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Anthropometric Characteristics, Handgrip Strength, and Upper Limb Asymmetries in Highly Trained Chilean Shot Put Para-Athletes

Características Antropométricas, Fuerza de Prensión Manual y Asimetrías de Miembros Superiores en Para-Atletas Chilenos de Lanzamiento de Bala Altamente Entrenados

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SUMMARY: Anthropometric characteristics, including body size, shape, and composition, can have a significant impact on sports performance due to their influence on various physiological and biomechanical factors. However, limited research has been conducted on the anthropometric characteristics of highly trained throwing para-athletes. The purpose of this study was to describe the anthropometric characteristics, handgrip strength, and upper limb bilateral asymmetries of highly trained Chilean shot put para-throwers. Five male Chilean shot put para-athletes (average age of 38.8 ± 7.7 years) were assessed for their anthropometric characteristics, including skinfold thickness at six anatomical sites, girth at five sites, and bone breadth at two sites. Handgrip strength and bilateral asymmetries were also measured. The body mass and height of the athletes were found to be 90.5 ± 5.1 kg and 179.1 ± 8.9 cm, respectively. The athletes were found to have an endo-mesomorph somatotype (4.4-6.9-1.0) with high levels of fat mass (25.7 ± 2.8 %) and skeletal muscle mass (39.1 ± 3.7 %). The handgrip strength of the athletes was found to be 66.4 ± 6.7 kg with a bilateral asymmetry of 6.5 ± 6.2 %, with the dominant hand showing greater strength. The results indicate that the shot put para-athletes have a somatotype characterized by increased muscularity and body fat, along with a considerable stature. Although handgrip strength was found to be high, the athletes showed bilateral asymmetry, which requires further investigation to determine the cause and implications.

KEY WORDS: Body Composition; Somatotypes; Sports for Persons with Disabilities; Adaptive Sports; Para-Athletes.

INTRODUCTION

Para-throwing events are part of para-athletics, a sport competition for athletes with physical, intellectual, and visual disabilities (International Paralympic Committee, 2022). The goal of the competition is to throw implements such as shot put, discus, javelin, and club, as far as possible. Certain anthropometric traits, such as muscle power, can give para-athletes an advantage in shot put throwing (Lee *et al.*, 2015; Zaras *et al*., 2021).

While research has been conducted on the anthropometric traits of able-bodied track and field throwers, there is limited knowledge of the characteristics of throwers with disabilities (Cherif *et al*., 2022). Anthropometric traits play a significant role in predicting the outcome of a sports event and identifying promising athletes (Zaras *et al*., 2021). When evaluating an athlete's capabilities, it is crucial to consider not only height and weight, but also their body composition (fat and muscle masses) as two athletes with the same anthropometric characteristics but different body composition may have different sport performances (Zaras *et al*., 2021). Additionally, an athlete's disability can impact their functionality and sport performance, such as limb deficiencies or lack of trunk control (Jaarsma *et al*., 2014).

In addition to anthropometric characteristics, handgrip strength (HGS) can be a crucial attribute for throwing and is

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a widely recognized indicator of health and fitness (Cronin *et al*., 2017). However, there is a need to establish normative strength values for para-athletes, including those with different functional impairments (O'Connor *et al*., 2022). Further, regular HGS measurements may contribute to assess the level of asymmetry between upper limbs (Auerbach & Ruff, 2006), which is a concern as throws are unilateral and asymmetries, including strength asymmetries, may develop over time and become a risk factor for injury (Velarde-Sotres *et al*., 2022).

To the best of our knowledge, there has been no study to date that examines the anthropometric characteristics, HGS, and upper limb asymmetries in shot put para-athletes. Although there are studies on anthropometric characteristics in able-bodied track and field throwers, no research has been done specifically on para-throwers. The aim of this study is to fill this gap and describe the anthropometric characteristics, handgrip strength, and upper limb asymmetries in highly trained shot put para-athletes.

MATERIAL AND METHOD

Participants. Five male shot put throwing para-athletes participated in the study, two of whom were ambulant amputees and three had spinal cord injuries. To be eligible for the study, participants had to meet the following criteria: (i) healthy males above 18 years of age, (ii) current practice of shot put throwing as a para-athlete, and (iii) free from any acute skeletal muscle injuries. The athletes had an average of 3.6 ± 2.4 years of throwing experience and two of them had represented their country in international competitions. The measurements were taken prior to the Chilean Para-Athletics National Championships 2022.

Data collection. The data were obtained as part of the athletes' typical testing procedures, so ethics committee clearance was not required (Winter & Maughan, 2009). However, the investigation followed the ethical principles outlined in the Helsinki Declaration (World Medical Association, 2013) and the participants were provided with detailed information about the project design and aims, as well as their rights, benefits, and risks involved with participation. Signed informed consent forms were obtained from all participants.

