Vertical jump performance and the relationship with sprint speed at 20 m and 50 m in professional soccer players.

Vertical jump and the relationship with sprint speed

Carlos Wheeler Botero¹, Brayan Esneider Patiño Palma², Carlos Ramos Parraci³, Alejandro Gómez Rodas²,⁴, Diego Fernando Afanador Restrepo², José Armando Vidarte Claros⁵

¹Wheeler Sport Tech, Tampa, USA
²Fundación Universitaria del Área Andina, Bogotá, Bogotá, Colombia
³Universidad del Tolima, Ibagué, Colombia
⁴Universidad Tecnológica de Pereira, Pereira, Colombia
⁵Universidad Autónoma de Manizales, Manizales, Colombia

Abstract

Background: Jumping and sprinting are essential skills for several sports, especially for soccer, since they allow to determine neuromuscular function and maximum power of the lower extremities in athletes. This study aimed to establish the relationship between vertical jump performance and sprint speed at 20 m and 50 m in professional soccer players.

Methods: This study took place from June 2020 to November 2021 with participants from the U20 category of the Colombian professional team Fortaleza CEIF, and the U18 category of the Brazilian professional team Boston City. The vertical jump was assessed with the countermovement jump (CMJ), squat jump (SJ), and rebound jump (RJ) variants using the WheelerJump jump sensor while the sprint was measured using the Winlaborat horizontal encoder.

Results: 200 participants from the selected teams were included in this study. Almost perfect correlations (p < 0.05 – r: 0.97) and excellent coefficients of determination (R²: 0.95 – 0.93) were observed between the reactive force index with the mean height of the different jump protocols and the 50-meter sprint speed, indicating that the higher the altitude and/or the higher the reactive force index, the higher the 50-meter sprint speed. The same behavior was found with the 20-meter race, but the correlation levels (p <0.05, r: 0.63-0.62) and the determination coefficients were lower (0.40).

Conclusions: The results of this study suggest that, in professional soccer players, long sprint performance like 50 m is strongly
correlated and could be accuracy explained by the average height reached in SJ, CMJ, and RJ and by the ability to perform repeated jumps using short contact times, thus increasing the ground reaction forces, which translates into a similar behavior during successive contacts of the player's feet against the ground during the race.

**Keywords**
Muscle Strength, Jogging, Sport psychology, Plyometric exercise.
**Introduction**

Sprinting is one of the most used skills in professional soccer; Faude et al. (2012), described that short distance sprinting, with or without the ball is one of the most frequent actions in goal situations; for this reason, power and speed skills are important in decisive moments in professional soccer. Therefore, sprinting should be included in the assessment and training of soccer players. Sprinting is generally performed at distances between 20 m and 50 m and is performed up to 60 times per match, which can change according to the competitive level and playing position (Barnes et al., 2014; Varley and Aughey, 2013).

The ability to quickly generate and apply force has a dominant role in sprint performance (Slawinski et al., 2017). Different authors reported strong relationships between different neuromuscular capacities and sprint performance in different sports (Cronin and Hansen, 2005; Harris et al., 2008; Loturco et al., 2019). Moreover, different experimental studies described those improvements in muscular power resulted in significant improvements in speed, which may suggest a causal relationship between these variables (Loturco et al., 2015, 2018). In this sense, Morin et al. (2011) proposed that the technical capacity to apply force against the ground has more relevance for sprinting performance than for jumping performance itself (Loturco et al., 2015).

Jumping is commonly used to assess muscular power in athletes (Bishop et al., 2021; Carling et al., 2009; Read et al., 2016; Wake et al., 2013), especially in soccer. Different technological devices helped evaluate this capacity and its relationship with sports performance, in the case of soccer, mainly the sprint (Tejada and Suarez, 2013).

In soccer and several sports, sprinting and jumping are fundamental skills. The former is a cyclic motor task that relies on the mechanical capabilities of the neuromuscular system (Samozino et al., 2016); The second is a form of ballistic pushing movement in which the mechanical function of the neuromuscular system of the lower extremities depends on the maximal power capabilities and each athlete’s optimal force-velocity (F-v) profile (Jiménez-Reyes et al., 2017). Therefore, running and jumping can represent the ability of the athletes' neuromuscular system to produce high levels of strength, which can be transmitted to the ground and maintained through high contraction velocities (Morin and Samozino, 2016).

