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Original Article

Relationship between vertical jump, linear sprint and change of direction in Chilean female soccer players

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Abstract
Objective: To establish associations between physical performance indicators in two series of a Chilean women's soccer team and to know the differences between them. **Method**: 29 players from a Chilean first division team (Adult = 12 and Sub-17 = 19). Countermovement jump (CMJ), linear sprint 10 (T10) and 30 meters (T30) time, change of direction 180° (COD180°) and change of direction deficit (CODD), in the preparatory period were evaluated. Pearson correlation coefficient (r) tests were performed to determine associations between physical tests and magnitude-based inferences to determine differences between categories. **Results**: Strong negative correlations ($p<0.05$) were found between CMJ with T10 and T30 ($r = -0.72$ and -0.77 respectively) and moderate with COD180° ($r = -0.49$). T10 had a strong positive correlation with T30 ($r = 0.88$) and moderate with COD180° ($r = 0.59$). T30 had a moderate positive correlation with COD180° ($r = 0.54$) and finally CODD only had a correlation with COD180° ($r = 0.75$). Likely differences were found between CMJ, COD180° and CODD (Standardized Difference = 0.60, 0.68 and 0.70 respectively) in favor of the adult category. There were unclear differences at T10 and T30. Conclusion: From our results, we can conclude that there is an association between CMJ, T10, T30 and COD180° However, for CODD, they were not found with CMJ, T10 and T30, so it is recommended that coaches who work with female soccer players apply specific tests to measure these capabilities, and also try to match the total path of the change of direction test with one of the linear speed tests, so they can also know the CODD of their athletes.
Keywords: soccer, female, testing fitness, physical performance..

Introduction

From a conditional or physical analysis, soccer is a sport of intermittent, acyclic efforts, with muscular actions of an explosive type, such as jumps, sprinting and changes of direction (Mohr et al., 2003), these being crucial for performance in modern football, so knowing the factors that affect this type of actions for their optimization is fundamental (Hoff & Helgerud, 2004). One of the determinants of acceleration and speed capacity in short distances is the muscular power of the lower body (Zaras et al., 2016) and this has often been assessed through vertical jumps (Markovic et al., 2004). Relationships have been found between countermovement jumping (CMJ) and 30-meters linear sprint (T30), as well as 10-meter linear sprints (T10), in young and adult male football players (Köklü et al., 2015; Wisløff et al., 2004), but there is less evidence in women (Emmonds et al., 2019).

Change of direction ability is a specific skill in soccer (Mohr et al., 2003) and the factors affecting its performance are diverse, such as eccentric strength, concentric strength, and kinematic aspects (Spiteri et al., 2014; Dos'Santos et al., 2019). Recently, Horníková & Zemková, (2021) showed that there is a relationship between change of direction tests with sprint speed, muscle strength and jumping ability. To better understand this ability, Nimphius et al. (2016) proposed the measurement of the change of direction deficit, a calculation that consists of the difference between the time of the change of direction test and the linear speed test. In this sense, the study conducted by Loturco et al., (2019a), related acceleration performances and change of direction deficit (CODD) in professional soccer players, finding that the best performances in acceleration, had a higher CODD, so it is necessary to consider other factors that may affect their performance (Dos'Santos et al., 2019).

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However, due to the lack of research on elite female athletes, this becomes a challenge, thus limiting the ability to integrate evidence-based models, minimizing the action plan of coaches in pursuit of performance improvement of their female cohort athletes (Emmonds et al., 2019).

In recent years, women's soccer has grown greatly. Currently, Chile has a national tournament with youth national teams and adult national teams (Villaseca-Vicuña, et al., 2021b), where each one of the professionals who work today in this area have as their main objective to optimize the performance and well-being of female athletes, supported by science and evidence (Emmonds et al., 2019). Therefore, it is important for professionals working in women's sport to consider the possibility of being able to investigate and establish verifiable evidence applied to female athletes (Emmonds et al., 2019). At the same time, the differences in physical performance in these categories in Chile are not known. The aim of this study is to determine the relationships between physical performance indicators in two categories of a women's soccer team in Chile and to determine the differences between them.

