ANTHROPOMETRIC CHARACTERISTICS OF MALAYSIAN COMPETITIVE POWERLIFTERS WITH PHYSICAL DISABILITIES

***A Hamid MS*[1], *Shariff-Ghazali S*[2,3], *Abdul Karim S*[1].**

[1]Unit of Sports Medicine, Faculty of Medicine, University of Malaya, 50603 Kuala Lumpur, W.P Kuala Lumpur, Malaysia
[2]Department of Family Medicine, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Malaysian Research Institute on Ageing, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Correspondence:
Mohamad Shariff A Hamid
Unit of Sports Medicine,
Faculty of Medicine,
University of Malaya,
50603 Kuala Lumpur,
W.P Kuala Lumpur, Malaysia
Tel: +603 7967 4968
Fax: +603 7967 7511
Email: ayip@um.edu.my

Abstract

Background: Studies on the anthropometric, physical and physiological characteristics among Malaysian Paralympic powerlifters are limited. This study examined the sociodemographic, clinical information and anthropometric physical parameters of Paralympic powerlifters in Malaysia.

Methods: A cross-sectional study was conducted during a Powerlifting Workshop and National Championship in 2016. A structured questionnaire was used to collect data on powerlifters' sociodemographic, sports participation history and medical information. All participants underwent a structured physical medical examination and anthropometric assessments.

Results: Fifty-two powerlifters participated in this study. Mean age of participants was 24.50±SD8.25 year. The majority of the participants were men (82.7%) and most had spinal cord injury (34.6%) or amputation of the lower limb (26.9%). Most of the powerlifters competed at district and state level championships and 42.3% had represented Malaysia at international competitions. Women powerlifters had a significantly higher amount of body fat compared to men (35.61% vs 19.80%; p=0.003). Male power-lifters had significantly longer arm and forearm length (30.10±IQR3.00 cm vs 23.00±IQR2.13 cm; *p*=0.020). A significantly positive relationship was found between age, experience, weight, BMI, LBM, arm circumferences (relaxed and tensed) and the powerlifter's best lift. Age, experience, body weight, BMI, lean body mass, body fat, hip circumference and arm circumferences (relaxed and tensed) met the criteria for inclusion in a multivariate model. Years of experience and non-dominant arm circumference (tensed) were significant predictors of best lifts among powerlifters.

Conclusion: In conclusion, assessment of anthropometric measures could be useful in monitoring athletes' progress with training and have a role in the talent identification program for Paralympic powerlifters.

Keywords: *Paralympic, Physical Disability, Anthropometry, Powerlifters, Malaysia*

Introduction

Paralympic powerlifting is a sport that is an adaptation of powerlifting for individuals with physical disabilities (1). The only competitive discipline in Paralympic powerlifting is the bench press, which is open to both men and women who meet the eligible physical impairment criteria. All eligible powerlifters compete in one sport class, but in different weight categories. Historically, the current Paralympic powerlifting was first featured in the 1992 Paralympic games during which 106 powerlifters from 25 countries took part. Since then the number of Paralympic powerlifters increased with time and at the London Paralympic Games, 2012, more than 200 powerlifters from 74 countries competed in the event.

The type of activities and movements during each sport are unique and involves different physical and physiological demands of the body (2). Several studies have described specific components of physical and physiological factors that affect performance in different sports. Body composition and somatotype of an individual plays a significant role in sports performance besides other factors such as physical fitness, physiological fitness, skills and psychological strength (3).

Weightlifting is a dynamic strength and power sport; during each lift, the weightlifter achieves the highest absolute and relative peak power output (4). Previous studies on able-bodied weightlifters identified certain physical characteristics advantageous for the sport (5-7). Weightlifters at lower body weight categories (<85 kg) was found to have ectomorphic or mesomorphic somatotype with lower percentages of body fat (5-10% of body weight), whereas weightlifters in the heavy (>94 kg) or unlimited class (>105 kg) tend to be more endomorphic mesomorphs with higher body fat (>17%). Successful weightlifters were also noted to be shorter in height, have a larger biacromial breadth and have proportionally shorter arm span and tibial length. Such anthropometric characteristics provide mechanical advantages as follows: i) shorter lengths of the resistance level arms results in less mechanical torque needed to lift a given load and, ii) since the distance to lift the load is less (shorter arm span) the amount of muscle work required is also reduced (8,9). Previous studies that reported such findings were merely performed in Western population of male and female able-bodied weightlifters.

