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Influence of age and sex on grip strength levels applying a protocol with different elbow angles
Influencia de la edad y del sexo en los niveles de fuerza de agarre en función del ángulo del codo empleado

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Abstract. There are various protocols for conducting hand grip strength assessment, but there is different opinions and evidence on the best elbow posture to develop the test. Additionally, the possible variability in the biomechanical mechanism involved in the generation of force when comparing an adult and other age groups such as young adolescents and the elderly is an aspect to consider. Objective: To evaluate handgrip strength in two elbow positions, with elbow extension and 90 ° flexion, in men and women of two age groups, young adolescents and older adults, and to analyze whether these different conditions influenced the handgrip strength results obtained. Methods: 119 adolescents and 121 older adults, executed each handgrip strength testing protocol three times with the dominant hand and the highest reading was recorded. After that, anthropometric (Weight, Height, BMI) and demographic data have been collected. Results: In both age group, adolescents and older adults, presented a significant greater handgrip strength in both sex in the collection protocol performed with full elbow extension. A statistic difference also was found in the level of strength, between women and men, for adolescents and older adults. Conclusions: We conclude that the evaluation protocol with the elbow extended was significant better manual grip values in both age groups and in both sexes. The protocol used for the evaluation of grip strength is influenced by the age and sex of the participants.
Key words. Handgrip; Jamar dynamometer; Exercise test; Physical fitness; Muscular fitness.

Resumen. Existen varios protocolos para realizar la evaluación de la fuerza de prensión manual, pero existen diferentes opiniones y evidencias sobre la mejor postura del codo para desarrollar la prueba. Adicionalmente, la posible variabilidad en el mecanismo biomecánico involucrado en la generación de fuerza al comparar un adulto con otros grupos de edad como jóvenes adolescentes y ancianos es un aspecto a considerar. Objetivo: Evaluar la fuerza de prensión manual en dos posiciones de codo, con extensión de codo y flexión de 90°, en hombres y mujeres de dos grupos de edad, adolescentes jóvenes y adultos mayores, y analizar si estas diferentes condiciones influyeron en los resultados de fuerza de prensión manual obtenidos. Métodos: 119 adolescentes y 121 adultos mayores, ejecutaron cada protocolo de prueba de fuerza de prensión tres veces con la mano dominante y se registró la lectura más alta. Posteriormente, se han recopilado datos antropométricos (Peso, Altura, IMC) y demográficos. Resultados: En ambos grupos de edad, adolescentes y adultos mayores, se presentó significativamente mayor fuerza de prensión manual en ambos sexos en el protocolo de recolección realizado con extensión completa del codo. También se encontró diferencia estadística en el nivel de fuerza, entre mujeres y hombres, para adolescentes y adultos mayores. Conclusiones: Concluimos que el protocolo de evaluación con el codo extendido fue significativamente mejor en los valores de agarre manual en ambos grupos de edad y en ambos sexos. El protocolo utilizado para la evaluación de la fuerza de prensión está influenciado por la edad y el sexo de los participantes.
Palabras clave. Empuñadura; dinamómetro Jamar; prueba de ejercicio; Aptitud física; Aptitud muscular.

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Introduction

The level of grip strength is an objective parameter used by different health professionals (physiotherapists, orthopedists, hand surgeons) to assess the functional integrity of the hand and upper limb. Grip strength reflects the raw power of the hand and has been found to be strongly associated with physical activity level (Burdukiewicz et al., 2020; Bohannon, 2019). Measurement of maximal grip strength is an essential element to follow people during growth, aging, injury, rehabilitation, training or therapeutic trials (Hogrel, 2015; Hershkovitz, Avital, et al., 2019; Stock, Thrane, Askim, Anke, & Mork, 2019).

The American Society of Hand Therapists (ASHT) recommends that the handgrip strength test should be performed with the elbow flexed at 90° (MacDermid et al., 2015), and also that this test be used to measure grip strength in patients with various disorders that compromise the upper limbs. Nevertheless, it is not clear if the 90° elbow position is most appropriate for achieving the maximal handgrip strength, since in the literature there are a large number of studies that report that the maximum handgrip strength was found when the protocol was applied in the position of full elbow extension (Balogun et al., 1991; Desrosiers et al., 1995; Kuzala & Vargo, 1992; Mathiowetz et al., 1985; Oxford, 2000; Watanabe et al., 2005; Xu et al., 2021).

Must also consider that most studies on the influence of elbow position with regards to the assessment of handgrip strength have been conducted with adults. Furthermore, handgrip strength has been shown to be influenced by different factors, such as sex and age (Vianna et al., 2007). The possible variability in the biomechanical mechanism involved in the generation of force when comparing an adult and other age groups such as young adolescents and the elderly, generates the need to investigate, also in these age groups, the variability depending on the position of the elbow during the test.