Anthropometric measurement. Height, body mass, six skinfolds (subscapular, triceps, abdominal, suprailiac, front thigh, and medial calf), breadths (humerus and femur) and girths (arm, forearm, chest, medial thigh and medial calf) were assessed. The measurements were conducted by two accredited anthropometrists following the techniques recommended by the International Society for Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al*., 2012). A skinfold calliper (Harpenden, HSB-BI, HaB Direct, UK) was used to measure skinfolds with a precision of 0.2 mm. Breadths were measured using a flexible steel tape (Lufkin, TX, USA) with an accuracy of 1 mm and girths were measured using a small and long bone anthropometer (Health & Performance®, Chile). Body mass was measured in light clothing and no shoes, using an electronic scale (SECA 803, Seca GmbH & Co., Hamburg, Germany) with a precision of 0.1 kg and height was measured using a stadiometer (SECA 213, Seca GmbH & Co., Hamburg, Germany) with a precision of 0.1 cm.

Fat mass percentage was calculated using the formulas proposed by Durnin & Womersley (1974), which have previously been used in para-athletes (Bernardi *et al*., 2012; Cherif *et al*., 2022), and skeletal muscle mass was calculated using the formulas by Lee *et al*. (2000), which have been previously used in elite para-athletes. The somatotype (ectomorph, mesomorph, endomorph) was calculated using the Heath-Carter method (Carter *et al*., 1990).

Handgrip strength. A hand dynamometer (Lafayette Instrument, Lafayette, IN, USA) was used to measure the maximal voluntary grip-force (kg) in both hands of each participant. The testing procedures followed the guidelines recommended by the American Society of Hand Therapists, with participants seated comfortably in a straight-backed chair with their feet flat on the floor, shoulders adducted and neutrally rotated, elbow flexed at 90°, and forearms in a neutral position with the wrist self-selected between 0-30° extension and 0-15° ulnar deviation (Innes, 1999). Participants were instructed to exert maximum grip-force for 3 seconds with each hand, using the dynamometer vertically, and the process was repeated three times with a 60-second rest between trials (Innes, 1999). The average of the three trials was recorded as the test result.

Bilateral asymmetry analysis. Bilateral asymmetry (BA) between upper limbs was quantified based on maximal handgrip strength values using the following equation (Auerbach & Ruff, 2006):

$$\%BA = (\text{right [kg]} - \text{left [kg]}) / (\text{average of left and right [kg]}) \times 100$$

Data analysis. Results are presented as mean ± standard deviation or percentage. Data analysis was performed using Microsoft® Office Excel 2019 (Microsoft Corporation, Redmond, Washington, USA) and Somatotype® Calculation and Analysis Software version 1.1 (San Diego, CA, USA) for somatotype calculations. A 95 % confidence interval was set for all analysis.

RESULTS

Table I presents the mean ± standard deviation of the descriptive and anthropometric characteristics of shot put para-throwers. The para-athletes had an average age of 38.8 ± 7.7 years and weighed 90.5 ± 5.1 kg with a height of 179.1 ± 8.9 cm. Their body mass index was calculated to be 28.3 ± 2.1 and they had an average training experience of 3.6 ± 2.4 years. The Table I also lists measurements for 6 girths in centimetres, 2 breadths in centimetres, and 6 skinfolds in millimetres.

Table II displays the sum of 6, 4, and 3 skinfolds used for somatotype classification of the para-throwers. The athletes were found to have an endomorph-mesomorph somatotype (4.4 – 6.9 – 1.0) as illustrated in Figure 1. They had 25.7 % ± 2.8 % of fat mass and 39.1 % ± 3.7 % of skeletal muscle mass.

Values of HGS and BA are presented in Table III. A higher level of HGS in the throwing arm (66.4 ± 6.7 kg) vs non-throwing arm (66.4 ± 6.7 kg) was evidenced, with a quantification of a 6.5 ± 6.2 % of BA.

Table I. Descriptive and anthropometric characteristics.

