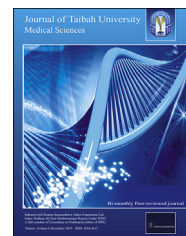




Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com



Original Article

Assessment of hand-grip and key-pinch strength at three arm positions among healthy college students: Dominant versus non-dominant hand

Tarek M. El-gohary, PhD^{a,*}, Samiha M. Abd Elkader, PhD^b,
Abdullah M. Al-shenqiti, PhD^c and Mahmoud I. Ibrahim, PhD^d

^a Department of Biomechanics, Faculty of Physical Therapy, Cairo University, Egypt

^b Department of Health Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, KSA

^c Physical Therapy Departments, College of Medical Rehabilitation Sciences, Taibah University, KSA

^d Department of Musculoskeletal Disorders & Its Surgery, Faculty of Physical Therapy, Cairo University, Egypt

Received 25 June 2019; revised 4 October 2019; accepted 7 October 2019; Available online 28 November 2019



المخلص

أهداف البحث: إن قوة القبضة مهمة للاستقلال بالرعاية الذاتية ومؤشر على الانخفاض الوظيفي. هدفت هذه الدراسة إلى تحديد ما إذا كان الأفراد الأصحاء سيظهرون قبضة لليد وقوة قرصة مختلفة: أولاً، عند اختبارهما في ثلاثة أوضاع مختلفة للذراع؛ وثانياً، عند المقارنة بين اليد المهيمنة واليد غير المهيمنة.

طرق البحث: تم استقطاب، وبصورة متتالية، ما مجموعه 61 من طلاب الجامعة الذكور من ذوي اليد اليمنى المهيمنة، الذين تتراوح أعمارهم بين 19 و23 سنة من كلية علوم التأهيل الطبي. أخذت القياسات عن طريق ثلاثة من الباحثين. ضُبط مقبض "جامار" لقياس القبضة اليدوية على الموضع الثاني لجميع الفحوصات. وتم توجيه المشاركين للضغط على المقبض اليدوي في حالة انثناء الكوع 90 درجة، وحالة انحناء الكتف 90 درجة، وحالة الذراع المتبدلية. فيما يتعلق بقوة القرصة، كان على كل مشارك أن يضغط على لوحة الإبهام مقابل الجانب الوحشي للعظمة الوسطى للسبابة. وتم قياس قوة القرصة من نفس المواضع المستخدمة لقياس قوة قبضة اليد. أخفيت النتائج عن المشاركين.

النتائج: لم تُظهر قبضة اليد وقوة القرصة تأثيراً كبيراً. كما أنه لم تكن هناك فروق ذات قيمة عند مقارنة قوة قبضة اليد اليمنى واليسرى. إلا أن قوة القرصة أظهرت زيادة كبيرة لصالح اليد المهيمنة.

الاستنتاجات: يمكن للأطباء اختيار أي موضع للطرف العلوي لقياس قبضة اليد وقوة القرصة. أظهرت هذه الدراسة أنه يجب على الأطباء الحفاظ على، واستعادة درجة قريبة جداً من قبضة اليد وقوة قرصة الأيدي المهيمنة وغير المهيمنة لتحسين وظيفة الأيدي.

الكلمات المفتاحية: مواضع الذراع؛ قبضة اليد؛ النزاهة؛ قوة قرصة المفتاح

Abstract

Objective: Grip strength is important for independent self-care and is a predictor of functional decline. This study aimed to determine if healthy individuals would demonstrate different hand-grip and key-pinch strengths at three different arm positions and in comparisons between dominant and non-dominant hands.

Methods: A total of 61 right-hand-dominant male college students aged 19–23 years were consecutively recruited from the College of Medical Rehabilitation Sciences. Three researchers performed the measurements. All tests were performed with the JAMAR® hand-grip dynamometer handle set in its second position. Participants were instructed to squeeze the handle of the hand-grip dynamometer in the 90° elbow flexion, 90° shoulder flexion, and arm dangled positions. For assessment of key-pinch strength, every participant had to squeeze the thumb pad against the lateral aspect of the middle phalanx of the index finger. Key-pinch strength was measured in the same positions used for assessment of hand-grip strength. Participants were blinded for the outcome measurements. The significance level was set at $p < 0.05$.

