Delgado-García, G.; Vanrenterghem, J.; Molina-García, P.; Gómez-López, P.; Ocaña-Wilhelmi, F.; Soto-Hermoso, V.M. (2022) Upper Limbs Asymmetries in Young Competitive Paddle-Tennis Players. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 22 (88) pp. 827-843 Http://cdeporte.rediris.es/revista/revista88/artasimetria1415.htm
DOI: https://doi.org/10.15366/rimcafd2022.88.007

ORIGINAL

UPPER LIMB ASYMMETRIES IN YOUNG COMPETITIVE PADDLE-TENNIS PLAYERS

ASIMETRÍA ENTRE LOS MIEMBROS SUPERIORES EN JÓVENES PADELISTAS DE COMPETICIÓN

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Código UNESCO / UNESCO code: 3212 Salud pública / Public Health
Clasificación del Consejo de Europa / Council of Europe Classification: 11 Medicina del Deporte / Sport Medicine

Acknowledgements

The authors would like to thank all the athletes who participated in this research. It was supported by the Spanish Ministry of Culture and Sport (FPU15/02949).

The authors declare that there is no conflict of interest.

ABSTRACT

There is little literature on asymmetries in paddle tennis, a sport of an asymmetrical nature. To study the development of upper limb asymmetries, 96 young paddle players and 76 skiers (control group) were evaluated via bioimpedance. The lean mass symmetry index was then compared, considering the sport (paddle tennis players and skiers) and the maturity offset (positive or negative). Paddle-tennis players had a systematically greater upper limbs asymmetry than skiers (7.2 ± 5 % *vs*. 1.4 ± 3.2 %; p < 0.001). This also occurs when comparing only the subsamples with a negative maturity offset (5.7 ± 3.2 % *vs*. 1.5 ± 3.8 %; p < 0.001) or with a positive maturity offset (8.3 ± 5.8 % *vs.* 1.3 ± 2.4 %; p < 0.001). The study reveals that paddle tennis generates asymmetries of lean mass in upper limbs, even before growth spurt.

KEYWORDS: Peak Height Velocity, Racket sport, Children's sport, Maturity Offset, Muscular imbalance.

RESUMEN

Existe escasa literatura sobre las asimetrías en el pádel, un deporte de naturaleza asimétrica. Para estudiar el desarrollo de asimetrías en este deporte se evaluó, con bioimpedancia, la masa magra de ambos miembros superiores de 96 jugadores de pádel jóvenes y de 76 esquiadores (grupo control) y se calculó el índice de simetría. Los jugadores de pádel tuvieron una asimetría entre ambos miembros superiores mayor que los esquiadores, cuando se consideró toda la muestra (7.2 ± 5 % *vs*. 1.4 ± 3.2 %; p < 0.001), en jugadores con un estado de madurez negativo (5,7 ± 3,2 % *vs*. 1,5 ± 3,8 %; p < 0,001) y en aquellos con un estado de madurez positivo (8,3 ± 5,8 % *vs.* 1,3 ± 2,4 %; p < 0,001). Este estudio revela que el pádel genera asimetrías de masa magra en los miembros superiores, incluso antes de la edad de crecimiento pico.

PALABRAS CLAVE: Velocidad de crecimiento pico, deporte de raqueta, deporte en la infancia, estado de madurez, desequilibrios musculares.

1. INTRODUCTION

Worldwide there are more than 12 million people who perform paddle-tennis. The sport is practised in 78 countries and has a total of 35 national federations (International Padel Federation [IPF], 2020). In the particular case of Spain, it is very popular, being number ten in the list of the most practiced sports (García et al., 2015) and one of the most popular in municipal sports centres (Águila et al., 2009). The number of practitioners in Spain in 2015 was 5.2 million (Courel-Ibáñez et al., 2017) and the number of licences increased from 6137 to 72266 between 2000 and 2018 (Ministry of Education, Culture and Sport of the Spanish Government [MECD], 2020). Professional paddle-tennis is also becoming very important, as can be deduced from the number of weekly training hours devoted by elite players (De la Fuente et al., 2014). Unfortunately, it also ranks sixth on the list of sports with the highest number of injuries and second on the list of sports requiring extensive rehabilitation after injury (García et al., 2015), with most injuries being of an intrinsic nature (García-Fernández et al., 2019).

