The association between chronological age and maturity status on lower body clinical measurements and asymmetries in elite youth tennis players

Abstract

Background: Tennis is one of the most popular sports among youth. At elite levels, a notable increase in injury incidence and a temporary decline in performance may occur when children progress through puberty. However, limited research has explored maturity-associated variations in clinical measurements suggested as predictors of injury and tennis performance in elite youth players. Therefore, the main purpose of this study was to analyse the association between chronological age and maturity status on several measures of neuromuscular capability and physical performance as well as bilateral asymmetries in elite youth tennis players.

Hypothesis: Youth tennis players around-peak height velocity (PHV) will show higher growth-related impairments or deficits in measures of neuromuscular capability and physical performance than their less (pre-PHV) and more (post-PHV) mature counterparts irrespective of sex.

Level of evidence: Level IV.

Methods: A total of 68 male (age: 13.7 ± 1.1 y; stature: 162.4 ± 9.4 cm; body mass: 51.4 ± 10.3 kg) and 60 female (age: 13.6 ± 1.1 y; stature: 162.8 ± 7.2 cm; body mass: 52.7 ± 7.5 kg) elite youth tennis players from two different age groups (under 13 [U13] and under 15 [U15]) and maturity status [pre, around and post-PHV], were tested during national training camps. Tests included the Y-Balance test, isometric hip abduction and adduction strength, hip ROMs and countermovement jump (CMJ) height. Bayesian analysis were used to establish any significant between-group differences.

Results: Only dynamic balance (in males) (Bayesian factor [BF_{10}] = 88.2) and jump height (in both males and females) (BF_{10} > 100) were significatively associated with chronological age, whereby U15 group showed lower Y-Balance reach distances (-6%; standardized effect size [δ] = -0.62) but higher CMJ height scores (+18%; δ = 0.73) than the U13 group. While males jump higher (+11%, δ = 0.62) and were stronger in isometric hip adduction strength (+14%, δ = 0.92) than females, the latter had greater hip internal ROM values (+15%, δ = 0.75). Furthermore, relevant maturity-associate effects (BF_{10} = 34.6) were solely observed for the CMJ test in males, with the most mature players demonstrating higher jump height scores (+12%, δ = 0.93). Finally, a significant percentage (>25%) of tennis players, independent of sex, demonstrated bilateral asymmetries in hip ROMs, hip strength and jump height values.

Conclusions: The findings of this study show that in U13 and U15 male and female tennis players there were neither positive nor negative maturity-associated variations in the clinical measurements analysed (with the exception of jump height in males). The high proportion of tennis players showing bilateral asymmetries in dynamic balance, hip ROM and strength and jump performance, highlight the need of future studies to analyse these factors in relation to unilateral tennis-specific adaptations in the musculoskeletal and sensorimotor systems.

Clinical relevance: These results may help to better understand how different clinical measurements are associated with the process of growth and maturation in elite youth tennis players and may aid in the design of specific training interventions during these stages of development.

Keywords: Y-Balance, racquet sports, injury, youth, growth.

INTRODUCTION

Tennis is a multidirectional sport characterized by repeated high-intensity efforts, such as strokes, sprints, accelerations, decelerations, and changes of direction (COD), sometimes requiring extreme positions (i.e., open stance strokes after under pressure runs) [38]. Despite the numerous evidence-based health benefits at both, amateur and elite levels (e.g., higher cardiovascular fitness, better body composition and psychological profile) [54], previous research has also shown the potential injury risk of competitive tennis, both, in the upper and lower body [1,55]. The most frequently diagnosed injuries in youth tennis players (i.e., thigh muscle strains, knee and ankle ligaments sprains and tears, groin and patellofemoral pain, femoroacetabular impingement) may lead to moderate absence from sport participation, negatively impact on short and long-term athlete development, cause long-term disability (development of knee osteoarthritis in adulthood) and increase medical costs [6]. Given the increased participation in tennis competitions from an early age (i.e., under-12 years) [14], screening protocols and the identification of potential injury risk-related factors (i.e., inter-limb asymmetries) should be taken into consideration in any injury risk management strategy in tennis [34,50].

As it has been documented in other sports (e.g., soccer,[69] athletics[70] and handball[41]), when children progress through puberty, particularly during periods of rapid changes in growth and maturation, they might have an increased injury risk [50]. In this regard, around the peak height velocity (PHV) (e.g., maximal rate of growth) [36], which occurs at approximately age 12 in girls and age 14 in boys [60], there is a disproportional increase in body dimensions (i.e., arms and legs relative to the trunk) and disruption of motor coordination (e.g., agility) [4], a phenomenon so-called "adolescent awkwardness" [31]. During this period, significant restrictions on joint ranges of motion (ROM) might occur [59], usually accompanied by underdeveloped neuromuscular mechanism (i.e. feedback and feedforward mechanisms) [22,66]. This may contribute to the presence of growth-related impartments or deficits in measures of neuromuscular capability (e.g., dynamic stability and muscle strength) [12,53] and physical performance (e.g., jump height) [57].

As previously mentioned, immature musculoskeletal systems [51] combined with the sport-specific requirements of tennis training and competition since early ages (i.e., repetitive accelerations, decelerations and COD) [13], could lead to unilateral tennis-specific adaptations in the musculoskeletal (i.e., strength) and sensorimotor (i.e., balance) systems, representing an intrinsic risk factor for potential injuries [33]. In this sense, previous research has suggested that bilateral asymmetries in the lower body may lead youth athletes [6,59], including tennis players [33,34], to adopt altered movements and motor-control strategies during the execution of high intensity tasks such as accelerations and COD [13,33,34]. Although these morphological and neuromuscular bilateral asymmetries associated with the intensive practice of unilateral sports in youth athletes might have no meaningful impact on physical performance (i.e., sprint time, jumping height) [13,33,34], they can lead to a lower extremity overload, which has been suggested as a primary and modifiable risk factor for some of the most frequently diagnosed lower extremity injuries in tennis (i.e., groin pain, ligament injuries) [23,45]. Thus, from an injury prevention perspective, the identification of these asymmetries at an early age may help to identify youth tennis players at high injury risk and thus aid in the design of specific training interventions during these stages of development [15]. In this regard, hip screening of elite youth tennis players demonstrated that a large percentage (>60%) of the athletes showed a hip "at-risk" for femeroacetabular impingement [10].

