Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 3), Art 72, pp. 605 - 613, March 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Impact of puberty on the correlation between strength and speed levels in young futsal players

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Published online: March 31, 2024
(Accepted for publication March 15, 2024
DOI:10.7752/jpes.2024.03072

Abstract:
Background: Vertical jumps are commonly prescribed in literature as a method to enhance speed performance, yet the impact of puberty on this relationship remains unclear. **Purpose:** This study aimed to investigate whether pubertal stage affects the correlation between jump performance and sprinting ability in young futsal players. **Methods:** Seventy-six male players were categorized into pre-pubertal, pubertal, and post-pubertal stages. The pubertal stage was evaluated by the peak height velocity (PHV) in which it differentiated the players in prepubescent (pre-PHV), pubescent (mid-PHV) and post-pubertal (post-PHV). All of them performed the squat jump (SJ) and countermovement jump (CMJ), straight-line sprint (SLS-20 m) and sprint with change of direction (COD-25 m). The Shapiro-Wilk normality test was used and when comparing the morphological and performance variables between the stages, the ANOVA one way with Tukey post hoc was used. To analyze the correlations between performance of sprints and jumps, the Pearson correlation test was used and in all analyzes a significance level of $p < 0.05$ was adopted. Parents and players signed specific terms for the inclusion of athletes in the survey. **Results:** A significant correlation only being found in the pre-PHV stage for SJ vs SLS (r = - 0.63) and COD (r = - 0.50); CMJ vs SLS (r = - 0.56) and COD (r = - 0.48) compared to mid-PHV and the post-PHV for the same correlations. **Conclusions:** The results demonstrate that the pubertal stage influences the level correlation between vertical jumps and sprint performance. Training to improve muscle strength through jumps to develop speed, to the detriment of specific training in this capacity, in players in mid- and post-PHV stages needs to be used with caution.
Key Words*: Jump; Sprint; Physical performance; Maturation stage; Indoor soccer; Adolescent development.*

Introduction

During puberty there is a high development of the morphological, neural and functional aspects of the human being (Malina et al., 2004), which can increase performance in sports such as futsal, which is the most practiced indoor sport in the world and growing in popularity. Futsal is played by two five-player teams, with 40-minute competitive games of intermittent activities requiring tactical, technical, and high-intensity physical efforts (Rodrigues et al., 2011; Dos Santos et al., 2024). The presence of intermittent high-intensity motor actions (kicks, jumps and sprints) means that physical strength and speed are extensively evaluated and trained in the preparation of athletes in this modality (Naser et al., 2017). Despite the robust scientific literature showing a strong influence of lower limb strength on speed (Bedoya et al., 2015), to date, to the best of our knowledge, we have not found experimental studies that assessed how puberty influences this relationship in young futsal athletes. Such studies will provide support for coaches and fitness coaches in choosing training strategies to improve speed at different puberty stages.

