessary to know the intra-player differences because the group analysis is influenced by the external load. It is necessary to carry out analyses in a larger sample to corroborate these results and for a longer period (48 and 72 hours), to find an optimal moment to evaluate and analyze the neuromuscular fatigue of the athlete.

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ACKNOWLEDGEMENTS: We would like to thank, Fernando Piccolella, Francisco Vidal, Audax Italiano Femenino team and its technical staff for their collaboration and willingness to carry out this research.