The pubertal development is a nonlinear process with significant inter-individual differences in terms of timing and tempo among youth of the same chronological age [60]. These differences in the timing and tempo of maturation impact both physical and psychological development [63], Therefore, the maturity status has been suggested as an adjunct to the chronological age to better understand the physical performance development and fluctuations in injury risk of youth athletes [35]. Some cross-sectional studies have investigated the association of maturation on several measures of physical performance (i.e., speed, COD, jumping, or upper body power) [29,46,47], showing that, in youth tennis players, early maturing boys and girls generally perform better. However, the information regarding maturity-associated variations in potential lower extremity injury risk factors (e.g., hip ROM, dynamic balance and muscle strength) is scarce. To the best of our knowledge, only Madruga-Parera et al.[34] have examined the association of biological maturity on bilateral asymmetries in both dynamic balance and lower extremity power, showing that inter-limb differences may be heightened during PHV. However, the use of group average values of inter-limb differences may distort the true extent of the potential unilateral adaptations that tennis play can elicit in youth players. In this regard, it seems necessary to achieve a more realistic diagnosis regarding the presence (or absence) of sport-specific bilateral asymmetries in measures of neuromuscular capability [18,42,44]. A recent study has suggested the use of a new comprehensive profile in which not only average scores of inter-limb differences should be reported in each measure, but also the number of athletes showing clinically relevant bilateral asymmetries (i.e., >8º in hip ROMs) [32].

Therefore, the main purpose of the present study was to analyse the association of chronological age and maturity status on hip joint ROM (abduction, internal and external rotation), unilateral dynamic balance, isometric hip strength (abductors and adductors) and unilateral countermovement jump (CMJ) height absolute scores, as well as bilateral asymmetries in elite male and female youth tennis players. We hypothesized that tennis players around PHV, would show growth-related impartments or deficits in measures of neuromuscular capability and physical performance compared to pre- and post-PHV players [47].

METHODS

Participants

A total of 147 youth tennis players were invited to participate in this study, of which 128 players (68 males and 60 females) from two chronological competition age groups (U13 [n = 32 males (12.6 ± 0.2 years old; 154.9 ± 7.0 cm; 43.5 ± 6.8kg) and 32 females (12.6 ± 0.3 years old; 159.8 ± 7.0 cm; 49.1 ± 7.3kg)] and U15 [n = 36 males (14.6 ± 0.3 years old; 169.0 ± 5.7 cm; 58.4 ± 7.3kg) and 28 females (14.6 ± 0.3 years; 166.3 ± 5.7 cm; 56.8 ± 5.4kg)]) finally accepted to take part in this study. Participants comprised the most talented players in each region and were selected by the regional federations coaching staff based on their technical or tactical abilities and competitive performance (i.e., ranking and/or number of matches won during the season) [11]. All players participated in an average of 14 ± 3.1 hours of combined tennis and physical training per week and had a sport-specific training background of 6.6 ± 3.2 years. To be included, all participants had to be free of pain to the lower extremities during the testing sessions and currently involved in tennis-related training. Participants were excluded if they reported histories of neuromuscular diseases or serious musculoskeletal injuries over the previous two months, a current upper respiratory tract infection, any bone or joint abnormalities, any uncorrected visual and vestibular problems and/or a concussion within the last three months. Before any participation, experimental procedures and potential risks were fully explained to both parents and children in verbal and written form. Written informed consent to the testing procedures and the use of the data for further research was obtained from the players' parents and the adolescents. Additionally, all players provided assent to participate in the study. Players completed a health questionnaire prior to participation in order to be included in the research. The study was approved by the Institution's ethics committee and conformed to the Declaration of Frontera regarding the use of human subjects (RFET-P1_18).

Experimental design

The current study is an observational study which used a cross-sectional design to analyse and compare the association of chronological age and stage of maturation on hip joint ROM (abduction, internal and external rotation), unilateral dynamic balance, hip (abductors and adductors) isometric strength and unilateral jump height in a cohort of elite male and female youth tennis players.

Testing sessions were conducted over a 4-week period beginning at the end of September 2017, and separated from important tournaments for at least one week, before or after the tests. Sessions were undertaken between 10:00 and 15:00 hours and players were tested at their respective federation base (i.e., 4 testing sites). To ensure standardization of test administration across the entire study period, all tests were performed in the same order, using the same testing devices, measurement protocols and operators. The testing took place in the physiotherapy room of each testing site (Temperature, 22˚C; relative humidity, 54% [Kestrel 4000 Pocket Weather Tracker, Nielsen Kellerman, Boothwyn, PA, USA]). To reduce the interference of uncontrolled variables, participants stayed at the same residence within the training facility to control meals and resting times. Participants were encouraged to withdraw all sources of caffeine for 24 h before testing and to have their habitual breakfast at least 3 h before the start of the measurements. Furthermore, players were required to refrain from any intense physical workout for 24 hours before the tests and to be in a fasting state for at least 2 hours.

The order of assessments was as follows: anthropometric measurements, unilateral dynamic balance, isometric hip abduction and adduction strength, hip ROMs and unilateral jumping height. Testing began after a 15-min standardized warm-up, which consisted of jump rope activation, general dynamic mobility, multi-directional acceleration runs, jumps of progressive intensity and hip strengthening exercises (e.g., adduction/abduction) with a mini elastic band. Familiarization of each testing protocol took place at the beginning of the testing session, which involved a demonstration and provision of standardized, child-friendly coaching cues. Participants then practiced the protocol until the principal investigator was satisfied with their technical competency.

Testing manoeuvres

Anthropometrics and maturity status

Body mass (kg) was measured on a calibrated physician scale (ADE Electronic Column Scales, Hamburg, Germany). Standing and sitting height (cm) were recorded to the nearest 0.1 cm on a measurement platform (Holtain Ltd., Crosswell, UK) with seated height measured using a purpose-built table (Holtain Ltd., Crosswell, UK). Leg length was calculated as the difference between the players height in both standing and seated conditions. Pubertal timing was estimated according to the maturity offset method, as previously described [40]. The age of peak linear growth (age at PHV–APHV) is an indicator of somatic maturity representing the time of maximum growth in stature during adolescence [64]. Maturity offset (MO) (in years) resulted from subtracting the chronological age at the time of measurement from the chronological peak velocity age. Thus, MO of -1.0 indicates that the player was 1 year before his PHV, a MO of 0 indicates that the player was at the time of PHV, and a MO of +1.0 indicates that the participant was 1 year post PHV [64]. To account for the reported error (approximately 6 months) in the equation, players were grouped into discrete bands based on their MO (pre-PHV [<-1], circa-PHV [-0.5 to 0.5], post-PHV [>1]) [40]. Players who achieved a maturational offset from -1 to -0.5 and 0.5 to 1 were subsequently removed (n = 14) from the dataset when players were analysed by stage of maturation.