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In boys, puberty usually occurs between 12 and 14 years of age and is identified by morphological changes, such as the growth (thickness and length) of the bone segments, called peak height velocity (PHV) (Beunen & Malina, 1988). It is widely known that this process increases muscle mass and matures neural functions, resulting in greater physical performance (Radnor et al., 2018). However, during the phase of greatest development in PHV (mid- PHV), a "growth spurt" occurs, which is considered responsible for a transient reduction in motor coordination, known as "motor awkwardness" (Beunen & Malina, 1988). The presence of the "awkwardness motor" has been reinforced by studies that have found reduced speed performance (Rommers et al., 2019; Philippaerts et al., 2006) in soccer athletes in mid-PHV, although this phenomenon does not seem to negatively influence the performance of muscle strength (Philippaerts et al., 2006; Gillen et al., 2019). Thus, together, these results indicate a distinct influence of puberty on motor speed and muscle strength, which could impact the common variance explained between these capacities. Philippaerts et al. (2006), in a longitudinal study (5 years) involving soccer players aged 10 to 14 years, observed that the physical capacity for speed showed a decline around the PHV. According to the authors, in activities requiring motor control and body balance such as movement, players demonstrated a clumsiness that can be attributed to the rapid longitudinal growth during this phase (Sayer et al., 2018). Another factor that occurs during puberty is the increase in tissue stiffness, meaning greater difficulty in tissue deformation and EPE storage during rapid force application (Hooren & Zolotarjova, 2017). These factors can also affect performance during tests and consequently influence correlations, which are most often conducted without differentiating by pubertal stage, allowing for the existence of players who may respond differently to the proposed tests. Even if only one pubertal stage is analyzed, it is impossible to assert that puberty was a factor influencing correlations, considering the absence of other maturational levels for comparison (Hammami et al., 2017). In the sports context, sprints in a straight-line (SLS) and with change of direction (COD) are widely used both for speed evaluation and as a training strategy (Hammami et al., 2017). In addition, as an alternative to specific speed training, muscle strength training, using vertical jumps (e.g. squat jumps (SJs) and countermovement jumps (CMJs) is widely used to improve sprint performance in adults (Bedoya et al., 2015; Torres-Torrelo et al., 2017) and it has also been used in young soccer athletes (Yüksel et al., 2016). However, this extrapolation to this audience needs to be better studied, as evidence shows that these effects depend on the maturation stage (Asadi et al., 2017; Alvares et al., 2020). Additionally, research evaluating the correlation between these tasks (jumps and sprints) found moderate correlations ($r = -0.43$; $p < 0.05$; common explained variance of only 18.50%) for the age of 13.52 ± 0.51 years (Orer, 2016) and high ($r = -0.77$; $p < 0.05$; common explained variance of 59.29% for the age of 16.00 ± 0.80 years (Köklü et al., 2015). Given the above, further studies are needed to increase the understanding of how puberty influences the common variance explained between strength and speed performances in futsal athletes. Most of the knowledge available in the literature is based on soccer athletes, and it has already been demonstrated that these athletes perform differently in these tasks compared to futsal athletes (Gorostiaga et al., 2009), which could impact the extrapolation of the results available so far. Therefore, we aim to verify the level of correlation between the performance of jumps and sprints in young futsal athletes in different puberty stage.

Material & methods

Participants:

The study consisted of 76 male futsal players (13.80 ± 2.49 years; 50.92 ± 12.84 kg; height of 161.14 cm) between the categories of under-11 to under-17 (8–16 years old), who were later grouped according to their current pubertal stage (pre-PHV, mid-PHV or post-PHV) (Table 1). Only individuals who trained at least twice a week and whose practice time was longer than two years were included in the sample. Individuals who did not complete all the collection phases (familiarization and experimental) were excluded. The study was approved by the local Research Ethics Committee Involving Human Beings. After being informed of the risks and benefits of the research, the layers and their guardians read and signed the terms of consent and informed consent, respectively.

Procedures:

At the beginning of each session, a five-minute warm-up (low-intensity run (~ 7 km/h) interspersed with 20 m sprints was performed. The values for the five and two attempts at each jump and sprint type, respectively, were recorded and used for intraday reliability analysis using the intraclass correlation coefficient (ICC) (Koo & Li, 2016). Anthropometric assessment - Body mass (BM) was assessed using a Filizola ® pendulum scale, height (H) by a stadiometer (Personal Caprice Sanny) with 0.1 cm precision and scale from 0 to 220 cm and for lower limb length (LL) and seated height (SH) a measuring tape (0–150 cm) was used.

Maturational assessment - The pubertal stage was determined through somatic maturation (Koo & Li, 2016). In this technique, anthropometric variables are inserted in a predictive equation capable of estimating the moment (pre-PHV, mid-PHV or post-PHV) that the players are in regarding the growth spurt. The predictive equation includes the values of age (A) and anthropometric values that are inserted later in the following equation for boys: [PHV = - 9.236 + 0.0002708 (LL x SH) - 0.001663 (A x LL) +0, 007216 (A x SH) + 0.02292