Despite a growing participation of athletes in Paralympic powerlifting, there remains a lack of anthropometric studies on Paralympic powerlifters. In particular, the physical and physiological characteristics among Malaysian powerlifters with physical disability are even more limited (10). The main objective of this study was to determine the sociodemographic and anthropometric parameters of Paralympic powerlifters in Malaysia. The results from this study could potentially be used as baseline data on the anthropometric and physical characteristics of powerlifters that would be useful for talent identification and selection of future powerlifters.

Materials and Methods

Participants

A cross-sectional study was conducted at the Kampung Pandan Sports Complex, during a Powerlifting Workshop and National Championship Circuit 1 from the 22nd to 27th April 2016. Participants included national and state level powerlifters with physical disability throughout Malaysia. All registered participants were invited to take part in this study. Information about the study including its purpose as well as the procedures involved was explained to potential participants by means of the patient information sheets. Participants were required to complete the informed consent form prior to participation. The University of Malaya Medical Centre Ethics Committee approved the study (MEC Ref no. 20164-2361).

A structured questionnaire was used to collect data on participants' socio-demographic, sports participation history and medical information (self and family). All participants underwent a structured physical medical examination and anthropometric assessments (height, weight, body mass index, hip circumference, waist circumference, biacromial breadth, upper limb length, arm girths), as well as body composition analysis.

Height, weight and body mass index measurements

Participants were weighed in minimal clothing; measurement was recorded to the nearest 0.1 kg using the Detectco Portable Wheelchair Scale (model 6500 Missouri, USA). Height was measured with participants in the supine position using a flexible measuring tape (Black & Decker, USA). The length between the vertex of the head and heel was measured to the nearest 0.1 cm. The body mass index (BMI) was calculated based on the formula; BMI=Weight (kg)/Height^2 (m^2) (11).

Musculoskeletal assessments

The upper limb (arm and forearm) lengths, arm girths (relaxed and tensed), biacromial length and waist circumference were measured using the method as described by the International Society for the Advancement of Kinanthropometry (ISAK) (12). Lengths or circumferences were recorded to the nearest 0.1 cm. For each measurement, two readings were obtained and averaged before being recorded in the participant's assessment form.

Body composition analysis

The body composition analysis was performed using the Biodynamics Bioimpedance Analyser 310e machine following the manufacturer guidelines (Washington, USA). Participants were advised to refrain from taking any fluids within eight hours prior to the test. Lean body mass and lean body fat were measured to the nearest 0.1 kg.

Data analysis

Data were analysed using Statistical Package for the Social Science (SPSS Inc., version 24.0 for Mac, Chicago). Descriptive analysis of participants' characteristics was performed. Continuous variables including participant's sociodemographic, history and measured variables were reported using mean and standard deviation (SD) or median and interquartile range (IQR), depending on the data distribution following the Shapiro-Wilk test of normality. Normal distribution of the data was assumed when the Shapiro-Wilk test had a p-value <0.05. Categorical data were presented as frequencies and percentages.

For group comparisons, powerlifters were subdivided into: lightweight (male: 65 kg class and below (n=20); female: 55 kg class and below (n=2), middleweight (male: 66 kg to 88 kg class (n=17); female: 56 kg to 74 kg class (n=3), and heavyweight (male: 88 kg class and above (n=6); women: 75 kg class and above (n=4). This classification was based on the current categorical classes as described under the International Paralympic Powerlifting Sport (1).