Variables	Mean ± SD	95% CI	
		LB	UB
Descriptive characteristics			
Age (years)	38.8 ± 7.7	29.1	46.5
Body mass (kg)	90.5 ± 5.1	84.2	96.8
Height (cm)	179.1 ± 8.9	168.0	190.2
Body mass index (kg/m-2)	28.3 ± 2.1	25.7	31.0
PTE (years)	3.6 ± 2.4	0.6	6.6
Girths (cm)			
Relaxed arm	36.3 ± 2.7	33.0	39.6
Flexed and tensed arm	39.4 ± 2.5	36.3	42.5
Forearm	31.5 ± 2.0	29.0	34.0
Chest	111.5 ± 4.1	106.3	116.6
Medial thigh	57.1 ± 9.0	45.9	68.3
Medial calf	36.8 ± 5.1	30.5	43.1
Breadths (cm)			
Humeral	7.3 ± 0.4	6.9	7.8
Femoral	10.6 ± 0.2	10.4	10.9
Skinfold thicknesses (mm)			
Subscapular	19.8 ± 5.4	13.1	26.5
Triceps	11.2 ± 2.4	8.2	14.2
Abdominal	27.6 ± 4.8	21.6	33.6
Suprailiac	29.8 ± 5.3	23.3	36.3
Front thigh	15.6 ± 6.8	7.2	24.0
Medial calf	16.4 ± 5.8	9.2	23.6

SD = standard deviation; CI = confidence interval; LB = lower bound; UB = upper bound; PTE = para-throwing experience.

Table II. Body composition of shot put para-athletes.

Variable	Mean ± SD	95% CI	
		LB	UB
Sum of skinfolds			
3SKF (mm)	45.8 ± 8.9	34.7	56.9
4SKF (mm)	106.6 ± 19.9	81.9	131.3
6SKF (mm)	144.0 ± 18.7	120.7	167.3
Body composition			
Fat mass (%)	25.7 ± 2.8	22.3	29.2
Fat mass (kg)	23.2 ± 1.3	21.6	24.8
Muscle mass (%)	39.1 ± 3.7	34.6	43.7
Muscle mass (kg)	35.4 ± 3.5	31.0	39.8
Somatotype			
Endomorph	4.4 ± 0.9	3.2	5.6
Mesomorph	6.9 ± 1.6	4.8	9.0
Ectomorph	0.9 ± 0.9	-0.2	2.1
Somatotype classification	Endomorph - Mesomorph		
Somatotype attitudinal distance	1.7		

SD = standard deviation; CI = confidence interval; LB = lower bound; UB = upper bound; 3SKF = triceps, subscapular, and suprailiac; 4SKF = triceps, biceps, subscapular, and suprailiac; 6SKF = subscapular, triceps, abdominal, suprailiac, front thigh, and medial calf.

Table III. Handgrip strength and asymmetries.

Variable	Mean ± SD	95% CI	
		LB	UB
Grip strength right hand (kg)	66.4 ± 6.7	58.1	74.8
Grip strength left hand (kg)	62.1 ± 4.0	57.1	67.1
Bilateral asymmetry (%BA)	6.5 ± 6.2	-1.2	14.2

SD = standard deviation; CI = confidence interval; LB = lower bound; UB = upper bound

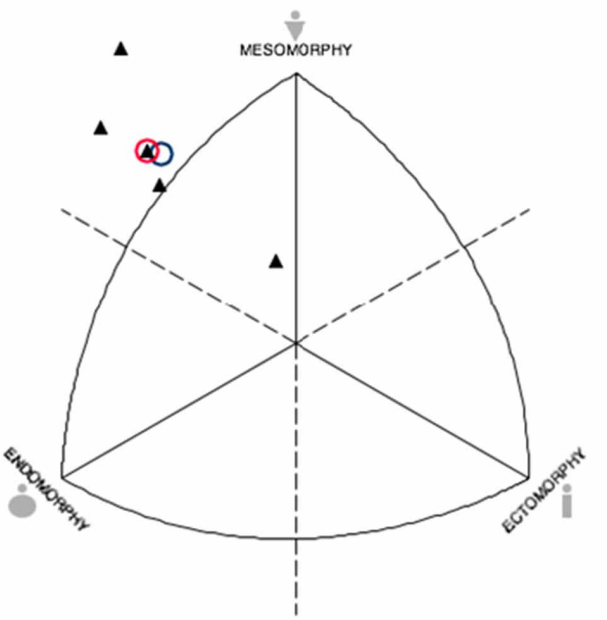

Fig. 1. Somatochart of male highly trained shot put para-athletes.

DISCUSSION

Para-athletes in the study showed an endomorph-mesomorph somatotype (4.4-6.9-1.0), characterized by a higher skeletal muscle mass and adipose tissue. This somatotype confers an advantage for shot put throwers as more skeletal muscle mass can increase overall power and strength, resulting in greater throwing distances, as previously observed in studies that showed a positive relationship between body composition (fat-free mass) and shot put performance, particularly with the linear technique (Kyriazis *et al*., 2010). However, it is important to note that excess body fat can negatively impact a thrower's speed and agility (Miller, 2012; Zaras *et al*., 2021). Further research is needed to determine the impact of body fat on throwing performance.