Material & methods

Design

This is a descriptive-correlational study using a quantitative approach. The type of design corresponds to a non-experimental, cross-sectional study.

Participants

The sample consists of 29 female players belonging to two categories, U-17 (n=17; Age=16.4 ±0.75 years; Weight=58.2 ±8.35 kilograms; Height=1.57±0.03 meters) and Adult (n=12; Age=26.4 ±4.82; Body mass=58.2 ±6.81; Height=1.61 ±0.04) of a Chilean women's soccer team. To be included, participants were required to: i) participate in all physical tests, ii) have no injuries and/or discomfort at the time of the tests, and ii) have at least 2 years of experience playing football on a regular basis. All participants were informed of the procedures, objectives, and voluntariness of the research, through informed consents, respecting the Declaration of Helsinki (World Medical Association, 2013). In the case of minors (< 18 years of age), the documents were reviewed by their legal tutor. Along with the above, authorization was requested from the entities responsible for the club.

Procedures

The evaluations were carried out during the 3rd week of pre-season 2020. Anthropometric measurements, jumping tests, using the countermovement jump, 10 meters (T10) and 30 meters (T30) linear sprint tests and a changes of direction 180° test (COD180°) were performed. On day 1, anthropometric measurements and the vertical jump test were performed for both categories. On day 2, the speed and change of direction tests were performed in the following order: T10; COD180° and T30.

Table 1. Sample characteristics

	Age (years)		**Body mass (kg)**		**Height (m)**	
Category	**M**	**±SD**	**M**	**±SD**	**M**	**±SD**
Adult (n=12)	26.4*	4.82	58.2	6.81	1.61	0.04
Sub-17 (n=17)	16.4	0.75	58.2	8.35	1.57	0.03

* Differences p<0.05 with U-17; M mean; ±SD standard deviation. Own elaboration.

Instruments

Anthropometry

The height (m.) was evaluated by a professional with ISAK II certification, with a mechanical Seca 216 wall stadiometer, and the weight was recorded using the Seca 803 Scale, instructing the players to place their hands on their sides and look straight ahead for 3 seconds to obtain the body mass (kg.). To facilitate the measurement, players were asked to wear light clothing.

Physical Assessments

The week before the tests the players were instructed in learning and familiarizing themselves with the techniques of performing the jumping test and changes of direction. All assessments were carried out on artificial turf, so each player was instructed to wear football shoes with studs. A 15-minute warm-up was divided into 3 blocks. The first consisted of gentle jogging and joint mobility (6 min), the second in explosive actions specific to the test to be performed, such as accelerations, sprinting and vertical jumps (6 min) and ended with a block of dynamic flexibility of the lower body (3 min). The average of all the attempts was used for the subsequent analyses.

Vertical jump

For the assessment of the vertical jump, the CMJ of the Bosco test was used (Bosco et al., 1983). The players had to position themselves with their hands on their hips during the jump and landing. The DmJump® contact platform, Prometheus Sportech® (DMJ), connected to the DMJ V2.5 Beta software on a smartphone via Bluetooth, which estimates the height of the jump according to the flight time, was used to obtain the data for each jump (Moir, 2008). Two attempts were performed with a 1-minute pause between jumps.