Univariate associations between the potential predictors and best lifting performance were assessed with Pearson correlation. A linear regression analysis with the stepwise forward method was conducted to identify independent predictors of the best lift. Variables that were significant at less than 0.25 on univariate testing were included in the multivariate model. The significance level was set at p-value of <0.05.

Results

Sociodemographic characteristics

Fifty-two powerlifters representing 13 states in Malaysia participated in the event. The sociodemographic characteristics of participants are displayed in Table 1. The majority of participants were men. Almost all powerlifters (n=47; 97%) completed the basic education level. The vast majority had completed secondary schools, whilst four powerlifters (<10%) obtained tertiary education.

Table 1: Participants' characteristics (N=52)

Characteristics	Mean (SD) / Median (IQR) (range)	Frequency (%)
Age (year)	24.50 (IQR8.25) (13.00 – 47.00)	
Duration of disability (years)	18.06 (SD10.88) (1 – 45)	
Gender		
Men		43 (82.7)
Women		9 (17.3)
State		
Sarawak		11 (21.2)
Kedah		8 (15.4)
Kelantan		5 (9.6)
Terengganu		5 (9.6)
Sabah		4 (7.7)
Others		19 (36.5)
Education level		
Primary		2 (3.8)
Secondary		41 (78.7)
Tertiary		4 (7.7)
Others		4 (7.7)
Disability category		
Spinal cord injury		18 (34.6)
Amputee		14 (26.9)
Les autres		13 (25.0)
Poliomyelitis		3 (5.8)
CP		3 (5.8)
Dominant side		
Right		37 (71.2)
Left		8 (15.4)
Ambidextrous		7 (13.5)

IQR=interquartile range
SD=standard deviation

Most powerlifters competed at the district and state level powerlifting championships while another 42.3% represented Malaysia at international competitions. The majority of the powerlifters were trained under the guidance and supervision of coaches at the state and national facilities. The median duration of powerlifting participation was 2.00±IQR3.75 years (range: 0 to 22 years), with the majority (76.9%) having at least 1 year or more experience in powerlifting. Powerlifters typically trained between two to four sessions per week (90 minutes per session). Most (71.2%) powerlifters were right-hand dominant. A few (5.8%) of the participants were involved in other sports, including athletics, basketball and wheelchair tennis. With the exception of three (5.8%) powerlifters who were diagnosed with chronic hypertension, the remainder were considered healthy and did not report any form of medical condition. Women powerlifters were slightly older and had longer experience in participation compared to men; the difference, however, was not statistically significant.

Anthropometric parameters

The physical and anthropometric characteristics of men and women powerlifters are displayed in Table 2. The body mass indices (BMI) between the two genders were comparable. In general, men were taller in supine height than women. Correspondingly, the BMI of women (BMI=33.50 kg/m^2) was greater compared to men (BMI=28.10 kg/m^2); however, the difference was not statistically significant (p=0.196). Women powerlifters had a significantly lesser amount of lean body mass (LBM), higher percentages (%BF) and higher amount body fat (kg) compared to men. Men powerlifters demonstrated significantly longer arm and forearm lengths compared to women. No significant difference in arm girths (relaxed and tensed), biacromial breadths, hip and waist circumference was noted between genders.

Table 2: Demographics and anthropometric characteristics for men and women (N=52)

Parameters	Mean (SD) / Median (IQR)*		p value
	Men (n=43)	Women (n=9)	
Age (year)	23.00 (IQR9.25)	28.00 (IQR11.50)	0.092
Experience (year)	2.00 (IQR4.5)	4.00 (IQR8.50)	0.201
Weight* (kg)	66.60 (IQR25.90)	66.10 (IQR32.65)	0.971
Height (cm)	159.00 (IQR20.00)	148.00 (IQR10.75)	0.075
Body mass index (BMI)(kg/m2)	28.10 (IQR8.90)	33.50 (IQR8.60)	0.196
Lean body mass (LBM)(kg)	54.90 (IQR14.32)	43.50 (IQR9.78)	0.031
% Body fat	19.80 (SD10.56)	35.61 (SD6.08)	< 0.001
Body fat (kg)	14.10 (SD11.55)	26.50 (SD10.80)	0.003
Hip circumference (cm)	94.11 (SD21.24)	109.75 (SD17.93)	0.057
Waist circumference (cm)	90.10 (IQR24.74)	87.75 (IQR29.72)	0.672