Unilateral dynamic balance

Unilateral dynamic balance was measured using the Y-balance test (Y-Balance Test, Move2Perform, Evansville, IN) and followed the guidelines proposed by Shaffer et al.[62]. Players were allowed a maximum of five trials to obtain three successful trials for each reach direction (anterior, posteromedial and posterolateral). To obtain a global measure of the unilateral dynamic balance performance, the greatest distance reached in each direction was normalised (by dividing by leg length) and then averaged (by multiplying by 100) to establish a composite balance score [62].

Isometric hip abduction (ABD) and adduction (ADD) strength

For the measurement of maximal isometric hip ADD and ABD strength in dominant (defined as the lower extremity of the ipsilateral side of the forehand ground stroke and the same side as the upper extremity with which the player served) and non-dominant limbs, a handheld dynamometer (Lafayette Instrument Company, IN, USA), which was calibrated prior to each test, was used. For this measurement, participants were lying in a supine position on a plinth with legs extended and were tested following the methods previously described [67]. Participants performed two practice trials of five seconds before measurement (50 and 80% of the self-perceived isometric maximal voluntary contraction), and then, three sets of five seconds of isometric maximal voluntary contraction for each hip movement were registered. Normalized hip strength values were expressed as the maximal torques per kilogram of body weight (Nm/kg) [3]. During the tests, participants were told to stabilize themselves by holding onto the sides of the table. The highest value of three attempts, for both dominant and non-dominant sides, was used in the analysis. There was a 30-second rest period between trials. One experienced examiner suppervised all the tests and gave standardised verbal encouragement during the effort.

Hip range of motion (ROM)

The passive hip abduction with hip flexed at 90º in a supine position and hip external (ER) and internal rotation (IR) ROM, with hip in a neutral position and 90º knee flexion in a prone position, measures of the dominant and non-dominant leg were assessed using an ISOMED Unilevel inclinometer (Portland, Oregon) with an extendable telescopic arm and followed the methodology described by Cejudo et al.[9].Two maximal trials of each ROM test for each leg were performed in a randomized order and the best score for each test was used in the statistical analyses. One of the following criteria determined the endpoint for each test: a) palpable onset of pelvic rotation, and/or b) the tennis player feeling a strong but tolerable stretch, slightly before the occurrence of pain [9].

Unilateral countermovement jump (CMJ)

Jump height was determined from an unilateral CMJ using a contact-time platform (SportJump System Pro, DSD Sport system, Spain), following the methodology previously described [19]. Participants were instructed to step onto the centre of the contact-time platform (foot pointing forward) with their designated test leg with hands placed on hips and were required to remain in the same position for the duration of the test. The jump was initiated by performing a countermovement to a self-selected depth before accelerating vertically as explosively as possible into the air. The test leg was required to remain fully extended throughout the flight phase of the jump before landing back onto the force plate as per the set up. The non-jumping leg was slightly flexed with the foot hovering at mid-shin level and no additional swinging of this leg was allowed during trials. Each player performed 2 maximal attempts for each leg, interspersed with 45 seconds of passive recovery, and the highest jump was recorded and used for statistical analysis.

Statistical analysis

Statistical analyses were performed using JASP software version 0.13.01 (Amsterdam, Netherland). A descriptive statistic (mean and 95% credible intervals [CI]) was calculated for each measure separately by leg (dominant and non-dominant legs), age group (U13 and U15), stage of maturation (pre-PHV and around-PHV) and sex (males and females). The distribution of raw data sets was checked for homogeneity and skewness using the Shapiro-Wilk expanded test. Bayesian paired samples t-tests were carried out to determine the existence of significant bilateral differences for all normal data distribution separately by age group and stage of maturation. Wilcoxon signed-rank tests were run to explore significant bilateral differences in non-normally distributed variables.

In order to analyse the effects of the fixed factors sex (males vs. females) and age group (U13 vs. U15) on the measures previously described, separate Bayesian ANOVAs were conducted. For those non-normally distributed variables, the non-parametric alternative technique to the Bayesian ANOVA was performed. The potential interaction between the factor sex with the factor age group (sex x age group) was also explored in each measure.

The well-documented sex-related differences in the timing and tempo of their maturation processes [24], resulted in a very limited number of females and males classified as pre-PHV and post-PHV, respectively. Therefore, for the fixed factor stage of maturation, between groups differences in each variable were explored separately by sex (males = pre-PHV vs. around-PHV; females = around-PHV vs. post-PHV) using separate Bayesian independent t-tests.

For all the Bayesian inference tests run, the BF_{10} was interpreted using the evidence categories previously suggested:[67] < 1/100 = extreme evidence for H_0, from 1/100 to < 1/30 = very strong evidence for H_0, from 1/30 to < 1/10 = strong evidence for H_0, from 1/10 to < 1/3 = moderate evidence for H_0, from 1/3 to < 1 anecdotical evidence for H_0, from 1 to 3 = anecdotical evidence for H_1, from >3 to 10 = moderate evidence for H_1, from >10 to 30 = strong evidence for H_1, from > 30 to 100 = very strong evidence for H_1, > 100 extreme evidence for H_1.

Only those models that showed at least strong evidence for supporting H_1 ($BF_{10} > 10$) with a percental error < 10 were considered robust enough to describe the main effects and a posterior post hoc analysis was then carried out. In the post hoc analysis, posterior odds were corrected for multiple testing by fixing to 0.5 the prior probability that the null hypothesis.

The median and the 95% central credible interval of the posterior distribution of the standardized effect size (δ) (i.e., the population version of Cohen's d) was also calculated for each of the paired-comparisons carried out. Magnitudes of the posterior distribution of the standardized effect size were classified as: trivial (<0.2), small (>0.2 – 0.6), moderate (>0.6 –1.2), large (>1.2 – 2.0) and very large (>2.0 – 4.0) [23].

