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Section III – Sports Training

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# Muscle Strength and Speed Performance in Youth Soccer Players

*by*
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*This study aimed to examine the relationship between maximum leg extension strength and sprinting performance in youth elite male soccer players. Sixty-three youth players (12.5 ± 1.3 years) performed 5 m, flying 15 m and 20 m sprint tests and a zigzag agility test on a grass field using timing gates. Two days later, subjects performed a one-repetition maximum leg extension test (79.3 ± 26.9 kg). Weak to strong correlations were found between leg extension strength and the time to perform 5 m (r = -0.39, p = 0.001), flying 15 m (r = -0.72, p < 0.001) and 20 m (r = -0.67, p < 0.001) sprints; between body mass and 5 m (r = -0.43, p < 0.001), flying 15 m (r = -0.75, p < 0.001), 20 m (r = -0.65, p < 0.001) sprints and agility (r =-0.29, p < 0.001); and between height and 5 m (r = -0.33, p < 0.01) and flying 15 m (r = -0.74, p < 0.001) sprints. Our results show that leg muscle strength and anthropometric variables strongly correlate with sprinting ability. This suggests that anthropometric characteristics should be considered to compare among youth players, and that youth players should undergo strength training to improve running speed.*

**Key words**: *sprint, maturation, strength training, soccer, youth players, development.*

## Introduction

Performance in a soccer match depends on a variety of factors such as skills, tactics, and players' physiological, physical and mental capacities (Stolen et al., 2005). Small changes in these capacities can have significant effects on the development and result of a match and/or a championship (Chelly et al., 2009; Comfort et al., 2012; Stolen et al., 2005). In soccer, numerous attempts have been made to determine whether adult players' muscle strength is related to their speed. Although sprint actions only constitute 11% of the total distance covered during a match, they represent crucial parts of the game, directly contributing to possession of the ball, making assists and passes or scoring a goal (Reilly et al., 2000).

Various studies have shown a direct relationship between muscle strength and running speed: the strongest athletes achieve the greatest running speed (Chelly et al., 2009; Seitz et al., 2014; Wisloff et al., 2004). For instance, Chelly et al. (2009) showed a significant correlation between one-repetition maximum (1RM) measured in a back squat and sprint speed over 5 m (r = 0.66) in adult soccer players aged between 17 and 19 years. Likewise, Wisloff et al. (2004) reported a very strong correlation (r = 0.94) between 1RM in a half squat and a 10 m sprint in adult soccer players. Furthermore, similar results were found by Peterson et al. (2006) in young collegiate athletes, showing a positive relationship between the knee extensors maximum muscle strength and running acceleration in the first 18 m (20 yards; r = 0.82) and running speed over 36 m (40 yards; r = 0.85). Relative muscle strength (1RM squat/body mass) and running time in 36 m (40 yards; r = -0.60) and 9 m (10 yards; r =-0.54) also significantly correlated, but not in the first 4.5 m (5 yards; McBride et al., 2009). It is pertinent to mention that maximum muscle strength and

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agility also correlate in male and female college students (Negrete and Brophy, 2000), as does agility and speed in female college athletes (Vescovi and Mcguigan, 2008). However, muscle strength and running speed do not correlate (Baker and Nance, 1999; Cronin and Hansen, 2005; Sheppard and Young, 2006). In addition, Harris et al. (2008) found no correlation between maximum strength and running time for 10, 30 and 40 m, and only a moderate correlation between gains in maximum strength relative to body mass and time to run 30 and 40 m (r = -0.29 and r = -0.33, respectively) after training in elite rugby league players. Similarly, Cronin and Hansen (2005) found no correlation between maximum strength and running velocity for 5, 10 and 30 m in professional rugby players. Thus, there are ambivalent results regarding the relationship between muscle strength and speed performance in adults. Moreover, it is not known if this relationship exists in youth athletes and how anthropometric characteristics influence their physical performance.

The difficulty in finding a consensus among the relationships between muscle strength, speed and agility could be due to the fact that these qualities do not only depend on a player's capacity to generate force or movement, but also on their age, training level, gender, anthropometric characteristics, and the training period (Papaiakovou et al., 2009). For instance, Mujika et al. (2009) found that sprint time progressively decreased between 10 and 14 years of age in highly trained youth soccer players, but not between 15 and 18 years. The authors concluded that this could be due to the large variations in height and body mass experienced until the age of 14.