Linear sprint

Both, linear velocity and change of direction assessments were performed on a synthetic grass surface, on which a 10m and 30m straight line were measured. To measure time, 2 single beam photocells (Witty gate, Microgate, Bolzano, Italy, http://www.microgate.it) were used. One photocell was placed at the start gate and one at the end of the test to quantify the time taken by the participant to perform each test, these were placed at a height of 1 meter to decrease the risk of a double beam break (Haugen & Buchheit, 2016). For the starting position, the players had to have one foot one meter away from the starting line. Four sprints were performed, 2 for 10 meters and 2 for 30 meters. A complete pause (>3 minutes) was given between each attempt, at each distance.

change of direction 180°

As in the linear speed, a 5-meter straight line was measured, with a single photocell at the start and a mark at 5 meters, the players got in position with one foot 1 meter behind the starting gate and had to start and at least step over the 5-meter mark to return. Two attempts were made for each profile, where the result was obtained by averaging the 4 attempts. To calculate the change of direction deficit (CODD), the average of the 4 attempts of COD180° was subtracted from the average of the two time attempts of the T10 test.

Statistical analysis

Descriptive statistics were performed on the data and the mean and standard deviation were presented for all variables. Absolute reliability was presented through the coefficient of variation (CV) expressed as a percentage, calculating the CV per athlete and averaged over the whole sample, along with their maximum and minimum values, considered < 10 % acceptable values (Turner et al., 2015) and relative reliability through the intraclass correlation coefficient (ICC) with a random two-factor absolute agreement type model, using the following thresholds for qualitative categorization: <0.49 poor; 0.5 to 0.74 moderate; 0.75 to 0.89 good and >0.9 excellent (Koo & Li, 2016) presenting the confidence intervals (CI) at 90%. For differences between categories, magnitude-based inferences with a 90% CI (Batterham & Hopkins, 2006) were used through a customized spreadsheet, determining the small worthwhile difference (SWD) as the standard deviation * 0.2 (Turner et al., 2015). Clear effects are reported with a qualitative descriptor for magnitudes with probabilities that are >25% using the following scale: >0.25, possible; >0.75, likely; >0.95, very likely; >0.995, almost certain. If the probability was >5% in all 3 areas it was considered unclear (Hopkins et al., 2009). The effect size (ES) of the difference was determined using Cohen's d to quantify the standardized difference between categories (Turner et al., 2015). To qualitatively signal differences, ES categories (0.2, 0.6, 1.2, 1.2, 2.0 and 4.0 for trivial, small, moderate, large, very large and extremely large respectively) were used (Hopkins et al., 2009) and the percentage difference (PD) between categories was also calculated (Merino-Muñoz et al., 2020a). To determine the relationship between the physical tests, Pearson's correlation coefficient test (r) was performed assuming a normal distribution of the data with the Shapiro-Wilk test. 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 (Schober & Schwarte, 2018). Correlation coefficients were carried out through IBM SPSS statistics version 24.0® using an alpha of 0.05.

Results

Table 2 presents the absolute and relative intra-test reliabilities of the physical tests. All tests had acceptable absolute reliabilities (CV < 10%). Only the CMJ and T30 tests had excellent relative reliabilities (ICC of 0.90 to 0.97 and 0.97 to 0.99 respectively). The T10 test had good to excellent reliability (ICC 0.82 to 0.95) and COD180° had moderate to excellent reliability (ICC 0.67 to 0.91).

Table 2. Absolute and relative intra-test reliability

Physical test	Coefficient of variation	Min	Máx	ICC	CI (90%)		Categorization
					LL	UL	
CMJ	4.15	0.6	12.3	0.95*	0.90	0.97	*Excellent*
T10	1.15	0.0	5.6	0.91*	0.82	0.95	*Good to Excellent*
T30	0.54	0.0	1.4	0.99*	0.97	0.99	*Excellent*
COD180°	1.86	2.7	4.8	0.82*	0.67	0.91	*Moderate to Excellent*

* p < 0.05; CMJ: countermovement jump; T10: sprint time 10 meters; T30: sprint time 30 meters; COD180°: change of direction 180°; CODD: change of direction deficit; Min: coefficient of variation minimum; Max: coefficient of variation maximum; ICC: intraclass correlation coefficient; CI: confidence interval; LL: lower limit; UL: upper limit.