Paddle-tennis players (PTPs), as well as other racquet sports players, provide an interesting case for studying the muscle and bone phenotypic plasticity in response to asymmetrical training and relative overuse as they consistently exert greater forces with the dominant upper limb than with the opposite arm (Lucki & Nicolay, 2007). This has led to numerous studies that have analysed the differences in upper limbs in racquet sports players, typically concluding that these sports promote early development of asymmetry due to muscular hypertrophy in the dominant upper limb (Sanchis-Moysi et al., 2010; Sanchis-Moysi et al., 2016). Racquet sports athletes show differences between dominant and non-dominant upper limb in volume (Rogowski et al., 2008), segmental circumference (Lemos et al., 2019), lean mass (Filipcic et al., 2016; Sanchis-Moysi et al., 2010), bone mineral density (Haapasalo et al., 1998; Sanchis-Moysi et al., 2010), bone mineral content and bone area (Sanchis-Moysi et al., 2010). These asymmetries appear to occur early on, already before the growth spurt as defined by peak height velocity (PHV) (Rogowski et al., 2008) and depend among other factors on the number of weekly training hours (Haapasalo et al., 1998; Sanchis-Moysi et al., 2010) or the age at which sports participation was initiated (Ireland et al., 2014).

Although there are few studies on this subject, some authors suggest that muscular asymmetries could be associated with overuse injuries due to the repetition of specific actions and gestures (Castillo-Lozano & Casuso-Holgado, 2014). Thus, an unbalanced muscle profile of the shoulder muscles (at the dominant/non-dominant and agonist/antagonist levels) in sports involving overhead throws is associated with an increased risk of overuse injuries due to repetitive micro-trauma in the soft tissues (capsule and ligament structures) (Edouard et al., 2013). On the other hand, muscular imbalances of the upper limbs produced by asymmetric training could lead to thoracic scoliosis (Swārd, 1992). Contrary to this idea, Zaina et al. (2016) concluded that tennis does not cause spinal deformities in growing children. In view of the above, it seems necessary to study and quantify the asymmetries in this population in order to determine to what extent training programmes should include exercises aimed at reducing asymmetries. Although there are numerous studies in other racket sports that have investigated asymmetries, we do not know of any studies in this line in the case of paddle-tennis.

Understanding the likelihood of developing upper limb asymmetries in PTPs could aid the prevention of overuse injuries. The aim of the study was to describe the development of upper limb asymmetries in young PTPs, and compare this to a matched sample of young alpine skiers. It is hypothesized that PTPs would show greater upper limb asymmetries than alpine skiers already in the youngest competitive ages prior to reaching the growth spurt defined by PHV.

2. METHODS

2.1. PARTICIPANTS

The present study is a cross-sectional study performed with two samples of high level young competitive sports players: one of 96 PTPs (43 girls) and one of 76 alpine skiers (from now on we will use only the term skiers) of which 33 were girls. The demographics and anthropometric characteristics appear in detail in Table 1. All subjects had national rankings and were participating in high-level competitions at the time of data collection (May 2018).

All participants started competitive sports at an early age, they were nationally ranked and participated in high level competition at the time of data collection. The selected sample of PTPs included some of the best players from all cities of Andalusia (Spain) that could be considered as one of the regions with the best PTPs in the world. In a recent study, skiers showed a low level of asymmetry both for upper and lower limb lean mass (Björklund et al., 2017) so these athletes could be considered as a control population for the present research. Previous studies also used a sample of a supposedly symmetric sport as a control group (Rogowski et al., 2008).

The inclusion criteria of the study were the following: I) training at least 3 days a week; II) periodically participating in regional, national and/or international competitions; III) not had any musculoskeletal injuries in the previous month. We asked the participants to fast at least two hours prior to the test and to not engage in any kind of vigorous physical activity for at least 48 hours before the test.

The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki (World Medical Association, 2001). Individual athletes and their parents received information about the study before the tests, and their consent before collecting the data was obtained.