Previous evidence suggest that the kinematic and kinetic parameters of the runners’ center of mass (CM) during sprinting and jumping reflects a relationship between the F-v profile and the power-velocity profile (P-v) of both motor tasks (Jiménez-Reyes et al., 2018). Based on the differences in the force vector between sprinting (horizontal) and jumping (vertical), this study aimed to determine the relationship between vertical jumping performance and sprinting speed at 20 m and 50 m in soccer players from two professional teams. We hypothesized a moderate and/or strong relationship between the study variables.

**Methods**

**Ethical statement**

The research was carried out in accordance with the Declaration of Helsinki, Resolution 008430 of 1993 of the Ministry of Health and Social Protection of Colombia and Resolution 196 of October 10, 1996 of the National Health Council of Brazil and was approved by the committee of ethics of the Santiago de Cali University (CEB-USC-08). Each participant accepted and signed the informed consent, in addition to the informed assent for minors, through which they expressed their voluntary desire to be part of the research project.

**Study design**

This study was cross-sectional with a quantitative approach and a correlational scope. The sample consisted of 200 soccer players, of which 100 were from the under 20 years old (U20) category of the Colombian professional team Fortaleza CEIF, and another 100 were from the under 18 years old (U18) category of the Brazilian professional team Boston City.

Football players under the age of 20 were recruited who willingly wanted to participate in this research. Therefore, the sample was constituted at convenience. The players studied had more than six years of sports history, of which the last ones were specifically in soccer. They did not present any medical condition that could prevent them from participating in the testing sessions.

**Data collection**

Data collection started in June 2020 and ended in November 2021. Before the testing session, the participants performed a standardized warm-up of 20 minutes. The warm-up consisted of an aerobic activity with an intensity of 75% of the maximum heart rate measured by heart rate monitor (Polar Monitor, H10); then, the participants executed a neuromuscular activation through short and explosive movements of high intensity (sprint, multi jumps, changes of rhythm).
The participants performed five repetitions of sprint in 5m with one minute rest, five repetitions of zigzag running in 10m, with the same rest time, and four series of five vertical jumps with knee elevation with one minute rest between each series, based on the protocol applied by Patiño-Palma et al. (2022).

The jump assessment was performed with the WheelerJump photoelectric sensor (Version 2-3, Wheeler Sports Tech, Tampa Florida), which has reported concurrent validity (Rho 0.92-0.99) and reliability (ICC 0.91-0.98) in athletes from different sports (Patiño-Palma et al., 2022). The squat jump (SJ), countermovement jump (CMJ), and rebound jump (RJ) were used to determine lower limb power. For the SJ, the participants performed a vertical jump starting from the half squat position (knees bent at 90°), with the trunk upright and with the hands placed at the waist. For the CMJ, the participants performed a vertical jump starting from a two-legged position with an upright trunk and hands on the waist, then performed a quick downward movement and immediately after a quick upward countermovement to achieve the highest possible height. Finally, for the RJ, participants used the same technique as the CMJ and executed the highest number of successive jumps in 10s with the shortest contact time and the highest height in each jump. The average height RJ in 10s was calculated, and the RJ allowed us to calculate the Reactive Strength Index (RSI) by dividing the flight time over the contact time and then averaging the RSI of each jump performed in the test (Jarvis et al., 2022). The elastic percentage (% elastic) was determined from the percentage difference between the SJ and the CMJ (Kozinc et al., 2022).

The technique of each jump was explained to the participants. Two practice jumps were performed for each protocol to achieve the correct technique for each jump. Knee angle was monitored in the sagittal plane using real-time video digitizing software (Simi Motion® 2D). We developed sprint assessments at 20 m and 50 m in which the participants covered the distance of 20 m and 50 m in the shortest time possible. The best time in seconds of two trials was recorded. The participants had two minutes to rest between each trial. The evaluation was performed with a horizontal encoder (Winlaborat, Buenos Aires, Argentina) with a sampling capacity of 100/1000 Hz and a maximum evaluation distance of up to 110 m.