Results: The hand-grip and key-pinch strengths did not show significant effects. Comparison of right and left hand-grip strengths also showed insignificant differences. However, the key-pinch strength showed a significant increase in favour of the dominant hand.

Conclusions: Clinicians can choose any upper-extremity position to measure hand-grip and key-pinch strength.

* Corresponding address: College of medical rehabilitation, Taibah University, 7th Ahmed Elzayyat st. Dokki, Giza, Almadinah Almunawwarah, 12612, KSA.

E-mail: dr.elgohary@cu.edu.eg (T.M. El-gohary)

Peer review under responsibility of Taibah University.



Production and hosting by Elsevier

Furthermore, clinicians should aim to maintain and restore almost equal scores for hand-grip and pinch strength of the dominant and non-dominant hands to ensure better hand function.

Keywords: Arm positions; Hand-grip; Handedness; Key-pinch strength

© 2019 Taibah University.

Production and hosting by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

The Jamar-grip dynamometer is a simple,¹ viable,² valid, and reliable³ assessment tool that has been extensively used for assessment of upper-extremity strength impairments.^{4,5} Hand-grip dynamometer and pinch gauge readings are extremely useful tools to measure baseline function.^{5,6} Studies have revealed that grip strength is a reliable predictor of functional decline and disability.⁷ Syddall et al.² reported that maximum grip strength is significantly correlated with self-care independence. Maintaining muscle strength above the safety margin allows individuals to remain functionally independent for as long as possible.⁸ Therefore, good muscle strength acts as a reserve that protects healthy adults.⁹ Numerous studies have indicated that changes in upper limb positions during testing affect hand-grip strength,^{10–12} while other researchers did not observe any changes in hand-grip strength as result of changes in upper limb positions.¹³

In assessments of hand dominance, multiple studies have indicated differences in hand-grip strength between the dominant and non-dominant hands,^{14,15} However, several investigators have reported no such differences.¹⁶ With reference to pinch strength, several studies have investigated pinch strength using different ways of pinching; however, to the best of our knowledge, very few studies have examined the effect of changing upper limb position on specific pinch strengths.¹⁰ Similarly, there is no evidence to support differences in pinch strength between dominant and non-dominant hands.

Few studies have established reference values for hand-grip and key-pinch strengths in different positions.^{4,9} Moreover, despite the close interaction between posture and upper-extremity function, there is no recent consensus among researchers regarding the testing postures.¹⁷ In addition, norms for certain populations to which patients' hand-grip and key-pinch strength scores can be compared are not readily available.¹⁸ Therefore, this study aimed to investigate variations in hand-grip and key-pinch strengths at different upper limb positions. Furthermore, there is conflicting evidence regarding the relationship between right and left hand-grip and key-pinch strengths in normal healthy adults. Inclusion of novel measurement concepts will enable clinicians to arrive at an educated decision when designing a rehabilitation program¹⁹ to restore hand-grip and key-pinch strengths after any upper-extremity functional decline.

Materials and Methods

Participants

Sixty-one consecutive healthy, right-handed males aged between 19 and 23 years were recruited to participate in the study. The sample size was calculated using a sample size table and an online sample size calculator. We used a type I error of 5% and type II error of 20% for one study group. Many researchers encourage using a sample of participants close in age to obtain normal reference values of hand-grip strength among healthy subjects. The participants' demographic information was collected. All participants were students at the College of Medical Rehabilitation, Physical Therapy Division. Participants were included if they were between 19 and 23 years of age, right-hand dominant, healthy, and free from any physical disability or significant pain. The operational definition of handedness in the current study was the relative preference for one hand in the performance of unilateral tasks. Such a definition has been widely reported in the literature. We excluded subjects who had a history of spinal or arm surgery, were suffering from major health problems, showed physical disability or diabetes, or were underweight.