2.2. PROCEDURES AND INSTRUMENTS

Bioimpedance measurement

Body composition was measured by bioelectric impedance (BIA), with a dual-frequency device (20 kHz and 100 kHz) using an eight-point tactile electrode system (Inbody 230, Biospace Co., Ltd.; Seoul, Korea) (Faria et al., 2014; von Hurst et al., 2016). According to the manufacturers it is suitable for individuals of a wide age range (3-99 years old) and allows the measurement of all five body segments: trunk, right and left lower limb and right and left upper limb. BIA is a good method for determining body water and fat-free mass in people without alterations in body fluids and electrolytes (Alvero et al., 2011). Age- and sex-adjusted prediction equations should be used, which are appropriate for the population and have been validated against reference methods. They are based on the close relationship between the electrical properties of the human body, the body composition of different tissues and the total water content in the body (Alvero et al., 2011). Like all indirect methods of estimating body composition, BIA depends on some assumptions about the electrical properties of the body, its composition and state of maturity, its level of hydration, age, sex, race and physical condition (Kyle et al., 2004). Furthermore, it is shown to be a valid alternative to dual x-ray absorptiometry for assessing muscle mass with a correlation coefficient above 0.85 (Ling et al., 2011; Miyatani et al., 2000) and is valid in appendicular body composition studies in children (Kriemler et al., 2008).

The time spent evaluating a subject was approximately three minutes. First a Seca 220 stadiometer (Seca, Hamburg, Germany; 1 mm precision) was used to measure the subjects' height in centimetres based in the ISAK methodology (Carter, 2002). Then the BIA was performed. The eight electrodes of the BIA are distributed as follows (bilaterally): heels (2), metatarsals (2), fingers (II-V) of the hand (2) and thumb (2). According to the guidelines of the manufacturers, arms were held open approximately 20 degrees from the trunk. Manufacturer's software (Lookin'Body 120, Biospace Corp., Seoul, Korea) automatically computed body composition parameters.

Asymmetry variables

To evaluate asymmetries, the symmetry index (%) with the formula that uses the average in the denominator was used (Björklund et al., 2017). For computing the symmetry index between the upper limbs, we employed this formula:

$$SI(\%) = \frac{(LM_d - LM_{nd})}{0.5 \times (LM_d + LM_{nd})} \times 100$$

where LM_d and LM_{nd} are the lean mass of the dominant upper limb and non-dominant upper limb, respectively.

We also computed asymmetries between lower limbs as a control measurement, to check that the asymmetries occurred locally in the upper limbs. To determine the asymmetry between lower limbs we used the same equation but using the absolute value of the difference in the numerator, as such only focusing on the magnitude of asymmetries. This allows to eliminate the effect of the direction of asymmetry. This decision was made as the asymmetry is not expected to be in similar way determined by limb dominance as in the arms, this due to the fact that both legs are involved extensively in supporting the body.

Determination of maturity offset

Maturity offset (MO) is the time before or after growth spurt, defined by the PHV which is the time when the child grows the fastest during the adolescent growth. We computed MO based on the equations obtained by Moore et al. (2015) that use height and age as predictors:

$$Maturity\ offset\ (girls) = -7.709133 + (0.0042232 \times age \times height);$$

where $R^2 = 0.898$ & SEE= 0.528

$$Maturity\ offset\ (boys) = -7.999994 + (0.0036124 \times age \times height);$$

where $R^2 = 0.896$ & SEE= 0.542

We then divided both samples (PTPs and skiers) into two groups: subjects with a negative MO and subjects with a positive MO. Peak velocities of upper and lower extremity lean mass increases seem to occur after the PHV (Rauch et al., 2004). Therefore, it is very likely that most of the subjects with a negative MO had not yet reached their maximum growth peak of lean body mass.

2.3. STATISTICAL ANALYSIS

The analysis was carried out using the OriginLab 9 software (OriginLab Northampton, MA). Descriptive outcome measures were body height (cm), body mass (kg), body fat (kg), body mass index (kg/m^2), dominant arm lean mass (kg), non-dominant arm lean mass (kg), right leg lean mass (kg) and left leg lean mass (kg). The body mass index was transformed into centiles (Centers for Disease Control and Prevention [CDC], 2010). We also computed linear regression equations that relate age with arms and legs lean mass.

