



## The stretch–shortening cycle utilization in futsal players at different pubertal stages

*Utilización del ciclo estiramiento-acortamiento en jugadores de fútbol sala en diferentes etapas puberales*

### Authors

Sarah Cristina do Rêgo Santos <sup>1</sup>  
 Augusto Ribeiro De Oliveira <sup>1</sup>  
 Kananda Stephany Batista Nascimento <sup>1</sup>  
 Poliane Dutra Alvares <sup>1</sup>  
 Raphaela da Silva Sousa <sup>1</sup>  
 Nathaniel Gomes Oliveira <sup>1</sup>  
 Rogerio Araujo Costa <sup>1</sup>  
 Gabriel Rodrigues da Silva <sup>1</sup>  
 Bianca Fernanda de Almeida Silva <sup>1</sup>  
 Gustavo Ferreira Pedrosa <sup>2</sup>  
 Christiano Eduardo Veneroso <sup>1</sup>  
 Emerson Silami Garcia <sup>1</sup>  
 Christian Emmanuel Torres Cabido <sup>1</sup>

<sup>1</sup> Federal University of Maranhão (UFMA), São Luís, MA, Brazil.

<sup>2</sup> Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil.

Autor de correspondencia:  
 Nathaniel Gomes Oliveira  
 nathaniel.oliveira@discente.ufma.br

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### Abstract

**Introduction:** Futsal is a high-intensity intermittent sport that imposes physical, technical, and psychological demands. During youth development categories, athletes experience puberty, a period marked by considerable maturational variability among individuals of the same chronological age, which may influence physical performance and the efficiency of motor actions that rely on the stretch–shortening cycle (SSC).

**Objective:** This study aimed to examine the influence of pubertal stage on SSC utilization in youth futsal players.

**Methodology:** Pubertal stage was determined through somatic maturation, and participants were classified as PRE-PUB (before puberty), PUB (during puberty), and POST-PUB (after puberty). SSC utilization was assessed using the percent of prestretch augmentation (PPA =  $[(CMJ - SJ) / SJ] \times 100$ ), calculated from the difference between squat jump (SJ) and countermovement jump (CMJ) performance.

**Results:** SJ and CMJ were significantly lower in pre-pubertal than pubertal and post-pubertal groups ( $p < 0.01$ ) for both jump tests analyzed. No significant differences were observed in PPA among the pubertal stages assessed (PRE-PUB vs. PUB vs. POST-PUB:  $2.78 \pm 7.4\%$ ,  $4.84 \pm 10.03\%$ , and  $4.37 \pm 8.13\%$ , respectively).

**Conclusion:** Although the maturational process influences physical performance, SSC utilization does not appear to be significantly affected.

### Keywords

Percent of prestretch augmentation; puberty; jumps; squat jump; countermovement jump.

### Resumen

**Introducción:** El fútbol sala es un deporte intermitente de alta intensidad que impone exigencias físicas, técnicas y psicológicas. Durante las categorías de formación, los atletas atraviesan la pubertad, un periodo caracterizado por una considerable variabilidad madurativa entre individuos de la misma edad cronológica, lo cual puede influir en el rendimiento físico y en la eficiencia de las acciones motoras dependientes del ciclo estiramiento-acortamiento (CEA).

**Objetivo:** El objetivo de este estudio fue examinar la influencia del estadio puberal en la utilización del CEA en jóvenes jugadores de fútbol sala.

**Metodología:** El estadio puberal se determinó mediante la maduración somática, y los participantes fueron clasificados como PRE-PUB (antes de la pubertad), PUB (durante la pubertad) y POST-PUB (después de la pubertad). La utilización del CEA se evaluó mediante el porcentaje de aumento por pre-estiramiento ( $PPA = [(CMJ - SJ) / SJ] \times 100$ ), calculado a partir de la diferencia de rendimiento entre el salto *squat jump* (SJ) y el salto *countermovement jump* (CMJ).

