Handgrip Strength Evaluation on Tennis Players
Using Different Recommendations

ORIGINAL ARTICLE

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ABSTRACT

It is important to assess the handgrip strength (HS) in competitive tennis players due to asymmetry between the dominant and contra lateral hands that players might develop. In order to assess HS, clinicians can use separate, already established protocols (from European Test of Physical Fitness Handbook [Eurofit] or American Society of Hand Therapists [ASHT]. The objective of this study was threefold: Firstly to compare the HS using the Eurofit and ASHT technique; secondly to compare HS between dominant/non-dominant hands, and last, to compare the handgrip between different ages of juvenile tennis player athletes. 137 male and 45 female tennis players (aged between 8 and 18 years) participated in the study. In order to assess HS following the Eurofit and ASHT recommendations, a Jamar dynamometer was used. None of the athletes had any injury that could compromise tests. There was no difference in handgrip strength between Eurofit and ASHT recommendations regardless of sex. The best curve to describe the regression of HS and age for both genders was a sigmoid function. Males presented a higher slope at 11 years and females had a higher slope at 10 years. Moreover, in male athletes dominant HS presented higher values than non-dominant HS beginning at 14 years. However, for the females the asymmetry in HS did not occur for any age until 18 years.

Keywords: Tennis, Hand strength, Child. Adolescent, Racket Sports.

INTRODUCTION

Due to its simplicity, low cost and technique reproducibility, the handgrip strength measurement (HS) is widely used to assess hand injuries[1,2]. HS can be assessed on the patient's first visit to the clinician who, following predetermined standard parameters, can consequently plan the treatment. Interestingly, during HS the carpi extensors need to contract avoiding the flexor moment generated on the wrist; hence, individuals with lateral epicondylitis present pain during HS. Therefore, HS may be used as a functional outcome to help in the discharge after a treatment[3,4]. Using the HS it is also possible to estimate the body composition and mortality rate[5,6]. Some HS normality values for subjects who do not present injuries have been determined[7,8]; however, the use of these values for tennis players brings problems, because training with a racket may produce a neuromuscular adaptation which consequently increases the HS of the dominant hand.

Studies mention asymmetry between the dominant and contralateral upper limbs for tennis players[9,10]. Such asymmetry has been attributed to intrinsic characteristics of the sports gesture and hampers the use of the contralateral limb as reference during a treatment. Moreover, a possible correlation between HS and lateral epicondylitis of the humerus has been proposed[11,12]. This injury presents a long recovery process[13] and, therefore, it is believed that the HS is very useful tool in the assessment of these athletes[11]. Nevertheless, specific HS values for the junior tennis players have not been found.

In order to assess the HS there are two well-spread guidelines; one recommends the elbow evaluation in extension (European Test of Physical Fitness – Eurofit)[14] while the other suggests elbow flexion (American Society of Hand Therapists – ASHT)[15]. Due to this divergence, there are studies such as the one by Vianna et al.[8] and Chau et al.[16] which use in their evaluation protocol the elbow in extension, while other studies such as the ones by Armstrong and Oldham[17], Figueiredo et al.[2] and Anakwe et al.[18] that use the elbow in flexion. This disagreement between references causes difficulties when comparing different studies.

The elbow position may influence on the HS, since the musculature which moves the wrist also passes through the elbow; therefore, alterations in the flexors tension/length ratio could alter the result of the test[11]. Additionally, it should be considered that in order to increase the HS is it necessary not only greater recruiting of flexor muscles, but also to increase the activity of the extensor muscles with the aim to keep the wrist in slight extension[18]. Thus, the alteration of the elbow position could also alter the relation between the flexor and extensor muscles and allow better wrist functioning.

Using the HS it is possible to estimate some characteristics of

the individual, such as the muscular area of the forearm[18], presence of hormones[19], body composition[20] and physical fitness [21]. Thus, the existence of a HS reference value for tennis players would be also valuable to track the development of adolescents from this modality.

Consequently, due to divergence between positioning guidelines for HS assessment and the importance of this measure in tennis athletes, the aims of this study were: 1) to compare HS in the guidelines suggested by the Eurofit and ASHT; 2) to compare HS between the dominant and contralateral sides and 3) to evaluate the nature of the association between HS and age.

