

Original Article

Determining correlations between hand grip strength and anthropometric measurements in preschool children

Amira G. Mahmoud, MPT^{a,*}, Eman I. Elhadidy, PhD^b, Mohamed S. Hamza, PhD^c and Nanees E. Mohamed, PhD^b

^a Faculty of Physical Therapy, Misr University for Science and Technology, Giza, Egypt

^b Faculty of Physical Therapy, Cairo University, Giza, Egypt

^c Faculty of Medicine, Misr University for Science and Technology, Giza, Egypt

Received 2 November 2019; revised 13 January 2020; accepted 14 January 2020; Available online 5 February 2020



المخلص

أهداف البحث: تحديد القيم الطبيعية لقوة قبضة اليد لدى أطفال في سن ما قبل المدرسة، ومعرفة علاقتها بالقياسات الجسمانية.

طرق البحث: ضمت الدراسة أطفال ما قبل المدرسة، الذين تتراوح أعمارهم بين 3-6 سنوات، من كلا الجنسين. تم تقسيم الأطفال إلى ثلاث فئات عمرية، 3-4، 4-5 و 5-6 سنوات. وتم استخدام مقياس القوة المنتفخ لقياس قبضة اليد، واستخدام شريط القياس لتقييم المقاييس الجسمانية.

النتائج: تم إدراج 636 طفلاً عادياً في سن ما قبل المدرسة في هذه الدراسة. وكانت قوة قبضة اليد المهيمنة 26.87 ± 6.77 كيلو باسكال و 29.78 ± 8.43 كيلو باسكال و 38.04 ± 8.55 كيلو باسكال و 25.03 ± 7.19 كيلو باسكال و 28.13 ± 8.43 كيلو باسكال و 33.74 ± 8.14 كيلو باسكال، على التوالي. بينما كانت قوة القبضة المحسوبة في اليد غير المهيمنة 25.03 ± 7.19 كيلو باسكال، على التوالي. في المجموعة الأولى، كان هناك ارتباط ضعيف بين قوة القبضة ومحيط الساعد ومحيط اليد. في المقابل، وجدنا علاقة إيجابية بدون دلالة إحصائية مع طول اليد في اليد المهيمنة. في اليد غير المهيمنة، كانت العلاقة سالبة مع محيط الساعد، وموجبة لكن بدون دلالة إحصائية مع محيط اليد، وإيجابية مع طول اليد. أظهرت المجموعة الثانية ارتباطاً معتدلاً إيجابياً مع جميع القياسات الجسمانية في كل من الأيدي المهيمنة وغير المهيمنة. وكانت هناك علاقات إيجابية ضعيفة مع محيط الساعد وعلاقات إيجابية متوسطة الدلالة الإحصائية مع محيط اليد وطول اليد لكل من الأيدي المهيمنة وغير المهيمنة في المجموعة الثالثة.

الاستنتاجات: أظهرت هذه الدراسة القيم الطبيعية لقوة قبضة والعلاقات الإيجابية بين قوة قبضة ومحيط الساعد ومحيط اليد وطول اليد مع زيادة العمر في الأطفال في سن ما قبل المدرسة.

الكلمات المفتاحية: المقاييس الجسمانية؛ قوة قبضة اليد؛ القيم المعيارية؛ الأطفال ما قبل المدارس

Abstract

Purpose: We aimed to assess normal values of hand grip strength in preschool children and to determine their correlations with anthropometric measurements.

Methods: According to (Indira and Rajeswari, 2015) a pilot study was performed before the current study in order to confirm the variation in values of grip strength in age ranged from 3-6 years old. Therefore, ten children from each age group was assigned and it showed a significant changes in the measurements of grip strength corresponding to the age. Thus, it was important to assign them to three groups based on age so the first group from 3 to 4 years old, the second group from 4 to 5 years old, the third group from 5 to 6 years old.