**Resultados:** El rendimiento en SJ y CMJ fue significativamente menor en el grupo prepuberal en comparación con los grupos puberal y postpuberal ( $p < 0.01$ ) en ambas pruebas de salto analizadas. No se observaron diferencias significativas en el PPA entre los estadios puberales evaluados ((PRE-PUB vs. PUB vs. POST-PUB:  $2.78 \pm 7.4\%$ ,  $4.84 \pm 10.03\%$ , and  $4.37 \pm 8.13\%$ , respectivamente).

**Conclusión:** Aunque el proceso madurativo influye en el rendimiento físico, la utilización del CEA no parece verse afectada de manera significativa.

### Palabras clave

Porcentaje de aumento por estiramiento previo; pubertad; saltos; squat jump; countermovement jump.

## Introduction

Futsal is characterized as a high-intensity intermittent sport, imposing high physical, technical, tactical, and psychological demands on athletes (Barbero-Álvarez et al., 2008; Rodrigues et al., 2011). The process of sport initiation and specialization occurs predominantly within youth categories, which are organised according to the chronological age of the participants (Santos & Ré, 2014). In this context, young athletes experience puberty, a period marked by significant biological and morphological changes associated with the transition from childhood to adulthood (Alvares et al., 2024).

Puberty can be subdivided into three stages: prepubertal, pubertal, and postpubertal, each characterized by its own specific physiological features (Sahrom et al., 2013). The hormonal and structural changes associated with this process are reflected in the progressive increase of physical capacities, such as muscular strength and power, thereby exerting a direct influence on sports performance (Linhares et al., 2009; Ré, 2011; Dantas et al., 2020).

However, there is no precise chronological age capable of determining the onset, duration, or end of puberty, as the rate of maturational progression varies widely among individuals (Malina et al., 2015; Philippaerts et al., 2006). Consequently, adolescents of the same chronological age may present different maturational stages, resulting in significant variations in physical characteristics and motor performance (Linhares et al., 2009; Madarsa & Mohamad, 2025). In the sporting context, this variability may favour biologically more mature athletes and, conversely, contribute to the early exclusion of those at lower maturational stages (Santos & Ré, 2014; Malina et al., 2015).

Thus, chronological age is considered a limited parameter for characterising young athletes during adolescence (Chipkevitch, 2001; Jones, Hitchen & Stratton, 2000). In contrast, classification based on pubertal stage, particularly through somatic maturation, has been widely employed in the sporting context, as it considers anthropometric variables associated with growth and bodily development (Mirwald et al., 2002; Malina et al., 2015; Wenly et al., 2025).

In futsal, motor actions such as sprints, rapid changes of direction, kicking, and jumping depend to a large extent on the efficient use of the stretch-shortening cycle (SSC) (McGuigan et al., 2006; Turner & Jeffreys, 2010). The SSC corresponds to a rapid sequence of muscular actions in which an eccentric phase is immediately followed by a concentric phase, thereby optimising force and muscular power production (Komi, 2000; Hall, 2016).

A widely used approach to assess the contribution of the SSC is the percent of prestretch augmentation (PPA), obtained from the comparison between performance in the squat jump (SJ) and the countermovement jump (CMJ) (Komi & Bosco, 1978; Suchomel, Sole & Stone, 2016; Van Hooren & Zolotarjova, 2017). Previous studies indicate an increase in PPA with advancing chronological age (Bosco & Komi, 1980; Castagna & Castellini, 2013); however, few have considered pubertal stage.

In this regard, Santos et al. (2024), when investigating soccer players at pre- and post-pubertal stages, reported significant differences in SJ and CMJ performance between maturational stages, whereas no differences in PPA values were observed between groups. These findings suggest that improvements in jumping performance with advancing maturation do not necessarily reflect greater efficiency in SSC utilization. Collectively, this evidence supports the hypothesis that pubertal stage influences in the jump performance, but not necessarily the relative contribution of the SSC. Accordingly, the present study aimed to examine the influence of pubertal stage on the utilization of the stretch-shortening cycle (SSC) in youth futsal players.