Table 2: Demographics and anthropometric characteristics for men and women (N=52) (continued)

Parameters	Mean (SD) / Median (IQR)*		p value
	Men (n=43)	Women (n=9)	
Biacromial breadth (cm)	42.00 (IQR7.40)	57.00 (IQR38.50)	0.240
Arm length (cm)			
Dominant	30.30 (IQR2.75)	27.00 (IQR2.55)	0.014
Non-dominant	30.10 (IQR3.00)	23.00 (IQR2.13)	0.020
Forearm length (cm)			
Dominant	26.40 (IQR2.45)	23.00 (IQR2.13)	0.002
Non-dominant	25.75 (IQR2.75)	22.15 (IQR1.75)	0.006
Arm girth (relaxed) (cm)			
Dominant	36.83 (SD6.60)	36.12 (SD9.04)	0.78
Non-dominant	36.45 (SD5.80)	36.34 (SD8.93)	0.96
Arm girth (tensed) (cm)			
Dominant	38.12 (SD5.80)	37.77 (SD9.18)	0.88
Non-dominant	37.77 (SD5.92)	37.37 (SD9.44)	0.87

*1 missing data
IQR=interquartile range
SD=standard deviation

Only the anthropometric characteristics among men powerlifters were analysed based on weight categories as the number of women powerlifters was small (n=9). In general, the anthropometric characteristics of powerlifters from the three weight classes showed that heavyweight powerlifters were significantly heavier, had higher BMI, lean body mass and body fat than powerlifters of lighter classes (Table 3). Middleweight powerlifters generally had anthropometric parameters that were intermediate between lightweights and heavyweights.

There were significant differences in the mean BMI between powerlifters of the three weight classes (p<0.001). The BMI was highest among powerlifters of the heavyweight class (42.08±SD11.39 kg/m^2) followed by middleweight (31.33±SD5.46 kg/m^2) and lightweight (25.55±SD kg/m^2). Powerlifters in the heavier weight classes had significantly higher LBM (p<0.001) compared to powerlifters in the lighter classes. The LBM among lightweight, middleweight and heavyweight powerlifters were 45.90±SD9.13 kg, 63.41±SD8.29 kg and 71.70±SD10.16 kg, respectively. The amount of body fat and hip circumference of powerlifters in heavier weight classes were significantly higher compared to those in the lighter weight classes.

Table 3: Male powerlifters' anthropometric characteristics based on weight categories (N=38)