Procedure

The subjects provided written informed consent after the study protocol was explained to them. The investigator examined the functional mobility of the right and left shoulder joints. Three investigators were trained to carry out reliable measurements. Researchers instructed every subject to demonstrate superior Apley's test of the right shoulder and inferior Apley's test of the left shoulder, followed by superior Apley's test of the left shoulder and inferior Apley's test of the right shoulder. The therapists measured the distance between the fingertips of the right and left middle fingers using a tape measure. A single JAMAR hand-grip and key-pinch strength dynamometer (Sammons Preston, Bolingbrook, IL) was calibrated according to the manufacturer's specifications.^{4,5} The JAMAR hand-grip dynamometer handle was set in its second position²⁰ and used for all tests. A pinch gauge was used for testing the key-pinch strength. The investigators demonstrated the activity to the participants. Hand-grip strength and key-pinch strength for both hands were recorded in a single session. The order of measurements was counterbalanced, and every participant was instructed to generate the maximum possible force during a single repetition. Every participant was instructed to sit comfortably in an armless chair with the feet touching the floor. Participants had to sit with the trunk upright, elbow flexed to 90°, forearm and wrist in a neutral position, and not touching the trunk. The face of the gauge was positioned away from the participant's face. Every participant was instructed to squeeze the handle of the dynamometer as hard as possible. For assessment of key-pinch strength, the examiner held the distal end of the pinch gauge while the participant was instructed to squeeze the thumb pad against the lateral aspect of middle phalanx of the index finger. The key-pinch grip was chosen since it has been widely reported in literature.⁵ All measurements for hand-grip and key-pinch

strengths were recorded in one-pound (1 lb = 0.45 kg) increments. Measurements were taken in three different positions: 90° elbow flexion, 90° shoulder flexion, and with the arms dangled (Figures 1a, b, and c and 2a, b, and c).

Statistical analysis

A two-way mixed factorial design analysis of variance (ANOVA) was run to compare the strength output in multiple arm positions and between dominant and non-dominant hands. The analysis was conducted for hand-grip strength as well as for key-pinch strength. A paired-sample *t* test was run to compare the mean scores of the right and left sides during the tests for hand-grip strength and key-pinch strength. Pearson correlation analyses were performed to examine the relationship between participants' strength output values obtained for every position when testing for the hand-grip strength and key-pinch strength. A paired-sample *t* test was run to compare the mean mobility

score in the right superior left inferior Apley's scratch test with that in the left superior right inferior Apley's scratch test. Statistical significance was set at $\alpha \leq 0.05$. IBM SPSS 20.0 was the software used for all data analyses (IBM Corp. Armonk, N.Y., USA).

Results

Participants' descriptive statistics and demographics are presented in Table 1. A 3×2 mixed-design ANOVA was performed to examine the effects of arm positions (elbow flexed to 90°, shoulder flexed to 90°, and arms dangled) and arm dominance (dominant and non-dominant hands) on hand-grip and key-pinch strength.

For hand-grip strength, no significant main effects or interactions were found. The arm position \times hand dominance evaluation [$F(2,240) = 0.371, P > 0.05$], the main effect of arm positions [$F(2,240) = 2.173, P > 0.05$], and the main effect of hand dominance [$F(1,120) = 0.308, P > 0.05$] were

