

GRIP AND PINCH STRENGTH IN HEALTHY CHILDREN AND ADOLESCENTS

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ABSTRACT

Objective: This study aimed to determine and compare the values of maximum isometric palmar grip and pinch forces in healthy children between 6 and 19 years old using dynamometry, considering gender, dominance and age. **Methods:** 199 subjects were evaluated using Jamar® dynamometer to measure palmar grip strength and Preston Pinch Gauge® dynamometer to evaluate pulp to pulp, lateral and three points pinch strength in a standardization testing protocol. The mean of three consecutive grip tests was recorded. Linear regression with mixed effects was used to statistically analyze the differences between data. **Results:** Mean values found for palmar grip, pulp to pulp, three points and lateral pinch were 24,51kgf, 3,64kgf, 5,37kgf and 6,78kgf, respectively,

regardless of the variables. There was statistical difference in all measures by gender and dominance, and the dominant hand and the males had higher grip forces. It was verified that mean values varied with age, with significant difference in most of comparisons between the age groups. **Conclusion:** We concluded that pinch and palmar grip strength demonstrated significant differences in gender, dominance and in most of age subgroups studied, being important to consider them on dynamometry. This study was relevant as reference of normality of hand strength in children and adolescents.

Keywords: Evaluation. Muscle strength dynamometer. Pinch strength. Child. Adolescent.

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INTRODUCTION

The complex anatomical and functional structure of the hands converges mainly in gripping,¹ which is observed constantly during the activities of daily living (ADL) of any individual. For this reason the analysis of hand grip strength is an important item in the functional evaluation of the upper limb.

There are many classifications cited for gripping movements,^{1,2} yet there are four types recommended for functional evaluation with dynamometers: palmar grip, pulp to pulp, three-point and lateral pinch.²⁻⁵

Dynamometers perform quantitative measurements of maximum isometric muscle strength of the hand, and their use as a final result, that is, the mean value of the strength of three successive measurements is recommended.^{3,6} The data found can be compared with the contralateral hand of the same individual, when this is normal; alternatively, the parameters of normality existing in literature can be used.

This evaluation is useful to detect the degree of disability of the individual, to establish clinical, surgical or rehabilitation treatment goals, to verify the efficacy of the treatment performed through the patient's evolution, and also, to determine the functional prognosis. Palmar grip is performed by all the fingers. The integrity of the digitorum superficial and profundus muscles and of the intrinsic muscles of the hand allows the performance of powerful flexion of the phalanges from the 2nd to 5th finger. The action of the muscles of the thenar region and of the long flexor of the thumb perform the flexion of the 1st finger.⁷

The pulp to pulp pinch is performed between the pulps of the thumb and index finger, used to seize small objects, and is the most delicate and precise of the digital pinches.^{3,7}

The three-point (or tridigital) pinch is performed between the pulps of the thumb, index and middle fingers. It is used in about 60% of the ADLs, such as picking up a pen. It is a pinch of intermediate strength.^{1,8} In this position it is necessary for the superficial flexor

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muscle of the 2nd and 3rd fingers to stabilize the middle phalanges and for the thenar muscles to stabilize the proximal phalange of the thumb in flexion.⁷

The lateral pinch is performed between the pulp of the thumb and the radial lateral side of the middle phalange of the index finger, such as when a person picks up a key to introduce it into the lock.⁹ In this pinch the adductor musculature of the thumb plays an important role, confirmed by electromyography.¹ The first dorsal interosseous muscle stabilizes the index that is also assisted by the support of the other ulnar fingers, and the thumb acts through the action of the muscles of the thenar region and the long flexor.⁵ It is considered the strongest of the three pinches.^{3,8}

The standardization and the understanding of the method applied to measure strength, as well as the demographic factors, are important for studies that aim to discover the standards of normality of a population. There are few studies that seek to define the standards of normality of a sample of the Brazilian population for strength of palmar grip and of pulp to pulp, three-point and lateral pinch.^{8,10,11}

Therefore, the objectives of this study were to determine and compare the values of the isometric strengths of palmar grip and of the strengths of pulp to pulp, three-point and lateral pinch in healthy individuals, in the age bracket from six to 19 years through dynamometry.

MATERIAL AND METHODS

The participants of this survey were children and youths aged between six and 19 years, from a city located in the northeast of São Paulo state, who returned the informed consent terms, signed by the guardians, and a completed questionnaire, within one to two weeks.