All anthropometric variables and symmetry index (%) were compared between both samples of sport practitioners (for all subjects, only considering the subjects with a negative MO or only those with positive MO) by performing independent t-tests. A Chi-square test was performed to see if the number of girls, left-handed players and boys categorised into weight groups according to BMI centiles was similar between the two samples. Based on a Bonferroni correction the alpha level was set at $p < 0.001$ (0.05/41 comparisons ≈ 0.001). Prior to this analysis a Shapiro Wilk test or Kolmogorov Smirnov test (when sample size was higher than 50) for normality and Levene test for homogeneity of variances were performed. Effect sizes of the mean comparisons were calculated with the freeware Psychometrica (Lenhard & Lenhard, 2016). The effect size was assessed following Cohen's scale (1988): I) 0-0.20, "negligible effect"; II) 0.20-0.50, "small effect"; III) 0.50-0.80, "average effect"; IV) 0.80-1, "large effect".

Finally, a multiple linear regression analysis was done, including symmetry index as the dependent variable and age, sex and sport as the independent variables.

3. RESULTS

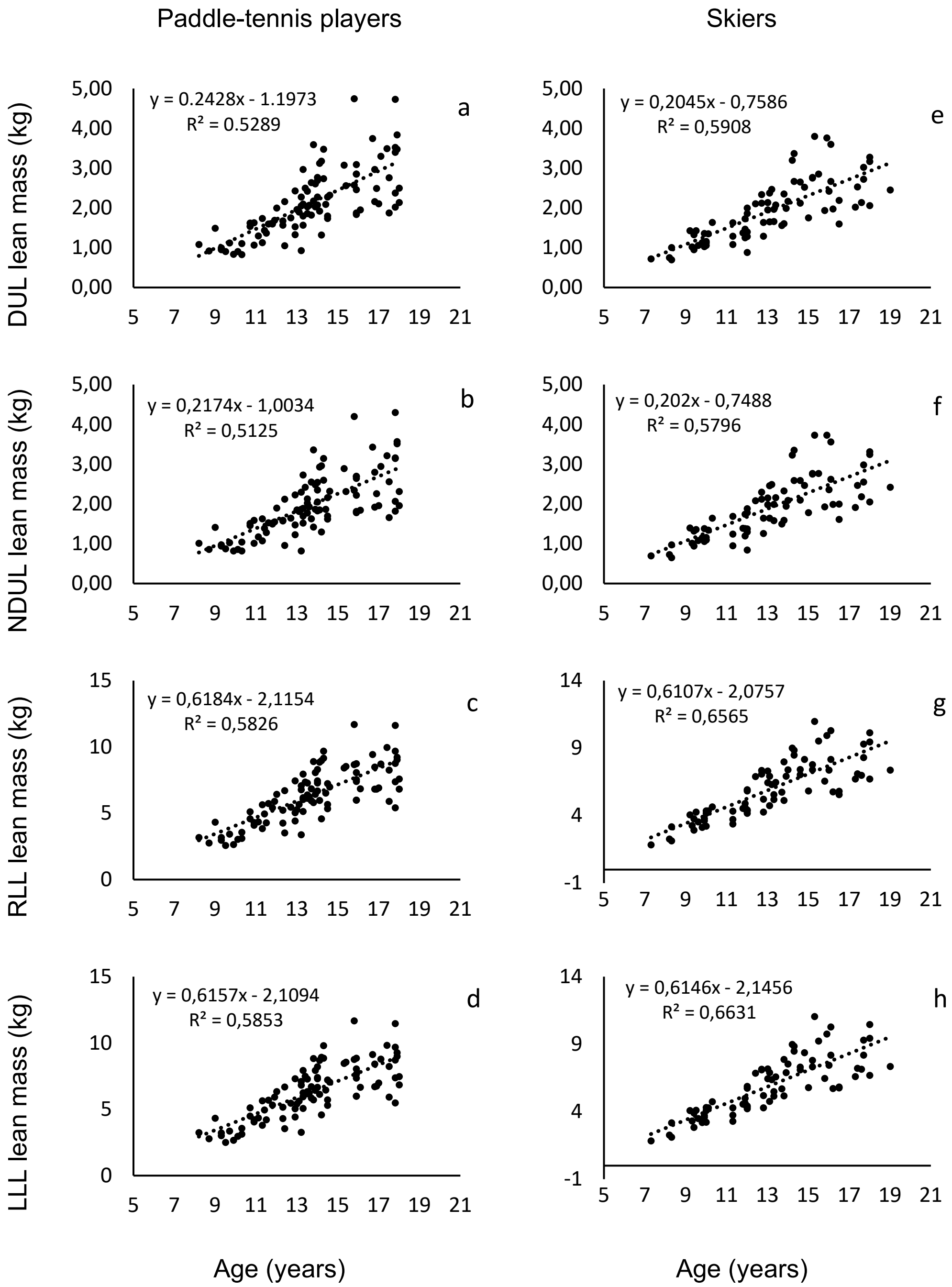
There were no significant differences between PTPs and controls for basic demographic and anthropometric parameters. This was the case for the complete sample as well as when only the subjects with a negative or positive maturational state were compared separately ($p > 0.05$ in all cases; Table 1)