The statistical analysis was performed with R version 4.1.3 under the R Studio interface R; we reported means, standard deviations (SD), and 95% confidence intervals (CI) for each variable. We tested if the variables had a normal distribution using the Crawley’s graphical methodology, which is a tool that compares the behavior of observed data with those expected in a normal distribution (Crawley, 2015) (Figure 1) and the Shapiro-Wilk test, which is recommended with large
sample sizes (Seier, 2011). Since the data was non-parametric, we performed a correlation analysis using the Spearman's correlation coefficient.

We categorized the correlations based on the following thresholds for the effect sizes: <0.1 trivial; 0.1-0.3 small; 0.3-0.5 moderate; 0.5-0.7 large; 0.7-0.9 very large; and >0.9 almost perfect (Hopkins et al., 2009). Finally, the coefficient of determination was applied to define the coincident pattern not explained by chance between the study variables.

**Results**

A total of 200 soccer players from two professional soccer teams were evaluated (age: 17.45±2.3 years). Table 1 shows the descriptive data of the performance of the different jumps executed and the 20 m and 50 m sprint tests.

A mean SJ height of 34.88±3.31 cm, CMJ of 41.08±4.24 cm, and an average of 34.95±4.54 cm for the RJ. For the RSI evaluated in 10 s a mean value of 2.37 was determined, being a result between moderate to high as established in the work of Healy et al., 2018. Regarding the speed, in the evaluated soccer players, a better performance is evidenced in the sprint at 50 m compared to the sprint at 20 m (7.06±0.62 m·s⁻¹ vs. 6.32±0.40 m·s⁻¹).

Figure 2 shows the correlation coefficients between time and sprint of the different distances evaluated with the variables resulting from the different jumping protocols. Average jump height in absolute terms was significantly correlated with running performance in 20-m and 50-m sprints. The strength of these correlations were moderate to strong. (average height vs Speed 20 m: P<0.05; r: 0.63; IC: 0.55-0.72; average height vs Speed 50 m: P<0.05; r: 0.97; IC: 0.96-0.98).

**Table 1. Descriptive data of the sample.**

<table>
<thead>
<tr>
<th></th>
<th>Mean ±SD</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSI 10°</td>
<td>2.37±0.35</td>
<td>2.32-2.41</td>
</tr>
<tr>
<td>elastic %</td>
<td>18.48±1.4.18</td>
<td>16.5-20.45</td>
</tr>
<tr>
<td>Average height RJ (cm)</td>
<td>34.95±4.54</td>
<td>34.31-35.58</td>
</tr>
<tr>
<td>Time 20 s</td>
<td>3.18±0.20</td>
<td>3.15-3.20</td>
</tr>
<tr>
<td>Time 50 s</td>
<td>7.14±0.62</td>
<td>7.05-7.22</td>
</tr>
<tr>
<td>Speed 20 m (m·s⁻¹)</td>
<td>6.32±0.40</td>
<td>6.26-6.37</td>
</tr>
<tr>
<td>Speed 50 m (m·s⁻¹)</td>
<td>7.06±0.62</td>
<td>6.97-7.14</td>
</tr>
</tbody>
</table>

SJ: The Squat Jump, CMJ: Countermovement Jump, RJ: Rebound Jump, RSI: Reactive strength index in 10 seconds, SD: Standard deviation, cm: Centimeters, m·s⁻¹: Meters per second, CI 95%: Confidence interval at 95%.

**Figure 2.** Correlation matrix between time and sprint of the different distances evaluated with the variables resulting from the different jumping protocols.
A positive correlation between moderate and high was found between the RSI in 10 s and the sprint speed at 20 m and 50 m (RSI vs Speed 20 m: P <0.05; r: 0.62; IC: 0.51-0.69; RSI vs Speed 50 m: P <0.05; r: 0.97; IC: 0.89-0.98). Meanwhile, the elastic percentage had a positive and moderate correlation with CMJ (P <0.05, r: 0.54; IC: 0.51-0.68) and a negative and small correlation with SJ (P <0.05; r: -0.47; IC: -0.62 to -0.42).

Given the strong correlation between jump height and RSI with 50 m sprint performance, the coefficient of determination was applied to explain the coincident pattern between these variables (Figure 3). These coefficients varied between 0.4 and 0.9, showing an intensity between moderate and strong.