METHOD

PARTICIPANTS

As inclusion criterion, the tennis players should be from the junior category affiliated with the Brazilian Tennis Confederation with regular participation in the championships organized by this entity. The individuals should have not presented any injury in the upper limbs for at least two months. 182 tennis players, 137 male (aged between nine and 18 years) and 45 female (aged between eight and 17 years) were evaluated. On average the tennis players trained 13 (SD = 3.5) hours / week. All of them were divided into the game categories 10, 12, 14, 16 and 18 years old (table 1). Training time of these athletes was categorized as follows: two to five years; six to nine years and over 10 years. The most recurrent frequency in the categories 10, 12, 14, 16 and 18 years was, respectively: two to five years; two to five years; six to nine years; six nine years and over 10 years. The parents or legal guardians of the participants signed a consent from according to resolution form the National Health Committee/Ministry of Health – 196/96, approved by the Ethics Committee of the involved Institution (190/06).

Table 1. Athletes distribution in gender and game categories.

		Game category				
		10	**12**	**14**	**16**	**18**
Male	**n = 137 (%)**	11 (8.0)	29 (21.2)	42 (30.7)	30 (21.9)	25 (18.2)
	Mass kg (SD)	40.5 (8.0)	41.5 (5.4)	54.5 (8.6)	66.5 (9.4)	69.4 (8.0)
	Stature cm (SD)	145 (8.0)	150 (6.5)	168 (9.0)	175 (7.8)	177 (6.0)
Female	**n = 45 (%)**	4 (8.8)	9 (20)	19 (42)	9 (20)	4 (8.8)
	Mass kg (SD)	35.5 (7.5)	40.8 (9.0)	50.2 (8.2)	55.5 (7.0)	60.5 (6.5)
	Stature cm (SD)	141 (5.5)	150 (6.0)	155 (8.0)	163 (9.5)	165 (9.0)

Mass and stature are presented in mean and standard deviation (SD).

Test protocol and variables

Data was collected on an evaluation sheet with the following items: athlete's identification; body mass; stature; game category and HS. HS was evaluated using a hydraulic dynamometer with an analog visor (Jamar) and all tests were applied by a single evaluator. Firstly, the tennis players performed one trial with each hand for familiarization. This trial was excluded in the analysis.

HS measurement with flexed elbow was performed following guidelines from the American Society of Hand Therapists (ASHT). The athlete was hence placed with adducted shoulder, elbow flexed at 90°, forearm at neutral position and wrist between 0° and 30° of extension[7,15]. HS measurement with the elbow in extension was obtained according to guidelines from the European Test of Physical Fitness (Eurofit) with the individual standing and keeping the dynamometer in a comfortable way without body contact[14]. The order of the tests (Eurofit or ASHT) was randomized. In both positions, the athlete was instructed to squeeze the dynamometer as strong as possible, for three consecutive times and the highest value was used for the analyses[22].

Statistical analysis

Normality distribution was verified by the Shapiro-Wilk test. To compare HS between: dominant and contralateral hands; game categories; and guideline used, a 3 factor (2 x 5 x 2) analysis of variance was used with repeated measures on hand (dominant vs contralateral) and guideline used (Eurofit vs ASHT). Mauchly's sphericity test was applied and, in case it was violated, technical corrections were performed by the Greenhouse-Geisser test. When the F test was significant, multiple comparisons were performed by the Bonferroni post hoc test. Interactions were also evaluated. Intraclass correlation coefficient (ICC) and Bland & Altman plots were used to verify the agreement between techniques (Eurofit versus ASHT) and agreement between hands (dominant versus contralateral). The sigmoid function best described the regression between the HS variation with age. Boundary age in the HS curve was determined using dummy variables. Significance was set in 5% (P ≤ 0.05) and the analysis were performed in the SPSS software, version 13.0. The plots were designed with the SigmaPlot 7.101 software. The MedCalc 11.3.0.0 software was used for Blant-Altman agreement analysis.