To our knowledge, the relationship between muscle strength and speed performance in youth players has not been investigated and this relationship may differ to that of adult soccer players due to the different levels of maturity. Therefore, our aim was to examine the relationship between knee extension maximum muscle strength with running speed over 5, 15 and 20 m and agility in youth elite soccer players. We hypothesized that there would be a strong relationship between knee extensors maximum muscle strength and the time to complete a 5, 15 and 20 m speed test and the agility test in youth elite soccer players.

## Material and Methods

### *Participants*

Sixty-three youth players volunteered to participate in this study. The age, body mass, height and the body mass index (BMI) of the players were 12.5 ± 1.3 years, 49.2 ± 11.1 kg, 158.6 ± 12.7 cm and 19.4 ± 2.1 kg·m², respectively. All players were born between 1998–2001, and belonged to the youth division of a professional soccer club of the Chilean First Division. Participants trained on average 12.5 ± 2.3 hours/week (4-5 training sessions per week). The teams were not participating in the national youth championship at the time of the study (off-season), and were among the top three Chilean youth soccer teams in their respective categories. Written authorization was obtained from the player's' parents or guardians and the study itself was approved by the Finis Terrae University Ethics Committee.

### *Procedures*

The tests were conducted in two non-consecutive days, 48 h apart, to allow participants to fully recover. Running speed (acceleration, flying and maximum speed) and agility tests were performed on the first day. During the second day, the players were tested for their leg extension one-repetition maximum (1RM). All tests were carried out between 4 and 7 pm. Ambient temperature was 28.3 ± 2.3º C and humidity was 24 ± 4%. The players were asked to refrain from any physical exercise one day before the tests and during the recovery days, as well as drinking caffeinated drinks during the 4 hours prior to testing. Before the tests started, the players performed a general group warm-up (15 min), including moderate-intensity aerobic exercises and dynamic stretching. All players took part in a familiarization session before the 1RM test during which they were taught the appropriate techniques, such as controlled movements and adequate breathing, and all the questions raised by the players were answered as previously reported (Faigenbaum et al., 2003). The players were familiar with the acceleration, speed and agility test procedures, which they performed regularly in-season, so there was no need for a familiarization session. All tests were conducted at the same time of the day with a maximum of 25 min variation.

***Measures***

*Maximum muscle strength*

The bilateral leg extension 1RM was determined using a Cybex VR 4850 (Lumex, Ronkonkoma, NY, USA). Before assessing the 1RM, the players performed six repetitions with a relatively low load (~30% of self-perceived 1RM), then three repetitions with a heavier load (~50% of self-perceived 1RM) and finally the 1RM assessment started with a series of isolated repetitions with incremental loads. The 1RM test was taken as the maximum weight that could be lifted for the entire range of movement using the correct technique. If the weight was lifted with adequate technique, it was increased by 0.5-2.3 kg, and the players attempted the next repetition following the protocol reported by Faigenbaum et al. (2003). On average, the 1RM measures were determined in 7-11 attempts. Failure was defined as a lift that did not complete the full range of movement in two attempts with 3 min of rest between attempts. A standardized and constant verbal stimulus was given to all players. This protocol had been proven to be safe and effective in children (Faigenbaum et al., 2003), and to have test-retest reliability greater than 0.93 (Faigenbaum et al., 1998).

*5 m acceleration, 20 m and flying 15 m running*

Five meter acceleration, 20 m (maximum speed at short distance) and flying 15 m (maximum speed while in motion) times were obtained from the same test as reported by Mirkov et al. (2008) and were measured using timing photocells (Ergo Timer, Globus, Codogne, Italy). Players performed assessments on a natural grass pitch and wore their normal competition soccer shoes, with three attempts per test (Chamari et al., 2004; Mirkov et al., 2008; Sayers et al., 2008), separated by at least 3 min of recovery. The players stood behind the starting line (the first pair of photocells), with the front foot positioned on the line, in a static upright position, and started running at maximum speed in response to an auditory stimulus (time started when players crossed the first pair of photocells), ran through a second pair of photocells at 5 m and continued until the 20 m finish line (the last pair of photocells) at maximum speed. When the player passed the second pair of photocells (5 m), the acceleration time (0-5 m) was measured, and when the player went through the third pair of photocells (20 m), the total distance time was measured and the time over 15 m (5-20 m) was then calculated. The fastest time was used for statistical analyses.