Results: The study included 636 normal preschool-age children. Grip strengths with the dominant hand were 26.87 ± 6.77 kPa, 29.78 ± 8.43 kPa, and 38.04 ± 8.55 kPa in the 3–4, 4–5, and 5–6 years age groups, respectively. With the non-dominant hand, grip strengths were 25.03 ± 7.19 kPa, 28.13 ± 8.43 kPa, and 33.74 ± 8.14 kPa, respectively. In the 3–4 years group, there were negative significant correlations between grip strength of the dominant hand and forearm circumference (FC) or hand circumference (HC). However, we

* Corresponding address: Faculty of Physical Therapy, Misr University for Science and Technology, Giza, Egypt.

E-mail: mamiragalalmahmoud178@gmail.com (A.G. Mahmoud)
Peer review under responsibility of Taibah University.



found a positive non-significant correlation with hand length (HL). Grip strength of the non-dominant hand showed a negative significant correlation with FC, a positive non-significant correlation with HC, and a positive significant correlation with HL. Grip strength of both dominant and non-dominant hands in the 4–5 years group showed moderately positive significant correlations with all anthropometric measurements. Grip strength of both dominant and non-dominant hands in the 5–6 years group showed weak positive significant correlations with FC and moderate positive significant correlations with HC and HL.

Conclusion: This study established normal values of grip strength and demonstrated positive significant correlations between grip strength and FC, HC, and HL with increasing age in preschool children.

Keywords: Anthropometric measures; Grip strength; Norm values; Preschool children

© 2020 The Authors.

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

Introduction

Grip strength is an important characteristic in ageing, development, injury, training, therapy, and rehabilitation.¹ Hand grip strength has been evaluated most frequently, due to its significance as an indicator for hand function. Establishing normative values of hand grip strength in a population of healthy children would enable us to identify baseline values to aim for when attempting to regain normal function and prevent early locomotor dysfunction among children.²

Children of pre-school age are marked by improvements in locomotive skill development, object control abilities, and maturation of the nervous system. There are major differences between individuals in both basic motor skills and physical fitness.³

Physical activity is complex and involves several dimensions of behaviour, including subjective aspects (e.g. sports) and measurable aspects (e.g. frequency, duration, intensity). Locomotive skills are considered to be one of the most important movement skills, that enable the child to manipulate an object in action situations, such as throwing a ball. A high level of movement skills may increase participation in physical activities.⁴

Relationships between hand grip strength and various functional medical parameters in different populations have been well documented. Hand grip strength measurement is non-invasive, easy, and inexpensive, and it may allow exploration of acute nutrition status changes and help with evaluating and providing prognoses for muscle strength in juvenile idiopathic arthritis, congenital myotonic dystrophy, and traumatic hand injuries.^{5–8}

Various factors affect hand grip strength among children, including height, weight, bone density, and muscle mass.⁹

Spherical hand grip strength has clinical significance for the evaluation and comparison of surgical techniques, following progress in rehabilitation, documentation of treatment reactions, and evaluating the degree of disability after injury. Hand grip strength is also used to assess the performance of athletes who rely on a proper level of grip strength to increase control and performance and to minimise possible injuries.¹⁰

This study used a bulb dynamometer to measure grip strength, which is considered an appropriate instrument for measuring hand grip strength in young children, as its simple construction and handling enables children to perform the required action easily. It is a standardised measure for testing hand grip strength in the 3–5.5 years age group. It is considered more effective and efficient than other types of dynamometer for measuring hand grip strength under specific conditions.¹¹

Hand grip strength can vary widely. Measuring grip strength throughout development is very important to understand changes in grip strength with age. Furthermore, surgical interventions have a significant impact on hand grip strength and, without normative baseline data, we lack the ability to differentiate between the effects of growth, disease progression, and interventions.⁹

No studies have previously investigated normative values of hand grip strength in preschool children, and thus establishing normative data will enable us to make judicious decisions regarding clinical diagnoses, prognoses, and treatment plans.¹² In addition, this data will provide an opportunity to optimise rehabilitation programmes, which have a direct impact on the social and psychological wellbeing of children. This is due to the important role of hand grip in playing, handwriting, and children's daily living activities.