RESULTS

Table 2 shows the HS mean and standard deviation in the two different guidelines divided by category. For the male group, the comparisons between the dominant and contralateral hands did not present statistically significant differences in the categories 10 and 12 years in both guidelines of the test. However, in the categories 14, 16 and 18 years, the dominant hand presented greater HS compared to the contralateral, regardless of the guideline used.

Table 2 also present that for the young males, comparison between Eurofit and ASHT guidelines did not show any statistical difference for any game category.

Furthermore, table 2 shows that no comparison for the female gender presented statistically significant difference; that is to say, the dominant side presents the same HS as the contralateral side and no difference was observed in the HS when guidelines were compared.

Table 2. HS comparison (kgf) in the game categories.

		HS – Mean (standard deviation)			
		ASHT		Eurofit	
		D hand	ND hand	D hand	ND hand
Male	10	16.0 (6.8) [a]	16.6 (3.8) [b]	19.0 (5.1)	18.7 (8.1)
	12	18.7 (4.2) [a]	13.5 (4.0) [b]	20.4 (5.0)	27.1 (32.5)
	14	25.7 (7.2) [a]	15.5 (4.1) [* b]	29.6 (7.1)	18.3 (3.7) [‡]
	16	33.1 (5.7) [a]	22.2 (4.4) [* b]	38.1 (3.3)	24.1 (4.2) [‡]
	18	44.2 (7.4) [a]	20.1 (5.5) [* b]	48.4 (9.0)	21.5 (7.0) [‡]
Female	10	11.0 (2.5) [a]	9.0 (2.9) [b]	14.0 (2.1)	10.7 (2.2)
	12	16.5 (3.6) [a]	13.7 (4.2) [b]	18.5 (3.1)	14.2 (1.8)
	14	20.2 (6.6) [a]	16.0 (7.0) [b]	23.5 (7.8)	19.0 (6.9)
	16	27.5 (6.1) [a]	23.5 (5.5) [b]	31.5 (5.9)	25.7 (6.9)
	18	32.5 (9.1) [a]	28.5 (6.3) [b]	34.7 (11.8)	30.7 (5.1)

D = dominant; ND = non-dominant.
* = P < 0.05 for D hand x ND hand in the ASHT guideline.
‡ = P < 0.05 for D hand x ND hand in the Eurofit guideline.
a = P > 0.05 in the comparison between D hand in the ASHT guideline and D hand in the Eurofit guideline.
b = P > 0.05 in comparisom between ND hand in the ASHT guideline with the ND hand in the Eurofit guideline.

Regarding the female gender, the HS comparisons between any game categories did not present statistically significant difference, regardless of the hand assessed or the protocol for assessing HS. Contrary to what occurred to the male group, no significant difference was observed in the HS between the younger game categories (10 or 12 years) compared to the older categories (16 or 18 years).

Tables 3-6 show the ICC values and the Bland & Altman agreement results. It is possible to observe that in the comparison between the dominant and contralateral sides, the ICC values are small and the Bland and Altman plot presents a large limit of agreement. When the techniques are compared (Eurofit vs. ASHT), regardless of the hand assessed (dominant or contralateral), the ICC values are higher and the Bland and Altman presented smaller limits of agreement.

Table 3. Concordance values between dominant and contralateral hands using the ASHT guideline.

		ICC			Bland and Altman			
		ICC	95% CI		$\bar{d}$	SD of $\bar{d}$	95% CI of $\bar{d}$	95% CI
Male	10	0.33	-1.33; 0.81		-0.59	7.16	-5.40; 4.22	-14.6; 13.4
	12	-0.22	-1.57; 0.42		-1.86	10.55	-5.85; 2.15	-22.5; 18.8
	14	0.44	-0.20; 0;70		3.40	9.48	0.44; 6.36	-15.18; 22.0
	16	-0.08	-1.10; 0.51		6.23	9.06	2.84; 9.61	-11.5; 24.0
	18	-0.53	-0.76; 0.19		16.6	11.2	12.0; 21.3	-5.3; 38.7
Female	10	0.67	-0.31; 0.97		-2.00	1.41	-4.25; 0.25	-4.77; 0.77
	12	0.70	0.17; 0.92		2.77	1.64	1.51; 4.03	-0.43; 6.00
	14	0.69	0.23; 0.88		5.05	1.89	4.13; 5.96	1.32; 8.77
	16	0.77	0.06; 0.94		2.55	4.41	-0.84; 5.95	-6.10; 11.21
	18	0.74	-0.18; 0.98		5.00	3.55	-0.66; 10.66	-1.97; 11.97

ICC = intraclass correlation coefficient (one factor – random effect); $\bar{d}$ = mean difference; SD = standard deviation. CI = confidence interval and CT = concordance threshold.