Discussion

The study aimed to determine the relationship between vertical jump performance in SJ and CMJ variants and sprint speed at 20 m and 50 m in professional soccer players. We found a strong and positive correlation between the sprint speed at 50 m with the average height RJ in 10 s (0.97) and the RSI in 10 s (0.97), while a moderate positive relationship was found between elastic % and CMJ (0.6) and an inverse and negative correlation was established with SJ (-0.53). This means that average jump RJ in 10 s and the reactive force are linked to performance in 50 m sprint and that a higher CMJ the better elastic % was developed. Furthermore, the elastic percentage was not found to be linked to SJ performance since this jumping variant precisely eliminates the elastic energy input in its execution. The last is related to the shortening-stretching cycle, a common phenomena that reveal how elastic energy enhance motor performance and the specific contribution of contractil and elastic components of muscles in explosive elastic motor tasks like CMJ (Turner and Jeffreys, 2010).

In relation to jump height and its association with sprint performance, our findings are consistent with that evidenced by Köklü et al. (2015); Rodríguez-Rosell et al. (2017) and Zileli and Söyler (2021) who also reported strong relationships between vertical jump and sprint performance. However, these authors evidenced this strong relationship in short sprint like 20 m and 30 m. Moreover, we found strong correlation between RSI in 10 s and 50 m sprint performance, which agree with the substantial relation stablished between these two variables in other studies (Jarvis et al., 2022). However, in the case of the present study, this relationship was solid with long sprinting type 50 m.

We observed a moderate correlation coefficient between average jump height RJ in 10 s and RSI in 10 s with speed sprint in 20 m (0.63 and 0.62). Considering that the correlation between RSI 10s and sprint in 20 m is lower than the correlation between RSI and sprint in 50 m, the hypothesis that RSI correlates better with long sprints than for short distances sprints is supported. Thus, the capacity to sustain high levels of muscular power in very short contact times with high rates of explosive force development is better explained by the RSI (Barker et al., 2018), especially for long-distance sprints. The last is reinforced by the highest goodness of fit between the RSI in 10 s and the sprint performance in 50 m evidenced by the coefficient of determination in this study (0.937).

Our data are particularly relevant in the sense that, even though jump height has been the most used and functional variable to represent the explosive and elastic components of strength using the SJ and CMJ, respectively, the RSI by normalizing jump height or flight time with ground contact time, has been reported as a more accurate variable to quantify jump performance and reflects to a better way the mechanicals phenomena during these movement patterns (Barker et al., 2018).

Our findings in regards to a strong correlation between average jump height RJ in 10s with long distances sprints like 50 m (0.97) are in agreement with Shalfawi et al. (2011). Who evaluated professional basketball players finding progressively
higher correlations between sprint speeds at 10, 20, and 40 m with jump height in SJ (0.53, 0.57 and 0.74, P<0.05) and CMJ (0.45, 0.49 and 0.74, P<0.05), suggesting that sprint performance depends on a substantial variation and combination of muscle performance factors. Similarly, Barr and Nolte (2011) found progressively higher correlations for both SJ and CMJ in female rugby players as fractional sprint distance increased from 0-10 m, 10-30 m, and 30-60 m (-0.53 to -0.74, P<0.05); however, they did not find a significant association between sprint performance and RSI.

Contrary to our results, Healy et al. (2019) evaluated male and female sprint athletes and did not find significant correlations between RSI and fractional sprint performance of 0-10 m, 10-20 m, 20-30 m, and 30-40 m, possibly due to prolonged contact times related to the measurement method with the vertical jump variant drop jump (DJ). Moreover, Jones et al. (2016) reported low to moderate correlations in female rugby players between sprinting at 5, 10, 15, 20, 30, and 40 m and jump height in SJ and CMJ (-0.41 to - 0.61, P<0.05), however, they only found a significant correlation between RSI and sprint speed at 30 m also using DJ as measurement protocol.

In contrast, in accordance with our findings, Loturco et al. (2019) evidenced moderate to high correlations in elite field and track athletes between sprint speed and vertical jump performance in SJ (-0.79 to -0.83, P<0.05) and CMJ (-0.76 to -0.80, P<0.05) that became stronger as sprint distance increased from 10 to 60 m. However, did not find significant correlations between sprint distance and RSI using DJ as the measurement protocol. In addition, Smirniotou et al. (2008) also using DJ, found a significant correlation between sprint distances at 10, 30, 60, and 100 m with RSI increasing in strength of association as sprint length increased in regional level sprint athletes.