The average height of the examined para-athletes was found to be 179.1 ± 8.9 cm, taller when compared to the of amputee (163 cm) or cerebral palsy (161 cm) track para-athletes (Cherif *et al*., 2022), or elite para-athletes from various sports including table tennis, football, swimming, rugby, powerlifting, and wheelchair tennis (167.2 ± 11 cm) (Durán-Agüero *et al*., 2016). Height plays a significant role in the performance of throwing events in track and field (Lee *et al*., 2015), as taller athletes are likely to have a higher release height, which is crucial for maximizing performance in the shot put event (Zaras *et al*., 2021). Longer trunk and limbs, which are typically seen in taller athletes, can provide a larger throwing angle, a higher landing point height, and greater leverage and power when throwing, increasing the chances of success (Alhumaid & Atta, 2022).

Para-athletes exhibit higher HGS levels, averaging 66.4 ± 6.7 kg, compared to healthy able-bodied individuals who average 50.6 ± 7.6 kg at 30-34 years old (Romero-Dapueto *et al*., 2019). Previous studies have shown that athletes engaged in handgrip activities tend to have high HGS levels and HGS is significantly associated with seated throwing performance in athletes with spinal cord injuries (Hyde *et al*., 2017). It has also been found that certain hand dimensions, such as finger spans, lengths, and perimeters, can predict handgrip strength in athletes, which may aid in the development of targeted training programs to improve HGS and overall athletic performance (Fallahi & Jadidian, 2011).

It is important to assess any imbalances between the two arms in HGS measurements, as throwing sports often put excessive demands on one arm. A study of elite judo athletes suggests that bilateral asymmetry affects performance in shoulder external rotations and unilateral seated shot put, but to a small extent ($\eta 2 = 0.07$) (Delorme *et al*., 2023). Upper limb asymmetries can have a significant impact on the para-athlete performance in track and field throwing events, but the extent of the impact and when it becomes detrimental or increases injury risk is still unknown (Afonso *et al*., 2022).

This study has several limitations, including a small sample size, the absence of female participants, and the inability to make valid comparisons with other athletes due to the limited number of similar studies. While there have been a few studies examining anthropometric characteristics in throwers with disabilities, the majority of these have combined the results with track or jump athletes (Lemos *et al*., 2016; Cherif *et al*., 2022). In the future, it will be important to increase the sample size and include female participants, as well as to compare parameters between athletes of different sport levels.

CONCLUSION

The somatotype of the shot put throwing para-athletes was characterized by increased muscularity and body fat, along with a considerable stature. High levels of handgrip strength were also observed, although some bilateral asymmetry was noted. Further research is needed to understand the implications of this asymmetry on athletic performance.

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RESUMEN: Las características antropométricas, incluido el tamaño, forma y composición del cuerpo, pueden tener un impacto significativo en el rendimiento deportivo debido a su influencia en diversos factores fisiológicos y biomecánicos. Sin embargo, las investigaciones sobre las características antropométricas para-atletas de lanzamiento altamente entrenados son limitadas. El propósito de este estudio fue describir las características antropométricas, la fuerza de prensión manual y las asimetrías bilaterales de miembros superiores de paralanzadores chilenos altamente entrenados en lanzamiento de la bala. Se evaluaron las características antropométricas de cinco atletas masculinos chilenos de lanzamiento de bala (edad promedio de 38,8 ± 7,7 años), inclui-

do el grosor de los pliegues cutáneos en seis sitios anatómicos, la circunferencia en cinco sitios y la anchura de los huesos en dos sitios. También se midieron la fuerza de prensión manual y las asimetrías bilaterales. Se encontró que la masa corporal y la altura de los atletas eran 90,5 ± 5,1 kg y 179,1 ± 8,9 cm, respectivamente. Los atletas tenían un somatotipo endo-mesomorfo (4.4-6.9-1.0) con altos niveles de masa grasa (25.7 ± 2.8 %) y masa muscular esquelética (39.1 ± 3.7 %). Se encontró además que la fuerza de prensión manual de los atletas era de 66,4 ± 6,7 kg con una asimetría bilateral de 6,5 ± 6,2 %, mostrando mayor fuerza la mano dominante. Los resultados indican que los atletas de lanzamiento de bala tienen un somatotipo caracterizado por una mayor musculatura y grasa corporal, junto con una estatura considerable. Aunque se encontró que la fuerza de agarre era alta, los atletas mostraron asimetría bilateral, lo que requiere de más investigaciones para determinar las causa e implicaciones.

PALABRAS CLAVE: Composición Corporal; Somatotipo; Deporte para personas con discapacidad; Deporte Adaptado; Para atletas.

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