(BM / H)]. The result of the equation is incorporated into a set of intervals, in years, which shows the individual's chronological position regarding PHV (moment with variation of +1 year), the classification being given by the following intervals: pre-PHV (PHV < - 1), mid-PHV (-1 > PHV < +1) and post-PHV (PHV > +1) (Mirwald et al., 2002). Strength of lower limbs - Ten minutes after warming up, vertical jumps (VJs) were performed according to the protocol described by Komi and Bosco (1978). 1) SJ: semi- squat position, knee angle close to 90º and hands on the waist. After three seconds in this position, the subject performed the jump and landed initially with the balls of his feet. 2) CMJ: The movement pattern was similar to the SJ, however the individual, instead of starting from the semi-squat position, started from a standing position. From there, he performed a countermovement (descending phase) followed by a rapid extension of the joints of the lower limbs (ascending phase). Each player made five attempts with an interval of 10 s between them. The mean of five values was considered for statistical analysis. The jumps were performed on a contact mat (Cefise, São Paulo, Brazil) and the data were analyzed using the Jump System 1.0 software. The intraday ICC of the squat jump for pre-PHV, mid-PHV and post-PHV was ICC = 0.98, ICC = 0.92 and ICC = 0.94, respectively. For the countermovement jump the ICC = 0.96, ICC = 0.93 and ICC = 0.92, respectively.

Speed performance - The sprint tests were based on the Torres-Torrelo et al. (2017) protocol. 1) SLS: players were guided and encouraged to run in a straight-line for a distance of 20 m as quickly as possible. 2) COD: The players performed a sprint of 25 m, with a change of direction with an angle of 45º every five meters. For both sprints, each player performed two repetitions, with a three-minute break between them. The mean of two attempts was used for analysis. To obtain the time in both tests, the electronic photocell Speed Test 4.0 (Cefise, São Paulo, Brazil) was used, positioned at the beginning (0 m – starting line) and at the final distance of each sprint. The player was instructed to start the race one meter before the first photocell and maintain speed up to one meter after the last photocell, whose places were marked with cones. The intraday ICC of the SLS and COD was ICC = 0.93 and ICC = 0.91, respectively.

Statistical Analysis:

The normality of the data was verified by the Shapiro–Wilk test and for the comparison of anthropometric and performance data between the pubertal stages, analysis of variance with a variation factor (ANOVA One Way) was used. For all analyses of variance performed, when a significant Fisher F value was found, Tukey's post hoc test was used to perform multiple comparisons. Pearson's correlation was used to analyze the correlations between VJ and sprint performances (SJ vs SLS; SA vs COD; CMJ vs SLS and CMJ vs COD). For classification of the level of correlation, r > 0.10 weak, r > 0.30 medium and r > 0.50 strong (Cohen, 1988) were used. For the analysis of the ICC the following were considered: > 0.9 excellent, 0.75–0.9 good, 0.5–0.74 moderate and < 0.5 poor (Koo & Li, 2016) The effect size (ES) was calculated to determine the magnitude of the differences between pubertal stages in morphological and physical performance characteristics. Values were categorized into trivial (≤ 0.2), small (> 0.2–0.6), moderate (> 0.6–1.2), large (> 1.2–2.0), very large (> 2.0-4.0) and extremely large (> 4.0) (Lloyd et al., 2009). The results will be presented as mean and standard deviation (SD). All analyses were performed using the computer software SPSS 18.0 (Statistical Package for Social Science, SPSS Inc. Chicago, USA) and Sigma Plot 12.0. The level of significance was set at p < 0.05.

Results

Table 1 shows the comparison of the anthropometric characteristics and performances of VJs and sprints between the puberty stages. Higher values were observed in the variables analyzed in mid- and post-PHV individuals, demonstrating that puberty influences morphological and physical performance aspects.

Table 1. Descriptive statistics of anthropometry, physical performance, and differences between the pubertal stages of young futsal players.