Correlations between the physical tests are presented in table 4. Strong negative correlations (p<0.1) were found between CMJ with T10 and T30 (r = -0.72 and -0.77 respectively) and moderate with COD180°. T10 a strong positive correlation with T30 (r = 0.88) and moderate with COD180° (r = 0.59). T30 a moderate positive correlation with COD180° (r = 0.54) and finally CODD only a correlation with COD180° (r = 0.75).

Table 3. Correlation coefficients between physical tests

		T10	T30	COD180°	CODD
CMJ	r	-0.72*	-0.77*	-0.49*	-0.03
	p	0.00	0.00	0.01	0.89
T10	r	-	0.88*	0.59*	-0.09
	p	-	0.00	0.00	0.65
T30	r	-	-	0.54*	-0.04
	p	-	-	0.00	0.82
COD180°	r	-	-	-	0.75*
	p	-	-	-	0.00

* p < 0.05; Pearson's r correlation coefficient; T10: sprint time 10 meters; T30: sprint time 30 meters; COD180°: change of direction 180°; CODD: change of direction deficit.

Table 4 presents the descriptive statistics of the data together with the differences between categories which can be visualized in figure 1. Probable differences were found between CMJ, COD180° and CODD in favor of the adult category with effect sizes. There were unclear differences at T10 and T30.

Table 4. Descriptive and inferential statistics across categories

	Sub-17		Adult		Differences between categories					
	M ±SD	CV	M ±SD	CV	SWD	PD	Effect size		% Chances to favor Sub-17/trivial/Adult	
CMJ	23.3 ±3.9	16.8	25.5 ±3.4	13.1	0.73	9.0	0.60	*moderate*	02/13/85	*Likely*
T10	2.0 ±0.1	3.5	2.0 ±0.1	4.0	0.02	0.5	0.21	*small*	10/46/44	*Unclear*
T30	5.0 ±0.2	4.6	4.9 ±0.2	3.1	0.04	1.0	0.25	*small*	12/34/54	*Unclear*
COD180°	2.9 ±0.1	3.1	2.8 ±0.1	4.6	0.02	2.4	0.70	*moderate*	01/07/92	*Likely*
CODD	0.9 ±0.1	5.6	0.8 ±0.1	14.5	0.02	7.0	0.68	*moderate*	01/11/87	*Likely*

M: mean; SD: standard deviation; CV: coefficient of variation; SWD: small worthwhile difference; PD: percentage difference; CMJ: countermovement jump; T10: sprint time 10 meters; T30: sprint time 30 meters; COD180°: change of direction 180°; CODD: change of direction deficit.

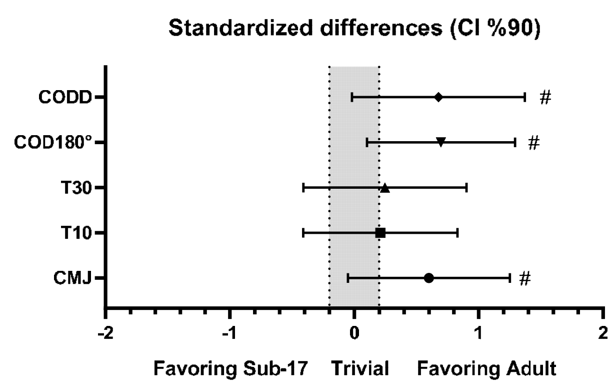

Figure 1- CMJ: countermovement jump; T10: sprint time 10 meters; T30: sprint time 30 meters; COD180°: change of direction 180°; CODD: change of direction deficit; CI: confidence interval; # likely differences.

Discussion

In recent years, women's soccer has grown in a big way, Chile has a competition at national level with different categories and there are youth and adult teams (Villaseca-Vicuña et al., 2021b). Currently, due to the lack of research on elite female athletes, the possibility of integrating evidence-based models in search of performance improvement is limited (Emmonds et al., 2019). Given this context, it is important to be able to investigate and establish testable, applied evidence in female athletes (Emmonds et al., 2019). This study determined the relationships between physical performance tests and differences in physical tests between two categories of a female soccer team.