Anthropometric measurements have an effect on grip strength in this age group (3–6 years). This is an important element to consider in the design of orthoses and prostheses for use in cases of traumatic or congenital anomalies of the hand, to ensure that they will accommodate most of the population. These measurements can also be used to confirm that an item fits a certain group of people.¹³

The purpose of this study was to measure hand grip strength values in normally developing preschool age children (3–6 years), and to detect correlations between grip strength and forearm circumference (FC), hand circumference (HC), and hand length (HL).

Materials and Methods

Study design

An observational, cross-sectional study was performed from January 2017 to May 2018. The work was performed in four kindergartens or nurseries in East and West Cairo, Egypt, which were randomly selected by the researcher. Approval from the Ethical Research Committee of the Faculty of Physical Therapy, Cairo University, Egypt, in addition to signed consent forms from parents of all children involved, were obtained before starting the study.

Subjects

The study included 636 normal preschool-age children of both genders, aged 3–6 years. They were divided into three

age groups: 3–4 years ($n = 188$), 4–5 years ($n = 181$), and 5–6 years ($n = 267$). Children were selected from kindergartens and nurseries in Cairo using the following criteria: physically normal, able to perform normal activities of daily living, conformed with normal averages of weight and height according to the WHO (2000) normal growth charts for boys and girls,¹⁴ and able to follow instructions and understand commands given during test procedures to produce accurate and reliable measurements.

Children were excluded if they had undergone orthopaedic or neuromuscular surgery in their upper limbs, if they had musculoskeletal problems or neurological disorders that affected their upper extremities, if they participated in regular sports that involved the upper extremities, or if they had visual, auditory, or vestibular defects.

The estimated required sample size for this study was 400, according to Israel (1992).¹⁵ From the selected nurseries and kindergartens, 700 children were assessed for eligibility, of whom 650 met the inclusion criteria and were stratified into the three age groups. As shown in Figure 1, 14 children were omitted from the sample as they did not correctly follow the instructions, therefore 636 participants were ultimately included for analysis.

Instrumentation and procedures

Firstly, subjects' parents were informed about the terms of the protocol and procedures before giving their written consent. All data were obtained by the same examiner who trained all the children to perform the procedures, in order to minimise inter-observer bias. A weight and height scale (RGZ-120 Health Scale, SMIC, Shanghai, China) was used to confirm that the children conformed to normal averages of height in cm and weight in kg.

1) Tape Measurements

A measuring tape was used to assess each child's anthropometric measurements in cm, including FC, HC, and HL. FC was measured around the widest part of the forearm, where the bulk of the brachioradialis muscle was situated in the proximal forearm. HC was measured around the middle of the hand, at the two major transverse palmar creases. HL was measured from the tip of the middle finger to the distal crease of the wrist. All anthropometric measurements were recorded to the nearest millimetre, with the hand in a supinated, outstretched position, according to the methods used by Hogrel (2015).¹

2) Dominancy Detection

Each child was asked to sit on a suitable chair, facing the examiner, with a suitable table in front of him/her. The child was asked to pick up a pencil from the table and draw either a circle or a line on the white paper located on the table. The examiner recorded the hand used to draw the shape as the dominant hand, according to the method used by Ploegmakers et al. (2013).¹⁶

3) Pneumatic Bulb Dynamometer and Pinch Gauge Combo

A pneumatic bulb dynamometer and pinch gauge combo was used to measure the spherical grip strength of the

children. It consisted of three interchangeable rubber bulbs of different sizes (diameters 4 cm, 5 cm, and 6 cm) and a dial that tracked the spherical grip force. For younger children 3–6 years, the smallest bulb was used.¹⁷

Before starting the test, the examiner demonstrated how to hold the bulb of the hand dynamometer. According to the American Society of Hand Therapists (ASHT) recommendation, standardised positioning¹⁸ was used, with the child sitting on a child-size chair that allowed the child's feet to be flat on the floor. The position of the upper extremity being tested was as follows: shoulder adducted with neutral rotation, elbow flexed to 90°, forearm neutral, and wrist extended to 30°, while the wrist and elbow were maintained on the table.