Variáveis	Pré-PHV (n=26)	Mid-PHV (n=25)	Post-PHV (n=25)	Pré-PHV vs. Mid-PHV (ES)	Pré-PHV vs. Post-PHV (ES)	Mid-PHV vs. Post-PHV (ES)
Age (years)	11.03 ±1.18	14.52 ±1.08*	15.84 ±0.85*$^{\#}$	3.09 (very large)	4.74 (extremely large)	2.05 (very large)
Stature (cm)	145.15 ±1.08	164.00 ±5.51*	174.28 ±6.28*$^{\#}$	5.72 (extremely large)	7.92 (extremely large)	2.69 (very large)
LL (cm)	75.02 ±5.80	84.36 ±4.54*	90.60 ±4.86*$^{\#}$	1.81 (large)	2.92 (very large)	1.99 (large)
BM (kg)	37.20 ±6.95	52.92 ±7.14*	62.65 ±7.39*$^{\#}$	2.23 (very large)	3.55 (very large)	2.01 (very large)
SJ (cm)	21.48 ±4.55	30.04 ±4.21*	29.70 ±4.40*	1.95 (large)	1.76 (large)	0.16 (trivials)
CMJ (cm)	21.57 ±4.83	30.08 ±4.30*	31.09 ±4.78*	1.96 (large)	2.08 (large)	0.47 (small)
SLS (s)	3.43 ±0.45	3.00 ±0.25*	2.96 ±0.29*	1.18 (moderate)	1.27 (large)	0.32 (small)
COD (s)	9.06 ±1.23	8.06 ±0.77*	8.12 ±0.80*	1.06 (moderate)	0.98 (moderate)	0.16 (trivials)

Legend: pre-PHV = pre-pubescent; mid-PHV= pubescent; post-PHV = pos-pubescent; * different of the pre-PHV ($p < 0{,}01$); # difference of the mid-PHV ($p < 0{,}01$); ES= effect size; LL= lower limb; BM= body mass; SJ= squat jump; CMJ= countermovement jump; SLS= straight-line sprint; COD= change of direction.

With regard to the correlations between the performances of VJs and sprints in the different pubertal stages, only in the pre-pub was a strong and significant correlation between the jumps and sprints performances found (Fig. 1 and 2 (A and B)) differently from the correlation values between the performances of the different types of jumps and sprints for the mid and post- PHV puberty stages (Fig. 1 and 2 (A and B)).

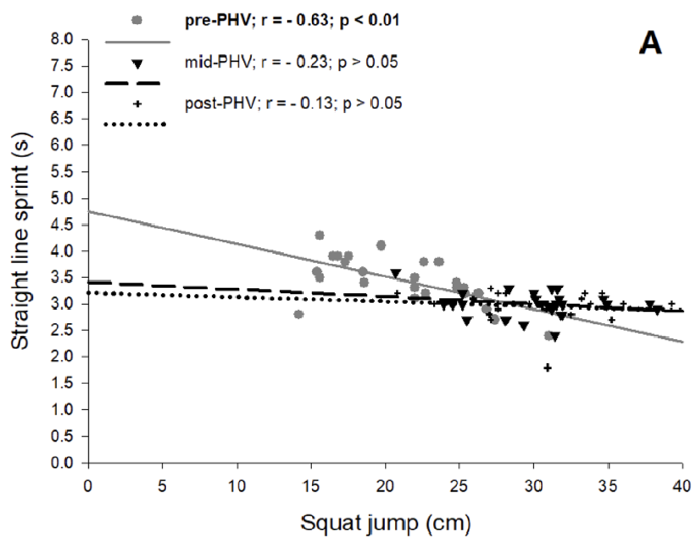

Figure 1A. Correlations between the squat jump and sprint performance in a straight-line sprint.

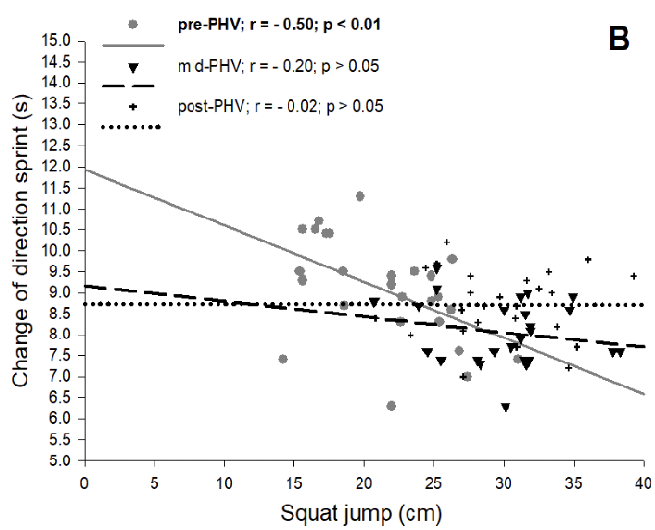

Figure 1B. Correlations between the squat jump and sprint performance in a change of direction sprint.