Table 4. Concordance values between dominant hand and contralateral hand using the Eurofit guideline.

		ICC			Bland and Altman			
		ICC	95% CI		$\bar{d}$	SD of $\bar{d}$	95% CI of $\bar{d}$	95% CI
Male	10	0.07	-2.79; 0.70		0.27	10.01	-6.45; 6.99	-19.3; 19.8
	12	0.30	-1.72; 0.39		-6.13	25.69	-15.91; 3.63	-56.5; 44.2
	14	0.45	-0.01; 0.70		3.47	11.19	-0.01; 6.96	-18.4; 25.4
	16	0.23	-1.56; 0.41		7.93	9.51	4.38; 11.48	-10.7; 26.5
	18	0.55	-6.75; 0.53		20.0	9.72	16.02; 24.05	-5.9; 32.1
Female	10	0.27	-6.22; 0.95		-3.25	1.50	-5.63; -0.86	-6.1; 0.31
	12	0.65	-0.07; 0.90		2.88	2.08	1.28; 4.49	-1.2; 6.9
	14	0.44	-0.41; 0.78		6.15	3.98	4.23; 8.08	-1.6; 13.9
	16	0.52	-3.71; 0.96		-5.44	2.96	-7.72; -3.16	-11.2; 0.3
	18	0.57	-0.94; 0.61		4.00	8.83	-10.05; 18.05	-13.3; 21.3

ICC = intraclass correlation coefficient (one-way random effect); $\bar{d}$ = mean difference; SD = standard deviation. CI =confidence interval and CT = concordance threshold.

Table 5. Concordance values between the ASHT and the Eurofit for dominant hand.

		ICC			Bland and Altman			
		ICC	95% CI		$\bar{d}$	SD of $\bar{d}$	95% CI of $\bar{d}$	95% CI
Male	10	0.80	0.30; 0.94		2.90	2.66	1.12; 4.69	-2.3; 8.1
	12	0.86	0.71; 0.93		2.55	2.59	1.56; 3.54	-2.5; 7.6
	14	0.86	0.75; 0.92		3.50	3.18	2.50; 4.49	-2.7; 9.7
	16	0.80	0.57; 0.90		4.83	4.01	3.33; 6.33	-3.0; 12.7
	18	0.80	0.48; 0.90		4.72	5.01	2.65; 6.78	-5.1; 14.5
Female	10	0.50	-4.0; 0.96		3.00	1.41	0.74; 5.20	0.2; 5.7
	12	0.82	0.26; 0.95		2.33	2.34	0.53; 4.13	-2.2; 6.9
	14	0.80	0.47; 0.92		3.68	2.60	2.42; 4.93	-1.4; 8.7
	16	0.81	0.24; 0.95		4.22	2.63	2.19; 6.24	-0.9; 9.3
	18	0.94	0.48; 0.99		1.25	5.18	-7.00; 9.50	-8.9; 11.4

ICC = intraclass correlation coefficient (one factor – random effect); $\bar{d}$ = mean difference; SD = standard deviation. CI = confidence interval and CT = concordance threshold.

Table 6. Concordance values between the ASHT and the Eurofit for non-dominant hand.