The bulb dynamometer was placed in the child's palm with his/her fingers wrapped around the bulb, with the thumb opposed to the middle or ring finger. All participants followed a standardised instruction: a simple command to "squeeze the bulb as hard as possible for the count of 3 s". Between each trial, a rest of 2–5 s was given, allowing the examiner to record the maximal hand grip strength.¹⁹ Three trials were performed with each hand, alternating between the dominant and non-dominant hands to prevent fatigue.

Data analysis

According to the ASHT protocol, the mean value of hand grip strength was calculated from the three trials.^{17,18} The mean and standard deviation (SD) were calculated for all measured variables. The Pearson product–moment correlation coefficient was calculated to assess correlations between variables.

The level of significance for all statistical tests was set at $p < 0.05$. For all quantitative measurements, Statistical Package of Social Studies (SPSS, version 19, for Windows) software was used.

Results

Physical characteristics of the three age groups, including age, weight, height, and anthropometric measurements, are presented in Table 1. Figure 2 shows mean values of hand grip strength in the three age groups. In the 3–4 years group, the mean \pm SD hand grip strengths of the dominant and non-dominant hands were 26.87 ± 6.77 kPa and 25.03 ± 7.19 kPa, respectively. In the 4–5 years group, they were 29.78 ± 8.43 kPa and 28.13 ± 8.43 kPa, and in the 5–6 years group they were 38.04 ± 8.55 kPa and 33.74 ± 8.14 kPa, respectively.

In the 3–4 years group, hand grip strength ranges of the dominant and non-dominant hands were 15–45 kPa and 13–42 kPa, respectively. In the 4–5 years group, they were 17–52 kPa and 10–47 kPa, and in the 5–6 years group they were 18–60 kPa and 18–52 kPa, respectively.

The relationships between hand grip strength and anthropometric measurements (FC, HC, and HL) in the 3–4 years group are shown in Table 2. Hand grip strength of the dominant hand showed a moderate negative significant correlation with FC and a weak negative significant correlation with HC, but a weak positive non-significant correlation with HL. Hand grip strength of the non-dominant hand showed a weak negative significant

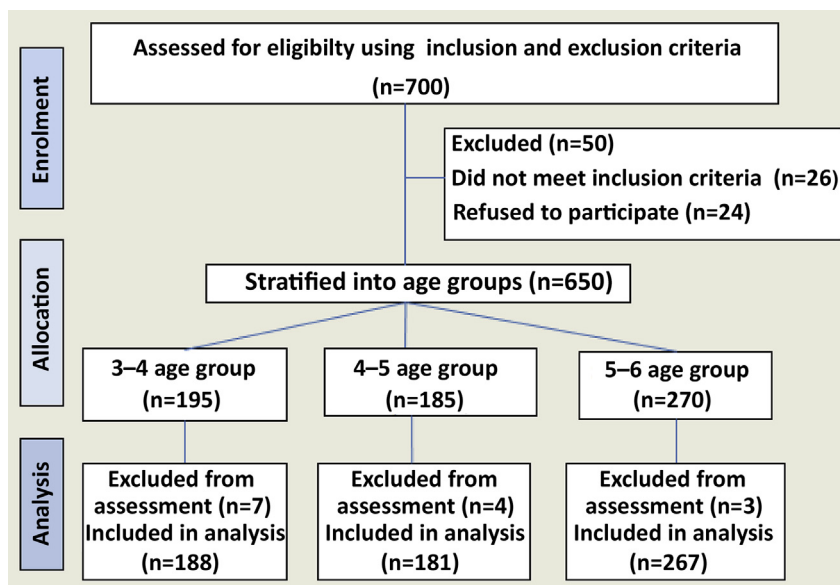


Figure 1: Flow chart of participants' inclusion in the study.

Table 1: Characteristics of subjects in the three age groups. \bar{X} Mean; SD: Standard Deviation; FC: Forearm Circumference; HC: Hand Circumference; HL: Hand Length.