Bearing in mind that the protocol used when measuring handgrip strength influences the levels of strength achieved by those evaluated and that there are few publications on the differences between protocols in relation to

the generation of force depending on the sex and age of the individuals, the aim of this study was to evaluate handgrip strength in two elbow positions, with an elbow extension of 90 ° and 180 °, in men and women of two age groups, young adolescents and older adults, and analyze whether these different conditions influenced the handgrip strength results obtained.

Material and methods

Study participants

The sample was made up of a total of 119 adolescents (Age, 12.28 ± 0.52 years; 38.6% women) and 121 healthy older adults (Age, 71.40 ± 6.70 years; 61.4% female) who volunteered to participle in the present study. The sample selection was based on the facts that the assessment of handgrip strength in adolescents is a measure of "health" and that in older adults it is an indicator of their functional capacity.

Study design

A cross sectional study has been developed.

Testing procedures

Two days before the initiation of the study, the participants underwent a familiarization session, in which the testing procedures and the operation of the instrumentation (Handgrip) were explained. All performed each test twice (Elbow extended and Elbow flexed) with both the right hand and the left hand. Following the familiarization session, the research staff traveled 8 times to the primary school and 8 times to the gym where healthy older adults performed their physical exercise programs. The participants executed each testing protocol three times. After the evaluation of the manual pressure force was completed, anthropometric (Weight, Height, BMI) and demographic data have been collected.

The research staff reported to the building (Primary school and Municipal Gym) on the morning of testing. On each visit, the participants performed a standardized warmup that included 3 preliminary handgrip trials at a very low intensity, a level incapable of provoking muscle fatigue. We followed the ASHT recommendations for hand-grip strength testing, using a portable hydraulic dynamometer (Jamar, 5030J1; Jamar Technologies, Horsham, PA) which was professionally calibrated before the study. Instructions were given to the participants in the same sequence and included: 1. Proper handling of the dynamometer with the uppermost handle resting on the thenar eminence, 2. Adequate provision for the fingers to maintain a firm grip on the lower adjustable handle of the dynamometer and 3. A clear command “to squeeze the handle of the dynamometer as hard as possible and to hold it in place for five seconds (Balogun et al., 1991).

We measured the grip strength of the dominant hand in two positions: 1. Standing with elbow in full extension. 2. Standing with elbow in 90º flexion. The two conditions of the tests were randomly presented, and one tester was responsible for all the measurements. With each position, three attempts were made, and the highest reading was recorded for the test (MacDermid et al., 2015), but in this study the adolescents and older adults were standing. Handgrip strength levels are higher when the test is performed in a standing position as compared to sitting (Innes, 1999). The participants were instructed to maintain the shoulder slightly abducted (approximately 10º), elbow flexed at 90º (fixed with universal goniometer), forearm in neutral position (España-Romero et al., 2010).In the protocol with the elbow extended, the adolescents and older adults were standing during the entire test with their arm straight down at their side, with the shoulder slightly abducted (approximately 10º), the elbow in full extension, the forearm in neutral position, and the wrist also extended.

The study conforms to the standards set out in the Declaration of Helsinki. In the case of minors, parents or legal guardians were informed of the study. The parents of the primary school students and also the healthy older adults signed an informed consent form. Prior to the initiation of the study, the local ethics committee approved the study.

Data analysis

A descriptive analysis stratified by sex (men *vs* women) and age group (young adolescents *vs* older adults) of the main anthropometric variables was carried out. Differences between elbow position (full extension and 90º flexion), within each group, were analyzed by unpaired Student's t-test. Whether there were differences according to sex in each elbow position was also analyzed through unpaired Student's t-test. An analysis of variance (ANOVA, 2X2) of two factors (sex and age group) was carried out to determine the existence of significant differences and percentage of difference between the two elbow positions.

Results

The characteristics of the sample are shows in Table 1. In total 240 individuals were evaluated, and the values of each group are shown in the table for age, weight, height, and body mass index.

Table 2 shows the differences between the handgrip assessments protocols in the two groups evaluated: adolescents and the elderly. For adolescents, greater handgrip strength was observed in both genders in the collection protocol performed with full elbow extension. For men the difference was 3.87% between the values, this being significant ($p>0.001$). For women, the difference was 4.06% and was also significant ($p>0.001$). As for the comparison between sexes in the adolescent group, significant differences were also observed in both protocols for the values obtained between boys and girls ($p>0.05$).