From the sport performance and injury prevention standpoints, small differences in the variables selected in the current study are unlikely to influence a coach's prescription of drills during training. Therefore, this study established that only those differences between paired-comparisons were considered substantial or clinically relevant if: a) $BF_{10} > 10$ (at least a strong evidence for supporting H_1), b) percental error < 10 (which indicates great stability of the numerical algorithm that was used to obtain the result) and c) $\delta > 0.6$ (at least moderate).

The mean value of the cut-off scores previously suggested [11,17] was used to calculate the number of players with bilateral differences (>8°) in each ROM measure. For the dynamic balance, isometric hip strength and jump height measures, bilateral differences higher than 15% were considered as asymmetry [8]. In each variable, a Bayesian Pearson's chi-squared (x^2) test was used to examine potential sex, chronological age, and maturational-related differences in the proportion of players showing bilateral asymmetries.

RESULTS

Descriptive data for participants grouped by age and sex are shown in table 1 with the U15 male and female players being significantly older, taller and heavier than their counterparts in the U13 group. All variables presented a normal distribution ($p > 0.05$) (with the exception of the hip external rotation ROM measures).

Table 1 Participants descriptive anthropometric scores (mean and 95% credible intervals) for each chronological age group.

Variable	U13		U15	
	Males	Females	Males	Females
Age (y)	12.6 (12.5 to 12.7)	12.6 (12.5 to 12.8)	14.6 (14.5 to 14.7)	14.6 (14.5 to 14.7)
Body mass (kg)	43.8 (41.0 to 45.9)	49.1 (46.4 to 51.7)	58.4 (55.9 to 60.9)	56.8 (54.6 to 58.9)
Stature (cm)	154.9 (152.4 to 157.5)	159.8 (157.2 to 162.3)	169.0 (167.0 to 170.9)	166.3 (164.1 to 168.5)
Leg length (cm)	85.0 (83.5 to 86.5)	88.9 (87.3 to 90.6)	92.7 (91.5 to 93.9)	91.4 (90.0 to 92.8)
Maturity offset	-2.4 (-2.6 to -2.2)	0.2 (0.1 to 0.4)	-0.7 (-0.9 to -0.5)	1.7 (1.5 to 1.8)

Y: year; kg: kilogram; cm: centimeter.

Data from all players combined or separated by sex, age group and stage of maturation reported no clinically relevant bilateral differences (BF_{10} < 10 and δ < 0.6) for all the variables selected and hence, the mean scores for both legs were used for the subsequent inter-group comparisons (supplemental files 1-3).

Age and sex-related differences

For dynamic stability, the Bayesian inference analysis revealed the existence of substantial effects for the fixed factor age (BF_{10} = 88.2 [extreme evidence for H_1]), with U13 players demonstrating significantly higher scores in the Y-Balance test than the U15 players (inter-group difference [△] = 6.5 cm [95%CI = 2.9 to 10 cm], δ = 0.62 [95%CI = 0.27 to 0.97]). However, there were no significant effects for the fixed factor sex (BF_{10} = 0.2 [moderate evidence for H_0]). The Bayesian analysis also indicated significant two-way interaction for sex x age (BF_{10} = 11.7 [strong evidence for H_1]. Post hoc analysis conducted indicated that U13 male players performed better in the Y-Balance test that their counterpart U15 males (△ = 10.3 cm [95%CI = 3.8 to 16.7 cm, δ = 0.89 [95%CI = 0.39 to 1.41]), and these latter reached statistically significant lower distances than the U13 females (△ = -7.5 cm [95%CI = -13.9 to -1.1 cm], δ = 0.75 [95%CI = 0.23 to 1.25]) (Table 2).

Regarding hip ABD strength, no significant effects were found for the factors sex (BF_{10} = 7.3) and age (BF_{10} = 0.3). Statistically significant effects in hip ADD strength based on sex were observed (BF_{10} = 47430 [extreme evidence for H_1]) with males demonstrating higher values than female players (△ = 0.4 N*m/kg [95%CI = 0.26 to 0.55 N*m/kg], δ = 0.92 [95%CI = 0.55 to 1.29]). Analyses showed no significant two-way interaction for sex x age group for either hip ABD (BF_{10} = 0.8) or ADD (BF_{10} = 0.2) strength (Table 2).

For both, hip ABD strength and ER ROM, no statistically significant effects were found for the factors sex and age group (BF_{10} < 10). Regarding hip IR ROM, and in contrast to the factor age group (BF_{10} = 0.3), significant effects were observed for sex (BF_{10} = 1067 [extreme evidence for H_1]), with male players displaying lower hip IR ROM scores than females (△ = -7.1º [95%CI = -10.2 to -3.9º], δ = -0.75 [95%CI = -1.11 to -0.39]). For all three ROM measures no two-way interactions for sex x age were observed (Table 2).

Clinically relevant individual effects for the factor sex (BF_{10} = 86.9 [very strong evidence for H1]) and age group (BF_{10} = 772 [extreme evidence for H_1]) were found for the unilateral CMJ test, with male players jumping higher than females (△ = 1.7 cm [95%CI = 0.8 to 2.6 cm], δ = 0.62 [95%CI = 0.27 to 0.97]) and U15 players jumping higher than U13 players (△ = 1.9 cm [95%CI = 1 to 2.8 cm; δ = 0.73 [95%CI = 0.37 to 1.01]). However, no two-way interaction effects for sex by age were reported for this measure (BF_{10} = 2.4) (Table 2).

Table 2 Mean and 95% credible interval (CI) scores for each variable per age group (under 13 [U13] and under 15 [U15] years) and sex. The percentage [%] of players with bilateral asymmetries (BA) in each variable was also presented.