Table 1. Descriptive and anthropometrics measurement of the analysed samples (means ± SD)

Sample	Variable	PTPs	Skiers	T, Z (#), X² (##)	P-value
All subjects	N	96	76		
	Left-Handed (n)	8	6	0,017##	0,900
	Girls (n)	43	33	0,032##	0,857
	Estimated MO (years)	0,8 ± 2,3	0,3 ± 2,5	1,388	0,167
	Age (years)	13,8 ± 2,5	13,2 ± 2,8	1,512	0,132
	Height (cm)	159.1 ± 12.6	156.6 ± 14.9	1,145	0,253
	Weight (kg)	53,5 ± 14,8	50,7 ± 15,3	1,220	0,224
	SMM (kg)	23,2 ± 7	21,6 ± 6,9	1,498	0,136
	BF (kg)	11,1 ± 6,2	10,9 ± 6,7	0,196	0,844
	BMI	20,7 ± 3,7	20,2 ± 3,7	0,954	0,341
	Underweight (n) (< 5º centil)	2	4	1,290##	0,525
	Normal weight (n) (Centil 5º – 85º)	70	53		
	Obesity (n) (≥ 85º centil)	24	19		
Negative estimated MO	N	38	37		
	Left-Handed (n)	2	2	0,001##	0,978
	Girls (n)	10	12	0,338##	0,561
	Estimated MO (years)	-1,5 ± 1,2	-1,9 ± 1,2	1,245#	0,213
	Age (years)	11,5 ± 1,6	10,9 ± 1,7	1,591	0,116
	Height (cm)	147.6 ± 10.1	145.5 ± 11.5	0,820	0,415
	Weight (kg)	42,3 ± 12,2	39,9 ± 9,4	0,599#	0,549
	SMM (kg)	17,7 ± 4,6	16,7 ± 4,3	0,960	0,340
	BF (kg)	9,1 ± 6,3	8,4 ± 4,2	0,001#	1
	BMI	19,1 ± 3,7	18,6 ± 2,8	0,355#	0,723
	Underweight (n) (< 5º centil)	1	2	0,400##	
	Normal weight (n) (Centil 5º – 85º)	26	24		
	Obesity (n) (≥ 85º centil)	11	11		
Positive estimated MO	N	58	39		
	Left-Handed (n)	6	4	0,0002##	0,989
	Girls (n)	33	21	0,088##	0,767
	Estimated MO (years)	2,2 ± 1,4	2,3 ± 1,5	0,011#	0,991
	Age (years)	15,3 ± 1,7	15,4 ± 1,8	-0,173#	0,863
	Height (cm)	166.6 ± 7.4	167.2 ± 8.9	-0,295	0,768
	Weight (kg)	60,8 ± 11,4	60,9 ± 12,5	-0,052#	0,959
	SMM (kg)	26,9 ± 5,8	26,3 ± 5,5	0,394#	0,694
	BF (kg)	12,3 ± 5,8	13,3 ± 7,7	-0,408#	0,683
	BMI	21,8 ± 3,2	21,7 ± 3,7	0,158#	0,874
	Underweight (n) (< 5º centil)	1	2	0,920	0,631
	Normal weight (n) (Centil 5º – 85º)	44	29		
	Obesity (n) (≥ 85º centil)	13	8		