Table 1.
Descriptive analysis of the sample

		Men (n=87)				Women (n=153)			
		mean	SD	Min	Max	mean	SD	Min	Max
Adolescents (n=119)	Age (years)	12,25	0,51	12,00	14,00	12,31	0,53	12,00	14,00
	Weight (Kg)	51,17	12,94	35,00	91,00	47,75	8,71	34,00	78,00
	Height (cm)	157,73	8,38	140,00	177,00	156,07	6,59	140,00	172,00
	BMI (kg/m^2)	20,33	3,57	15,18	30,06	19,55	2,93	13,17	27,16
Older adults (n=121)	Age (years)	74,70	5,71	62,00	85,00	70,46	6,69	60,00	82,00
	Weight (Kg)	74,79	6,79	59,30	93,90	69,79	9,38	44,70	100,20
	Height (cm)	161,03	5,37	147,50	169,00	154,27	6,28	142,00	165,00
	BMI (kg/m^2)	28,91	3,02	23,35	35,97	29,35	3,71	20,13	41,71

BMI: Body Mass Index

Table 2.
Differences between handgrip evaluation protocols according to age and sex.

		Men (n=87)		Women (n=153)	
		mean	SD	mean	SD
Adolescents (n=119)	Extended (kgf)	27,60	7,28	26,05	4,18$
	Flexed (kgf)	26,53	6,87	24,99	3,83$
	Difference	-1,07	2,20	-1,06	2,57
	% difference	3,87		4,06	
	t; p	t=-3,741; p > 0,001;		t=-5,518; p > 0,001;	
Older adults (n=121)	Extended (kgf)	34,11	7,06	28,30	6,03$$
	Flexed (kgf)	32,22	6,61	26,85	5,42$$
	Difference	-1,88	1,31	-1,44	0,87
	% difference	5,12		5,54	
	t; p	t=-7,488; p > 0,001		t=-16,028; p > 0,001	

$$ differences between genders p>0.001; $ differences between genders p>0.05

The same behavior of the values was also observed in the older adult group, with greater handgrip strength demonstrated in the elbow extension protocol. Significant differences were recorded in both sexes for the two handgrip strength protocols performed. For men, the difference was 5,12% between the values, this being significant ($p > 0.001$). For women, the difference was 5,54% and was also significant ($p > 0.001$). As for the comparison between the sexes in the group of older adults, significant differences were also observed in both protocols for the values obtained between men and women (p>0,001).

Analysis of variance (2X2) revealed that both factors have significantly interacted in levels of handgrip strength regardless of the assessment protocol applied (elbow in full extension protocol: $F = 5,981$; $p = 0.015$ and elbow flexed 90º protocol: $F = 3,576$; $p > 0.040$).

In figure 1 the average of the measurements obtained by the two protocols is plotted by Bland and Altman plots, versus the difference in measurements between them. The results reveal how the group of adolescents presents greater dispersion within the differences in the measurements, as compared to older adults.