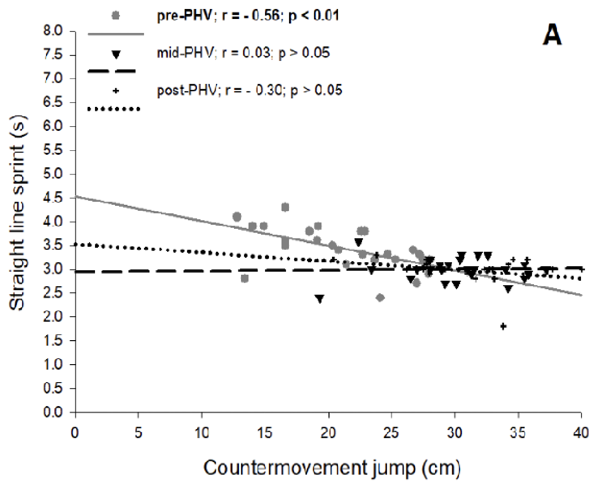

Figure 2A. Correlations between the countermovement jump and sprint performance in a straight-line sprint.

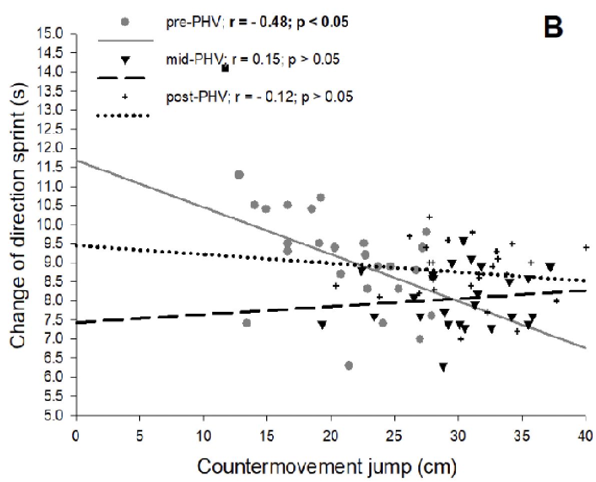

Figure 2B. Correlations between the countermovement jump and sprint performance in a change of direction sprint.

Discussion

The aim of the present study was to verify whether the pubertal stage influences the correlation between the performance of VJs and sprints in young futsal players. When differentiating the subjects by their current pubertal stage, a strong and significant correlation was found between both VJs (SJs and CMJs) with the performances of SLR and COD only in the pre-PHV, demonstrating the effect of the pubertal stage in this correlation, confirming the hypothesis of the present study.

Although VJs have strong correlation coefficients with SLS, possible explanations for the lower correlation values between SJ and SLS compared to CMJ vs SLS are reported in the literature (McFarland et al., 2016). The SJ characteristic is mainly similar to the acceleration phase of the sprints (short distances), in which a longer contact time of the player with the ground during the pass is verified, due to the athlete's lower speed (Coelho et al., 2011; McFarland et al., 2016). Such behavior can be used to explain the lower correlation found between the SJ and the SLS as the distance from the SLS increases, for example, 10 m ($r = -0.44$; $p < 0.05$) and 30 m ($r = -0.55$; $p < 0.05$) (McFarland et al., 2016). The moderate and significant correlations between SJ and COD (Fig. 1B) found in the present study can be explained by the characteristics of the COD. In this test, constant phases of deceleration and acceleration occur, resulting in braking forces followed by a propulsive force to resume acceleration (Brughelli et al., 2008), generating greater demand for the concentric actions of the lower limbs. Due to these aspects, maximum strength seems to positively influence the best performance of players during the performance of COD, a frequent task in futsal. The performance in the SJ, due to its characteristic, depends mainly on the capacity of neural recruitment and the number of activated fibers provided by the time available for strength production, factors that influence the maximum strength production (Komi & Bosco, 1978; Wisløff et al., 2004). In adult soccer athletes, Wisloff et al. (2004) found higher correlation values between maximum squat strength and 10 m SLS ($r = 0.94$; $p < 0.05$) compared to the 30 m SLR ($r = 0.71$; $p < 0.05$), confirming greater participation of the maximum force in shorter running distances.

