Original article

Correlation between handgrip strength and carrying angle in young women with different body mass indices – A cross-sectional observation study

Correlação entre a força de preensão manual e o ângulo de transporte em mulheres jovens com diferentes índices de massa corporal – Um estudo de observação transversal

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ABSTRACT | INTRODUCTION: Hand grip strength is an indicator to predict the health status of individuals in clinical practice. Age, gender, anthropometric characteristics, and health status influence grip strength performance of the hand through their influence on the musculoskeletal system. The dearth of data exists in the literature to identify the hand grip strength performance with carrying angle in females with different body mass indices. **OBJECTIVE:** The objective of this study is to compare and correlate the hand grip strength performance and carrying angle in young females with different body mass indices. **MATERIALS AND METHODS:** A total of 64 young women aged between 19 and 24 years participated in this cross-sectional observational study. Participants were randomly assigned to three groups based on their body mass index: the underweight group (n = 22), the normal weight group (n = 22), and the overweight/obese group (n = 20). Evaluations of hand grip strength and carrying angle were conducted on both the dominant and non-dominant sides. A Pearson correlation coefficient analysis was performed to determine the relationship between carrying angle and hand grip strength. ANOVA was utilized to compare hand grip strength and carrying angle among the three groups of young women. **RESULT:** The average age of females participating in the study varied from 20.78 to 21.56 years across all three groups. In correlation analysis, hand grip performance and carrying angle showed a negative correlation in both the underweight (dominant side r = -0.15, non-dominant side r = -0.35) and the overweight/obese group (dominant side r = -0.16, non-dominant side r = -0.14). No correlation was found between hand grip strength and carrying angle for females in the normal weight category. ANOVA statistics indicated that there were no significant differences in handgrip performance and carrying angle among females of varying body weight classifications. **CONCLUSION:** Though the carrying angle in underweight and overweight/obese females was negatively correlated with hand grip performance, the measures varied insignificantly among females with different body mass categories.

KEYWORDS: Body Mass Index. Elbow Joint Physiology. Hand Strength.

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RESUMO | INTRODUÇÃO: A força de preensão manual é um indicador para prever o estado de saúde dos indivíduos na prática clínica. A idade, o gênero, as características antropométricas e o estado de saúde influenciam o desempenho da força de preensão da mão através de sua influência no sistema musculoesquelético. A escassez de dados existe na literatura para identificar o desempenho da força de preensão manual com o ângulo de carregamento em mulheres com diferentes índices de massa corporal. **OBJETIVO:** O objetivo deste estudo é comparar e correlacionar o desempenho da força de preensão manual e o ângulo de transporte em jovens do sexo feminino com diferentes índices de massa corporal. **MATERIAIS E MÉTODOS:** Um total de 64 jovens mulheres com idades entre 19 e 24 anos participaram deste estudo observacional transversal. Os participantes foram aleatoriamente distribuídos em três grupos com base no índice de massa corporal: o grupo de baixo peso (n = 22), o grupo de peso normal (n = 22) e o grupo de sobrepeso/obesidade (n = 20). Avaliações da força de preensão manual e do ângulo de carregamento foram realizadas em ambos os lados, dominante e não dominante. Uma análise do coeficiente de correlação de Pearson foi realizada para determinar a relação entre o ângulo de carregamento e a força de preensão manual. ANOVA foi utilizada para comparar a força de preensão manual e o ângulo de carregamento entre os três grupos de mulheres jovens. **RESULTADO:** A idade média das mulheres participantes do estudo variou de 20.78 a 21.56 anos em todos os três grupos. Na análise de correlação, o desempenho da força de preensão manual e o ângulo de carregamento mostraram uma correlação negativa tanto no grupo de baixo peso (lado dominante r = -0.15, lado não dominante r = -0.35) quanto no grupo de sobrepeso/obesidade (lado dominante r = -0.16, lado não dominante r = -0.14). Nenhuma correlação foi encontrada entre a força de preensão manual e o ângulo de carregamento para mulheres na categoria de peso normal. As estatísticas ANOVA indicaram que não houve diferenças significativas no desempenho da força de preensão manual e no ângulo de carregamento entre mulheres de diferentes classificações de peso corporal. **CONCLUSÃO:** Embora o ângulo de carga em mulheres abaixo do peso e acima do peso/obesas estivesse negativamente correlacionado com o desempenho da força de preensão manual, as medidas variaram insignificativamente entre mulheres com diferentes categorias de massa corporal.