The sample was probabilistic by clusters, with the random selection of three teaching institutions: two public schools and a University Center. The directors of these institutions authorized the performance of this survey.

A total group of 800 subjects was initially recruited and the exclusion criteria were: presence of previous or present pathology in the upper limbs; history of previous trauma in these limbs; ambidextrous individuals, as the proposal of this study, besides gathering the normative data for this population, was to compare the values determined for the dominant and non-dominant hand and subjects with signs of learning disorders due to delayed motor development, which could influence the measurements of strength. The final sample of the participants, after the exclusions, totaled 199 individuals.

The equipment used for the evaluation consisted of two dynamometers: *Jamar*® in the second position, for the measurement of palmar grip strength, and the *Preston Pinch Gauge*® for the strength of the digital pinches.

The dynamometers used and the positioning of the individuals during the collection were those recommended by the American Society of Hand Therapists (ASHT), Sociedade Brasileira de Terapeutas da Mão e do Membro Superior (SBTM) and by the International Federation of Societies for Surgery of the Hand (IFSSH).^{3,12,13}

The positioning during the evaluation was seated in a chair without armrests, with the feet resting fully on the ground and the

hip against the back of the chair. The arm remained parallel to the body, shoulder adducted, elbow flexed at 90° and forearm in neutral position, wrist between 0° and 30° of extension and 0° to 15° of ulnar deviation. (Figure 1) The fingers not involved in the pinches were semiflexed, since in this position it was demonstrated that the highest reliability coefficients were achieved.^{3,6,14}

A physical and functional assessment with inspection, palpation and active movement of the upper limbs to check the integrity of the musculoskeletal and neurofunctional system was carried out before the dynamometry. The dynamometers were calibrated prior to the start of each data gathering.

Three consecutive measurements of the hands were performed for each pinch and for the palmar grip, alternating between the dominant and non-dominant sides, with minimum interval of one minute between them to avoid muscle fatigue,¹⁵ totaling 24 measurements for each individual. All the measurements were made on a single occasion, always by the same examiner. The statistical model used was that of linear regression with

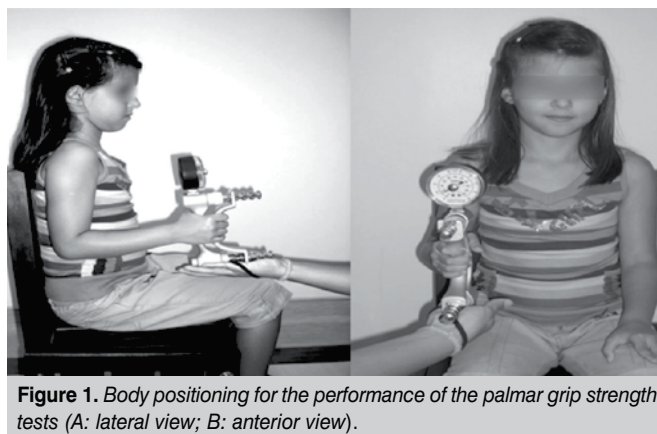


Figure 1. Body positioning for the performance of the palmar grip strength tests (A: lateral view; B: anterior view).

mixed effects (random and fixed effects). The mixed effects linear models are used in the data analysis when the answers are grouped (repeated measures for the same individual) and the supposition of independence among observations in the same group is not adequate.¹⁶ The variables analyzed were strength, age bracket, gender and dominance.

The age brackets were divided into subgroups of 6-7 years, 8-10 years, 11-13 years, 14-16 years and 17-19 years.

The survey was approved by the Committee of Ethics in Research of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto – Universidade de São Paulo (HCFMRP-USP).

RESULTS

Of the 199 participants, 118 were female and 81 male. In relation to dominance within the sample, 183 right-handed and 16 left-handed individuals (8%) were found.

Mean values of palmar grip strength were higher than those of the digital pinches ($24.51 \pm 5.6\text{kgf}$), while lateral pinch was the highest in relation to the others ($6.78 \pm 1.3\text{kgf}$). Pulp to pulp pinch obtained the lowest values ($3.64 \pm 0.8\text{kgf}$) and three-point pinch presented an intermediate result ($5.36 \pm 1.3\text{kgf}$).

The strengths increased as age progressed, with significance in the majority of age brackets.

The mean results found in the male and female genders by age brackets and by dominance, for the strengths of palmar grip and pinches, are listed in Table 1.