The main study findings were interesting associations between performance tests, specifically between CMJ, T10, T30 and COD180°, but not between these and CODD, except for COD180°. Likely differences between categories were also found for CMJ, COD180° and CODD and unclear differences for T10 and T30. Finally, acceptable, and moderate to excellent absolute and relative reliabilities were found, respectively.

Regarding the correlations found between the physical assessments, it is observed that the CMJ test has a strong association with T10 and T30, results similar to those published by Wisløff et al, (2004), Villaseca-Vicuña et al., (2021a) and Barrera et al., (2021) with a correlation between the vertical jump test with T10 (r=-0.72; -0.605 and -0.69 respectively, p<0.05) and T30 (r=-0.60; -0.415 and respectively, p<0.05). On the other hand, Köklü et al., (2015) and McFarland et al., (2016), only found significant correlations between CMJ and T30, not so with between CMJ and T10, for both male and female soccer players, respectively. The increase in the correlation in T30 can be explained due to the predominance of vertical force, in relation to the speed that is achieved as the distance is greater (Marcote-Pequeño et al., 2019), while Wisløff et al., (2004) did not find this increase, probably due to the type of jump that was used (CMJ with free arms), where perhaps the movement of the arms has altered the jump height (Lees et al., 2004).

With respect to the linear speed tests (T10 and T30), strong relationships were found between them, showing that the players who reached the highest speed at 10 meters were also those who took the least time to reach 30 meters. This agrees with the findings of Villaseca-Vicuña et al., (2021a) and Köklü et al., (2015) who also found strong correlations between these tests (r= 0.78 and 0.71; p<0.05 respectively), contrary to Wisløff et al., (2004), who found no correlations between them, which could be explained by the analysis performed in T10 with the Split from 10 to 30 meters, and not from the start of the test. These differences in the relationships between CMJ, T10 and T30 may be due of the different populations analyzed, as it has been suggested that the effect of age and expertise may interfere in these motor tasks (Chamari et al., 2004).

In another study (Suarez-Arrones et al., 2020), moderate to strong correlations were found in young athletes from different team sports between jump, sprint, and squat power tests with a change of direction test equal to the one applied in this study. It was established that, despite the statistical correlations, all tests appear to be separate motor qualities (r^2 from 14% to 34%). This may also explain that for the CODD, a strong association was only found with COD180°, demonstrating that the players who took the least time to change direction are also the most efficient (Nimphius et al., 2016), but not necessarily the fastest players in linear tests (T10 and T30) will perform better in a test with change of direction. In that sense, our results agree with Loturco et al., (2019a), who compared the relationship between acceleration and DCCD performances in professional soccer players, evidenced that the best accelerators had a higher DCCD, reinforcing the idea that to have an efficient performance in a change of direction test, there are other factors that must be considered, in addition to strength, power and acceleration (Dos'Santos et al., 2019). Finally, it is important to note that due to the wide variety of tests used in the literature to evaluate changes of direction, their comparisons should be taken with caution (Nimphius et al., 2018).

In relation to the differences found between categories, probable differences were observed in favor of the adult category for CMJ, COD180° and CODD, results that coincide with Doyle et al., (2021), where interesting differences were reported in CMJ (p<0.05) in favor of the selected adult players in comparison to the U-19 and U-17 players. On the other hand, Vescovi et al., (2011) evidenced a plateau in CMJ performance after the age of 16, which could be due to a stagnation of biological maturation after that age (Malina et al., 2004). As for the tests referring to changes of direction (COD180° and CODD), the results obtained in this study partly contradict those obtained by Loturco et al., (2019b) in which 4 different categories (U-15, 17, 20 and adult) of the same male football team were compared, and lower probable and very probable results were observed for the adult category in the change of direction test, assigning as a possible cause the high specialization of the training contents of the higher category. However, for the CODD data, the opposite results were obtained, with the players in the adult category achieving the best performance. These discrepancies found in relation to the study by Loturco et al., (2019b), could be due to possible differences in strength training in the female U-17 category, which could be a factor affecting their performance in the COD180° test, as observed in the study by Jones et al., (2017), in which a relationship between eccentric strength levels and speed in a 180° change of direction was evident.