*Agility*

The capacity to change direction was assessed by a zigzag running test divided in four 5 m sections with each change of trajectory angled at 100° as reported by Little and Williams (2005). This zigzag running test requires acceleration, deceleration and balance control (Mirkov et al., 2008). The players started the test by standing behind the starting line, with the front foot positioned on the line, in a static upright position, and then freely ran at maximum speed after an auditory stimulus. A pair of photocells was placed at the start and another at the finish line of the test. One-meter high poles were used as obstacles for the zigzag test and players were not allowed to touch them while running around (Mirkov et al., 2008). Players performed all the assessments on a natural grass pitch and wore their normal competition soccer shoes, with three attempts per test, separated by at least 3 min of recovery (Chamari et al., 2004; Mirkov et al., 2008; Sayers et al., 2008). The fastest time was used for further analyses.

The running times were measured using a timing gate photocell system incorporated to specific software that translates electrical signals to time with accuracy of a millisecond (sampling frequency: 1000 Hz) and the best time was used for the statistical analyses (Little and Williams, 2005). The infrared beam of each photocell was placed 0.9 to 1.0 m from the ground depending on the player's height, so that the photocell beam cut at the hip level. At the starting position, the player placed his foot just behind the start line, the knee of the advanced limb in semi flexion and the arms flexed to avoid cutting the infrared beam. The forward body movement cutting the infrared beam started the stopwatch.

***Statistical analyses***

Descriptive statistics included mean and standard deviation. After determining the normal distribution of the data, correlations were calculated using a Pearson product-moment correlation coefficient (r). The correlation magnitude effect was based on the following scale: trivial (<0.10), small (0.10 – 0.29), moderate

(0.30 – 0.49), high (0.50 – 0.69), very high (0.70 – 0.89) almost perfect (≥ 0.90), and perfect (r = 1) (Hopkins, 2002). Prism statistical software version 5.03 (GraphPad Software, San Diego, CA, USA) was used for data analysis. Statistical significance was set at $p$ <0.05.

## Results

***Performance***

On average, leg extension 1RM was 80.7 ± 27.4 kg (range: 31.7-136.8), the 5 m sprint was 1.75 ± 0.09 s (range: 1.57-1.96 s), the flying 15 m sprint was 2.30 ± 0.17 s (range: 2.01-2.62 s) and the 20 m sprint was 4.06 ± 0.24 s (range: 3.61- 4.55 s).

***Strength and speed – agility relationships***

Moderate to very high correlations were observed between maximum muscle strength and 5 m sprint time (r = -0.40, $p$ = 0.001), flying 15 m sprint time (r = -0.72; $p$ < 0.001) and 20 m sprint time (r = -0.67, $p$ < 0.001). However, although the correlation between maximum muscle strength and agility was statistically significant, it was small (r = -0.29; $p$ < 0.05) as can be seen in Figure 1.

***Strength and anthropometric measures relationships***

As shown in Table 1, leg extension 1RM strength was highly correlated with age (r = 0.67, $p$< 0.001), body mass (r = 0.92, $p$ < 0.001) and height (r = 0.86, $p$ < 0.001).

***Speed and agility relationships with anthropometric measures***

*Age*

Age and time very highly correlated with the time needed to cover 20 m (r = -0.74, $p$ < 0.001) and flying 15 m run (r = -0.76, $p$ < 0.001). Also, moderate correlations between age and 5 m sprint time (r = -0.49, $p$ < 0.001) and agility (r = -0.44, $p$ < 0.001) were found as shown in Table 1.

*Body Mass*

There were high to very high correlations between body mass and time to cover 20 m (r = -0.64, $p$ < 0.001) and time to perform flying 15 m (r = -0.74, $p$ < 0.001). There were moderate correlations between body mass and 5 m sprint time (r = -0.38, $p$ = 0.002) and agility (r = -0.30, $p$ < 0.001) as is shown in Table 1.