	Males		**Females**	
	U13 (n = 32)	**U15 (n = 36)**	**U13 (n = 32)**	**U15 (n = 28)**
	Mean and 95% CI [% of players with BA]	**Mean and 95% CI [% of players with BA]**	**Mean and 95% CI [% of players with BA]**	**Mean and 95% CI [% of players with BA]**
Dynamic balance (Y-Balance) (cm)*‡	105.4 (100.6 to 110.2) [3]	95.1 (92.7 to 97.5) [0]	102.6 (99.1 to 106.2) [0]	99.9 (96.1 to 103.7) [0]
Hip ranges of motion (º)				
▪ Abduction	65.3 (62.0 to 68.6) [9]	58.3 (55.7 to 60.9) [25]	58.0 (54.4 to 61.6) [25]	65.9 (63 to 68.8) [14]
▪ Internal rotation†	52.6 (48.9 to 56.4) [28]	48.4 (45.0 to 51.8) [25]	56.8 (54.3 to 59.3) [34]	58.3 (55.3 to 61.3) [21]
▪ External rotation	60.6 (57.6 to 63.6) [16]	58.6 (55.8 to 61.8) [22]	58.8 (55.8 to 61.8) [25]	60.8 (58.0 to 63.7) [21]
Isometric hip strength (N*m/kg)				
▪ Abduction	2.8 (2.6 to 2.9) [28]	2.7 (2.6 to 2.8) [25]	2.5 (2.3 to 2.7) [37]	2.6 (2.4 to 2.7) [28]
▪ Adduction†	2.9 (2.8 to 3.1) [41]	2.8 (2.7 to 2.9) [44]	2.5 (2.3 to 2.6) [47]	2.5 (2.3 to 2.6) [25]
Jump height (SL-CMJ) (cm)*†	11.8 (10.8 to 12.8) [28]	14.3 (13.5 to 15.2) [28]	10.7 (9.9 to 11.5) [28]	12.0 (11.0 to 13.0) [32]

*: clinically relevant effects for the fixed factor age; †: clinically relevant effects for the fixed factor sex; ‡: significant two-way interaction for sex x age group. cm: centimeter; º: degree; N: Newton; m: meter; kg: kilogram; SL: single-leg; CMJ: Countermovement jump.

Maturation-related differences

For males, the analyses only exhibited substantial maturation-related differences (pre-PHV vs. around-PHV) for unilateral jumping height (BF_{10} = 34.6 [very strong evidence for H_1], δ = 0.93 [95%CI = 0.32 to 1.56]) with players in the around-PHV jumping higher than pre-PHV players. Female players did not present significant maturation-related differences (around-PHV vs. post-PHV) in any of the variables collected in this study (BF_{10} <10).

The comprehensive analysis conducted in this study showed that a significant proportion of the total players displayed bilateral asymmetries in their hip IR (27%) and ER (21.1%) ROM, isometric hip ABD (28.1%) and ADD (39.4%) strength and jumping height (28.9%) values. Furthermore, this analysis also indicated no sex and chronological age-related differences in the proportion of players showing bilateral asymmetries (BF_{10} <10). In addition, neither for male nor for female players, maturation-related differences in the proportion of players showing bilateral asymmetries were observed (BF_{10} <10) (Table 3).

DISCUSSION

The main purpose of the present study was to analyse the influence of chronological age, maturity status and sex on several lower-body clinical measurements (i.e., dynamic balance, hip ROM and strength, jump height, and bilateral asymmetries) in elite male and female youth tennis players. The present findings indicate that only Y-Balance test and jump height were clearly influenced by chronological age in this cohort of players. Likewise, results also showed that in females, maturation had no influence on either unilateral Y-balance, hip ROM and hip strength, nor unilateral jumpping height, whereas the only relevant maturity-associate effect was observed for on the unilateral jumpping height in male players.

Regarding unilateral dynamic balance, the composite score reached by U15 was worse (△ = 6.5%) than the U13, with the magnitude of this change, being moderate (△ = 10%) in males. Although maturation did not affect Y-Balance performance, males and females around-PHV and post-PHV respectively, obtained worse performance scores than the pre-PHV group. These results are in agreement with previous studies analyzing tennis and a youth soccer players [25,27,34], showing that more immature players have better balance performances than their peers. Balance deficits during maturation might be partially explained by a disproportional growth and disruption of motor coordination in complex motor coordination tasks at the ages around and after the PHV [4], a time-point corresponding to "adolescent awkwardness". For example, these alterations may temporarily

Table 3 Mean and 95% credible interval (CI) scores for each variable per stage of maturation and sex. The percentage [%] of players with bilateral asymmetries (BA) in each variable was also presented.

	Males		**Females**	
	Pre-PHV (n = 40)	**Around-PHV (n = 18)**	**Around-PHV (n = 25)**	**Post-PHV (n = 30)**
	Mean and 95% CI [% of players with BA]	**Mean and 95% CI [% of players with BA]**	**Mean and 95% CI [% of players with BA]**	**Mean and 95% CI [% of players with BA]**
Dynamic balance (Y-Balance) (cm)	103.4 (99.6 to 107.3) [2]	95.1 (91.3 to 98.9) [0]	103.6 (100.1 to 107.1) [0]	99 (95.2 to 102.7) [0]
Hip ranges of motion (º)				
▪ Abduction	64.1 (61.3 to 66.9) [12]	59.4 (55.0 to 63.8) [27]	59.4 (55.5 to 63.3) [32]	65.0 (62.0 to 68.0) [13]
▪ Internal rotation	52.2 (49.0 to 55.4) [26]	50.2 (45.1 to 55.3) [33]	57.7 (54.8 to 60.6) [36]	58.1 (55.3 to 60.9) [20]
▪ External rotation	60.4 (58.0 to 62.8) [19]	58.8 (52.6 to 65.1) [20]	59.6 (56.0 to 63.2) [24]	60.6 (57.9 to 63.3) [20]
Isometric hip strength (N*m/kg)				
▪ Abduction	2.9 (2.8 to 3.0) [26]	2.8 (2.6 to 3.1) [33]	2.5 (2.3 to 2.7) [40]	2.6 (2.4 to 2.7) [20]
▪ Adduction	2.8 (2.6 to 2.9) [42]	2.7 (2.5 to 2.9) [46]	2.5 (2.3 to 2.8) [48]	2.5 (2.3 to 2.6) [23]
Jump height (SL-CMJ) (cm)	12.2 (11.3 to 13.2) [33]	15.2 (14.2 to 16.2) [20]*	11.1 (10.1 to 12.1) [24]	11.9 (10.9 to 12.8) [33]

PHV: peak height velocity; *: score substantively higher than the pre-PHV group. cm: centimeter; º: degree; N: Newton; m: meter; kg: kilogram; SL: single-leg; CMJ: countermovement jump.

compromise, among other parameters, the regulation of the lower extremity joint stiffness [17], leading to impairments in the individual´s ability to control multi-joint movements [7]. Moreover, the higher center of mass that results from growth and subsequent mass gain during PHV, may also make muscular control of body position more difficult [22]. In this regard, the decreased dynamic balance reported for the older and more mature tennis players, might place them in a more vulnerable state to suffer a ligament injury (i.e., knee and/or ankle joints) [57]. This information highlights the usefulness of the Y-balance test as a screening tool, especially at the ages around or just after PHV, and reinforces the need for implementing training strategies focused on injury risk management (i.e., neuromuscular training, including dynamic balance) during this growth period [48].