In the comparison by gender, the male subjects obtained higher measurements of strength in palmar grip and in all the pinches, with significant difference ($p < 0.05$), when the data were analyzed without any relationship with dominance and age bracket. However, when analyzed by age bracket, no significant difference was observed between the genders in subgroups 6-7, 8-10 and 11-13 years in palmar grip and in all the pinches, except in the three-point pinch, in the subgroup of 11-13 years, with $p < 0.04$. (Figures 2, 3, 4 and 5)

Comparing the results by the variables gender and dominance, the male gender exhibited higher values, with a significant difference in comparison with the female gender. In palmar grip the male strength was 30.6% higher than female strength in the dominant hand and 32.4% in the non-dominant hand. In the lateral pinch, the male group obtained higher mean strength, equivalent to 18.2% of the female gender for the dominant hand and 19.5% for the non-dominant hand. In the pulp to pulp pinch an increase of 18.3% was evidenced in the dominant hand with an increase of 16.7% in the non-dominant hand. This profile was the same in the three-point pinch, with the strength of the male gender 13% higher in the dominant hand and 18.5% in the non-dominant hand. (Table 2)

The muscle strengths of grips in the dominant hands exhibited higher mean values than those of the non-dominant hands, regardless of gender and of age bracket, with significant difference verified in both palmar grip and the pinches. In palmar grip it was 5% higher; in lateral pinch it was 4.6% higher; in the pulp to pulp pinch it was 12.5% higher and in the three-point pinch it obtained a value 6.5% higher. (Figure 6) However, when the variable dominance was analyzed by age bracket, there was no significant difference in the bracket of 8-10 years in palmar grip, 11-13 and 14-16 years in lateral pinch and 6-7 and 11-13 years in the three-point pinch.

In the comparison by age brackets in the measurements of strength of palmar grip and three-point pinch, regardless of gender and of dominance, a significant different was verified

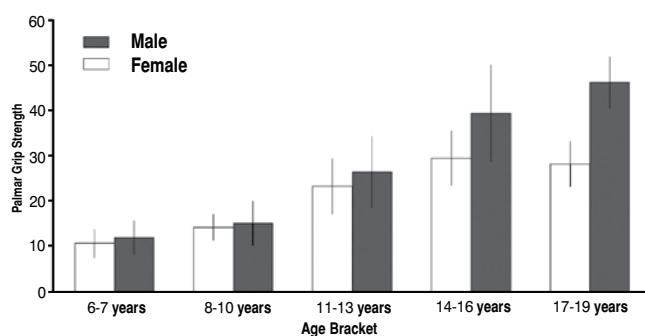


Figure 2. Mean muscle strength and standard deviation in kilogram-force (kgf) of palmar grip according to gender and age bracket.

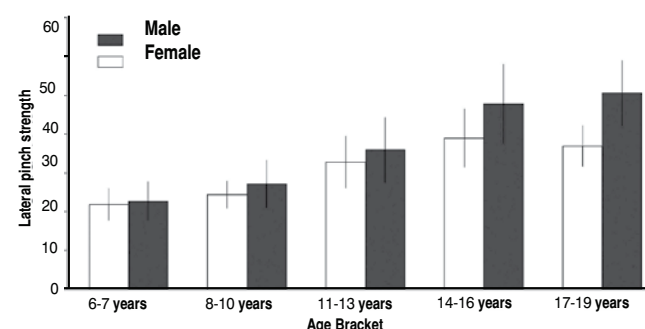


Figure 3. Mean muscle strength and standard deviation in kilogram-force (kgf) of lateral pinch according to gender and age bracket.

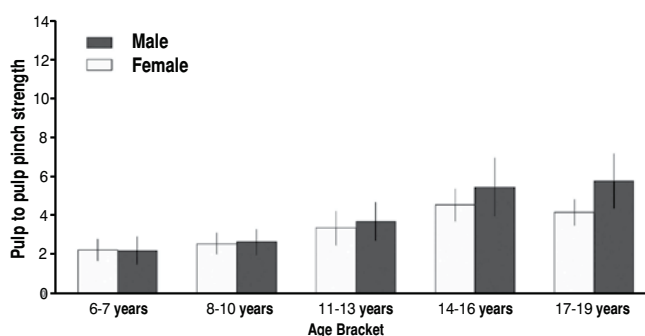


Figure 4. Mean muscle strength and standard deviation in kilogram-force (kgf) of pulp to pulp according to gender and age bracket.