*MO: Maturity Offset; SMM: Skeletal Muscle Mass; BF: Body Fat; BMI: Body mass index
T, Z (#), χ^2 (##) : Statistics for the Student *t*, Mann-Whitney and Chi-square tests

The regression lines that relate the age and appendicular lean mass were visually similar between skiers and PTPs in almost all cases (Figure 1). The regression lines for the dominant and non-dominant upper limb for the skiers (Figure 1e vs. Figure 1f) were really similar both in the intercept value and in the slope. The same happens for the regression lines of the right and left lower limbs, both in the PTPs (Figure 1c vs. Figure 1d) and in the skiers (Figure 1g vs. Figure 1h). The only case where there seems to be a noticeable difference is between the slopes of the regression lines of the upper limbs of the PTPs (0,24 *vs.* 0,21; Figure 1a vs. Figure 1b).



*DUL: Dominant upper limb; NDUL: Non-dominant upper limb; RLL: Right lower limb; LLL: Left lower limb

Figure 1. Relationship between upper and lower limbs lean mass and age in paddle-tennis players and in skiers.

Appendicular lean mass values of extremities showed no significant differences between PTPs and controls (Table 2). However, the only parameter that was statistically different between the two samples was upper limb asymmetry (7,2 ± 5 % *vs.* 1,4 ± 3,2 %; p < 0,001) with a large effect size (Cohen's d = 1.698). This was still the case when only subjects with a negative (5,7 ± 3,2 % *vs.* 1,5 ± 3,8 %; p < 0,001) or positive MO (8,3 ± 5,8 % *vs.* 1,3 ± 2,4; p < 0,001) were considered with Cohen's d being 1.261 and 2.049 respectively, which correspond to a large effect size.

Table 2. Appendicular lean mass and asymmetry values of the analysed samples (means ± SD)

Sample	Variable	PTPs	Skiers	T, Z (#), X^2 (##)	P-value
All subjects	N	96	76		
	DUL lean mass (kg)	2,15 ± 0,84	1,93 ± 0,75	1,744	0,082
	NDUL lean mass (kg)	1,99 ± 0,76	1,91 ± 0,75	0,708	0,479
	RLL lean mass (kg)	6,41 ± 2,04	5,97 ± 2,14	1,388	0,166
	LLL lean mass (kg)	6,38 ± 2,03	5,95 ± 2,14	1,353	0,177
	UL asymmetry (%)	7,2 ± 5	1,4 ± 3,2	8,487#	**< 0,001**
	LL asymmetry (%)	1,1 ± 0,8	1,2 ± 1,1	-1,127	0,260
Negative estimated MO	N	38	37		
	DUL lean mass (kg)	1,51 ± 0,52	1,4 ± 0,44	0,731#	0,465
	NDUL lean mass (kg)	1,43 ± 0,49	1,38 ± 0,45	0,297#	0,767
	RLL lean mass (kg)	4,72 ± 1,43	4,40 ± 1,36	1,009	0,316
	LLL lean mass (kg)	4,69 ± 1,42	4,37 ± 1,35	1,110	0,316
	UL asymmetry (%)	5,7 ± 3,2	1,5 ± 3,8	4,700#	**< 0,001**
	LL asymmetry (%)	1,1 ± 0,9	1,4 ± 1,1	-0,906#	0,365
Positive estimated MO	N	58	39		
	DUL lean mass (kg)	2,57 ± 0,74	2,44 ± 0,63	0,585#	0,559
	NDUL lean mass (kg)	2,36 ± 0,68	2,41 ± 0,63	-0,640#	0,522
	RLL lean mass (kg)	7,52 ± 1,57	7,45 ± 1,60	0,186	0,853
	LLL lean mass (kg)	7,48 ± 1,55	7,44 ± 1,60	0,121	0,904
	UL asymmetry (%)	8,3 ± 5,8	1,3 ± 2,4	7,117#	**< 0,001**
	LL asymmetry (%)	1 ± 0,8	1,1 ± 1	0,453#	0,651

*DUL: Dominant upper limb; NDUL: Non-dominant upper limb; RLL: Right lower limb; LLL: Left lower limb

*P-values minor than 0.05 accompanied with large effect sizes are marked in bold.