Following what we suggest, Lockie et al. (2014) when evaluating recreational field athletes, found moderate correlations between fractional sprint distances of 0-10, 0-20, and 0.40 m for both CMJ (-0.721 to -0.629, P<0.05) and RSI (-0.53 to -0.68, P<0.05) using DJ as the measurement protocol. Likewise, Furlong et al. (2021) after evaluating semi-professional Rugby players, found moderate correlations between sprint time at 30 m with SJ (-0.695, P<0.01), CMJ (-0.665, P<0.01) and RSI assessed with DJ protocol (-0.685, P<0.01) demonstrating the relevance of the evaluation of these variables in the control and monitoring of sprint performance.

Concerning the RSI, all the studies mentioned above used the DJ vertical jump variant for its calculation, but only some studies have used repeated vertical jumps (RJ) for its estimation. In this sense, Nagahara et al. (2014) determined the relationship between the 60 m sprint in athletes specialized in 100 m flat distance with the performance in SJ, CMJ, and RJ using the six repeated jumps method for the latter and using the best RSI of the five available bounces between jumps as the final data. Although they found moderate correlations between the 60 m sprint with SJ (-0.55, P<0.05) and CMJ (-0.52, P<0.05), no significant correlations were found with RSI (-0.07). Likewise, Kariyama and Zushi (2016) determined the relationship between the 60-m sprint with kinetic parameters of torque and power using a force platform and sagittal plane motion data captured by a high-speed video camera during the execution of five repeated jumps, finding moderate correlations between 60 m sprinting with knee and ankle torque in both concentric (0.736 - 0.674, P<0.05) and eccentric (0.616-0.719, P<0.05) phases without finding significant correlations with RSI (0.295).

All of these considerations regarding our findings show contradictory and diverse results that may be associated with the type of athletes assessed, the evaluation methods and protocols used, and how we calculated the reactive strength indexes. In this regard, this study has some limitations. First, due to the cross-sectional nature of this study, it is impossible to establish causality. Second, using the RSI calculation based on the mean of repeated jumps over time did not favor the comparison with other studies. Third, the specific physical characteristics of the soccer players evaluated, who are in the training process, not only affected the results of the variables addressed in this study but also their comparison with other groups of athletes. For these reasons, the implications of our findings must be contextualized, verified, and replicated in future research.

Conclusions
The ability to sprint over long distances such as 50 m is essential for athletic performance and success in soccer. The results of this study suggest that, in professional soccer players, performance in this type of sprint is strongly associated with the ability to perform repeated jumps using short contact times, thus increasing ground reaction forces, which results in similar behavior during successive contacts of the soccer player's feet against the ground during running in typical strategic offensive and defensive tasks in this sport. Furthermore, considering the strong correlation between the RSI in 10s and the 50 m linear sprint suggested by our results, it is also convenient to recommend its inclusion to monitor and control of curved sprint performance as pointed out by Loturco et al. (2020); therefore, its relationship with other manifestations of motor performance should also be addressed.
The practical applications inferred from our findings are related to optimal monitoring, planning, and control training in soccer players. First, given the strong correlations between long sprinting and RSI in the short time to suggest that the RJ performance in 10 s may be an easy and saved time way to infer and explain the 50 m sprint performance in soccer players and its inclusion in future research in other sports and performance conditions that involve the use of high-power production in a short time. Second, this assessment method can be used to plan, control, and program the training process with particular focus on the reactive strength performance and its impact on quick technical skills used in soccer and other sports with similar characteristics. Finally, concerning elastic percentage, namely the SJ and CMJ differences, this variable explains the contribution of the series and parallel elastic components of the muscles during the jump performance, it is highly useful to identify by separate the unique biomechanics characteristics of these two components and their contribution to explosive strength profile in these athletes. However, these considerations must be interpreted with caution because the changing behavior of these same variables in other studies.

Data availability

Underlying data

Mendeley Data: Vertical jump performance and the relationship with sprint speed at 20 m and 50 m in professional soccer players, https://doi.org/10.17632/z727frmfdw.1 (Wheeler et al., 2023).

The project contains the following underlying data:

- base datos.xlsx (Anonymized results from jumps, average height, and speed).

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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