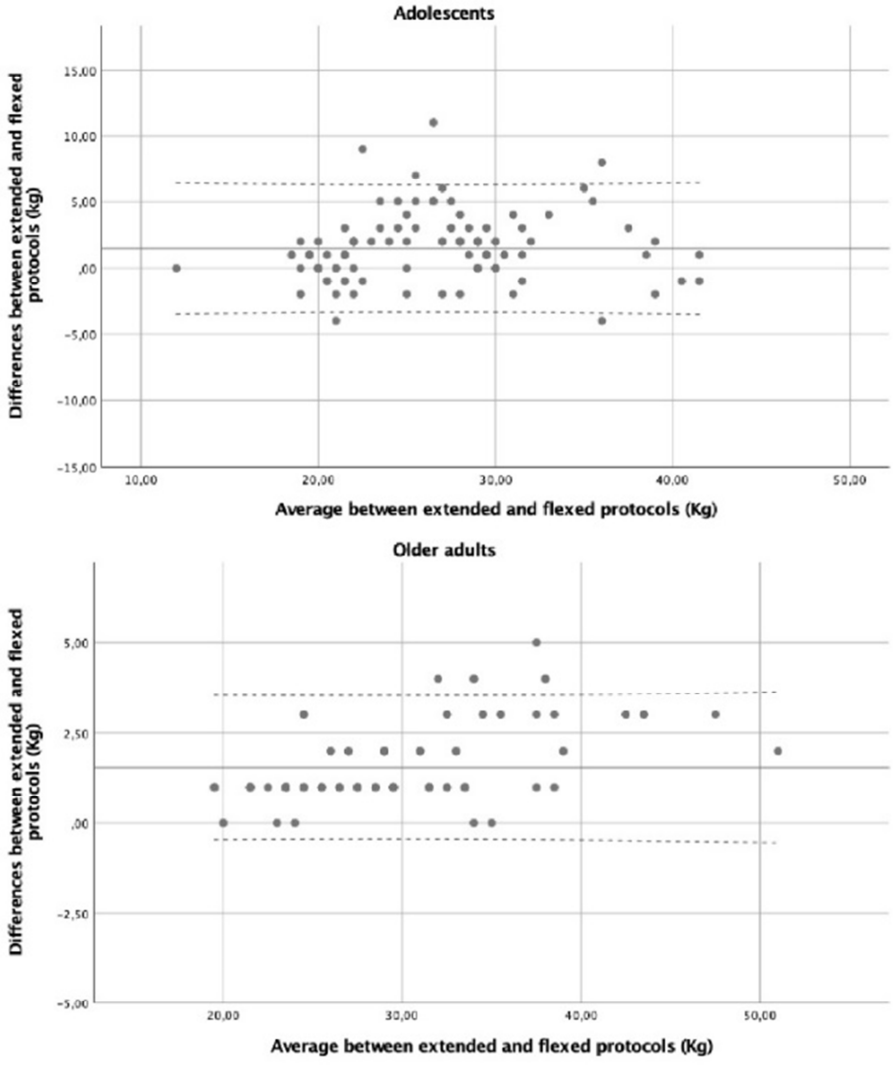

Figure 1. Average of the measurements obtained by the two protocols is plotted by Bland and Altman plots versus the difference in measurements between them

In figure 2, the average of the measurements obtained by the two protocols is represented by the graphs of Bland and Altman versus the level of force reached between them. The results show that the higher the level of strength, the greater the difference between the protocols.

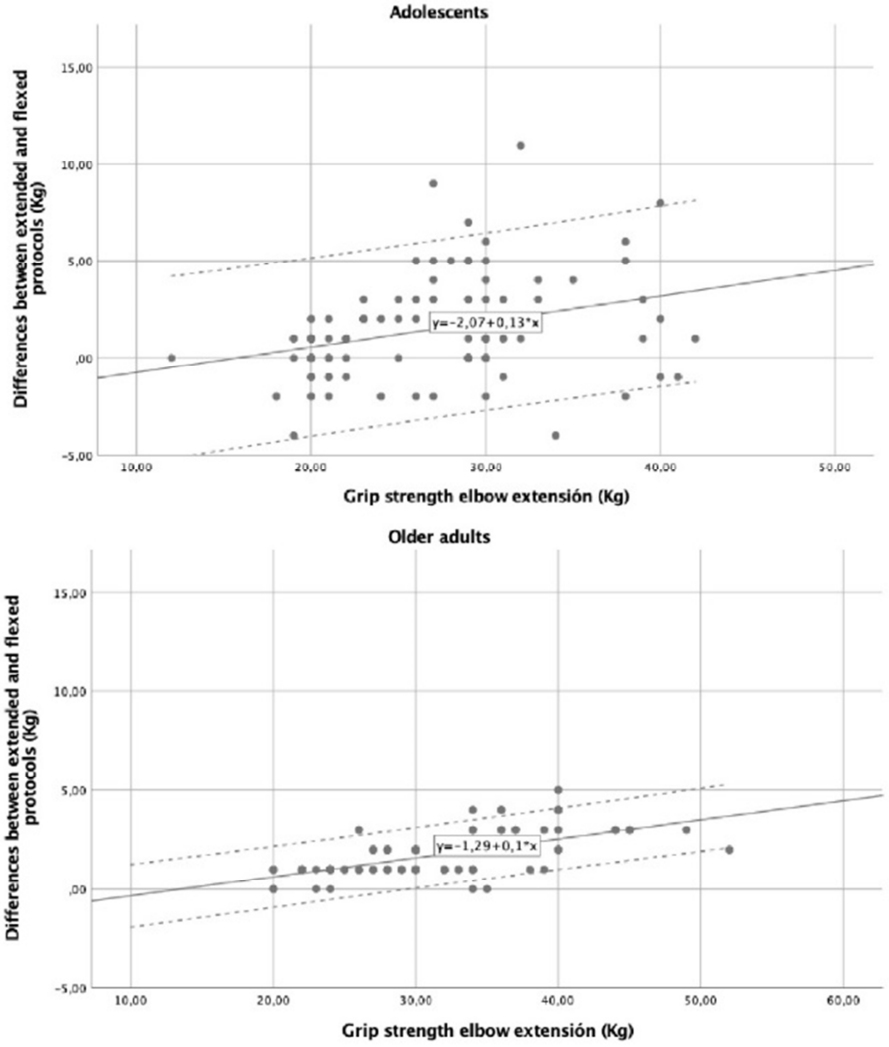

Figure 2. Average of the measurements obtained by the two protocols is represented by the graphs of Bland and Altman versus the level of force reached between them

Discussion

The results of the present study provide useful and relevant information regarding the position of the elbow in achieving maximum handgrip strength in young adolescents and older adults. Our findings suggest that, for the assessment of handgrip strength in young adolescents and older adults, the elbow must be in full extension, showing significant differences between the protocols in both sex and age groups, contradicting the protocol proposed by ASHT.