## Method

### Participants

Seventy male futsal players participated in the study and were classified according to their maturation stage into pre-pubertal ( $n = 24$ ;  $11.04 \pm 1.2$  years), pubertal ( $n = 23$ ;  $14.40 \pm 1.0$  years) and post-pubertal ( $n = 23$ ;  $15.70 \pm 1.0$  years) groups (Table 1). All participants were members of youth futsal academies, with ages ranging from 9 to 17 years, representing the under-11 ( $n = 18$ ;  $10.16 \pm 0.90$  years), under-13 ( $n = 15$ ;  $12.43 \pm 0.51$  years), under-15 ( $n = 17$ ;  $14.58 \pm 0.50$  years), and under-17 ( $n = 20$ ;  $16.24 \pm 0.44$



years) age categories. All legal guardians signed an Informed Consent Form, while the athletes signed an Assent Form. The study was approved by the Research Ethics Committee (no. 6,904,028) and was conducted in accordance with the principles of the Declaration of Helsinki.

### ***Inclusion and exclusion criteria***

Players were included in the study if they: (1) had at least two years of systematic training in the sport; (2) trained with a minimum frequency of three sessions per week; and (3) were part of the team roster competing in official competitions.

Players were excluded from the study if they: (1) did not train regularly at least three times per week; (2) presented an injury that prevented the performance of maximal effort; or (3) did not complete the tests established for this research.

### ***Study design***

The athletes underwent two assessment phases, separated by a minimum interval of 48 hours and a maximum of 72 hours. On separate days, they underwent a familiarization session and an experimental session, in which they performed the vertical jump, SJ and CMJ tests at the beginning of the training session. During the familiarization session, anthropometric variables were also measured for participant characterization and for the calculation of somatic maturation. The variables assessed included stature, body mass, lower limb length, and sitting height. Participants were instructed to avoid high-intensity training in the 48 hours preceding each experimental session. All participants were instructed to arrive fed and hydrated for the assessments, wearing their training uniforms, and water intake was permitted during the tests.

### ***Procedure***

Initially, an anamnesis was conducted with all participants in order to obtain personal data and to characterize the sample through information related to the sport, such as playing position, dominant side, training experience, and training frequency. Subsequently, anthropometric assessments were performed, followed by the calculation of somatic maturation and the execution of jump tests for the assessment of SSC utilization.

**Anthropometry:** Stature was measured using a stadiometer (Persona Caprice Sanny), with a precision of 0.1 cm and a measurement range of 0 to 220 cm. Body mass was assessed using a pendulum balance of the brand (Fitizola®), with a precision of 0.1 kg and a maximum capacity of 150 kg. Lower limb length was measured with a measuring tape (0–150 cm), from the femoral head to the plantar region. Sitting height was measured with the participant seated against a wall with a fixed measuring tape, maintaining the hips at a 90° angle and the gluteal region, shoulder girdle, and occipital region in contact with the tape; the measurement was taken from the seating surface to the vertex.

**Maturation Age:** Maturation age was determined through somatic maturation, using values of age (A), lower limb length (LLL), sitting height (SH), body mass (BM), and stature (S) in the peak height velocity (PHV) equation:  $PHV = -9.236 + 0.0002708 (LLL \times SH) - 0.001663 (A \times LLL) + 0.007216 (A \times SH) + 0.02292 (BM/S)$ . The result reflects the chronological position relative to PHV, and participants were classified as follows:  $PHV < -1 = PRE$  (puberty not yet initiated);  $-1 \leq PHV \leq +1 = PUB$  (during puberty); and  $PHV > +1 = POST$  (puberty completed) (Mirwald et al., 2002).