PALAVRAS-CHAVE: Índice de Massa Corporal. Ângulo Cubital. Força da Mão.

1. Introduction

Studies[1-4] reporting the positive predictive ability of hand grip strength parameters in various health conditions are increasing in the literature. Maximal voluntary muscle contraction is produced during the grip strength assessment. Irrespective of health status, the hand grip performance is also influenced by anthropometric and body composition parameters. Hand dimensions, forearm length, and breadth of wrist joint are the static factors related to anthropometric variables associated with hand grip performance[5]. Extrinsic muscles of the forearm, namely, *flexor digitorum profundus* and *flexor pollicis longus*, move the thumb and four fingers in a prismatic grasp and contribute to the dynamic force production6. The length of those muscles changes with the position of the wrist[7] and elbow joint[8], and thus the force produced during grip performance varies accordingly[9].

Hand grip strength differs between males and females. Males could be able to generate higher hand grip force than compared to that of females. Increased forearm muscle cross-sectional area in males contributes to increased force production during gripping tasks[10]. Also, posture and anatomical alignment of the upper extremity contribute to the differences in grip strength among males and females[11]. Smaller forearm muscle cross-sectional area and increased carrying angle in females interfere with their maximal force production during hand grip performance. Flexors of the forearm contribute dynamic stability to the medial elbow against the valgus stress produced by increased carrying angle in females[12]. Studies[4,13,14] in the literature indicate that an increase in carrying angle reduces the force production during hand grip performance. The effect of active insufficiency and altered length-tension relationship of forearm flexors was the mechanism proposed for the decrease in hand grip force production in individuals with increased carrying angle.

In a recent study, Verma et al. (2022)[15] reported a positive correlation between carrying angle and anthropometric characteristics. Their study results indicate that the carrying angle at the elbow varies with body mass index and trans-trochanteric diameter. The association between carrying angle and hand grip strength in individuals with different body mass indices is not reported in the literature. Irrespective of the body mass index, ligament laxity, and wider pelvis were proposed for increased carrying in females (10º – 15º) compared to males (5º – 10º)[15]. The carrying angle increases in both genders until skeletal maturity, and the rate of increment is slightly higher in females (0.60/year) compared to males (0.40/year). Morphologically shoulder breadth to pelvic breadth ratio also varies according to the body mass category. In addition to this, the carrying angle tends to increase in response to pronation of the forearm to keep the swinging arm away from the pelvis during walking and other tasks[16,17].

Few studies[18,19] analyzing the association of anthropometric and body composition variables reported a positive correlation between body mass index and pelvic width. The pelvic width is higher in individuals with high body mass index. The literature presents inconsistent findings regarding the effect of individual differences in BMI on hand grip strength and carrying angle. This indicates a practical gap in our comprehension of how carrying angle, hand grip strength, and BMI are interconnected. There is a limited understanding of physiological or biomechanical mechanisms that link body mass and carrying angle to hand grip strength. Existing studies have investigated the effects of body mass on carrying angle and the influence of body mass on hand grip strength. However, the possible interaction effects between body mass and carrying angles on hand grip strength have not been thoroughly explored. This also hinders the development of precise predictive models for hand grip strength among individuals with differing body mass and carrying angles. The objective of this study is to examine the relationship and differences in carrying angle and hand grip strength among young women of varying body mass indices.

2. Materials and methods

2.1 Study approval and registration

Institutional review board approval for the study is obtained from Alva's College of Physiotherapy and Research Centre, Moodbidri, DK, Karnataka – 574227, India. The study protocol was registered in the Clinical Trial Registry of India (CTRI/2023/07/055674) and the study procedures are conducted according to the STROBE guidelines for conducting cross-sectional studies.

2.2 Study design and source of sample

In this study, the correlation of hand grip strength and carrying angle is compared between young females in 3 body mass index categories. The study participants are recruited from educational institution in Dakshina Kannada district, Karnataka and the study is conducted in a fitness performance center near the population source.

2.3 Sample size estimation

Based on a previously published study[20], using G*power statistical application (version 3.1.94) with following parameters; effect size 0.494, alpha 0.05, and power 0.95, the estimated sample size for this study was 64.