	3-4 years	4-5 years	5-6 years
	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
Age, years	3.29 ± 0.34	4.19 ± 0.24	5.36 ± 0.42
Weight, kg	15.12 ± 1.98	16.98 ± 3.16	19.82 ± 3.33
Height, cm	99.86 ± 4.01	104.47 ± 5.89	111.65 ± 6.02
FC, cm (Dominant/Non-Dominant)	16.26 ± 1.1/16.28 ± 1.10	16.56 ± 1.15/16.48 ± 1.11	17.12 ± 1.37/17.07 ± 1.36
HC, cm (Dominant/Non-Dominant)	13.71 ± 0.66/13.75 ± 0.66	14.18 ± 0.92/14.11 ± 0.90	14.66 ± 0.93/14.51 ± 0.89
HL, cm (Dominant/Non-Dominant)	12.10 ± 0.59/12.13 ± 0.60	12.63 ± 0.85/12.64 ± 0.87	13.34 ± 0.76/13.32 ± 0.77

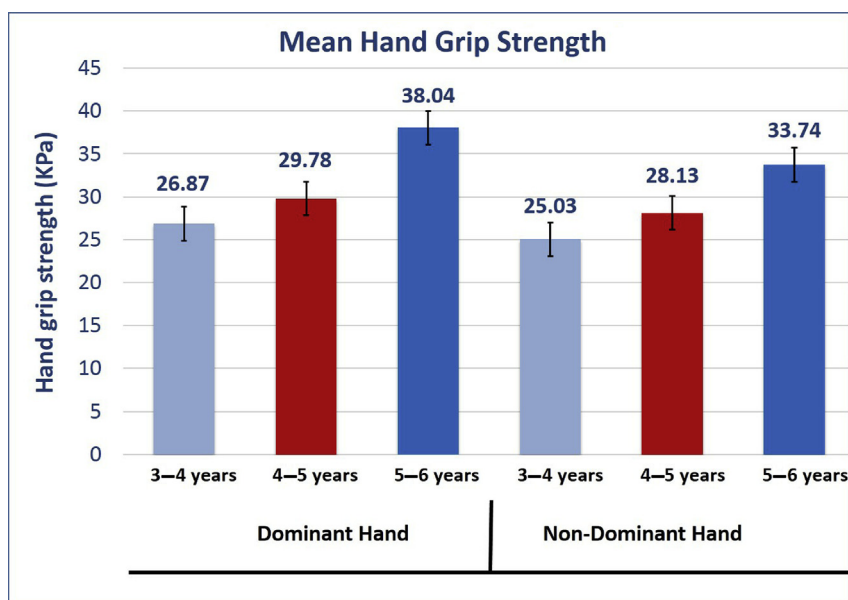


Figure 2: Mean hand grip strength in each group.

Table 2: Correlations between hand grip strength and FC, HC, and HL in the 3–4 years group. FC: Forearm Circumference; HC: Hand Circumference; HL: Hand Length; r value: Pearson correlation coefficient; p value: Probability value; S: Significant; NS: Non-significant.

3–4 years group	Dominant side	r value	p value	Significance
Dominant hand grip strength (kPa)	FC (cm)	–0.34	0.0001	S
	HC (cm)	–0.19	0.009	S
	HL (cm)	0.05	0.44	NS
3–4 years group	Non-dominant side	r value	p value	Significance
Non-dominant hand grip strength (kPa)	FC (cm)	–0.18	0.01	S
	HC (cm)	0.05	0.44	NS
	HL (cm)	0.15	0.03	S

Table 3: Correlations between hand grip strength and FC, HC, and HL in the 4–5 years group. FC: Forearm Circumference; HC: Hand Circumference; HL: Hand Length; r value: Pearson correlation coefficient; p value: Probability value; S: Significant; NS: Non-significant.

4–5 years group	Dominant side	r value	p value	Significance
Dominant hand grip strength (kPa)	FC (cm)	0.50	0.0001	S
	HC (cm)	0.49	0.0001	S
	HL (cm)	0.47	0.0001	S
4–5 years group	Non-dominant side	r value	p value	Significance
Non-dominant hand grip strength (kPa)	FC (cm)	0.47	0.0001	S
	HC (cm)	0.39	0.0001	S
	HL (cm)	0.43	0.0001	S

Table 4: Correlations between hand grip strength and FC, HC, and HL in the 5–6 years group. FC: Forearm Circumference; HC: Hand Circumference; HL: Hand Length; r value: Pearson correlation coefficient; p value: Probability value; S: Significant; NS: Non-significant.