In the present study, the CMJ showed a significant strong and moderate correlation with SLS (Fig. 2A) and COD, respectively (Fig. 2B). With regard to the SLS, previous research involving adult players found greater correlations between the CMJ and the SLS as the distance covered increases, 20 m ($r = 0.54$ to 0.83) (Hori et al.,2008) and close to 30 to 40 m ($r = - 0.62$ a - 0.72) (Wisløff et al., 2004). The main explanation found for these correlations is the presence of the stretching-shortening cycle (SSC), an element common to the CMJ and sprint, and whose use is influenced by the storage capacity and use of elastic potential energy (EPE) in the tendon muscle unit (Hammami et al., 2017). Additionally, it was found in the present study greater common variance explained between the CMJ vs SLS (R2 = 30%) compared to the CMJ vs COD (R2 = 23%), which can be explained by the CMJ characteristic. In this test, there is a rapid transition between eccentric and concentric muscle actions, a characteristic that is also present when the linear distance travelled (> 10 m) allows greater speeds to be reached (López-Segovia et al., 2011) which did not occur in COD, due to the shorter distances between each change of direction (5 m).

The strong correlations found between the performances of VJs and sprints in the pre-PHV phase can be explained by the neural and morphological aspects that are present in this phase of body development. In the pre-PHV phase (close to 10 years old), there is an increase in neuromuscular coordination, which can influence the performance of sprints and contribute to the production of strength (Hammami et al., 2017). Furthermore, in addition to body proportions (lengths and widths of bone and muscle segments), external stimuli, such as the practice of the sport, are able to generate neural adaptations and improve motor coordination in this phase (Yüksel et al., 2017; Iaia et al., 2015). Although puberty is the time of greatest responses in physical performance that can favor the production of muscle strength and speed (Philippaerts et al., 2006), an aspect that needs to be considered is that pre-PHV players, aged 9–10 years old, have structures of a more compliant (less rigid) tendon muscle unit, allowing greater deformation of the elastic tissue of the musculature and absorption of EPE (Fernandez-Gonzalo et al., 2010), elements that contribute to rapid applications of force, as in the VJs and sprints.

In the current study, there was an increase in the physical performance of pre- PHV for mid- and post-PHV for VJs and sprints (Table 1). These changes are associated with morphophysiological factors that contribute to these responses, such as growth of bone segments (Beunen & Malina, 1988), neural functions (Laffaye et al., 2016) and muscle mass (Fernandez-Gonzalo et al., 2010). Changes in stiffness of the tendon muscle unit during puberty is another factor that influences the performance of VJs and sprints (Gillen et al., 2019). Laffaye et al. (2016) observed an increase in lower limb stiffness as the chronological age increased (11 and 20 years old). These changes in stiffness can be explained by the significant increase in muscle mass resulting in a greater amount of connective tissue, a greater number of collagen fibers, which may explain the increase in tissue stiffness during puberty (Radnor et al., 2018). This greater rigidity would allow for a shorter transition time between eccentric and concentric actions, resulting in greater use of neural mechanisms and the use of EPE, with increased performance in SSC (Otero-Esquina et al., 2017). However, despite the significant increase in physical performance throughout the puberty stages, the effect size of the increased strength was greater in relation to speed (Table 1). A large effect size was found between the pre-PHV and the mid- and post-PHV phases, for SJ and CMJ. For the same comparison using sprint performances, the effect size was moderate, indicating less magnitude of increase. These different magnitudes in both physical capacities, in addition to demonstrating that puberty influences muscle strength and speed in the transition between the pre-PHV and mid-PHV stages in different magnitudes, may also have contributed to explaining the low correlations between physical performance for the mid- and post-PHV stages.

