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Relationship of carrying angle with grip strength and anthropometric measurements in young adults

Subhasmita Nayak[1*], Pravin Kumar[1] and Anil Kumar Oraon[2]

Abstract

Background and purpose Increase or decrease in the carrying angle may affect the functional activity and lead to elbow instability and pain during exercise or activity of daily living. Grip strength is commonly evaluated as a component of hand function in clinical settings as an indicator of disease and functional activity. The objective of this study was to find out correlation of carrying angle with grip strength and anthropometric measurements in healthy young adults.

Methodology Two hundred three participants (female 121 and male 82) with mean age 22.95 ± 2.11 years were included as per the inclusion and exclusion criteria. Carrying angle was measured by goniometer, and grip strength was measured by handheld dynamometer. Anthropometric data like forearm length and hand span was measured by the measuring tape and ruler scale respectively.

Results Spearman's correlation test showed that carrying angle is negatively correlated with grip strength ($r = -0.18$; $p < 0.05$) and forearm length ($r = -0.14$; $p < 0.05$) on the left side but no significant correlation on the right side. Body height and carrying angle have negative correlation on the right ($r = -0.20$, $p < 0.05$) and left sides ($r = -0.23$, $p < 0.05$).

Conclusion As the carrying angle increases, grip strength decreases. The height and length of the forearm are inversely related to the carrying angle. Grip strength is directly proportional with forearm length and hand span. Early identification of increased carrying angle will help in the prevention of various complications and identification of biomechanical alteration in sports activities.

Keywords Goniometer, Hand held dynamometer, Forearm length, Hand span, Correlational study

Introduction

The carrying angle of the elbow is defined as the angle-formed by long axis of the humerus and ulna in the frontal plane which plays an important role while carrying objects and loads. Furthermore, besides its ergonomic significance, the carrying angle value is also important for the restoration of normal elbow anatomical and biomechanical orientation in various orthopedic reconstructive surgeries of diseased elbow joint [1, 2]. The main functional importance of the carrying angle is to help in keeping the forearm away from the pelvis when the upper limb swings during walking and is also significant for holding objects [3, 4].

Kapandji [5] (2007) explained that the position of the trochlear groove results in the formation of carrying angle in extension. The average value of carrying

*Correspondence:
Subhasmita Nayak
subhasmita943727@gmail.com
[1] Department of Physiotherapy, National Institute for Locomotor Disabilities (Divyangjan), Kolkata, West Bengal, India
[2] Department of Surgical Disciplines, All India Institute of Medical Sciences, New Delhi, India

angle is 12.5 ± 0.57 degrees in males and 15.26 ± 0.45 degrees in females [6]. It has been reported that the angle increases with age and is greater in girls than in boys. However, there is conflicting data regarding its association with height, humeral length, ulnar length, and hyper laxity [7] and also with gender and dominance of the upper extremities in children and adult populations.

Increase in the carrying angle in a healthy individual may lead to elbow instability and pain during exercise or in sports participation, predispose to increased risk of elbow dislocation and fractures of distal humerus when falling on an outstretched hand [8, 9].

The grip strength is the result of forceful flexion of all finger joints with the maximum voluntary force that the subject is able to exert under normal bio kinetic conditions. The grip strength estimation is important in determining the efficacy of different treatment strategies of the hand and also plays a significant role in hand rehabilitation program [10–12]. Several studies have supported the correlation of handgrip with nutritional status, bone mineral content, hand length, body mass index, age, and upper arm circumference [13–15]. There are several methods and instruments used to measure hand grip strength. Jamar dynamometer is one of the recommended reliable and valid tools to measure grip strength.

The forearm length and hand span are an important predictor for grip strength [16, 17]. There are studies available in the literatures which has correlated grip strength with dominant hand in the individuals with age range between 20 and 23 years. These studies are conducted with small number of samples with weak methodology, but robust evidence is still lacking. Therefore, the aim of this study was to find out the relationship of carrying angle with grip strength and anthropometric measurements in young adults with large number of samples. And hence, research hypothesis was formulated as that there will be significant correlation of the carrying angle with the grip strength and anthropometric parameters in young adults.