Multiple regression analysis, including upper limb asymmetries as dependent variable and age, sex and sport as independent variables, showed a statistically significant relationship (gl. = 168; residual sum of squares = 3091,2; p < 0,001; adjusted r^2 = 0,32). Age and sex were not significant predictors (sum of squares= 63,5; p = 0,064 and sum of squares = 0,28; p = 0,902; respectively) but sport was (sum of squares = 1355,6; p < 0,001). In the case of the lower limb asymmetries the same model was not statistically significant (gl. = 168; residual sum of squares = 147,6; p = 0,123).

4. DISCUSSION

To our knowledge, this has been the first study describing the development of upper limb asymmetries as a health concern in young PTPs. Even before MO there was already a meaningful upper limb asymmetry, which persisted into adolescence. This was seen in boys and girls, and for both early and late mature PTPs.

The lean mass values of the upper limb are in agreement with data reported in previous research. In a similar study evaluating the body composition of pre-pubertal children under 10 years of age (also using BIA), the lean mass of the upper limbs was approximately 1.35 kg (Kriemler et al., 2008). In the present study, higher values were found in the subjects with a negative MO (1.38-1.51 kg; Table 2), but the sample was also older than in the study of Kriemler et al. (2008). Filipcic et al. (2016), in a sample of tennis players aged 11.29 ± 0.77 years (similar in age to the sample of subjects with a negative MO in this study) obtained higher values of lean mass for the dominant and non-dominant upper limb (1.61 ± 0.44 kg and 1.52 ± 0.42 kg, respectively) but the average height of the athletes they evaluated was also slightly higher (151.5 cm vs. 147.6 cm [Table 1]). The same was true for the lean mass of the lower limbs, where these authors obtained values greater than 5 kg, whereas in the present study the averages were 4.69 kg for PTPs and 4.37 kg for skiers [Table 2]. In a group of tennis players with an average age of 14.4 years, Filipcic et al. (2016) also obtained higher lean mass values than PTPs with a positive MO (with an average age of 15.3 years) for the dominant (2.75 kg vs. 2.57 kg) and non-dominant (2.61 kg vs. 2.36 kg) upper limbs. Although the tennis players in the study by Filipcic et al. (2016) were slightly younger than the PTPs with a positive MO, they were taller (170.4 cm vs. 166.6 cm), which may account for the differences. This difference in height could be explained by the fact that the study by Filipcic et al. (2016) was conducted with young Slovenians who are taller than Spaniards with the same birth cohort (NCD Risk Factor Collaboration, 2016).

The main finding of this study was that paddle-tennis promotes asymmetries in the upper limbs of adolescents of approximately 7.2 per cent (5.7 per cent in subjects with a negative MO and approximately 8.3 per cent in subjects with a positive MO [Table 2]). These results are similar to data reported in previous studies in racquet sports, such as that of Filipcic et al. (2016), who reported a lean mass asymmetry in the upper limbs of tennis players of 4.4-6.4%; or Rynkiewicz et al. (2013) who found an asymmetry of approximately 4%. Such asymmetries may be greater in professional tennis players (Sanchis-Moysi et al., 2010). In both tennis and paddle-tennis, the asymmetry between the upper limbs is evident, although it is not clear which sport causes greater asymmetries. To be able to answer this question, it is necessary to investigate the role of certain differences between the two sports that could influence the magnitude of the asymmetries, such as: the weight of the racket, the paddle racket being heavier than the tennis racket; the type of strokes that are executed, being in paddle-tennis very frequent volleys, smashes and other strokes above the head (Muñoz-Marín et al, 2016; Sánchez-Alcaraz et al., 2020) and one-handed backhands; or the size of the court, with the tennis court being larger, which may require greater striking power.