5–6 years group	Dominant side	r value	p value	Significance
Dominant hand grip strength (kPa)	FC (cm)	0.32	0.0001	S
	HC (cm)	0.47	0.0001	S
	HL (cm)	0.43	0.0001	S
5–6 years group	Non-dominant side	r value	p value	Significance
Non-dominant hand grip strength (kPa)	FC (cm)	0.31	0.0001	S
	HC (cm)	0.38	0.0001	S
	HL (cm)	0.53	0.0001	S

correlation with FC, a weak positive non-significant correlation with HC, and a weak positive significant correlation with HL.

The relationships between hand grip strength and anthropometric measurements in the 4–5 years group are shown in Table 3. Grip strengths of both the dominant and non-dominant hands showed moderate positive significant correlations with FC, HC, and HL.

The relationships between hand grip strength and anthropometric measurements in the 5–6 years group are shown in Table 4. Grip strengths of both the dominant and non-dominant hands showed weak positive significant correlations with FC and moderate positive significant correlations with HC and HL.

Discussion

Hand grip strength is used as a tool to predict health throughout an individual's lifetime. No previous studies have

investigated normative values of hand grip strength in preschool children. Establishing normative data would enable us to make judicious decisions regarding clinical diagnoses, prognoses, and treatment plans,¹² and give us an opportunity to optimise rehabilitation programmes, which have a direct impact on the social and psychological wellbeing of children because of the important role of hand grip in playing, handwriting, and children's daily living activities.

Anthropometric measurements have an effect on grip strength in this age group (3–6 years). This is an important element to consider in the design of orthoses or prostheses for use in cases of traumatic or congenital anomalies of the hand, to ensure that they will accommodate most of the population. These measurements can also be used to confirm that an item fits a certain group of people.¹³

Thus, the purpose of our study was to establish normative values of hand grip strength among preschool age children and to explore the correlations between anthropometric measurements and spherical hand grip strength.

Our study showed that there was a wide range between the minimum and maximum grip strength values within each age group. This was to be expected, as human development normally has ranges based on age.

Ünveren (2013)²⁰ reported that age plays an important role in changing children's height, weight, and physical structure. He also noted that usually the hands and feet develop faster than other parts of the body. Therefore, hand grip strength is considered to be an important indicator of children's developmental level.

The results of this study showed that there were significant increases in hand grip strength with age. The rapid increases in grip strength in young children may be attributed to environmental factors, such as increased physical activity with growth or nutritional status, or could be due to differences in children's growth rates with respect to weight, height, FC, HC, and HL in the age groups studied. Hand grip strength is influenced by multiple factors such as age, gender, and body size.²¹ Such findings have been confirmed by Ploegmakers et al. (2013),¹⁶ who observed increases in strength with each year of increasing age.

It was observed that the grip strength of the dominant hand was greater than that of the non-dominant hand. This could be due to the development of handedness in the age range of 3–7 years. Accordingly, physical activities are performed more with the dominant hand than the non-dominant hand. Souza et al. (2014)²² stated that, in both genders and at all ages, the grip strength of the dominant hand is 10% greater than that of the non-dominant hand. This was consistent with the results obtained in the current study, which confirmed that the dominant hand displays superior strength in children aged 3–6 years.

Koley and Singh (2009)²³ reported that dominant hand grip strength is strongly associated with hand length, hand width, and forearm girth. In agreement with our results, Alahmari et al. (2017)²⁴ reported that forearm circumference is the best predictor of hand grip strength related to muscle mass and is the most significant practical index of hand grip strength. They also found that hand circumference and length are significant contributors to hand grip strength.

Our results showed a strong correlation between grip strength and FC, HC, and HL. These correlations are in agreement with Fraser et al. (1999) and Mohamed et al. (2012).^{25,26} They stated that there is a clear relationship between grip strength and forearm girth. This may be due to the fact that the majority of finger flexor muscles are located in the forearm, as strength is directly proportional to muscle mass.