2.4 Selection criteria

Women who volunteered for the study were evaluated based on the selection criteria. Participants aged between 19 and 24 years, across all three categories of body mass index, were included. Female athletes, those with congenital or acquired deformities, recent upper limb immobilization or surgeries, systemic health issues, hereditary conditions, and individuals who declined to participate were excluded from the study.

2.5 Allocation and data collection

Individuals who met the eligibility criteria were stratified into underweight, normal weight, and overweight/obese categories. A lottery method (simple random sampling) was employed to choose the final samples from each category until the desired sample size was achieved. Once the allocation was complete, demographic information for each participant was gathered.

2.6 Categorizing samples according to their body mass index

To categorize participants, the standard BMI classification method is employed. Participants' body weight is measured in kilograms using a weighing scale, while their height is assessed in square meters using a wall-mounted stadiometer. By applying the formula weight in kilograms divided by height in square meters, individuals with a BMI of less than 18.5 kg/m² are classified as underweight, those with a BMI ranging from 18.5 to 24.9 kg/m² fall into the normal category, and individuals with a BMI over 25.0 kg/m² are grouped as overweight or obese.

2.7 Hand grip strength (method from American Society of Hand Therapists)[21]

A Baseline hydraulic hand dynamometer (Fabrication Enterprises, Inc., Irvington, NY) is utilized to measure grip strength in the hand. The study participants were positioned in an upright manner (with feet flat on the floor, shoulders adducted and held neutrally rotated, elbows bent at 90 degrees, forearm in a neutral posture, and wrist extended between 0 and 30 degrees) on a chair that did not have armrests, facing a mirror for visual feedback. To determine hand grip strength, participants were instructed to apply maximum force while gripping the dynamometer. Three attempts of maximum grip strength were recorded, allowing for a 15-second rest between each interval, and the average of the three grip trials was noted. The same procedure was conducted for the opposite hand.

2.8 Carrying angle[22]

The standard analog goniometer is utilized to assess the carrying angle. When the arm is in the anatomical position, the arm's axis is determined by drawing a line from the lateral border of the acromion to the midpoint between the lateral and medial epicondyles of the humerus. The forearm's axis is established by connecting the midpoint between the lateral and medial epicondyle of the humerus to the midpoint of the distal radius and ulnar styloid processes. The goniometer's arms are aligned along the axes of the arm and forearm, and the carrying angle is recorded. This same method was applied to the other side of the limb. To reduce measurement error, three measurements were taken and averaged. Two qualified and experienced physical therapists with a specialization in musculoskeletal therapy conducted individual assessments of hand grip strength and carrying angle for the participants.

2.9 Statistical analysis

Data analysis was conducted using version 27.0 of the Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois). Continuous variable characteristics of participants were analyzed for significance across the groups by comparing their means. Categorical variables were expressed in terms of frequency and percentages, and their significance was identified by the Chi-square test. The Shapiro-Wilk test was utilized to assess normality ($P > 0.05$). Pearson correlation coefficient (r) was employed to analyze the relationship between hand grip strength and carrying angle on both the dominant and non-dominant sides for female participants across all groups, with the interpretation of the r value reported as appropriate. The mean values of hand grip strength and carrying angle were compared among groups using one-way ANOVA, with significance set at $P < 0.05$.

3. Results

A total of 64 females were included in this study. The data were normally distributed. The mean age and height of all the females were similar with no significant differences ($P > 0.05$). The participants were assigned to the group according to the body mass index category and hence their mean weight and body mass index differed significantly in all groups ($P = 0.000$). Most of the participants reported the right hand as their dominant side (Table 1).

The correlation results of hand grip strength and carrying angle in the underweight group and overweight/obese body mass category were low negative for the dominant and the non-dominant sides. Whereas females with normal body mass did not correlate with hand grip strength and carrying angle on both sides (Table 2).

Inferential statistics to compare the hand grip strength and carrying angle (Table 3) mean scores for females in different body mass groups were performed with ANOVA. The P value obtained was > 0.05 in both variables, inferring insignificant differences in the hand grip strength and carrying angle measures among females in different body mass groups.