Parameters	Mean (SD)			p value
	Light weight (n=19)	Medium weight (n=15)	Heavy weight(n=4)	
Age (years)	25.21 (SD8.08)	23.80 (SD7.75)	23.00 (SD 3.38)	0.780
Experience (years)	2.69 (SD2.79)	3.00 (SD3.71)	2.25 (SD1.71)	0.911
Best lifts (kg)	78.75 (SD30.89)	86.90 (SD39.30)	108.25 (SD46.31)	0.290
Height (cm)	149.58 (SD15.78)	161.50 (SD10.52)	158.25 (SD15.74)	0.107
Weight (kg)	52.45 (SD8.06)	76.93 (SD7.06)	101.23 (SD5.23)	< 0.001α,β,δ
Body mass index (kg/m2)	25.55 (SD7.05)	31.33 (SD5.46)	42.08 (SD11.39)	<0.001α
Lean body mass (kg)	45.90 (SD9.13)	63.41 (SD8.29)	71.70 (SD10.16)	< 0.001α,β
% Body fat	17.63 (SD10.25)	21.48 (SD10.15)	20.28 (SD12.04)	0.083
Body fat (kg)	9.88 (SD6.04)	17.41 (SD8.40)	30.71 (SD12.31)	<0.001α,δ
Hip circumference (cm)	81.98 (SD20.51)	108.72 (SD7.62)	118.38 (SD8.03)	< 0.001β,δ
Waist circumference (cm)	94.17 (SD77.74)	101.54 (SD8.89)	111.50 (SD6.56)	0.861
Biacromial breadth (cm)	42.83 (SD10.80)	41.82 (SD8.97)	48.80 (SD15.73)	0.542
Arm length (cm)				
Dominant	28.14 (SD4.57)	30.33 (SD1.51)	32.50 (SD3.12)	0.078
Non-dominant	28.06 (SD4.11)	30.36 (SD2.32)	32.19 (SD2.73)	0.061
Forearm length (cm)				
Dominant	24.74 (SD3.44)	26.83 (SD1.79)	26.25 (SD1.46)	0.162
Non-dominant	24.51 (SD3.64)	26.52 (SD2.73)	25.03 (SD3.43)	0.304
Arm girth (relaxed) (cm)				
Dominant	33.21 (SD4.95)	41.63 (SD5.84)	43.29 (SD1.53)	<0.001α,β
Non-dominant	22.43 (SD4.58)	39.63 (SD4.27)	42.35 (SD2.09)	< 0.001α,β
Arm girth (tensed) (cm)				
Dominant	35.14 (SD4.89)	41.42 (SD3.59)	44.24 (SD2.26)	<0.001α,β
Non-dominant	34.78 (SD4.88)	41.15 (SD3.93)	43.85 (SD2.11)	<0.001α,β

$^{\alpha}$significant difference between lightweight and heavyweight
$^{\beta}$significant difference between lightweight and middleweight
$^{\delta}$significant difference between middleweight and heavyweight
IQR=interquartile range
SD=standard deviation

Both the dominant and non-dominant arm girths during relaxed and tensed were also significantly greater in heavier weight classes (p<0.001). Even though powerlifters of heavier weight classes had wider biacromial breadths and longer arm and forearm lengths, the differences were not statistically significant.

Factors associated with powerlifters' best lift are shown in Table 4. A weak to strong, significant positive relationship was found between age, experience, weight, BMI, LBM, arm circumferences (relaxed and tensed) and best lift (13). Age, experience, body weight, BMI, lean body mass, body fat (in kg), hip circumference and arm circumferences (relaxed and tensed) met the criteria for inclusion in a multivariate model. A multiple regression was run to predict powerlifters' best lift from years of experience and non-dominant arm circumference (tensed). These variable statistically predicted powerlifters' best lift, F (2,32)=44.059, $p<0.0005$, $R^2=0.734$. Both variables added statistical significance to the prediction, $p<0.05$.

Table 4: Factors associated with best lift among men powerlifters

Variables	Pearson correlation (r)	Strength	p-value
Age (years)	0.352	weak	0.030
Experience (years)	0.724	strong	<0.0001
Height (cm)	-0.057		0.734
Weight (kg)	0.418	moderate	0.009
BMI	0.462	moderate	0.008
LBM (kg)	0.389	weak	0.019
% BF	0.140		0.417
Body fat (kg)	0.241		0.156
Hip circumference (cm)	0.315		0.057
Waist circumference (cm)	0.008		0.961
Biacromial breadth (cm)	0.011		0.948
Dominant arm length (cm)	0.077		0.646
Non-dominant arm length (cm)	0.047		0.778
Dominant forearm length (cm)	0.035		0.836
Non-dominant forearm length (cm)	0.127		0.449
Dominant arm relaxed (cm)	0.549	moderate	<0.0001
Non-dominant arm relaxed (cm)	0.667	strong	<0.0001
Dominant arm tensed (cm)	0.648	strong	<0.0001
Non-dominant arm tensed (cm)	0.694	strong	<0.0001

Discussion

This study found that current Malaysian powerlifters with physical disability were young, with the median age in the mid-twenties; hence, with proper guidance and nurturing, these group of powerlifters has the potential to achieve greater success. The traditional Asian sociocultural norms and ideas of identifying the female body and feminine behaviour might have, to a certain extent, contributed to fewer women participating in powerlifting (14).