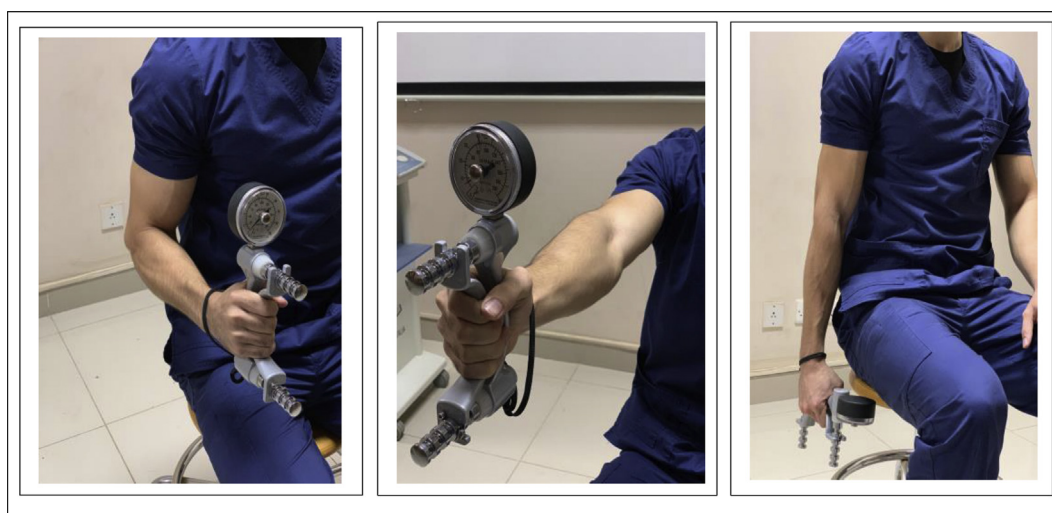


Figure 1: Hand-grip strength test using the hand-grip dynamometer (a. 90° elbow flexion, b. 90° shoulder flexion, and c. arm dangled position).



Figure 2: Key-pinch strength test using the pinch gauge (a. 90° elbow flexion, b. 90° shoulder flexion, and c. arm dangled position).

Table 1: Demographic data of the study participants (N = 61).

Characteristics	Mean	SEM	Range
Age (years)	20.36	0.11	19–23
Height (cm)	171.72	0.79	158–188
Weight (kg)	72.04	2.03	50–120
BMI	26.6	0.12	23.1–29.8
Upper arm length (cm)	37.2	0.06	35.3–39.1
Midarm circumference (cm)	31.2	0.10	28.9–33.1
Triceps skinfold (mm)	12.6	0.20	11.8–14.00
Subscapular skinfold (mm)	19.4	0.32	18.7–21.3
RtSupLtInfApley’sScratch (cm)	1.64	4.11	00–22
LtSupRtInfApley’sScratch (cm)	3.80	6.20	00–26

SEM, standard error of mean; RtSupLtInfApley’sScratch, right superior left inferior Apley’s scratch test.

LtSupRtInfApley’sScratch, Left superior right inferior Apley’s scratch test.

insignificant. Hand-grip strength scores were not influenced by either arm position or hand dominance. No post-hoc comparisons were needed since the results were insignificant. Mauchly’s test of sphericity yielded insignificant findings with $P > 0.05$, which indicates that the variances in the differences between all possible pairs of levels of arm positions are equal. Box’s test of equality of covariance matrices was significant at $P < 0.05$, which indicates that the observed covariance matrices of the dependent variables were equal across groups.

For the key-pinch strength, no significant interaction effect of the arm position \times hand dominance [$F(2,240) = 0.547, P > 0.05$] was found. The main effect of arm positions [$F(2,240) = 2.707, P > 0.05$] was also insignificant. However, the main effect of hand dominance [$F(1,120) = 4.327, P < 0.05$] was significant. A paired-sample t test was performed to compare the mean scores of the right and left hands. For the hand-grip strength, no significant difference was found in any comparison, as shown in Table 2.

In assessments of the key-pinch strength, significant differences were found for all comparisons (Figure 3). At the 90° elbow flexion position, a significant increase from the left side to the right side was found [$t(60) = 3.52, p < 0.005$]. A moderate positive correlation was found [$r(59) = 0.5$], indicating a significant linear relationship between the two variables. At 90° shoulder flexion, a significant increase from the left side to the right side was found [$t(60) = 2.49, p < 0.05$]. A moderate positive correlation was found [$r(59) = 0.6$], indicating a significant

Table 2: Strength outcomes of hand-grip and key-pinch comparing right and left side.

Strength output	Right side	Left side	t	p Value
Hand grip				
90° Elbow flexion	82.5 \pm 15.7	81.1 \pm 15.6	0.99	>0.05
90° Shoulder flexion	84.8 \pm 18.4	82.4 \pm 16.8	1.58	>0.05
Arm dangled position	82.9 \pm 16.6	81.9 \pm 16.1	0.57	>0.05
Pinch grip				
90° Elbow flexion	19.4 \pm 3.8	17.8 \pm 3.4	3.25	<0.005
90° Shoulder flexion	19.5 \pm 3.9	18.4 \pm 3.7	2.94	<0.05
Arm dangled position	18.6 \pm 4.2	18.8 \pm 4.1	2.68	<0.05