Lower limb muscle strength and power seems to be critical in order to perform explosive actions in tennis (e.g., acceleration, COD) [18]. More specifically, activation of the hip muscles may be an important factor in controlling lower extremity motion during dynamic activity [49], especially in females, who show a decreased ability to dynamically control the lower extremity as they age and mature [17,22]. Present results showed that males outperformed females in hip ABD and ADD strength, although no differences were found comparing age-groups, which can be explained by the body mass normalization. In this regard, the use of normalized strength values, relative to the body mass, may minimize inter-player variability and provide a more accurate approach to compare strength levels between youth tennis players of different body sizes [4]. Since there are no studies analyzing the hip strength of different age and sex-groups of youth tennis players, comparison is not possible. However, regarding female players, some of the present data are in line with previous research conducted with youth soccer players [49], and showing no differences in hip strength across time (i.e., 3 years) in their cohort (i.e., 14 years old). By contrast, there are studies that explored youth female soccer athletes across time and found decreased hip strength values (i.e., normalized ABD) as these athletes transitioned from pre-pubertal to pubertal stages [21,56]. Thus, although our data showed no chronological-age or maturation-related differences in female players, since hip strength has been shown to be related to important injuries (i.e., anterior cruciate ligament [ACL] injury) [17], the development of intervention programs aimed at improving the neuromuscular activation of the hip musculature would be recommended in youth female tennis players. However, more research is needed in youth tennis players in order to explore possible hip strength deficits during pubertal maturation.

Present results showed that, neither of the hip ROM measures assessed were influenced by chronological age and maturation in this cohort of youth tennis players. Comparison of results are difficult since there are no studies analyzing the evolution of lower body ROM during the maturation process of tennis players. Comparing our results to previous research from different sports [24], average IR/ER ROM values were higher, suggesting that these youth male and female players didn´t show restricted passive hip IR/ER ROM values [58]. Moreover, and in line with previous research [24,49], female players showed increased hip IR ROM values compared to males. In this regard, a greater passive IR hip ROM has been associated with greater dynamic knee valgus and chronic, repetitive loading of the patellofemoral joint, leading to potential increased risk of ACL injuries or patellofemoral pain [26,65]. Thus, hip joint laxity, combined with a lack of strength can be potentially dangerous for these youth athletes, and the inclusion of preventative programs should be included in tennis conditioning at an early age. However, more studies are needed to clarify these joint-specific differences and adaptations in youth players across maturational stages.

Analyzing jumping performance, results obtained in the present study are in line with previous research [16,47,68], showing that older (U15) male and female players achieved higher values (△ = 18%) than the younger group (U13), with more prominent differences in jump height in males (△ = 21.2%) than females (△ = 12.1%). Moreover, maturation influenced SL-CMJ performance, but only in males, with those around-PHV showing higher jump values than players in the pre-PHV stage (△ = 19.8%). The sex-specific physical performance differences can be attributed to higher absolute and relative strength levels in males compared to females [2]. It is well known that during the growth spurt, males have a significant rise in the growth of muscle mass and simultaneous loss of fat mass in limbs under the influence of testosterone [20]. Thus, an increase in testosterone may positively affect the performance of explosive muscle actions, such as jumps. On the other hand, during the growth spurt, females experience less of a gain in stature and muscle mass, but a significant accumulation of body fat [39], leading to less evident beneficial effect of maturational changes [30], as reported in the present study.

Tennis has been considered as an asymmetrical sport [8,61], leading to normal variations or adaptations in both the upper and lower body [37,42]. However, these adaptations can be pathological and should be individually analyzed. In this regard, a novel and more comprehensive analysis was performed, in which, the inter-player variability in the measures conducted was considered [32]. Present data indicate that a significant percentage (>25%) of tennis players, independent of sex, chronological age and maturation status, were identified as having bilateral asymmetries in their hip IR and ER ROM, hip ABD and ADD strength and jumping height values. Likewise, for all the measurements, more than 60% of the bilateral asymmetries documented were in favor of the dominant leg (with the exception of the hip internal rotation ROM in which the opposite situation was observed). These asymmetries may be explained by the demands of tennis training and competition, as players are required to perform multiple short high-intensity movements (e.g., acceleration, deceleration, and COD), with the majority of these movements performed side to side [28]. These movements impose an elevated concentric and eccentric load, especially on the leg adductor muscles, with large movement amplitudes [43]. Together with the short and repetitive on-court movements, players are required to maintain the hip flexor, extensor and adductor muscles in a shortened contracted position for long periods [18,44], and this could lead to a restriction in the hip ROM and strength values, especially in the dominant side.

LIMITATIONS

Some limitations to this study should be acknowledged. The first potential limitation of the current study is the population used. The sport background of participants was elite tennis and the generalizability to other sport modalities and level of play cannot be ascertained. Similarly, only youth tennis players from two chronological age groups (U13 and U15) and maturity status (males = pre and around-PHV; females = around and post-PHV) were recruited, which limited the external validity to other age groups and stages of maturation. It should be recognized that functional capacities (e.g., peak VO2, strength, power, and speed) also have adolescent growth spurts that vary, on average, relative to the timing of PHV in males and females [5,52]. Consequently, for both age groups, the results concerning the sex-related differences in the clinical assessments analyzed in the current study should be considered with a degree of caution since (as expected) male and female tennis players reported significant differences in their maturity offset (table 1). For example, most of the female players from the U13 group were around their time of maximal rate of growth (0.2 years from PHV) whereas their similar-aged males were in a much earlier maturity point (2.4 years before their PHV).

The age at PHV has been calculated using the Mirwald equation [40], which may not be as accurate as using skeletal imaging. However, to minimize the group allocation error derived from the equation, players with a maturational offset between -1 and -0.5 and 0.5 to 1 were removed from the data set. This decision led to a smaller sample size in the around-PHV group in comparison with the other groups (mainly in males). Nonetheless, the large total sample size attempted to mitigate differences in group sample size distribution. Future studies should evaluate balance, ROM, strength and power development longitudinally, as this study was cross-sectional. Furthermore, monitoring of other anthropometric and physical qualities may be advantageous to develop a greater understanding of the development trajectories of youth tennis players. Finally, although the average training experience of the whole group was reported, more detailed information about individual training/competitive volumes, as well as previous injuries, would positively impact the observed findings as they could be considered as covariables and their influence on the presence of bilateral differences in the variables selected may be also explored.