Methodology

This correlational descriptive study was conducted in an institute-based rehabilitation center and included young healthy participants. Approval of the Institutional Ethical Committee (IEC) was obtained before the commencement of the study (IEC/1610/R&D/08/NIOH/1291). The participants were assessed from March 2020 to February 2021 and were selected based on the following inclusion criteria: aged between 18 and 30 years, both genders, and willing to participate in the study. The participants were enrolled using non-probability convenient sampling method. Informed consent was obtained from all the participants who included in the study.

Demographic data was collected along with an initial assessment of upper extremity. Any history of fractures and surgeries of the upper extremities, pathology around the elbow and wrist joints like rheumatoid arthritis, tendinitis etc., median, ulnar and/or radial nerve palsy, any congenital deformities like absence of limb, e.g., hemimelia, adactyly, etc., any neurological disorders like cerebral palsy, stroke etc., cervical radiculopathy, and any infectious condition of the skin were excluded from this study.

Outcome Measures

a. Carrying angle was measured using Universal Goniometerwhich is a valid and reliable tool for measuring joint range of motion [18]. The participants were asked to stand in anatomical position with the elbow fully extended and supinated. The axis of the goniometer was placed at volar aspect at the midline of elbow joint, the fixed arm was placed along the long axis of the tested arm directed towards the acromion, and the movable arm of the goniometer was lined up along the long axis of the tested forearm directed

A. Carrying Angle	B. Grip Strength	C. Forearm length	D. Hand Span

Fig. 1 Measurement of outcome variables

toward the middle finger. The angle was noted from the measurement plate (Fig. 1A).

b. Grip strength was assessed by a hand-held dynamometer [19] as described by the American Society of Hand Therapists. Participants were in high sitting position on a straight-backed chair with both feet flat on the floor and the shoulder adducted and neutrally rotated. The elbow was flexed at 90°, the forearm in neutral, and the wrist between 0° and 30° extension and between 0° and 15° ulnar deviation. Participants were asked to grip the dynamometer very tightly within pain free range by placing the thumb round on one side of the handle and encouraged to squeeze as long and as tightly as possible until the needle stopped raising. Each participant was instructed to exert their maximum grip strength for 5 s and asked to take rest for 2 min before each trial (Fig. 1B).
c. Forearm length was measured in a standing position with the arm folded across the chest with the fingers pointing to the opposite shoulder. The distance between the midpoints of the bony protuberance of the olecranon process and the ulnar styloid process was measured by flexible measuring tape (Fig. 1C) [20].
d. Hand span was measured from the distance of the tip of the thumb to the tip of the small finger while the hand opened as wide as possible. Ruler scale was placed at the maximal width and by measuring the distance separating distal extremes of the first and fifth digits (Fig. 1D) [21].

All these measurements were taken for both dominant and non-dominant hand and repeated for three times; the mean value was included for the final analysis.

Data analysis

Statistical analysis was performed using IBM Statistical Package for Social Sciences (SPSS) version 26. Kolmogorov-Smirnov test was used to check normality. As the data was not normally distributed, Spearman's correlation test was used to correlate carrying angle with grip strength and anthropometric measurements. The tests were applied at a power of 80%, and significance p-value was set ≤ 0.05.

Results

In the present study, a total of 203 participants were included, in which 121 were females and 82 were males. Twelve participants were excluded from this study because of various reasons as mentioned in Fig. 2. Descriptive statistics was used to present the demographic data (Table 1). The result of this study is presented in Table 2. The carrying angle showed weak negative correlation with grip strength ($r = -0.18$; $p < 0.05$) and forearm length ($r = -0.14$; $p < 0.05$) on the left side and non-significant correlation on the right side. Carrying angle and hand span showed non-significant correlation in both the right and left sides. Carrying angle, both on the right ($r = -0.20$, $p < 0.05$) and on the left side ($r = -0.23$, $p < 0.05$) showed weak negative correlation with height of individual. Additionally, we also found significant strong positive correlation of forearm length on both the right ($r = +0.67$, $p \leq 0.05$) and left sides ($r = +0.67$, $p \leq 0.05$) and also with hand span on both the right ($r = +0.62$, $p \leq 0.05$) and left sides ($r = +0.66$, $p \leq 0.05$) with the grip strength in this sample (Table 2) (Fig. 3).