*Height*

There were very high correlations between height and time to perform a flying 15 m (r = -0.74, $p$ < 0.001) and 20 m run (r = -0.64, $p$ < 0.001). There was a moderate correlation between height and 5 m sprint time (r = -0.33, $p$ < 0.01). Agility and height had a small correlation (r = -0.28, $p$ < 0.05) as is shown in Table 1.

**Table 1**

*Pearson product-moment correlation coefficients (r) and p-values for anthropometric measures and 1RM strength, sprint and agility times*

| | 1RM-leg extension | 5 m Sprint | Flying 15 m Sprint | 20 m Sprint | Zigzag test |
|---|---|---|---|---|---|
| **Age (years)** | 0.67 ($p$<0.001) | -0.49 ($p$<0.001) | -0.76 ($p$<0.001) | -0.74 ($p$<0.001) | -0.44 ($p$<0.001) |
| **Body mass (kg)** | 0.92 ($p$<0.001) | -0.38 ($p$=0.002) | -0.74 ($p$<0.001) | -0.64 ($p$<0.001) | -0.3 ($p$<0.001) |
| **Height (cm)** | 0.84 ($p$<0.001) | -0.29 ($p$=0.02) | -0.74 ($p$<0.001) | -0.64 ($p$<0.001) | -0.25 ($p$=0.05) |
| **BMI ($kg \cdot m^{-2}$)** | 0.68 ($p$<0.001) | -0.4 ($p$=0.001) | -0.47 ($p$<0.001) | -0.42 ($p$<0.001) | -0.28 ($p$=0.03) |

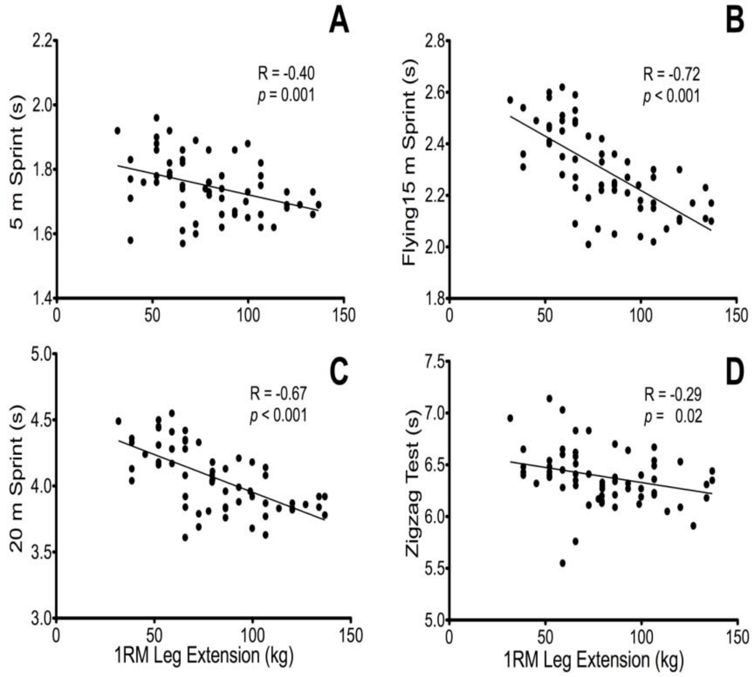


**Figure 1**

*The relationship between one-repetition maximum (1RM) and A) 5 m sprint, B) flying 15 m sprint, C) 20 m sprint, and D) zigzag agility test times*

## Discussion

To our knowledge, this is the first study that correlates maximum muscle strength of the leg extensor muscles and acceleration, maximum speed and agility in soccer players aged between 10 and 14 years. High correlations were found between leg extensors muscle strength and flying 15 m running time, and between muscle strength and 20 m running time. These results are similar to previous studies performed in adult elite soccer players and collegiate athletes (McBride et al., 2009; Peterson et al., 2006; Wisloff et al., 2004). Although a cause-effect relationship cannot be established, our results do show a strong relation between the leg extensors maximum strength and speed performance in children. The increase in muscle strength of the lower limbs could improve the ability to carry out short duration sprints as previously suggested (McBride et al., 2009). The data generally support our hypothesis that a strong relationship exists between maximum muscle strength and sprinting and agility abilities in youth elite soccer players.