**SSC Utilization:** SSC utilization was determined using the equation  $PPA = [(CMJ - SJ) / SJ] \times 100$ , resulting in the percentage of SSC utilization (McGuigan et al., 2006; Walshe, Wilson & Murphy, 1996; Young, 1995).

For the execution of the jumps used in the calculation of PPA, the protocol proposed by Bosco (1999) was followed. In the SJ, the initial position consisted of a semi-squat, with knee and hip angles close to 90° of flexion and an upright trunk; after approximately three to four seconds in this position, the jump was performed. In the CMJ, the initial position was standing, from which the athlete performed a downward countermovement, immediately followed by a rapid transition to the upward phase, culminating in the execution of the jump.



The jumps were performed on a contact mat (Jump Test System, Hidrofit, Brazil). Jump height was estimated from flight time using the equation  $\text{jump height} = 1/8 \cdot g \cdot t^2$ , in which “g” represents gravitational acceleration ( $9.81 \text{ m/s}^2$ ) and “t” corresponds to the time spent in the air, in seconds (Salles et al., 2011). Each athlete performed three attempts, and the mean value obtained was used for analysis. A 10-second interval was observed between each jump attempt.

### Data analysis

Data normality was assessed using the Shapiro–Wilk test, and comparisons among pubertal stages were performed using a one-way analysis of variance with one factor of variation (one-way ANOVA). For multiple comparisons, the Tukey post hoc test was applied. Statistical analyses were conducted using SPSS statistical software version 18.0 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, USA). Data are presented as mean and standard deviation, and the level of significance was set at  $p < 0.05$ .

## Results

Table 1 presents the characteristics of the sample, with players grouped according to pubertal stage. Significant differences were observed across all variables among pubertal stages ( $p < 0.05$ ).

Table 1. Sample characterization and comparison of values between pubertal stages

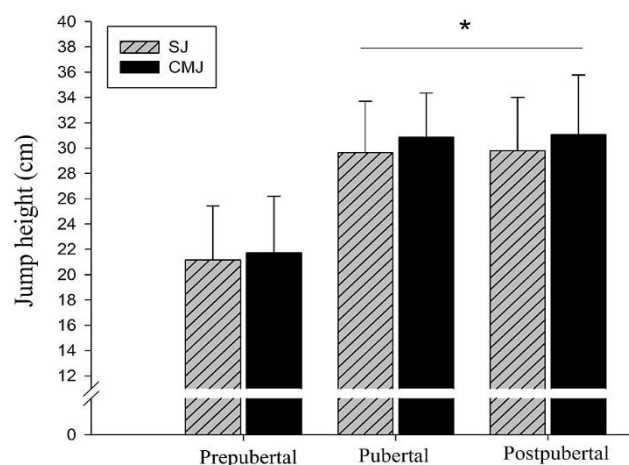
Variables	Pre-pubertal (n=24)		Pubertal (n=23)		Post-pubertal (n=23)		p (Tukey)
	Mean±SD	CI (95%)	Mean±SD	CI (95%)	Mean±SD	CI (95%)	
Age (years)	11.04±1.2	10.52-11.56	14.40±1.0*	13.96-14.81	15.70±1.0**	15.38-16.1	$p < 0.01$
Height (cm)	145.08±7.9	141.75-148.41	163.30±5.17*	161.06-165.54	174.09±6.5**	171.28-176.89	$p < 0.01$
LLL (cm)	74.85±6.0	72.34-77.37	84.54±4.6*	82.55-86.53	90.76±4.7**	88.70-92.81	$p < 0.01$
BM (kg)	36.94±6.8	34.05-39.82	52.49±7.3*	49.34-55.64	62.98±7.6**	59.71-66.25	$p < 0.01$

Legend: \*: different from PRE; #: different from PUB; CI95%: confidence interval; LLL: lower limb length; BM: body mass.