Discussion

The study was aimed to find out the relationship of carrying angle with grip strength and anthropometric measurements in young adults. The result of this study showed a negative correlation between carrying angle and grip strength, which indicates that as the carrying angle increases, the grip strength decreases. This may be due to insufficiency of muscle as there are three types of muscle insufficiency, viz. active, passive, and tonic. Muscles acting on more than one joint have shorter fibers and a smaller range of contractions in comparison with muscles acting only on one joint [22]. So, as carrying angle increases, there will be mild increase in the length of forearm muscles from its origin point. According to Jason Shea [23], increase in carrying angle increases the stretch on long finger flexors, which causes reduction in the resting length of sarcomere, which causes reduced force production, affecting grip strength. As grip is the result of synergistic action of all the flexor and extensor muscles and interplay of the muscle groups, change in the length of the forearm muscle may affect overall grip strength. There was no significant correlation found between carrying angle and grip strength on the right side. It may be because the presence of a large number of female participants with greater carrying angle in the right side might affect the result of this study.

In this study, carrying angle showed a significant negative correlation with height and forearm length on the left side, whereas no correlation was found on the right side. Height and forearm length both were more in males than in females in the present study. A person with shorter height will have short forearm (ulna), and then the proximal end has to rotate more in order to bring the hand in a pronated position for routine work.