Table 1. Mean muscle strength and standard deviation of palmar grip and of digital pinches, in kilogram-force (kgf), according to age bracket, gender and dominance.

Age Bracket	Palmar Grip				Lateral Pinch				Pulp to Pulp Pinch				Three-Point Pinch			
	Male		Female		Male		Female		Male		Female		Male		Female	
	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D	ND	D
6-7	11.8 3.94	12.19 3.66	9.97 3.25	11.44 2.79	4.41 1.00	4.68 1.00	4.25 0.89	4.52 0.74	2.05 0.67	2.32 0.75	2.12 0.59	2.3 0.50	3.24 0.95	3.2 0.91	2.91 0.82	3.13 0.69
8-10	15.16 4.89	15.20 5.02	13.84 2.62	14.66 3.01	5.34 1.21	5.54 1.26	4.72 0.63	5.04 0.70	2.50 0.58	2.76 0.70	2.38 0.47	2.69 0.57	3.63 1.13	3.86 1.04	3.73 0.80	4.15 0.82
11-13	25.39 7.84	27.64 7.96	22.78 6.32	23.77 5.84	7.11 1.82	7.25 1.59	6.47 1.36	6.66 1.33	3.51 0.98	3.85 0.98	3.24 0.82	3.44 0.88	5.81 1.86	5.52 1.56	4.63 1.30	4.97 1.20
14-16	38.20 10.2	40.56 11.28	29.09 6.23	29.84 5.84	9.48 2.23	9.67 1.91	7.68 1.52	7.91 1.49	5.13 1.64	5.78 1.31	4.28 0.84	4.77 0.79	8.15 2.34	8.64 2.04	6.44 1.01	7.19 1.63
17-19	45.69 5.47	46.66 6.01	27.19 5.12	29.19 4.84	9.79 1.63	10.43 1.72	7.10 0.99	7.66 1.08	5.28 1.05	6.24 1.60	3.79 0.47	4.50 0.65	7.35 1.56	8.08 2.14	6.09 0.98	6.54 1.08

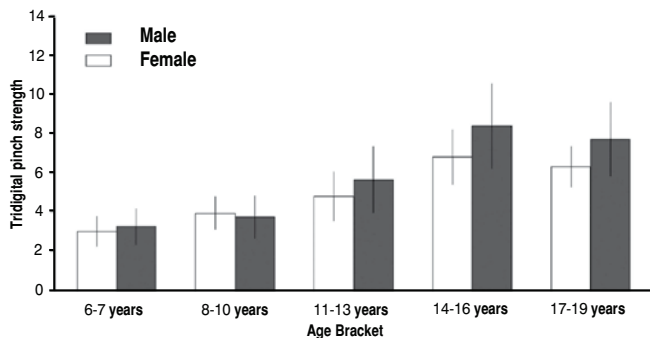


Figure 5. Mean muscle strength and standard deviation in kilogram-force (kgf) of the three-point pinch according to gender and age bracket.

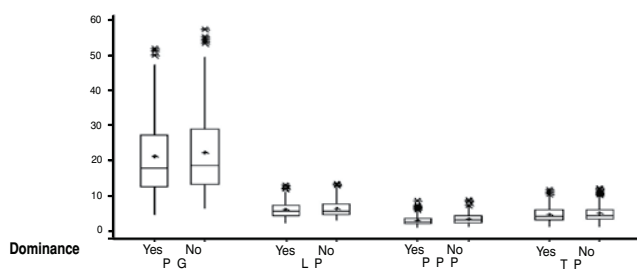


Figure 6. Results (in kgf) of Palmar grip (PG), lateral pinch (LP), pulp to pulp pinch (PPP) and three-point pinch (TP) according to dominance.

among all the subgroups. Between the measurements of strength of lateral and pulp to pulp pinch, a significant difference was verified among all the subgroups, except for the comparison of the age bracket of 14-16 years with that of 17-19 years. In the analysis by age bracket, in both the dominant and non-dominant hand, the mean value of the measurement of palmar grip strength were higher than those of the digital pinches. Lateral pinch presented higher values and the pulp to pulp pinch obtained the lowest values. The variability of the strength measurements was higher in palmar grip than in the digital pinches. (Figures 7 and 8)