With respect to the linear speed tests (T10 and T30), no clear differences were found between groups, coinciding in part with Haugen et al., (2012), who found no differences in speed over 20 meters between Norwegian players of different ages, data that contrast with Ramos et al, (2021), who compared different physical tests between selected Brazilian players of different categories (U-15, 17, 20 and adult), finding interesting differences between adult players and the rest of the categories in the 20-metre speed test, similar results to those obtained in the study by Doyle et al., (2021), who found a small to moderate effect size (ES= 0.54-0.69) between the adult and U-17 categories in all linear speed tests, including the T10 and T30 tests. One hypothesis that could explain these differences between adults and juniors in nationally selected populations, may be due to the training processes and competitive level that these players have in comparison to their younger peers (Griffin et al., 2021), in which it was evidenced that players competing in international matches cover significantly greater distances in sprinting, as well as spending more time accelerating compared to players in domestic leagues.

The acceptable and moderate to excellent reliabilities found in this study, using two attempts for all tests except COD180°, are scarce in the literature, most of the studies consulted use 3 attempts and/or do not present intra-test reliability measures. Haugen et al., (2012), present the two-attempt reliability of T10 and CMJ finding CVs of 2.91% and 3.26%, like ours. Suarez-Arrones et al., (2020) analyzed the absolute and relative reliability of two attempts of CMJ, T10 and COD180° of both legs, finding CV of: 1.6%; 1.4%; 1.1% (right COD180°) and 1% (left COD180°) respectively and ICC of: 0.98; 0.89; 0.92 (right COD180°) and 0.96 (left COD180°) Claudino et al, (2017) in a meta-analysis of the CMJ, mention that the derived variables should have a CV<10% to be acceptable. Haugen & Buchheit, (2016) mention that only one attempt at T10 is required to reduce the CV and that it is like the SWD.

Limitations are recognized in the study, due to the instruments and materials used, where there are gold standard instruments for strength assessments, such as strength platforms (Moir et al., 2005), which can deliver variables derived from the f-t curve that could be more sensitive between categories such as the rate of eccentric strength development in CMJ (Merino-Muñoz, et al., 2020b). At the same time, it would be necessary to consider the influence that the body composition indicators of the athletes could have on the physical performance tests, as well as the differences that the different playing positions have on physical performance (Slimani & Nikolaidis, 2017).

Conclusion

From our results, we can conclude that there is an association between CMJ, T10, T30 and COD180°. However, for CODD, they were not found with CMJ, T10 and T30, so it is recommended that coaches working with female soccer players apply specific tests to measure these abilities, together with trying to match the total distance of the change of direction test with one of the linear speed tests, to also be able to know the CODD of their athletes. Another practical recommendation based on what has been observed in this study is the differentiation that should be made with the younger players who move on to the adult category, in terms of training oriented towards neuromuscular and coordination abilities, as possibly, U-17 players may lack years of preparation to exercise sporting equity with their adult peers, ideally suggesting the creation of an intermediate category, so that the long-term developmental processes and phases of each player's sporting life can be respected (Lloyd & Oliver, 2012). For practical purposes, the acceptable and moderate to excellent absolute and relative reliability presented with only two attempts at each test is that teams could reduce the number of attempts, to optimize the available time as much as possible. It should be clarified that the fact of finding relationships between two or more tests does not necessarily imply causality, so that all the skills evaluated should also be trained specifically, given their greater relationship with certain actions specific to soccer.

Conflict of interest

None of the authors have any conflicts of interest.

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