		ICC			Bland and Altman			
		ICC	95% CI		$\bar{d}$	SD of $\bar{d}$	95% CI of $\bar{d}$	95% CI
Male	10	0.95	0.84; 0.98		2.04	2.41	0.42; 3.66	-2.6; 6.7
	12	0.96	0.92; 0.98		2.48	2.38	1.57; 3.38	-2.1; 7.1
	14	0.94	0.90; 0.97		3.42	3.47	2.34; 4.51	-3.3; 10.2
	16	0.92	0.83; 0.96		-3.13	2.52	-4.07; -2.18	-8.0; 1.8
	18	0.91	0.81; 0.96		1.36	4.28	-0.40; 3.12	-7.0; 9.7
Female	10	0.83	-0.65; 0.89		1.75	1.25	-0.25; 3.75	-0.71; 4.21
	12	0.64	-0.46; 0.91		2.22	3.07	-0.14; 4.58	-3.8; 8.2
	14	0.86	-0.64; 0.94		2.57	2.71	1.27; 3.88	-2.7; 7.8
	16	0.94	0.76; 0.98		-1.33	2.23	-3.05; 0.38	-5.7; 3.0
	18	0.88	-0.12; 0.99		2.25	3.40	-3.16; 7.66	-4.4; 8.9

ICC = intraclass correlation coefficient (one factor – random effect); $\bar{d}$ = mean difference; SD = standard deviation. CI = confidence interval and CT = concordance threshold.

Figure 1 shows the HS variation according to age in the male group and depicts the 11 years old with steeper HS slope.

The equation which represents the HS of dominant side, according to the guidelines by the ASHT, is: $HS = 14.99 + [31.19 / (1+exp^{-(Age - 14.19)/1.46})]$ with $R^2 = 0.67$ (figure 1). While the equation for the non-dominant side in the male gender is: $HS = 9.80 + [29.37 / (1+exp^{-(Age - 13.84)/1.95})]$ with $R^2 = 0.63$ (figure 1).
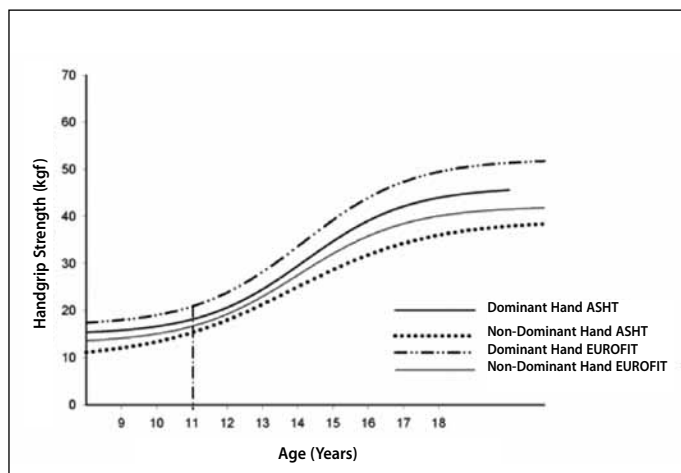

Figure 1. HS variation according to age in the male gender.

The test recommendation, according to the guidelines by the Eurofit, has the equation $HS = 16.82 + [35.35 / (1+exp^{-(age - 14.14)/1.54})]$ for the dominant side with $R^2 = 0.71$. In the non-dominant side, with the same guideline, the equation is: $HS = 13.07 + [29.07 / (1+exp^{-(Age - 14.00)/1.54})]$ with $R^2 = 0.66$ for the male gender (figure 1).

Regarding the female group, 10 years old represents the steeper slope on HS (figure 2). The equation which define strength for the dominant side in this gender according to the ASHT is: $HS = 5.06 + [36.61/(1+exp^{-(age - 13.25)/2.51})]$ with $R^2 = 0.70$. While for the non-dominant side, according to the ASHT, the equation is: $HS = 6.81 + [27.01 / (1+exp^{-(age - 13.56)/1.81})]$ with $R^2 = 0.68$.

The dominant side, according to the guidelines by the Eurofit, for the female gender, presents the equation $HS = 10.30 + [26.72 / (1+exp^{-(age-12.34)/1.53})]$ with $R^2 = 0.64$. The non-dominant side presents $HS = 7.01 + [31.25 / (1 exp^{-(age - 13.59)/2.31})]$ with $R^2 = 0.68$. All equations are represented by figures 1 and 2.
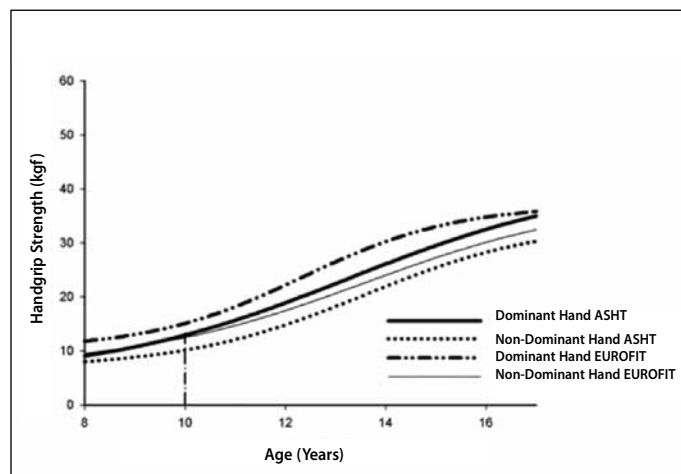