### Jump performance between pubertal stages

For the analysis of performance between SJ and CMJ, SJ performance was significantly lower ( $p < 0,01$ ) in the pre-pubertal group ( $21.16 \pm 4.9 \text{ cm}$ ) compared with the pubertal ( $29.65 \pm 4.0 \text{ cm}$ ) and post-pubertal groups ( $29.80 \pm 4.2 \text{ cm}$ ). Similarly, CMJ performance was lower ( $p < 0,01$ ) in the pre-pubertal group ( $21.72 \pm 4.5 \text{ cm}$ ) compared with the pubertal ( $30.86 \pm 3.5 \text{ cm}$ ) and post-pubertal ( $31.06 \pm 4.7 \text{ cm}$ ) groups (Figure 1).

Figure 1. Jump performance between pubertal stages.

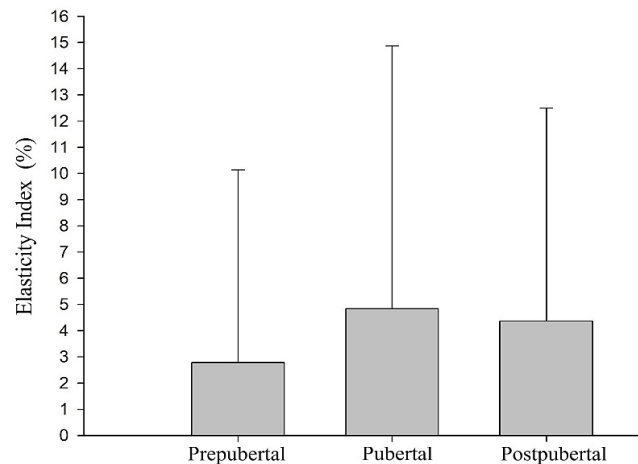


Legend: CMJ: counter movement jump; SJ: squat jump; \*: different from the PRE pubertal stage ( $p < 0.01$ ).

## SSC utilization between pubertal stages

In the analysis of PPA, no significant differences ( $p > 0,05$ ) were observed in SSC utilization between pre-pubertal ( $2.78 \pm 7.4\%$ ), pubertal ( $4.84 \pm 10.03\%$ ), and post-pubertal ( $4.37 \pm 8.13\%$ ) groups (Figure 2).

Figure 2. Pre-stretch augmentation percentage between pubertal stages.



## Discussion

The main findings of the present study indicate that, although puberty exerts a consistent influence on anthropometric variables and on vertical jump performance (SJ and CMJ), the efficiency of SSC utilization, expressed by PPA, did not show significant differences between pubertal stages. These results suggest that maturational advancement is associated with greater muscular force and power production, whereas the relative contribution of the SSC appears to remain largely unchanged.

Studies involving young athletes from team sports indicate that the maturational stage exerts a strong influence on physical and anthropometric parameters, such as stature, body mass, and muscle volume (Tounsi et al., 2024). In that regard, Alvares et al. (2020) and Alvares et al. (2024) observed that athletes at more advanced maturational stages present higher values in these variables when compared with prepubertal, as a result of the structural and hormonal adaptations associated with puberty, particularly those related to increases in testosterone and growth hormone.

With regard to neuromuscular performance, both SJ and CMJ performance show progressive increases across maturational stages (Tounsi et al., 2024). Pubertal and postpubertal athletes achieve higher values in these tests compared with prepubertal, which may be associated with increases in muscle mass and improvements in motor unit recruitment, thereby favouring rapid force production (Alvares et al., 2020; Alvares et al., 2024).

Recent evidence indicates that the relationship between SJ and CMJ performance is influenced by pubertal stage, particularly with regard to the shared variance explained between both jumps. Oliveira et al. (2025) observed strong correlations between SJ and CMJ in pre- and postpubertal athletes, but moderate correlations in pubertal athletes, suggesting that during puberty, rapid somatic growth and changes in neuromuscular control may increase variability in movement execution. Furthermore, the authors did not identify evidence of superior SSC utilization at more advanced maturational stages, corroborating the absence of differences in PPA observed in the present study. The absence of significant differences in PPA between pubertal stages suggests that the functional relationship between SJ and CMJ performance was preserved throughout maturation, despite the increases observed in the absolute performance of both jumps.