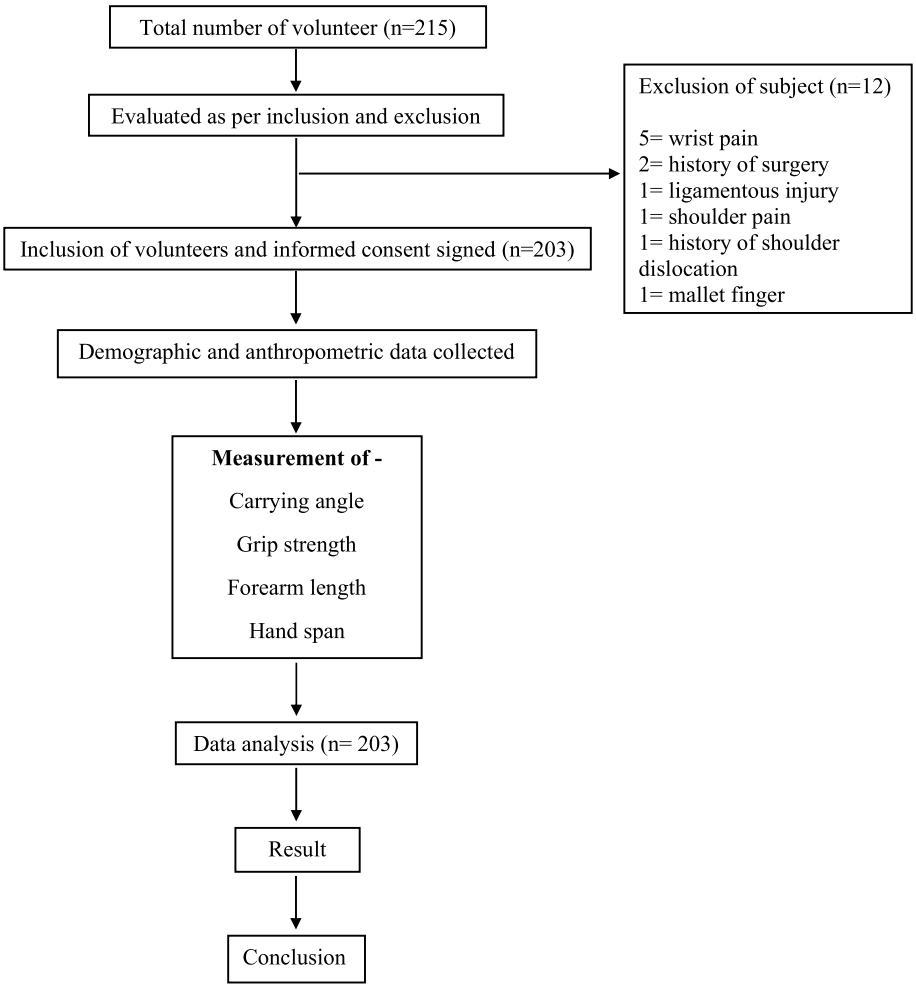

Fig. 2 Flow diagram of study

Table 1 Demographic data presented as mean ± SD of participants

		Male ($n = 82$) Mean ± SD	Female ($n = 121$) Mean ± SD	Total ($n = 203$) Mean ± SD	Median
Age (years)		23.55 ± 2.04	22.54 ± 2.06	22.95 ± 2.11	23
Height (cm)		170.56 ± 6.71	156.98 ± 2.92	162.46 ± 10.42	163
Carrying angle (degrees)	Rt-CA	13.99 ± 2.52	15.31 ± 2.87	14.78 ± 2.83	14.6
	Lt-CA	13.74 ± 2.72	15.02 ± 2.87	14.50 ± 2.88	14.3
Grip strength (kg)	Rt-GS	31.26 ± 7.00	18.43 ± 4.18	23.61 ± 8.36	21
	Lt-GS	29.45 ± 6.86	17.05 ± 4.20	22.06 ± 8.16	20
Forearm length (cm)	Rt-FL	27.12 ± 1.37	24.44 ± 1.40	25.52 ± 1.91	25.5
	Lt-FL	27.12 ± 1.36	24.44 ± 1.40	25.52 ± 1.91	25.5
Hand span (cm)	Rt-HS	21.35 ± 1.42	19.35 ± 1.24	20.16 ± 1.64	20
	Lt-HS	21.41 ± 1.42	19.39 ± 1.24	20.21 ± 1.64	20

Rt Right, *Lt* Left, *CA* Carrying angle, *GS* Grip strength, *FL* Forearm length, *HS* Hand span

Table 2 Relationship of carrying angle with grip strength, forearm, hand span, and height using Spearman's correlation coefficient (*r*)

		Carrying angle		Grip strength		Forearm length		Hand span		Height
		Right	Left	Right	Left	Right	Left	Right	Left	
Carrying angle	Right	--	--	− 0.01	--	− 0.09	--	− 0.08	--	**− 0.20[a]**
	Left	--	--	--	**− 0.18[a]**	--	**− 0.14[a]**	--	− 0.12	**− 0.23[a]**
Grip strength	Right	− 0.01	--	--	--	**+ 0.67[a]**	--	**+ 0.62[a]**	--	--
	Left	--	**− 0.18[a]**	--	--	--	**+ 0.68[a]**	--	**+ 0.66[a]**	--
Forearm length	Right	− 0.09	--	**+ 0.67[a]**	--	--	--	--	--	--
	Left	--	**− 0.14[a]**	--	**+ 0.68[a]**	--	--	--	--	--
Hand span	Right	− 0.08	--	**+ 0.62[a]**	--	--	--	--	--	--
	Left	--	− 0.12	--	**+ 0.66[a]**	--	--	--	--	--

"*r*"-value up to 0.79 denotes strong; 0.59 = moderate; 0.39 = weak, correlation between the variables

"[a]" denotes *p*-value was significant at the 0.05

Therefore, in a short-height person, because of shorter length of the forearm (ulna), the medial part of the trochlear notch goes more away from the medial flange of the trochlea, which can now grow more, compared to a person with longer forearm, leading to greater carrying angle. The greater the length of the forearm bones, the lesser is the angulation of the proximal articular surface which consequently results in a small carrying angle. A similar result has been seen in the study conducted by Ruparelia et al. [24].