A higher proportion of powerlifters were categorised in the spinal cord injury and lower limb deficiency; such disabilities are commonly associated with motor vehicle and occupational accidents. Advancement in the field of medicine through eradication of poliomyelitis and better management, early detection and prevention of cerebral palsy, could also have contributed to a lower proportion of powerlifters from these categories (15).

Compared with the able-bodied male weightlifters' physical characteristics, the powerlifters with physical disability in the current study were lighter in body weight (for the given weight categories) (16). Such an observation was anticipated as the majority of powerlifters either had spinal cord injury (SCI) or loss of lower limb(s). Powerlifters in the spinal cord injury (SCI) categories usually had complete or incomplete spinal cord lesions leading to abnormal lower limb muscle control resulting in muscle atrophy. At present, there is no data available for comparison among women powerlifters.

The anthropometric characteristics that were significantly different between men and women powerlifters in this study were lean body mass, percentage of body fat, body fat, arm length and forearm length. There is no previous study available for comparison. Hence, in our discussion, comparisons were made with studies conducted among able-bodied weightlifters, powerlifters and bodybuilders.

Women powerlifters had significantly higher percentages of body fat and lower amount of lean body mass compared to men. Such an observation was also observed by Ashtary-Larky et al, who reported a higher percentage of body fat among women bodybuilders (men=25.47% vs women=38.56%) (17). The differences could be attributed to hormonal differences between genders, in particular due to the higher amount of circulating oestrogen in women, which is responsible for higher percentages of body fat deposition (18).

Men powerlifters had significantly longer arm and forearm lengths, which concurred with a previous study. Yap et al reported a longer arm span among Singapore men regardless of ethnicity (Malay, Chinese and Indian) compared to women of the same ethnic background (19). Moreover, powerlifters arm girths (relaxed and tensed) of both genders were noted to be in the 95th centile of the mid-upper arm circumference norms for healthy adults (20). Such an observation could be the result of muscle hypertrophy in response to resistance training that powerlifters performed (20,21).

We found that body mass and BMI were highest among powerlifters in the heavyweight category followed by the middleweight and lightweight categories. Powerlifters in heavier weight categories have significantly higher lean body mass (LBM). Such an observation was also reported by the previous study. Keogh et al reported that the fat-free mass (fractionated muscle, bone and residual mass) of able-bodied powerlifters were increased proportionately to powerlifters weight (9). They also described an increasing trend in body fat levels (both percentage and fat mass) and hip circumferences across the lightweight, middleweight and heavyweight powerlifters. This corresponds to the findings of the current study. Both arm girths during relaxed and tensed positions were also greater in heavier weight categories. Our findings were consistent with those observed by previous studies (22,23).

The current study identified several variables that have significant correlation with powerlifters' best lift. Powerlifters' age, experience, body weight, BMI, LBM and arm circumference had a significant positive correlation with best lift. Such findings were consistent with several previous studies (24-26). Siahkouhian & Hedayatneja (2010) found significant positive correlation between weightlifting (snatch and clean & jerk) records and height, sitting height, weight, shoulder and chest circumference, BMI and LBM among young elite Iranian weightlifters (24). Additionally, a significant positive correlation between LBM and lifting performance was also reported by the same authors in a more recent study involving 42 elite level weightlifters (25). Our study found that years of experience and non-dominant arm circumference (tensed) significantly predicted Paralympic powerlifters' best lift. These findings were in agreement with previous literature (26).

Latella et al, using powerlifting competition records, reported meaningful differences in the total competition scores between powerlifters who competed in local competition and those who competed at the national level (27). Similar observations were also reported by a recent study which reported progressive increase in performance among female weightlifters over 10 years' follow-up (28). Differences in lifting performance between novices and the experienced could be attributed to the acquisition of skill mastery and physiological adaptation resulting from years of training. This might have been responsible for the greater performance seen among more experienced powerlifters (29).