In this context, Santos et al. (2024) highlight that PPA constitutes a composite variable, resulting from the relationship between SJ and CMJ performance. Thus, concurrent increases in the performance of these jumps throughout the maturational process may lead to similar PPA values across different pubertal stages. This characteristic of the index should not be interpreted as an absence of neuromuscular adaptations, but rather as an expression of the proportionality between its constituent components, reinforcing its usefulness in describing the functional relationship between jumps, particularly when analysed in conjunction with absolute performance measures.

Complementarily, Oliveira et al. (2025) reported that the shared variance between SJ and CMJ performance indicates that a substantial portion of performance in both jumps can be attributed to shared mechanisms, such as contractile capacity, rate of force development, and stiffness of the muscle-tendon complex. Accordingly, the stability observed in PPA values between pubertal stages may reflect the preservation of the functional relationship between the jumps, even in the presence of absolute increases in performance, reinforcing the interpretation of this index as a measure of proportionality between SJ and CMJ, rather than as an isolated measure of neuromuscular performance.

On the other hand, the absence of differences in PPA between pubertal stages may indicate that regular futsal training promotes neuromuscular adaptations capable of equalising SSC utilization among athletes at different maturational levels. Santos et al. (2024) suggest that systematic training, characterized by frequent actions of acceleration, deceleration, jumping, and plyometric activities, may attenuate discrepancies in SSC efficiency that would otherwise be expected solely as a function of biological maturation. In this context, future studies comparing youth athletes with similar maturational profiles engaged in different sports, as well as non-athletic or sedentary peers, would be valuable to better elucidate the influence of sport-specific demands—and their absence—on SSC utilization across pubertal stages.

These results reinforce the need for assessments and training prescriptions in young athletes to consider, in an integrated manner, maturational stage, training history, and the complexity of the neuromuscular demands involved, thereby avoiding simplistic interpretations based exclusively on absolute performance indicators.

## Conclusions

The present study found that the pubertal stage does not significantly interfere with SSC utilization in youth futsal players, as evidenced by the absence of differences in PPA among prepubertal, pubertal, and postpubertal stages. In contrast, anthropometric variables and vertical jump performance showed significant increases across maturation, reflecting the morphological and functional changes associated with puberty. These findings indicate that maturational advancement enhances absolute mechanical performance without necessarily altering the relative efficiency of SSC utilization, possibly due to neuromuscular adaptations resulting from regular sports training.

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**Authors' and translators' details:**

Sarah Cristina do Rêgo Santos	santos.sarah@ufma.br	Author
Augusto Ribeiro De Oliveira	augustorpro@gmail.com	Author
Kananda Stephany B. Nascimento	kanandabatista19@gmail.com	Author
Poliane Dutra Alvares	polianealvares87@gmail.com	Author
Raphaella da Silva Sousa	raphaella.ss@discente.ufma.br	Author
Nathaniel Gomes Oliveira	nathaniel.oliveira@discente.ufma.br	Author
Rogério Araujo Costa	rogerio.costa@discente.ufma.br	Author
Gabriel Rodrigues da Silva	gabriel.rs@discente.ufma.br	Author
Bianca Fernanda de Almeida Silva	biancasantosg2@gmail.com	Author
Gustavo Ferreira Pedrosa	gustavofpedrosa@gmail.com	Author
Christiano Eduardo Veneroso	christiano.veneroso@ufma.br	Author
Emerson Silami Garcia	silamigarcia@icloud.com	Author
Christian Emmanuel T. Cabido	christian.cabido@ufma.br	Author