The result of this study showed no correlation of carrying angle with hand span in males, females, and as a whole sample. In the present study, we observed that the carrying angle of females was greater than males which may be considered as a secondary sex characteristic in females because of the olecranon-coronoid angle exhibiting high sexual dimorphism, and the greater value of this angle in the female gender would be justified by the presence of ligamentous laxity. The findings of present study are similar to the study conducted by Kothapalli et al. [25] and Baskar et al. [26].

The average grip strength is found more in males compared to females. As gender has an influence on handgrip strength, for a similar age group, males have higher strength levels than females. This study showed greater carrying angle in the dominant hand as compared to the non-dominant hand in both males and females which may be due to the stress imposed over the dominant limb. It may result in developmental changes contributing to changes in the carrying angle and natural forces that act on elbows to modify the carrying angle. As a result, the carrying angle was found to be greater in the dominant limb than the non-dominant limb irrespective of gender difference. The carrying angle measurement of females was slightly higher than males in both dominant and non-dominant limbs. The adult men in this study reflected the worldwide trend for significantly greater right grip strength. In this study, the mean grip strength for the dominant side was greater than the non-dominant side in both sexes. The dominant hand was found to relate positively and significantly to grip strength in this study. This is because the constant use of a particular hand tends to be stronger according to the principle of reversibility. In accordance with recent studies like Incel et al., [27] we concluded that the dominant hand is significantly stronger in right-handed subjects, but no such significant difference was showed between sides for left-handed people.

We also found a positive correlation of forearm length and hand span with the grip strength. Forearm length and grip strength showed a significant positive correlation which suggests that grip strength increases with an increase in forearm length. There was a positive correlation between hand span and grip strength as well. Forearm circumference provides the most practical index of hand grip strength related to muscle mass and is the most significant predictor of hand grip strength, and also, hand span affects the grip strength, grip force, and exertion level [28, 29].

Limitations of this study were the presence of a larger number of female participants with greater carrying angle in the right side which might have affected the result of this study. Cubitus valgus or varus individuals were not excluded in this study. As the older and children were not included in this study, the result of this study cannot be applicable for these populations.

Future studies can be done with an equal number of male and female individuals with a broader age range. Further investigation of various fitness levels and particular activities in terms of long-term prospective