Table 1. Demographic characteristics of young females included in the study

Variables	Underweight body mass index (kg/m^2) (n = 22)	Normal body mass index (kg/m^2) (n = 22)	Overweight/obese body mass index (kg/m^2) (n = 20)	Significance
	Mean ± SD			
Age	21.00 ± 1.37	20.78 ± 1.25	21.66 ± 1.45	0.09
Height	155.5 ± 7.95	155.67 ± 6.77	159.44 ± 4.97	0.12
Weight	40.4 ± 4.52	51.25 ± 6.25	74.93 ± 11.63	0.000*
Body mass index	16.67 ± 0.89	23.70 ± 2.34	29.56 ± 3.95	0.000*
Carrying angle dominant side	11.60 ± 2.79	12.42 ± 2.33	13.22 ± 2.88	0.17
Carrying angle non-dominant side	10.80 ± 2.46	13.68 ± 6.59	14.11 ± 2.58	0.11
Hand grip strength on the dominant side	41.39 ± 9.19	42.48 ± 12.08	41.47 ± 13.13	0.55
Hand grip strength on the non-dominant side	35.73 ± 9.16	37.00 ± 12.55	36.76 ± 11.59	0.37
	Frequency (proportion)			
Right side dominant	19 (28.78%)	20 (30.30%)	16 (24.24%)	0.242
Left side dominant	3 (4.54%)	2 (3.03%)	6 (9.09%)	(chi square)

Source: the authors (2024).
ANOVA test is performed, and the significance is considered if P < 0.05.

Table 2. Correlation between handgrip strength and carrying angle for dominant and non-dominant sides in young females with different body mass index

Statistics	Underweight body mass index (n = 22)		Normal body mass index (n = 22)		Overweight/obese body mass index (n = 20)	
	Dominant side Hand grip strength & carrying angle	Non-dominant side Hand grip strength & carrying angle	Dominant side Hand grip strength & carrying angle	Non-dominant side Hand grip strength & carrying angle	Dominant side Hand grip strength & carrying angle	Non-dominant side Hand grip strength & carrying angle
Pearson r	- 0.004	- 0.09	0.05	0.49	- 0.16	- 0.17
Significance (p value)	0.985	0.66	0.81	0.02	0.47	0.42

Source: the authors (2024).
Pearson correlation coefficient is performed; significance is considered if P < 0.05.

Table 3. Analysis of variance for carrying angle and hand grip strength on the dominant and non-dominant side for participants in three groups

Variables	Category	Group	Sum of squares	Degree of freedom	Mean square	F	Significance	Eta-squared	
								Point estimate	95% confidence interval
Carrying angle	Dominant side	Between group	12.93	2	6.47	0.90	0.40	0.02	0.000 to 0.125
		Within group	448.81	63	7.12				
	Non-dominant side	Between group	126.07	2	63.03	2.88	0.06	0.08	0.000 to 0.214
		Within group	1377.91	63	21.87				
Hand grip strength	Dominant side	Between group	216.90	2	108.45	0.81	0.44	0.02	0.000 to 0.119
		Within group	8426.69	63	133.75				
	Non-dominant side	Between group	285.38	2	142.69	1.10	0.33	0.03	0.000 to 0.136
		Within group	8110.74	63	128.73				

Source: the authors (2024).
Significance is considered if $P < 0.05$.

4. Discussion

The primary aim of this research is to correlate and compare hand grip strength and carrying angle measurements among young women with varying body mass indices. The findings of this study indicate that there is a low negative correlation between hand grip strength and carrying angle in young females with underweight and overweight/obese body mass, while a very low (dominant side) to medium (non-dominant) positive correlation was observed in women with normal body weight. The mean scores for hand grip strength and carrying angle were found to be similar across all body mass categories in young females.

Previous studies[24-27] indicate that regardless of the carrying angle, factors such as arm span, shoulder width, humerus width, and hand span may contribute to variations in hand grip performance. A shorter forearm length with diminished force production in forearm flexors results in insufficient performance in hand grip. Conversely, in one study[27], it is proposed that an increase in muscle length could decrease force production during cross-bridge formation, which is contradicted by another finding[28] reporting that forearm length is directly proportional to hand grip strength. Moreover, the outward extension of the medial trochlea and a slight valgus tilt of the distal humerus may also affect the carrying angle[24]. To improve the alignment of the carrying angle, it is not feasible to alter these anatomical factors using conservative approaches.