CONCLUSIONS

The present findings show that in U13 and U15 male and female tennis players there were neither positive nor negative maturity-associated variations in the clinical measurements analysed (with the exception of jump height in males). The high proportion of tennis players showing bilateral asymmetries in dynamic balance, hip ROM and strength and jump performance, highlight the need of future studies to deeply analyse these factors in relation to unilateral tennis-specific adaptations in the musculoskeletal and sensorimotor systems and injury incidence.

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SUPPLEMENTAL FILES LEGEND

Supplemental material 1. Descriptive values[T] and inference about bilateral difference for all variables by players' sex.

Supplemental material 2. Descriptive values[T] and inference about bilateral difference for all variables by players' age group.

Supplemental material 3. Descriptive values[T] and inference about bilateral difference for all variables by players' stage of maturation.

SUPPLEMENTAL FILES

Supplemental file 1

Supplemental file 1. Descriptive values[T] and inference about bilateral difference for all variables by players' sex.

	Leg		Inference		
	Dominant	**Non-dominant**	**BF_{10}**	**Effect size (δ)**	**Error (%)**
		All players grouped			
Dynamic balance (Y-Balance)	100.2 (99.0 to 103.0)	101.0 (99.0 to 103.0)	0.7	-0.18 (-0.35 to -0.01)	<0.001
Hip ranges of motion (º)					
▪ Abduction	61.0 (59.3 to 62.8)	62.3 (60.6 to 63.9)	1.1	-0.19 (-0.36 to 0.01)	<0.001
▪ Internal rotation	54.7 (52.9 to 56.6)	52.7 (50.9 to 54.5)	11.7	0.27 (0.10 to 0.45)	<0.001
▪ External rotation	58.9 (57.3 to 60.6)	60.4 (58.8 to 62.0)	1.0	-0.19 (-0.36 to -0.02)	<0.001
Isometric hip strength (N*m/kg)					
▪ Abduction	2.6 (2.6 to 2.7)	2.6 (2.5 to 2.7)	0.1	0.04 (-0.13 to 0.21)	<0.001
▪ Adduction	2.8 (2.7 to 2.9)	2.6 (2.5 to 2.7)	639.9	0.38 (0.20 to 0.56)	<0.001
Jump height (SL-CMJ) (cm)	12.3 (11.8 to 12.8)	12.3 (11.8 to 12.8)	0.1	0.01 (-0.17 to 0.17)	<0.001
		Males (n = 68)			
Dynamic balance (Y-Balance)	99.5 (96.7 to 102.3)	100.4 (97.5 to 103.3)	0.4	-0.18 (-0.42 to 0.05)	<0.001
Hip ranges of motion (º)					
▪ Abduction	61.1 (58.7 to 63.5)	62.1 (59.9 to 64.4)	0.4	-0.17 (-0.40 to 0.07)	<0.001
▪ Internal rotation	50.9 (48.3 to 53.6)	49.8 (47.2 to 52.5)	0.3	0.15 (-0.09 to 0.38)	<0.001
▪ External rotation	58.5 (56.2 to 60.9)	60.8 (58.7 to 62.9)	4.0	-0.32 (-0.56 to -0.08)	<0.001

Isometric hip strength (N*m/kg)								
▪ Abduction	2.7	(2.6 to 2.8)	2.7	(2.6 to 2.9)	0.1	-0.06	(-0.29 to 0.17)	<0.001
▪ Adduction	3.0	(2.9 to 3.1)	2.8	(2.7 to 2.9)	548.3	0.52	(0.27 to 0.77)	<0.001
Jump height (SL-CMJ) (cm)	13.2	(12.5 to 13.9)	13.1	(12.3 to 13.9)	0.2	0.07	(-0.17 to 0.30)	<0.001
				Females (n = 60)				
Dynamic balance (Y-Balance)	101.0	(98.5 to 103.5)	101.7	(99 to 104.4)	0.3	-0.16	(-0.41 to 0.09)	<0.001
Hip ranges of motion (º)								
▪ Abduction	61.0	(58.2 to 63.7)	62.4	(59.8 to 65.0)	0.5	-0.21	(-0.46 to 0.04)	<0.001
▪ Internal rotation	59.1	(56.9 to 61.2)	56.0	(53.9 to 58.0)	18.0	0.41	(0.15 to 0.67)	<0.001
▪ External rotation	59.4	(57.1 to 61.7)	59.9	(57.5 to 62.3)	0.2	-0.06	(-0.31 to 0.19)	<0.001
Isometric hip strength (N*m/kg)								
▪ Abduction	2.5	(2.4 to 2.7)	2.5	(2.4 to 2.6)	0.2	0.12	(-0.12 to 0.37)	<0.001
▪ Adduction	2.5	(2.4 to 2.6)	2.4	(2.3 to 2.6)	0.5	0.20	(-0.05 to 0.45)	<0.001
Jump height (SL-CMJ) (cm)	11.3	(10.6 to 12.0)	11.4	(10.7 to 12.0)	0.2	-0.08	(-0.32 to 0.17)	<0.001

BF: Bayesian factor; T: mean ± 95% credible intervals. Cm: centimeter; N: Newton; m: meter; Kg: Kilogram; SL: Single-leg; CMJ: Countermovement jump.

Supplemental file 2. Descriptive values[T] and inference about bilateral difference for all variables by players' age group.