In previous studies, it has been reported that a greater handgrip force was exerted when the elbow was fully extended, explaining from a biomechanical perspective that these results were assessed with the elbow flexed, the superficial flexor muscle of the fingers, the only flexor muscle that crosses the elbow joint, is placed in a position which puts the subject at a mechanical disadvantage (Balogun et al., 1991; Desrosiers et al., 1995; Kuzala & Vargo, 1992; Mathiowetz et al., 1985; Oxford, 2000; Watanabe et al., 2005; Xu et al., 2021). In addition, the total extension of the elbow allows greater stabilization of the upper extremity and, therefore, more compensation, which produces a stronger grip (Desrosiers et al., 1995).

Our findings comparing the genders in the group of adolescents and the older adults are convergent with previous data for both groups, males show higher handgrip strength levels in both assessment protocols than females (Frederiksen et al., 2006; Godoy et al., 2004; Hillman et al., 2005; Hornby et al., 2005).

The confirmation of these findings was also performed with analysis of variance, where both the gender and age

interaction were significant in the two handgrip strength measurement protocols.

Corroborating our study, there is a previous study (Savva et al., 2013) that found evidence, in healthy young people, of greater handgrip strength with the elbow in extension, and which also indicated that the analysis of a broader age range was necessary in order to evaluate its usefulness as a result measure in clinical practice.

A further study (Werle et al., 2009) found a curvilinear relationship between handgrip strength and age in a large sample (n = 1023) of 18- to 96-year-old, with handgrip strength peaking in the 25 to 39 age group and declining gradually thereafter. It also recommended that the age and gender of the sample be reported along with reliability for any established normative data.

The data from our study shows significant differences in obtaining maximum handgrip strength with two different protocols, and calls to attention issues related to age and gender in this type of assessment. Furthermore, an important analysis was also carried out, the results of which showed that the higher the level of strength, the greater the difference shown between the different elbow positioning protocols.

Regarding the handgrip strength values obtained in the two protocols, the average difference in the measured values was greater in the group of adolescents, which showed greater dispersion in values as compared to the older adults. In the literature we found only one study that made the same comparison by age groups (Werle et al., 2009), and in this study behavior for dispersion contrary to our finding was reported. However, this difference can be explained by the average age of the groups evaluated - in the aforementioned study the age at which evaluation started was 18 years old, and for the elderly groups much older people were evaluated, the subjects being over 85 years old. In our study, the sample can be considered as inverse, since we evaluated adolescents with an average of 12 years of age and elderly people of 71 years, on average. In this study, it is further suggested that the group of elderly people over 75 be separated for the analysis of handgrip strength due to the continuous decline in the strength levels of this group.

Our study has some limitations such as the limited age group studied among adolescents, from 12 to 14 years old, which may imply a bias since they are young adolescents and many of them did not reach a stage of accelerated growth typical of them and we did not investigate those that have undergone this growth and development of musculoskeletal characteristics closer to those of adulthood. Similarly, the age group studied among the elderly is too wide, which can bias the variability that exists between the different groups within the elderly. The practical implication of this research is to begin to establish a reference framework for the variability that exists in the respective age groups studied in relation to the position adopted by the elbow during the measurement of force with this test and the possible publication of the values of reference in both elbow positions in the different age ranges, including the entire range of adolescence and the elderly.

Conclusion

This research has allowed us to conclude that the protocol used for the evaluation of manual grasping has a significant influence on the levels reached by adolescents and older adults. The evaluation protocol with the elbow extended was that which obtained the best manual grip values in both age groups and in both sexes. Sex was found to influence the levels of manual grasping, with men having the highest values regardless of the protocol used.

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Conflict of interests

None declared

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Author contributions

Design and concept of the study: KPPP, JMCC; the acquisition, analysis of data for the work: KPPP, JMCC; interpretation of data: JMC; drafting the manuscript of the study: JMCC, KPPP and IMO; revising the manuscript critically: JMCC and IMO; final approval of the version to be published: KPPP, JMCC and IMO.

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