The lower magnitude of the speed increase found in the present study may have influenced the correlations in the mid- and post-PHV phases. During puberty, individuals undergo the process of a growth spurt, with a linear increase in the body that occurs primarily in the lower limbs compared to the upper limbs, trunk and growth in width (muscle mass), causing a body disproportion and transient decreases in balance and motor coordination, directly affecting speed performance (Iaia et al., 2015). The ability to run requires high motor performance, which is influenced by neuromuscular maturation and body characteristics (size and proportions) that together contribute to a better balance in displacement actions (Iaia et al., 2015), as previously demonstrated by the moderate correlation ($r = - 0.49$; $p < 0.01$) between COD and balance test in soccer players (Hammami et al., 2017). Additionally, another aspect that could explain the lower magnitude of the increase in speed (Table 1), would be the absence of specific training for this capacity (e.g. motor coordination, SSC, balance, technique, flexibility) in the teams of the present study. It was verified during the research that the physical preparation of the teams occurs mostly in the same training sessions aimed at improving the technical and tactical aspects, with a frequency of between two and three times a week, which can negatively influence the physical performance mainly of the players mid- and post-PHV.

The performances of the jumps, for example, in the pre-PHV (SJ: 21.48 cm and CMJ: 21.57 cm), have values close to those found in soccer athletes of similar pubertal stages for the SJ (21.70 to 23.80 cm) and CMJ (23.52 to 24.20 cm) (Fernandez-Gonzalo et al., 2010; Negra et al., 2020). This was different from what was observed in the mid-PHV (SJ: 30.04 cm and CMJ 30.08 cm) and post-PHV (SJ: 29.70 cm and CMJ: 31.09 cm) compared to other studies using SJ (33.60 to 43.60 cm) and CMJ (35.10 to 46.40 cm) (Comfort et al., 2014) involving soccer athletes at similar pubertal stages and with similar practice time in the sport (> 3 years) for all players. The comparative studies in mid- and post-PHV evaluated young soccer players who competed nationally and presented weekly training frequencies ≥ 3 / week, a component that influences the responses to training (Asadi et al., 2017; Otero-Esquina et al., 2017).

The extrapolations of the results of the present study need to take into account the period of periodization in which the athletes were – competitive phase (Perroni et al., 2019). McGuigan et al. (2006) found a higher performance of the SSC in the pre-competitive period, compared to the competitive period, explained by the greater physical demand of the competition. However, as the athletes were not evaluated at other times of the periodization, it is impossible to say whether the competitive period influenced the performances evaluated regardless of the pubertal stage.

When implementing muscle strength and speed training planning in young futsal athletes, coaches and fitness coaches need to consider factors that can alter physical performance in these athletes, including puberty. Given the importance to the changes caused by puberty in the training planning is essential for the proper prescription and control of the physical requirements for the development of each player obeying his pubertal development. Considering the results of the present study, the prescription of muscle strength training using vertical jumps in order to improve speed performance needs to be performed with caution in mid-PHV and post-PHV athletes. In these puberty stages we suggest the inclusion of specific speed training and motor coordination to improve the performance of sprints in a straight-line and with a change of direction.

Conclusions

The results showed that the correlation between strength and speed in young futsal players was particularly strong and significant among pre-PHV athletes. This highlights how the pubertal stage significantly impacts the relationship between vertical jumps (squat and countermovement jump) and sprints (straight-line and with change of direction) performance. Consequently, while employing vertical jumps to enhance muscle strength and develop speed can be beneficial, this approach should be applied with caution for players in mid- and post-PHV stages. This cautious approach is advised because the observed correlation between strength and speed enhancements from VJ training is positive, strong, and significant exclusively among pre-PHV players.

Acknowledgments - We would like to thank all the futsal athletes who participated in this research. We would also like to acknowledge the support from the research laboratory in Physical Exercise: Health and Human Performance (EXEF) at the Federal University of Maranhão and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Financial Code 001. This work was supported by a scholarship from the Fundação de Amparo à Pesquisa do Maranhão - FAPEMA (process n° BM-07155/16).
Conflicts of interest - The authors declare that they have no competing interest.

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