Figure 2. HS variation according to age in the female gender.

DISCUSSION

The main hypothesis of this study was that there was no difference between the guidelines to assess HS. The results presented here support this hypothesis; however, we must consider the presence of type II error in the sample of the female gender. The data from the Brazilian Tennis Confederation presents the number of female tennis players as approximately one third of the male ones for the youth categories. This fact added to the inclusion criterion of the sample provided the difference between the number subject tested.

Other studies evaluated the difference in elbow position to assess the HS in non-athletes and the results are clashing. Kuzala and Vargo[23] found greater HS with extended elbow for adults, while Mathiowetz et al.[24] mentioned greater HS with elbow flexed at 90 degrees in female occupational therapy students. The study by Su et al.[25] refers greater HS value with elbow in extension for Chinese adults. These authors also suggest that the ethnic variation is decisive for the chosen guideline for HS assessment. Other factors which should be considered in the HS evaluation are the sports activity and age, characteristics which are approached in the present study.

A condition which can influence the chosen test guideline is the presence of lateral epicondylitis of the humerus. De Smet and Fabry[26] investigated the relation between this condition and the chosen guideline to assess HS in non-athletes and found lower HS in elbow extension only in the limb with the condition. Due to the difficulty in choosing suitable treatment for lateral epicondylitis of humerus in tennis players[26], the equations of the present study are an interesting instrument for the estimation of the suitable HS value, which would enable adequate return to the sport based on HS evaluations specific to tennis players.

Some studies show that adult tennis players present alteration in the body composition of the dominant side[9,10]; these alterations are influenced by the hormonal presence, a fact which justifies the reason why the difference between limbs occurs from 14 years old in the male gender. Other aspects besides hormonal ones, such as the enzymatic activity[27], muscle fiber composition[28] and stage of maturation[29], also present correlation with strength development in adolescents. Thus, the influence of metabolic factors should be specifically investigated for tennis players under development in future studies.

HS difference between the dominant and contralateral limbs has been approached by Lucki and Nicolay[30] in tennis players aged between 19 and 24 years. These authors demonstrated greater HS of the dominant hand compared to the contralateral one both for men and women. Sartorio et al.[31] studied a sample of individuals from both sexes who did not practice sports and found greater HS of dominant hand from nine years old. However, the metabolic factors of the difference between limbs and its variation according to age for adolescent tennis players have not been explored.

One of the indicators of the hormonal participation would be an increase in the HS strength. The study by Marrodán Serrano et al.[20] presented greater HS increase for the female gender at nine years of age, and at 13 years of age for the male gender.

The comparison of boundary ages in the increase of HS strength with the present study could be an indication that the sports activity would be responsible for acceleration in maturation. Nevertheless, there is usually variability of this boundary ages between studies. One example is shown by Sartorio et al.[31], in which the increase in HS is steeper at 11 years old regardless of gender. Both authors evaluated individuals who do not practice any sports activity.

CONCLUSION

HS evaluation did not present difference between the test protocols suggested by the ASHT and the Eurofit. The dominant side of tennis players presented greater HS compared to the contralateral side only for the male gender from the category 14 years old, regardless of the protocol used for HS evaluation. Women did not present asymmetry in the HS comparison between sides, regardless of the type of protocol used for evaluation; however, one should consider the smaller number of female individuals assessed. HS presents a steep increase for11 years old in the male group and from 10 years old in the female group.

Subtitle: exp is approximately equal to: 2.718 (exp = exponential).

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