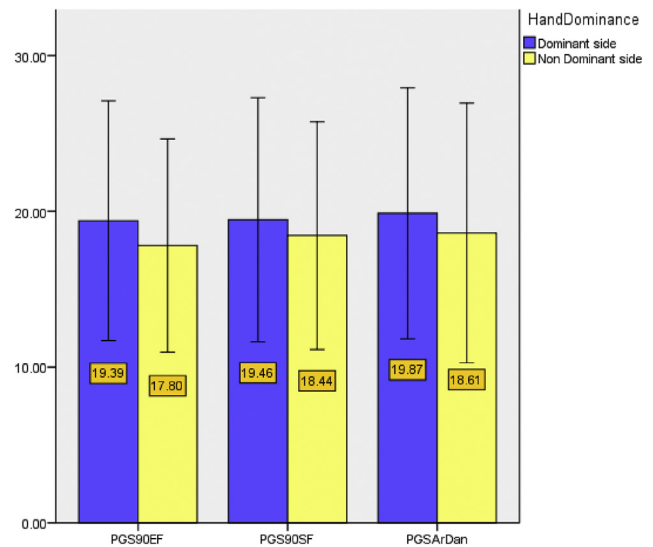


Figure 3: Key-pinch strength values in pounds (mean \pm SD) for the right and left hand at 90° elbow flexion, 90° shoulder flexion, and the arm dangled position.

linear relationship between the two variables. In the arm dangled position, a significant increase from the left side to the right side was found [$t(60) = 2.68, p < 0.05$]. A moderate positive correlation was found [$r(59) = 0.6$] indicating a significant linear relationship between the two variables.

The mean score on the left superior right inferior Apley’s scratch test was 3.80 [standard deviation (SD) = 6.21], and the mean score on the right superior left inferior Apley’s scratch test was 1.64 (SD = 4.11). A significant difference in mobility was found [$t(60) = -3.67, P < 0.001$]. Moreover, a moderate positive correlation was found [$r(59) = 0.68, P < 0.001$] indicating a significant linear relationship between the two variables.

Discussion

The findings of this study did not indicate any significant difference at different arm positions and between right and left hand-grip strength. However, left key-pinch strength was significantly less than right key-pinch strength.

Hand-grip strength values did not significantly vary with changes in arm positions since the shoulder and elbow positions have less effect on changes in the kinematics of the upper extremity when measuring distal gross motor strength. The findings reported by Farooq and Khan¹³ are in agreement with our results. In their study assessing 20 right-handed male participants with a mean age of 26.5 ± 6.4 years, upper limb postural deviations also showed no significant effect on grip strength. Conversely, Tayyari et al.¹² conducted a study on a sample of college students with a mean age of 22.5 ± 3.35 years to investigate the effect of elbow flexion on the hand-grip strength. Their results showed that elbow extension was associated with a significantly higher hand-grip strength than elbow flexion. Moreover, the hand-grip strength recorded in the 90° elbow flexion position was significantly higher than the values obtained in the 30°, 60°, and 120° elbow flexion positions.

Mullerpatan et al.¹⁰ investigated the grip strength in a sample of 1005 healthy adults, and their results showed that grip strength was significantly different at four different elbow positions. The maximum grip strength was recorded at the 0° elbow position, with a linear decline in grip strength noted at the 45°, 90°, and 135° positions. The findings obtained by Limbasiya et al.¹¹ are in agreement with the role of the interaction of elbow and wrist positions on grip strength. The researchers studied a sample of healthy participants and investigated the effect of joint interactions on hand-grip strength. La Delfa et al.²¹ confirmed the role of forearm rotation and wrist exertion direction on wrist strength.

Given that our sample contained a group of healthy subjects who were very close in age, no significant difference was detected. Our findings agree with the results of several studies that did not detect any difference in grip strength between dominant and non-dominant hands. Omar et al.¹⁶ studied 525 participants to compare the role of hand dominance in hand-grip strength. Their results showed that hand dominance has no effect on hand-grip strength. Their study sample consisted of a group of children who resided in KSA. The results obtained by McQuiddy et al.¹⁸ also showed that hand dominance has no significant effect on hand strength.