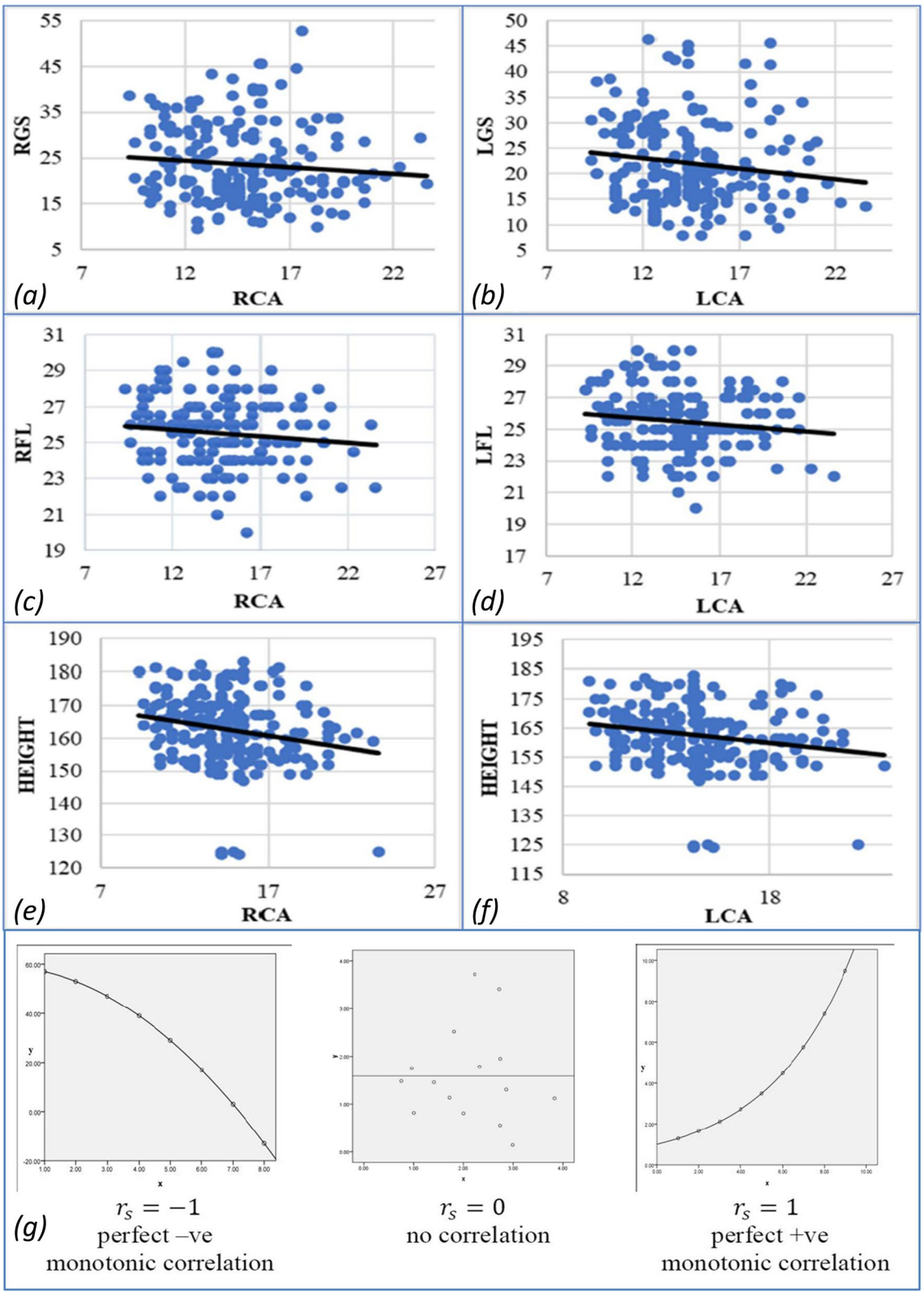

Fig. 3 Stem and leaf plots of variables using Spearman's correlation. RCA, right carrying angle; LCA, left carrying angle; RGS, right grip strength; LGS, left grip strength; RFL, right forearm length; LFL, left forearm length; RHS, right hand span; LHS, left hand span. **a** Correlation of RCA with RGS. **b** Correlation of LCA with LGS. **c** Correlation of RCA with RFL. **d** Correlation of LCA with LFL. **e** Correlation of RCA with RHS. **f** Correlation of LCA with LHS. **g** Ideal plots for Spearman's rank correlation showing positive and negative correlation

research protocol may be beneficial for the prevention of possible injury or other secondary abnormalities in the athletic population.

Conclusion

It can be concluded from the result of this study that there is negative correlation between carrying angle and grip strength, which means that with an increase in carrying angle, grip strength decreases. The height and length of the forearm were inversely related to the carrying angle. Forearm length and hand span showed a positive correlation with grip strength suggesting that grip strength increases with increase in forearm length and hand span. The result may be used in the identification of biomechanical alteration of various sports activities and variables of this study may be used as assessment tools.

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Authors' contributions
The author(s) read and approved the final manuscript.

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Availability of data and materials
The dataset used or analyzed during the current study will be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This correlational descriptive study was conducted in an institute-based rehabilitation center and included only young healthy participants. Approval of the Institutional Ethical Committee (IEC) was obtained before the commencement of the study (IEC/1610/R&D/08/NIOH/1291). Informed consent was obtained from all the participants who agreed to participate.

Competing interests
The authors declare no competing interests.

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