Both in the subjects of this study and in other samples of young tennis players, asymmetries were found in upper limbs, even in subjects with negative MO (Lemos et al., 2019; Rogowski et al., 2008). These results are not consistent with the conclusions of previous work indicating that strength training does not cause muscle hypertrophy in pre-adolescents, due to the low levels of circulating androgens in this population (Ozmun, et al., 1993; Ramsay et al., 1989). Resistance training of 20 weeks (3 days per week) applied in a group of pre-pubertal boys resulted in changes in some strength measures that were independent of the cross-sectional area of the muscle (Ramsay et al., 1989). Similarly, after 8 weeks of training, consisting of bicep curls three times a week, changes in muscle strength of the elbow flexors were detected in prepubertal boys, but no changes were observed in arm circumference or skin folds (Ozmun et al., 1993). The authors concluded that most gains in muscle strength at early ages were due to increases in muscle activation (Ozmun et al., 1993). In this line, other authors suggest that the development of muscle strength in pre-pubertal children is driven by neural factors and not by muscle hypertrophy (Granacher et al., 2011).

In the present research, a greater asymmetry of lean mass measured by BIA was found in PTPs than in a similar cohort of skiers, which leads us to think that paddle-tennis favours muscular hypertrophy or osteogenic activity even at early ages (in the case of PTPs with a negative MO the asymmetries were approximately 5.7 %). In paddle-tennis and other racket sports, the forces exerted on the musculoskeletal structures of the dominant upper limb - despite being of moderate intensity and short duration - are exerted over hundreds of repetitions per practice or match, and accumulate over several years of sporting participation (Lucki & Nicolay, 2007). The most important result of this study was that asymmetry between the upper limbs in PTPs occurs before the growth spurt. Therefore, it is important that coaches working with the younger age groups take this into account when developing training programmes as these asymmetries could lead to musculoskeletal health problems that are more difficult to treat in older age groups. Therefore, we suggest that in PTPs the compensatory work starts from the moment the sport begins. This can be done with exercises adapted for children, such as throwing with both arms, crawling, climbing with both arms, acrobatic exercises with both arms or playing paddle-tennis with the non-dominant hand. We also believe that young PTPs should be encouraged to continue combining their sport with activities that are symmetrical in nature and that serve to reduce muscular imbalances such as Pilates (Alves de Araújo et al., 2012).

This study is not without its limitations. Firstly, BIA is not the gold standard for measuring lean mass and cannot detect specific differences in muscle groups. A more detailed understanding of the muscle development responses of certain muscle groups could help reveal the early signs of the pathophysiological mechanisms of certain musculoskeletal injuries, such as shoulder impingement or rotator cuff tendinitis. Another limitation is the quantification of the state of maturity. Other more standardised procedures exist, such as that of Mirwald et al. (2002), which considers chronological age, height, sitting height and body mass. We use a relatively recent formula for estimating maturity that has been less widely used in the literature (Moore et al., 2015). Despite these limitations, this is - to our knowledge - the first study that attempts to describe the development of upper limb asymmetries in young PTPs. Furthermore, it is unlikely that the results would have been substantially different with the use of other methods due to the highly significant correlation between the BIA and Moore et al. (2015) equation with the reference methods, as already indicated in the methods section. Considering the previous literature on racquet sports that studies asymmetries, future studies on paddle-tennis could, in addition to assessing the body composition of PTPs using BIA, use methods that provide analytical information on asymmetries, based on anthropometric measurements (Lemos et al., 2019; Rogowski et al., 2008) or on mineral densitometry (Sanchis-Moysi et al., 2016). It would also be interesting to include variables such as the starting date for the practice of sport of an asymmetric nature or the relationship between the number of hours of training per week and the magnitude of the asymmetries, as other expert authors in the field have done (Ireland et al., 2014; Sanchis-Moysi et al., 2010).

We think that the observed lean mass decompensations are closely related to functional alterations. However, most research has focused on the structural or functional asymmetries in an isolated way. We believe that future studies are needed to better understand the structural and functional asymmetry as risk factor for common musculoskeletal disorders in racquet sports including paddle-tennis.

5. CONCLUSIONS

According to our knowledge of the subject, this is the first study that describes the development of asymmetries between upper limbs in young competitive paddle-tennis players. Asymmetries were observed before and after the age of peak growth in height and were greater than those of a control group formed by skiers. All this leads to think that these asymmetries are due to the intrinsic characteristics of the sport. More studies should be conducted to quantify asymmetries in paddle-tennis using more analytical methods (e.g. bone densitometry or anthropometric measurements) and studies on the relationship of these asymmetries to ensuing musculoskeletal health problems in adulthood.

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