Conversely, several studies have shown a significant difference in hand-grip strength associated with hand dominance. A general rule regarding hand-grip strength suggests that the strength values for the dominant hand are approximately 10% greater than those for the non-dominant hand.¹⁴ However, our findings are not in agreement with the results of several studies that detected a difference between dominant and non-dominant hands. Hepping et al.¹⁴ studied a group of healthy participants by investigating hand-grip strength. The results showed dominance-specific differences, with a higher score when using the preferent hand. The recorded value was 9.5 for right-preferent boys. The findings obtained by Tayyari¹² and Hepping et al.¹⁴ concur with the role of dominance since the hand grip of the dominant hand in their study was significantly stronger in right-handed participants. The results obtained by Ferreira et al.¹⁵ are also consistent with the findings reported by most other researchers; they reported that the dominant hand is stronger than non-dominant hand.

The current study did not show any significant differences in pinch-strength values with changes in arm positions. The investigators attributed this to the fact that the study population consisted of healthy subjects who were very close in age. On the other hand, the authors who found significant differences associated with changes in arm positions did not agree on favouring a particular arm position. Mullerpatan et al.¹⁰ reported that pinch strength was significantly different at four different elbow positions. The maximum pinch strength was recorded at the 0° elbow position, with a linear decline over the 45°, 90°, and 135° positions.

There is a scarcity of literature reporting the role of hand dominance in changing key-pinch strength. In the present study, the key-pinch strength of the left side was significantly less than that on the right side, and the values for both sides were less than the accepted norms reported in literature. These findings are consistent with the findings obtained by

several authors who reported lower normal values for hand-grip and pinch strengths among age- and gender-matched populations from other continents in comparison with the known values.^{5,10,22}

In essence, the findings of this measurement study provide preliminary reference values for hand-grip and key-pinch strengths among healthy students in the College of Medical Rehabilitation, which can improve the potential for objective evaluation of hand-grip and key-pinch strengths in their age- and sex-matched cohorts in KSA. Measurements should be recorded using identical upper-extremity positions.²³ One of the limitations of the present study was that all participants were males since we only had access to male students at the time of the study. Clinicians will need to further assess the obtained reference values for hand-grip strength since males and females, even though healthy, would have different hand-grip strength values.

Conclusions

In conclusion, no difference among arm positions was found, indicating that any position according to the clinician's preference can be used to test for hand-grip and key-pinch strength. However, the left key-pinch strength is expected to be less than the right key-pinch strength in right-hand-dominant subjects. The reference values for hand-grip and key-pinch strengths that were observed in this cohort can be used as preliminary objective indices in functional assessment. Furthermore, these reference values have practical value for clinical evaluation of patients with upper-extremity disorders. Studies with larger sample sizes are needed to elucidate more robust hand-grip strength values that can be used in the clinical settings.²⁴

Source of funding

The authors declare that they did not receive any financial support for this work.

Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

Ethical approval was achieved from the institutional review board of the College of Medical Rehabilitation (CMR-PT-2018-002).

Authors contributions

TME, AMA, and SMA conceived and designed the study, while TME and AMA conducted data collection. TME, MII, and SMA analysed and interpreted the data. TME, MII, and AMA wrote the initial and final drafts. TME, AMA and SMA sent the paper for publication. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Acknowledgment

We would like to thank the physiotherapy students at the College of Medical Rehabilitation Sciences for recruiting and preparing healthy volunteers.