	Leg		Inference		
	Dominant	Non-dominant	BF_{10}	Effect size (δ)	Error (%)
	U13 (n = 64)				
Dynamic balance (Y-Balance)	103.7 (100.9 to 106.6)	104.3 (101.1 to 107.4)	0.2	-0.09 (-0.33 to 0.14)	<0.001
Hip ranges of motion (º)					
▪ Abduction	61.3 (58.5 to 64.0)	62.1 (59.5 to 64.6)	0.2	-0.13 (-0.37 to 0.11)	<0.001
▪ Internal rotation	55.9 (53.3 to 58.4)	53.6 (51.2 to 56.0)	1.3	0.26 (0.02 to 0.51)	<0.001
▪ External rotation	59.0 (56.6 to 61.4)	60.3 (58.0 to 62.6)	0.3	-0.16 (-0.40 to 0.08)	<0.001
Isometric hip strength (N*m/kg)					
▪ Abduction	2.6 (2.5 to 2.7)	2.6 (2.5 to 2.8)	0.1	0.00 (-0.24 to 0.24)	<0.001
▪ Adduction	2.8 (2.6 to 2.9)	2.6 (2.5 to 2.7)	39.7	0.43 (0.18 to 0.69)	<0.001
Jump height (SL-CMJ) (cm)	11.3 (10.7 to 12.0)	11.2 (10.5 to 11.8)	0.2	0.11 (-1.30 to 0.35)	<0.001
	U15 (n = 64)				
Dynamic balance (Y-Balance)	96.7 (94.5 to 98.8)	97.8 (95.5 to 99.9)	2.1	-0.29 (-0.54 to -0.44)	<0.001
Hip ranges of motion (º)					
▪ Abduction	60.8 (58.5 to 63.1)	62.4 (60.2 to 64.7)	0.9	-0.24 (-0.48 to 0.00)	<0.001
▪ Internal rotation	53.6 (50.9 to 56.4)	51.8 (49.1 to 54.4)	1.6	0.28 (0.03 to 0.52)	<0.001
▪ External rotation	58.9 (56.6 to 61.2)	60.5 (58.3 to 62.7)	0.6	-0.21 (-0.45 to 0.03)	<0.001

Isometric hip strength (N*m/kg)					
▪ Abduction	2.7 (2.5 to 2.8)	2.6 (2.5 to 2.7)	0.2	0.07 (-0.16 to 0.31)	<0.001
▪ Adduction	2.8 (2.6 to 2.9)	2.6 (2.5 to 2.7)	3.2	0.31 (0.07 to 0.56)	<0.001
Jump height (SL-CMJ) (cm)	13.3 (12.5 to 14.0)	13.4 (12.6 to 14.2)	0.2	-0.07 (-0.31 to 0.16)	<0.001

BF: Bayesian factor; T: mean ± 95% credible intervals. Cm: centimeter; N: Newton; m: meter; Kg: Kilogram; SL: Single-leg; CMJ: Countermovement jump.

Supplemental file 3

Supplemental file 3. Descriptive values[T] and inference about bilateral difference for all variables by players' stage of maturation.

	Leg			Inference	
	Dominant	**Non-dominant**	**BF_{10}**	**Effect size (δ)**	**Error (%)**
			Pre-PHV (n = 43)		
Dynamic balance (Y-Balance)	102.9 (99.1 to 106.6)	104 (100.0 to 108.0)	0.4	-0.20 (-0.50 to 0.09)	<0.001
Hip ranges of motion (º)					
▪ Abduction	63.6 (60.5 to 66.7)	64.6 (61.9 to 67.3)	0.3	-0.15 (-0.43 to 0.14)	<0.001
▪ Internal rotation	52.6 (49.1 to 56.0)	51.8 (48.4 to 55.1)	0.2	0.10 (-0.19 to 0.39)	<0.001
▪ External rotation	58.9 (56.1 to 61.7)	61.9 (59.4 to 64.5)	3.4	-0.38 (-0.68 to -0.07)	<0.001
Isometric hip strength (N*m/kg)					
▪ Abduction	2.8 (2.6 to 2.9)	2.8 (2.6 to 2.9)	0.2	-0.03 (-0.32 to 0.26)	<0.001
▪ Adduction	3.0 (2.8 to 3.1)	2.8 (2.7 to 3.0)	2.1	0.34 (0.04 to 0.65)	<0.001
Jump height (SL-CMJ) (cm)	12.4 (11.5 to 13.4)	12.0 (11.0 to 13.0)	0.6	0.24 (-0.06 to 0.53)	<0.001
			Around-PHV (n = 56)		
Dynamic balance (Y-Balance)	100.3 (97.5 to 103.2)	100.5 (97.5 to 103.5)	0.2	-0.03 (-0.33 to 0.26)	<0.001
Hip ranges of motion (º)					
▪ Abduction	58.0 (55.1 to 60.9)	60.8 (57.8 to 63.8)	9.4	-0.46 (-0.78 to -0.14)	<0.001
▪ Internal rotation	56.1 (52.9 to 59.4)	53.6 (50.7 to 56.5)	0.9	0.29 (-0.02 to 0.60)	<0.001
▪ External rotation	58.3 (54.8 to 61.9)	60.3 (57.3 to 63.3)	0.8	-0.27 (-0.58 to 0.03)	<0.001
Isometric hip strength (N*m/kg)					

▪ Abduction	2.6	(2.4 to 2.7)	2.6	(2.4 to 2.8)	0.2	-0.03	(-0.33 to 0.27)	<0.001
▪ Adduction	2.8	(2.6 to 2.9)	2.5	(2.4 to 2.7)	15.3	0.49	(0.16 to 0.82)	<0.001
Jump height (SL-CMJ) (cm)	12.5	(11.6 to 13.5)	12.7	(11.7 to 13.7)	0.2	-0.12	(-0.42 to 0.18)	<0.001
					Post-PHV (n = 29)			
Dynamic balance (Y-Balance)	98.2	(94.5 to 101.9)	99.7	(95.7 to 103.6)	1.1	-0.33	(-0.69 to 0.02)	<0.001
Hip ranges of motion (º)								
▪ Abduction	64.6	(61.2 to 67.9)	65.4	(62.2 to 68.6)	0.2	-0.11	(-0.46 to 0.23)	<0.001
▪ Internal rotation	59.4	(56.4 to 62.4)	56.7	(53.8 to 59.7)	2.7	0.42	(0.06 to 0.79)	<0.001
▪ External rotation	60.6	(57.8 to 63.4)	60.7	(57.4 to 63.9)	0.2	-0.01	(-0.35 to 0.33)	<0.001
Isometric hip strength (N*m/kg)								
▪ Abduction	2.6	(2.4 to 2.8)	2.5	(2.4 to 2.7)	0.4	0.21	(-0.13 to 0.56)	<0.001
▪ Adduction	2.5	(2.3 to 2.6)	2.5	(2.3 to 2.6)	0.2	-0.07	(-0.41 to 0.27)	<0.001
Jump height (SL-CMJ) (cm)	11.8	(10.8 to 12.8)	11.9	(10.9 to 12.9)	0.2	-0.06	(-0.41 to 0.27)	<0.001

BF: Bayesian factor; T: mean ± 95% credible intervals. Cm: centimeter; N: Newton; m: meter; Kg: Kilogram; SL: Single-leg; CMJ: Countermovement jump.