In this study, the mean hand grip strength and carrying angles measured in underweight women were lower when compared to women in the normal and overweight/obese weight categories. This result aligns with the conclusions of Pan et al. (2022)[29], where the authors discovered that inadequate physical fitness and reduced forearm circumference, in underweight females, contribute to diminished hand grip performance. In addition, factors such as reduced muscle mass, lack of energy/nutrition, and lower overall body weight could be attributed to the reduced force generation during hand grip performance among underweight women. Factors such as reduction in muscle and fat tissue in the pelvic area may account for the decreased carrying angle in underweight women. Thus, it is inferred that body mass alone does not primarily influence the carrying angle in underweight women.

Regardless of body weight, the menstrual cycle and its accompanying hormonal changes influence the physiological cross-sectional area of muscles in females. Up until puberty, growth in epiphysis occur simultaneously in both the proximal forearm and distal humerus. Following puberty, the epiphyseal growth plate closes in the proximal forearm, while growth continues in the distal humerus, which results in the development of carrying angle at the elbow. Fluctuating levels of estrogen during the menstrual cycle, with disproportionate growth patterns in epiphyseal growth plates, could attenuate the carrying angle. This could be considered as the mechanism for increased carrying angle and decreased hand grip strength performance in underweight women[30].

In the present study, women in the overweight/obese body mass category had a lower mean score for hand grip strength and a higher carrying angle degree than normal weight and underweight women. A broader pelvic width is often proposed as the reason for increased carrying angle in overweight/obese women. The common explanation proposed for the increased carrying angle in these individuals is the deviation of the forearm away from the body during elbow extension. While the influence of obesity patterns (android or gynoid) on forearm deviation remains uncertain, obesity is often linked to an increased carrying angle. Our study results also showed that hand grip strength in overweight/obese women is lower compared to that of normal weight women. A higher prevalence of physical inactivity, coupled with reduced muscle mass and increased fat storage, may account for the decrease in hand grip strength seen in these women. This aligns with the research conducted by Tavares Junior et al. (2023)[25], where the authors indicated that body composition has a considerable impact on estimating hand grip strength in females. In a similar research[26,31], the authors found that waist circumference and body fat percentage are indicators that can predict hand grip performance in obese women. They also noted that a higher percentage of body fat is associated with lower scores in isometric hand grip strength. Recently in 2024, this finding is supported by authors from Pakistan in their cross-sectional study[32]. Nevertheless, the literature does not present any evidence concerning the relationship between carrying angles and hand grip strength in underweight and obese women.

The strength of the present study lies in its potential for clinical implications. In underweight women, diminished hand grip strength indicates poor physical fitness, smaller forearm circumference, or malnutrition. In contrast, among overweight or obese women, diminished hand grip strength indicates higher body fat, increased waist circumference, and reduced muscle mass. Therefore, focusing on physical fitness that enhances muscle mass in underweight women and aims to decrease fat-free mass (increasing muscle mass) in overweight or obese women could lead to better hand grip performances in this population.

4.1 Limitation

The current study has few limitations. Firstly, an analysis of body composition, including fat and muscle mass, could offer deeper insights into the relationship between carrying angle and hand grip performance among women with varying body mass indices. Secondly, examining the differences in carrying angle and hand grip strength between females and males might uncover consistent variations. Thirdly, the role of hormonal changes throughout the menstrual cycle could contribute to a better understanding of how hormones affect hand grip performance in women with different body mass. Fourthly, using alternatives to body mass index, such as Body Shape Index, Conicity Index, and Body Roundness Index, could provide a more detailed analysis of carrying angle and hand grip strength. Lastly, the study's findings may have been impacted by uncontrolled confounding variables influencing carrying angles, including genetic factors, skeletal maturity, and growth spurts. Although the inclusion criteria excluded known hereditary conditions and skeletal growth abnormalities, a thorough investigation is necessary to rule out these conditions and their effects on the participants. Future research that addresses the limitations outlined in this study could yield additional insights into the relationship between body mass, carrying angle, and hand grip strength.

5. Conclusion

It is concluded that there is no correlation between hand grip strength and carrying angle in females with normal body mass. Though there is a weak negative association between hand grip strength and carrying angle in underweight and overweight/obese individuals, their mean scores differed insignificantly between the groups in inferential analysis, indicating that body mass does not affect the hang grip and carrying angle in females.

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Authors contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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