References

1. Granic A, Davies K, Jagger C, Kirkwood TB, Syddal HE, Sayer AA. Grip strength decline and its determinants in the very old: longitudinal findings from the Newcastle 85+ study. *PLoS One* **2016**; 9: 1–14.
2. Syddall HE, Westbury LD, Shaw SC, Dennison EM, Cooper C, Gale CR. Correlates of level and loss of grip strength in later life: findings from the English longitudinal study of ageing and the Hertfordshire cohort study. *Calcif Tissue Int* **2018**; 102: 53–63.
3. Bohannon RW. Test-retest reliability of measurements of hand-grip strength obtained by dynamometry from older adults: a systematic review of research in the PubMed database. *J Frailty Aging* **2017**; 6: 83–87.
4. Gilbert M, Thomas JJ, Pinaro A. Adult grip and pinch strength norms for the baseline digital dynamometer and baseline digital pinch gauge. *Am J Occup Ther* **2016**; 70.
5. Habibi E, Kazemi M, Dehghan H, Mahki B, Hassanzadeh A. Hand grip and pinch strength: effect of workload, hand dominance, age, and body mass index. *Pak J Med Sci* **2013**; 29: 363–367.
6. Ho ES. Evaluation of pediatric upper extremity peripheral nerve injuries. *JHT* **2015**; 28: 135–143.
7. Nacul LC, Mudie K, Kingdon CC, Clarrk TG, Lacerda EM. Hand grip strength as a clinical biomarker for ME/CFS and disease severity. *Front Neurol* **2018**; 9: 992.
8. Koopman JJE, van Bodegom, van Heemst D. Handgrip strength, ageing and mortality in rural Africa. *Age Ageing* **2015**; 44: 465–470.
9. Amaral CA, Amaral TLM, Monteiro GTR, Vasconcellos MTL, Portela MC. Hand grip strength: reference values for adults and elderly people of Rio Branco, Acre, Brazil. *PLoS One* **2019**; 14: e0211452.
10. Mullerpatan R, Karnik G, John R. Grip and pinch strength: normative data for healthy Indian adults. *Hand Ther* **2013**; 18: 11–16. <https://doi.org/10.1177/1758998313479874>.
11. Limbasiya RD, Ramlingam AT, Savaliya D, Anu J, Patel N, Tailor N. Effect of elbow and wrist joint position on grip strength. *IOSR-JDMS* **2016**; 15: 73–77.
12. Tayyari F. Effect of elbow flexion on hand-grip strength. *Ergon Int J* **2018**; 2:000134.
13. Farooq M, Khan AA. Effect of elbow flexion, forearm rotation and upper arm abduction on MVC grip and grip endurance time. *JOSE* **2012**; 18: 487–498.
14. Hepping AM, Ploegmakers JJW, Geertzen JHB, Bulstra SK, Stevens M. The influence of hand preference on grip strength in children and adolescents; A cross-sectional study of 2284 children and adolescents. *PLoS One* **2015**; 10(11).
15. Ferreira ACC, Shimano AC, Mazzer N, Barbieri CH, Elui VMC, Fonseca MCR. Grip and pinch strength in healthy children and adolescents. *Acta Ortopédica Bras* **2011**; 19: 92–97.
16. Omar MTA, Alghadir A, Al Baker S. Norms for hand grip strength in children aged 6-12 years in Saudi Arabia. *Dev Neurorehabil* **2015**; 18: 59–64.
17. Harbourne R, Kamm K. Upper extremity function: what's posture got to do with it? *JHT* **2015**; 28: 106–113.
18. McQuiddy VA, Scheerer CR, Lavalley R, McGrath T, Lin L. Normative values for grip and pinch strength for 6- to 19-year-olds. *Arch Phys Med Rehabil* **2015**; 96: 1627–1633.
19. Duff SV, Aaron DH, Gogola GR, Valero-Cuevas FJ. Innovative evaluation of dexterity in pediatrics. *JHT* **2015**; 28: 144–150.
20. Gasior JS, Pawlowski M, Williams CA, Dabrowski MJ, Rameckers EA. Assessment of maximal isometric hand grip strength in school-aged children. *Open Med* **2018**; 13: 22–28.
21. La Delfa NJ, Langstaff NM, Hodder JN, Potvin JR. The interacting effects of forearm rotation and exertion direction on male and female wrist strength. *Int J Ind Ergon* **2015**; 45: 124–128.
22. Mohammadian M, Alireza C, Haghdoost AA, HashemiNejad N. Investigation of grip and pinch strengths in Iranian adults and their correlated anthropometric and demographic factors. *Work* **2015**; 53: 429–437.
23. Dodds RM, Syddall HE, Cooper R, Kuh D, Cooper C, Sayer AA. Global variation in grip strength: a systematic review and meta-analysis of normative data. *Age Ageing* **2016**; 45: 209–216.
24. Wozny R, Pratt AL, Pereira C. A study of grip strength among 20-49- year-old British adults and comparison to existing norms. *Hand Ther* **2015**; 20: 115–123.

How to cite this article: El-gohary TM, Abd Elkader SM, Al-shenqiti AM, Ibrahim MI. Assessment of hand-grip and key-pinch strength at three arm positions among healthy college students: Dominant versus non-dominant hand. *J Taibah Univ Med Sc* **2019**;14(6):566–571.