This can be further explained by Manoharan et al. (2015),²⁷ who reported that there are 35 muscles involved in forearm and hand movement, many of which contribute to gripping activities. Waldo (1996)²⁸ stated that, during gripping activities, the muscles of the flexor mechanism in the hand and forearm perform the gripping action while the forearm extensors stabilise the wrist.

It is well known that the longer the fingers, the better the accuracy of a shot or a throw in basketball and handball players.²⁹ It is well documented that individuals with longer fingers and larger hand surfaces have stronger grip power.³⁰ This is in agreement with our

results, which showed that hand length has a notable relationship with grip strength.

This study was limited by the relatively small geographical region from which we drew our participants. Future studies should include larger regions so that the sample is more representative of the population. Our study was also limited to children aged 3–6 years; further studies should include a wider age range. Despite the study limitations, our results provide a comprehensive set of normative data that will enable us to make more accurate diagnostic decisions and implement effective therapeutic plans.

Conclusion

An increase in hand grip strength is correlated with chronological age and shows considerable correlations with anthropometric measurements.

Source of funding

This research did not receive any specific grants from any funding agencies.

Conflict of interest

There is no conflict of interest.

Ethical approval

This study was approved by the Ethical Research Committee of the Faculty of Physical Therapy, Cairo University, Egypt.

Authors contributions

AM, EE, and MH formulated the idea and the study design; AM conducted research, provided research materials, was responsible for the clinical evaluation of the children, and organised data; AM, EE, and NM were involved in writing the manuscript; AM carried out the data analysis and interpretation; AM, EE, and NM revised the final draft; all authors confirmed the final manuscript and were responsible for the content of the manuscript. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

References

1. Hogrel JY. Grip strength measured by high precision dynamometry in healthy subjects from 5 to 80 years. *BMC Musculoskel Disord* 2015; 10: 1186–12891.
2. Shim JH, Si Young R, Jin SK, Dong CL, Sae HK, Jae WY, Man KJ, Sang ML. Normative measurements of grip and pinch strengths of 21st century Korean population. *Arch Plast Surg J* 2013; 40: 52–56.
3. Tanaka C, Hikiyara Y, Ohkawara K, Tanaka S. Locomotive and nonlocomotive activity as determined by triaxial accelerometry and physical fitness in Japanese preschool children. *Pediatr Exerc Sci* 2012; 24: 420–434.
4. Hofelder B, Schott N. Relationship of fundamental movement skills and physical activity in children and adolescents: a systematic review. *Psychol Sport Exerc* 2014; 15: 382e391.