DISCUSSION

The sample was probabilistic by clusters, which is a random sample of natural groupings of individuals in the population,^{17,18} since the study population is widely dispersed, with approximately 118,395 inhabitants in the age bracket of seven to 19 years. The initial sampling was of 800 students, but as the recruitment was mainly performed directly with individuals under 18 years of age, many (489 students) did not hand in the necessary documents to the persons in charge or did not return them by the stipulated deadline. Under the exclusion criteria 100 individuals were eliminated, with fractures and/or dislocations of the fingers having been the causes of greatest incidence. Nine individuals characterized as ambidextrous and three without authorization from the persons in charge were also excluded. When the losses within the sample occur at random, they do not produce a significant effect on the outcome of the investigation, being

interpreted as representative subsamples of the original sample.¹⁸ Therefore, these losses did not constitute selection bias. The choice of the minimum age for the survey to enable the analysis between dominant and non-dominant hand, was based on the concepts of: (a) normal psychomotor chronological development, in which a six-year-old child has already established dissociation of the hand and fingers, with the ability to write, and is also capable of distinguishing the two sides of the body⁹ and (b) in the Evolutionary Neurological Examination, according to Bachiega²⁰ in which the seven-year-old child recognizes right and left laterality in themselves. Since the individual is considered a young adult from the age of 20 years, henceforth considered a new phase in psychomotor development,¹⁹ the maximum limit of the age bracket of this study was stipulated as 19 years.

The female group was predominant, a result that is consistent with the population studied according to data from the Brazilian Institute of Geography and Statistics (IBGE).²¹ Another factor that influenced this result was that most of the individuals excluded due to traumatic lesions were male. In keeping with this fact, it was observed in the retrospective survey of Fonseca *et al.*²² that the male gender had the most traumas in the hands at a University Hospital from the same city (74%). Other related studies also obtained predominance of the female gender in the sampling.^{6,23}

When we compared strength between genders, it was observed that the male gender obtained higher values in palmar grip and in all the pinches, with a significant difference when the data were analyzed irrespective of dominance and of age bracket. Yet when this variable was analyzed in the age subgroups, there was only significant difference in the age bracket of 14-16 years and in that of 17-19 years, in both grip and the pinches, and in the 11 to 13 year bracket, in three-point pinch only. This can be explained by the onset of puberty, where the increase of strength between the genders can be different due to the androgenic action of testosterone,²⁴ and also because boys, during the growth spurt, which usually occurs after the age of 14, tend to increase the difference in strength gain in comparison to girls.²⁵

The male group exhibited a sharp increase in strength from the age of 14 years while the female group continued gradual. This fact was also verified in another study with children and adolescents, aimed at establishing the normative data in the North American population.⁶

Bear-Lehman *et al.*²³ conducted a study with 81 preschool children, between three and five years, with the *Jamar*® dynamometer in the second position and the *Preston Pinch Gauge*®. They concluded that children at this age can be tested using the conditions standardized for evaluation of these strengths. This study confirms the possibility of tests with dynamometers in children.

Comparing the results of palmar grip strength of this study and another national study that assessed adults between 20-59 years of age,¹¹ it was verified that the differences in strength between genders in individuals from 6-19 years of age (in the dominant hand 30.6% higher in the males, and in the non-

Table 2. Mean muscle strength of palmar grip and of digital pinches, in kilogram-force (kgf), according to gender and dominance (ND = non-dominant, D = dominant).

	Palmar grip		Lateral Pinch		Pulp to pulp pinch		Three-point pinch	
	ND	D	ND	D	ND	D	ND	D
Male	27.25	28.45	7.22	7.51	3.69	4.19	5.64	5.88
Female	20.57	21.78	6.04	6.35	3.16	3.54	4.76	5.20

-dominant hand 32.4%) are not similar to those found in adults, where the results were 39.9% and 42.6% higher in the males, respectively in the dominant and non-dominant hand. This reinforces the purpose of this survey, which sought to establish normative data for this age bracket.

In both the male and female groups, the values in adults cannot serve as a reference for the age brackets of children and youths in the comparison between the dominant and non-dominant side either. A study demonstrated that the mean percentage difference among the adults was 10% higher in the dominant hand in the men and 12% in the women,¹¹ while in the children and youths it was 4.4% in the males and 5.9% in the females. In the study by Mathiowetz *et al.*⁶ in the United States (USA), aimed at assessing the same age bracket as this survey, the mean values were very similar, yet slightly higher. A difficulty in this comparison was that the age subgroups were not divided

in the same way and the variable dominance was not considered, using right and left hand instead, even with the sample containing 14.5% of left-handed subjects.