It has been reported that during the first 10 m of a sprint, the leg extensor muscles mainly contract concentrically to accelerate the body, while it is being propelled upwards and forward (Seitz et al., 2014; Young et al., 2001). However, some authors propose that the stretch-shortening cycle (SSC) and the activation of the hip extensor muscles also play an important role in sprinting (Harris et al., 2008; Wisloff et al., 2004; Young et al., 2001). It was expected that the time to run the first 5 m of the sprint would be strongly correlated with leg extension strength. However, only a moderate albeit significant correlation was found between these variables (r=-0.4). This could be a result of the leg extension 1RM measurement being performed at a different speed and acceleration than the 5 m sprint (Cronin and Hansen, 2005), and also that leg extension mainly recruits the knee extensor muscles, whilst during the first meters of a sprint there are several leg muscle groups active, in addition to the role of tendons (SSC).

Agility is defined as the capacity to rapidly change direction (Sheppard and Young, 2006). Considering that soccer involves frequent changes of direction, we postulated that agility would be highly related to muscle strength. However, they only had a small correlation (r = -0.29). For one, this could be due to the maturity stage of young players, which affects coordination, important in agility (Sheppard and Young, 2006), but not strength or power performance. Indeed, a significant gain in strength and power occurs during the later stages of puberty (Malina et al., 2004). If the subjects in this study were in their early stages of puberty, their agility might be compromised, but not their strength or power (Sheppard and Young, 2006).

Wong et al. (2009) reported that speed during childhood and adolescence is related to height and body mass. They studied a group of soccer players under the age of 14 and found a significant relationship between body mass and time to run a 30 m sprint (r=-0.54). This is in accordance with other authors, for instance Malina et al. (2004) and Mujika et al. (2009) who demonstrated body mass to be the most significant predictor of running speed in children, reporting that faster running speed was achieved in lean subjects with greater body mass. This could be due to the increased muscle fiber size and mass in highly trained children (Malina et al., 2004; Mujika et al., 2009). Our results support these findings showing a high correlation between body mass and time to perform a 20 m sprint (r = -0.64). Likewise, height is another variable that indirectly affects the increase in speed in children, by increasing the length and stride frequency (Papaiakovou et al., 2009). In this study, players' height was highly correlated with the time to run flying 15 m and 20 m sprints. The data in this study clearly shows anthropometric characteristics to influence speed performance in youth players. Therefore, both weight and height should be taken into account when evaluating soccer players under 14 years old, as they are not just indicators of the players' biological maturity, but can also differentiate those players who are fast and those who obtain good results due to an advanced maturity only. Therefore, for a fairer comparison between players aged between 10 and 14 years, the speed performance relative to body mass, i.e. 20 m run time/body mass, should be utilized.

However, as the children become older and advance in their maturation stages, body mass and height play rather a secondary role in the development of muscle strength and speed than in the ages included in this study (Abrantes et al., 2004; Malina et al., 2004; Nedeljkovic et al., 2007). Moreover, it is disputable if our results were related to the training level or to the maturation state of the players since muscle strength was not only related to speed, but also to the anthropometric measures. Therefore, future research should be conducted to determine whether strength and speed could be improved independently from biological growth.

Furthermore, our study confirms that the maximum strength testing protocol described by Faigenbaum et al. (2003) is safe and applicable for children. No injury occurred and the evaluation was well tolerated by the players. No severe muscle pain was reported by the players following the leg extension 1RM test. In conclusion, our results encourage strength and conditioning professionals to include muscle strength assessments and resistance training at this early stage of development for youth soccer players.

## Practical applications

This study suggests that it is important to develop muscle strength in youth soccer players to improve their acceleration, speed and agility. However, anthropometric characteristics in relation to growth and maturation should be taken into account when children are compared since they correlate well with both speed and muscle strength. Finally, a strong and consistent relationship between strength and speed indicates that an increase in maximum muscle strength as a result of resistance and/or plyometric training, may improve soccer performance. It is important not to neglect other qualities that could also be important such as power and coordination, as suggested by the moderate relationships observed between maximum muscle strength and acceleration and agility.

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