Influence of anthropometric measures on arm strength was investigated in a cross-sectional study involving ninety-six (46 men and 50 women) college-age participants. This study found that, among men, the elbow circumference was a significantly stronger predictor of arm strength compared to arm length (30). Similarly, Winwood, Keogh & Harris (2012) found that flexed arm girth and calf girth demonstrated the highest interrelationships with strongman competition performance (31).

Strength and limitation of the study

This is the first study to describe the anthropometric characteristics of competitive powerlifters with physical disability. Several limitations, however, need to be addressed. First, the number of participants in the current study is small, especially among women powerlifters. The numbers of participants in this study, however, do reflect the current weightlifting/powerlifting situation in Malaysia. Currently, there are twenty-five elite able-bodied weightlifters (men=14 and women=9) under the various sports programmes (development, senior and podium) in Malaysia. A larger sample size could yield a significant difference between genders and between weight classes with higher effect size. Second, the nature of a cross-sectional design does not allow causal effect relationship to be established among the variables investigated in this study.

Conclusion

Paralympic powerlifters of the heavyweight class had significantly greater body weight, BMI, lean body mass, fat mass and arm girths than those in lighter weight classes. Our findings showed significant correlation between powerlifting performance (best lifts) and athlete's age, years of experience, and several anthropometric parameters. Moreover, years of experience and non-dominant arm circumference (tensed) were found to be significant predictors of best lift. Hence, assessment of anthropometric measures could play a role in the talent identification program for Paralympic powerlifters and could also be useful in monitoring athletes' progress with training. A longitudinal cohort study that explores anthropometric factors associated with powerlifting performance is recommended. Such a study should include assessment and comparison of factors that affect performance across powerlifters of different weight classes as well as within each class. Such a study would provide a more precise role of anthropometric characteristics for talent identification and assessment of training progress.

Acknowledgement

We thank Dr Yau May Yan, Dr Wan Mohd Ashraf Bin Abdul Manaf, Dr Lakhvinder Singh A/L Harbant Singh, Lt. Cdr. Kamaruzaman Kadir, the Department of Sports Medicine, University Malaya Medical Centre and the Malaysian Powerlifting Association for the Disabled for their assistance and support in conducting this study.

Financial support

We did not receive any financial support to conduct this study.

Competing interests

The authors declare that they have no competing interests.