In Midwest Brazil, a study with 30 healthy youths of both sexes, aged between 18 and 23 years,¹⁰ obtained results considered similar for palmar grip strength with *Jamar*[®] dynamometer in the 2nd position, yet slightly higher when compared with the older age subgroup of this survey (17-19 years), conducted in the Southeast region, particularly in the males. This probably occurred because the sample included individuals of a slightly higher age than the subgroup of this study.

Imrhan and Loo²⁶ assessed the lateral, three-point and pulp to pulp pinches with the 2nd, 3rd, 4th and 5th fingers, using the *Preston Pinch Gauge*[®] dynamometer on 62 children, from five to 12 years of age, of both genders, in the USA. In our study, regrouping the three subgroups of age bracket from six to 13 years, the results were similar, yet it is worth emphasizing that there was a significant difference in all the pinches in the comparison between the subgroups of 6-7 x 8-10 years and between 8-10 x 11-13 years. This finding demonstrated that, for an adequate evaluation of the isometric strength of these pinches, the use of a single mean in more extensive age bracket groupings might not be indicated.

Only one national study was found on measurements of pinch strength with hydraulic dynamometry. In this study, Araújo *et al.*⁸ assessed 315 individuals of both genders between 15 and 74 years of age, in the city of São Paulo. The division was established in subgroups, one of which in the 15 to 19 year age bracket, with 25 youths (nine males and 16 females). Neither the standard deviation nor the values of the dominant and non-dominant hand were discriminated in the subgroups. These results are similar to those found in our survey, when we did not take dominance into consideration, and regrouped the subgroups from 14-16 years to that of 17-19 years, where we totaled 57 youths (27 male and 30 female). Yet there was significant difference between the dominant and non-dominant hands in all the pinches in the two subgroups, with the exception of the 14-16 year group in lateral pinch. Consequently, we deduced that this differentiation of dominance in the results is necessary.

CONCLUSIONS

The mean isometric muscle strength analyzed with the use of dynamometers in healthy individuals from six to 19 years of age, for the sample studied, was 24.51kgf (±5.6) for palmar grip; 6.78kgf (±1.3) for lateral pinch; 3.64kgf (±0.8) for pulp to pulp pinch; and 5.37kgf (±1.3) for three-point pinch.

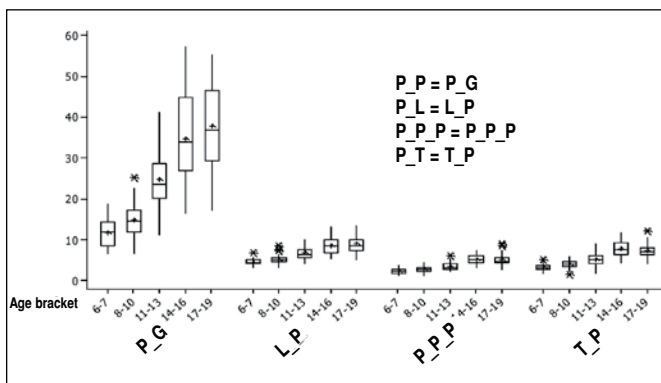


Figure 7. Results (in kgf) of palmar grip (PG), lateral pinch (LP), pulp to pulp pinch (PPP) and three-point pinch (TP) according to age bracket for the dominant hand.

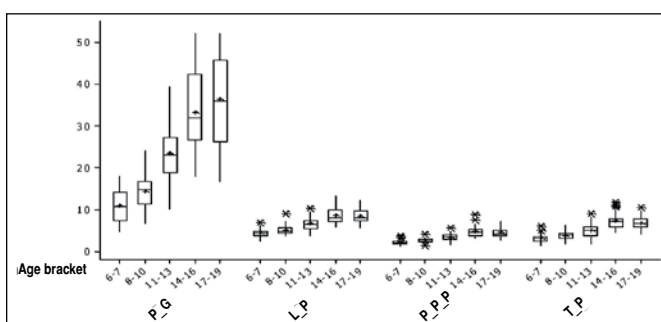


Figure 8 - Results (in kgf) of palmar grip (PG), lateral pinch (LP), pulp to pulp pinch (PPP) and three-point pinch (TP) according to age bracket for the non-dominant hand.

It is necessary to consider the influence of the age bracket, gender and dominance on the measuring with dynamometers. Finally, this study presents suggested reference values for the functional evaluations of isometric muscle strength of the hands in children and youths.

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