5. Lee-Valkov PM, Aaron DH, Eladoumikdachi F, et al. Measuring normal hand dexterity values in normal 3-, 4-, and 5-year-old children and their relationship with grip and pinch strength. *J Hand Ther* 2003; 16(1): 22–28.
6. Hoeksma AF, van Rossum MJ, Zinger WG, et al. High prevalence of hand- and wrist-related symptoms, impairments, activity limitations and participation restrictions in children with juvenile idiopathic arthritis. *J Rehabil Med* 2014; 46: 991–996.
7. Johnson NE, Butterfield R, Berggren K, et al. Disease burden and functional outcomes in congenital myotonic dystrophy. *Neurology* 2016; 87. Neurology.org.
8. Jensen KC, Bellini SG, Derrick JW, et al. Handgrip strength and malnutrition (undernutrition) in hospitalized versus nonhospitalized children aged 6–14 years. *Nutr Clin Pract* 2017; 32(5): 687–693.
9. Molenaar HM, Ruud WS, Michiel ZJ, Sten PW, Henk JS, Steven ER. Growth diagrams for grip strength in children. *Clin Orthop Relat Res* 2010; 468: 217–223.
10. Shiratori AP, Rodrigo RI, Noé GBJ, Susana CD, Monique SG. Evaluation protocols of hand grip strength in individuals with rheumatoid arthritis: a systematic review. *Rev Bras Reumatol* 2014; 54(2): 140–147.
11. Sipers WM, Verdijk LB, Sipers SJ, Schols JM, van Loon LJ. The Martin Vigorimeter represents a reliable and more practical tool than the Jamar Dynamometer to assess handgrip strength in the geriatric patient. *JAMDA* 2016; 17. 466.-466.e7.
12. McQuiddy VA, Carol RS, Ryan L, Timothy MG, Li L. Normative values for grip and pinch strength for 6- to 19-year-olds. *Arch Phys Med Rehabil* 2015; 96: 1627–1633.
13. Saied Alkholy WA, et al. Hand grip strength in relation to anthropometric measures of school children: a cross sectional study. *Ann Med Health Sci Res* 2017; 7: 447–453.
14. WHO. *National Center for Health Statistics in Collaboration with National Center for Chronic Disease Prevention and Health Promotion*; 2000 www.who.int/childgrowth/standards.
15. Israel GD. *Determining sample size, fact sheet PEOD-6, a series of the Program Evaluation and Organizational Development, Florida Cooperative Extension Service*. Institute of Food and Agricultural Sciences, University of Florida; 1992. pp. 1–5.
16. Ploegmakers JJ, Hopping AM, Geertzen JH, Bulstra SK. Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values. *J Physiother* 2013; 59: 255–261.
17. Indira E, Rajeswari M. Correlation of hand grip strength with anthropometric variables and quantifying hand grip strength in children of age 3 - 5.5 years with Martin Vigorimeter in Indian population. *Int J Physiother Res* 2015; 3(2): 1006–1011.
18. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, Sayer AA. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardized approach. *Age Ageing* 2011; 40(4): 423–429.
19. Boadella JM, Kuijer PP, Sluiter JK, Frings-Dresen MH. Effect of self-selected handgrip position on maximal handgrip strength. *Arch Phys Med Rehabil* 2005; 86: 328–331.
20. Ünveren A. The comparison of forearm volumes and some forearm parameters of female and male children in the adolescence period. *Life Sci* 2013; 10(10s): 155–160.
21. Koley S, Arvinder PS. Effect of hand dominance in grip strength in collegiate population of Amritsar, Punjab, India. *Anthropol Anzeiger* 2010; 12(1): 13–16.
22. Souza MA, Baptista CR, Benedicto MM, Pizzato TM, Mattiello-Sverzut AC. Normative data for hand grip strength in healthy children measured with a bulb dynamometer: a cross-sectional study. *Physiotherapy* 2014; 100: 313–318.
23. Koley S, Singh AP. An association of dominant hand grip strength with some anthropometric variables in Indian collegiate population. *Anthropol Anzeiger* 2009; 67: 21–28.
24. Alahmari KA, Silvian SP, Reddy RS, Kakaraparthi VN, Ahmad I, Alam MM. Hand grip strength determination for healthy males in Saudi Arabia: a study of the relationship with age, body mass index, hand length and forearm circumference using a hand-held dynamometer. *J Int Med Res* 2017; 45(2): 540–548.
25. Fraser A, Vallow J, Preston A, Cooper RG. Predicting ‘normal’ grip strength for rheumatoid arthritis patients. *Rheumatology* 1999; 38: 521–528.
26. Mohamed SS, Umama NS, Padmakumar S, Naajil M, Manjula S. Correlation between grip strength and physical factors in men. *IJHRS* 2012; 1: 58–63.
27. Manoharan VS, Sundaram SG, Jason JI. Factors affecting hand grip strength and its evaluation: a systemic review. *Int J Physiother Res* 2015; 3(6): 1288–1293.
28. Waldo B. Grip strength testing. *Natl Strength Cond Assoc* 1996: 32–35.
29. Jurimae T, Hurbo T, Jurimae J. Relationship of handgrip strength with anthropometric and body composition variables in pre-pubertal children. *Homo* 2009; 60(3): 225–238.
30. Hemberal M, Doreswamy V, Rajkumar S. Study of correlation between hand circumference and maximum grip strength (MGS). *Natl J Physiol Pharm Pharmacol* 2014; 4(3): 195–197.

How to cite this article: Mahmoud AG, Elhadidy EI, Hamza MS, Mohamed NE. Determining correlations between hand grip strength and anthropometric measurements in preschool children. *J Taibah Univ Med Sc* 2020;15(1):75–81.