References

1. Para Powerlifting Rules. (n.d.). Retrieved from http://www.paralympic.org/powerlifting/rules-and-regulations/rules.
2. Anup A, Nahida P, Nazrul Islam R, Kitab A. Importance of anthropometric characteristics in athletic performance from the perspective of Bangladeshi national level athletes' performance and body type. Am Journal Sport Sci Med. 2014; 2(4):123-127.
3. Bayios IA, Bergeles NK, Apostolidis NG, Noutsos KS, Koskolou MD. Anthropometric, body composition and somatotype differences of Greek elite female basketball, volleyball and handball players. J Sports Med Phys Fitness. 2006; 46(2):271-280.
4. Garhammer J. Power production by Olympic weightlifters. Med Sci Sports Exerc. 1980; 12(1):54-60.
5. Fry AC, Ciroslan D, Fry MD, LeRoux CD, Schilling BK, Chiu LZF. Anthropometric and performance variables discriminating elite American junior men weightlifters. J Strength Cond Res. 2006; 20(4):861-866.
6. Orvanová E. Somatotypes of weight lifters. J Sports Sci. 1990; 8(2):119-137.
7. Stone MH, Pierce KC, Sands WA, Stone ME. Weightlifting: A brief overview. Strength Cond J. 2006; 28(1):50.
8. Ford LE, Detterline AJ, Ho KK, Cao W. Gender- and height-related limits of muscle strength in world weightlifting champions. J Appl Physiol. 2000; 89(3):1061-1064.
9. Keogh JWL, Hume PA, Pearson SN, Mellow P. Anthropometric dimensions of male powerlifters of varying body mass. J Sports Sci. 2007; 25(12):1365-1376.
10. Abdullah NM, Appukutty M, Abdullah MD, Parnabas V. Physical fitness profiles among national powerlifters with disabilities. Media Ilmu Keolahragaan Indonesia. 2013; 3(1).
11. Clinical Practice Guidelines. Management of Obesity, 2004. Ministry of Health Malaysia. 2004.
12. Marfell-Jones MJ, Stewart AD, De Ridder JH. International standards for anthropometric assessment. New Zealand: Lower Hutt. 2012.
13. Cohen J. A power of primer. Psyc Bull. 1992; 112(1):155-159.
14. Scraton S, Fasting K, Pfister G, Bunuel A. It's still a man's game?: The experiences of top-level European women footballers. Int Rev for the Sociol Sport. 1999; 34(2):99-111.
15. The Travel Health Advisory for Measles and Polio, 2015. Ministry of Health Malaysia. 2015.
16. Wan Nudri WD, Wan Abdul Manan WM, Mohamed Rusli A. Body mass index and body fat status of men involved in sports, exercise, and sedentary activities. Malays J Med Sci. 2009; 16(2):21-26.
17. Ashtary-Larky D, NazaryVanani A, Hosseini SA, Rafie R, Abbasnezhad A, Alipour M. Relationship between the body fat percentage and anthropometric measurements in athletes compared with non-athletes. Zahedan J Res Med Sci. 2018; 20(2).
18. Porcari JP, Bryant CX, Comana F. Exercise Physiology. Philadelphia, PA: FA Davis Company. 2015.
19. Yap WS, Chan CC, Chan SP, Wang YT. Ethnic differences in anthropometry among adult Singaporean Chinese, Malays and Indians, and their effects on lung volumes. Respir Med. 2001; 95(4):297-304.
20. Bishop CW, Bowen PE, Ritchey SJ. Norms for nutritional assessment of American adults by upper arm anthropometry. Am J Clin Nutr. 1981; 34(11):2530-2539.
21. McArdle WD, Katch FI, Katch VL. Exercise physiology: nutrition, energy, and human performance. Philadelphia, PA: Wolters Kluwer Health. 2010.
22. Marchocka M, Smuk E. Analysis of body build of senior weightlifters with particular regard for proportions. Biol Sport. 1984; 1(1):57-71.
23. Mayhew JL, Piper FC, Ware JS. Anthropometric correlates with strength performance among resistance trained athletes. J Sports Med Phys Fitness. 1993; 33(2):159-165.
24. Siahkouhian M, Hedayatneja M. Correlations of anthropometric and body composition variables with the performance of young elite weightlifters. J Hum Kinet. 2010; 25(1):125-131.
25. Siahkouhian M, Azimi F, Hedayatnejad M. Lean body mass as a predictor of performance of young Iranian elite weightlifters. SAJR SPER. 2016; 38(2):179-186.
26. Solberg PA, Hopkins WG, Paulsen G, Haugen TA. Peak age and performance progression in world-class weightlifting and powerlifting athletes. Int J Sports Physiol. 2019.
27. Latella C, van den Hoek D, Teo WP. Differences in strength performance between novice and elite athletes: Evidence from powerlifters. J Strength Cond Res. 2018; 22(7s):S103-S112.
28. Miller JD, Ventresca HC, Bracken LE. Rate of performance change in American female weightlifters over ten years of competition. Int J Exerc Sci. 2018; 11(6):290-307.
29. Ericsson, KA. Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. Int J Sport Psychol. 2007; 38:4–34.
30. Green LA, Gabriel DA. Anthropometrics and electromyography as predictors for maximal voluntary isometric arm strength. J Sport Health Sci. 2012; 1:107-113.
31. Winwood P, Keogh J, Harris N. Interrelationships between strength, anthropometrics, and strongman performance in novice strongman athletes. J Strength Cond Res. 2012; 26(2):513-522.