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Anthropomorphic profile of masters competitive Olympic weightlifters

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ABSTRACT

The masters athlete is typically defined as older than 35 years who either trains for or takes part in athletic competitions often specifically designed for older participants. Masters athletes provide a unique research cohort to understand the role of regular vigorous exercise in optimizing physical potential and health with advancing age. Olympic weightlifting is a sport that demands specific physical attributes and rigorous training to excel. Anthropomorphic and competition data were collected for male and female athletes competing at the 2022 World Master Weightlifting Championships. Of the 820 eligible athletes, 172 from 17 countries participated in the physical assessment of the study. Female participants were slightly taller when compared to the general public and males shorter. Participants, both female and male, presented lower body mass index scores and waist circumference measures. Understanding the physical profiles of Masters athletes provides valuable insights for considering the impact of Olympic weightlifting. Masters Olympic weightlifters present physical profiles of aging with a functional capacity greater than that of an age-matched general population.

Contribution/Originality: This study uniquely examines anthropomorphic profiles of Masters Olympic weightlifters, a population underrepresented in sport science, offering insights into adaptations and informing training, performance, and health strategies specific to aging athletes.

1. INTRODUCTION

Olympic weightlifting is a popular competitive sport with numerous benefits. Individuals who participate in Olympic weightlifting perform two types of lifts: the snatch and the clean and jerk(Huebner, Lawrence, & Lusa, 2022). It has a long-standing tradition, dating back to ancient Greece and Egypt, and has been part of the modern Olympic Games since 1896 (Storey, Smith, & Cronin, 2012). Weightlifting is recognized for its unique biomechanical demands. The snatch and the clean and jerk are both dynamic, multi-joint movements that involve the entire neuromusculoskeletal system, requiring technical precision and presenting distinct biomechanical challenges (Storey & Smith, 2012). Biomechanical analysis has highlighted the complex nature of these lifts, emphasizing the importance of specific joint angles, force production, and timing for optimal performance (Kipp, Redden, Sabick, & Harris, 2012). The sport requires athletes to possess specific physical attributes and undergo rigorous training to excel. In the snatch, the barbell is lifted from the floor to overhead in one swift motion; while in the clean and jerk, the athlete lifts the barbell to the shoulders and then explosively drives it overhead. These two lifts require significant force to be released in a fraction of a second, achieving the highest rate of power output documented in sports (Garhammer, 1980; Huebner, Riemann, & Hatchett, 2023). Muscular power primarily depends on the type of muscle fibers involved in the contraction, the degree of neuromuscular activation, and the amount of lean muscle mass participating in a particular movement pattern (Komi, 2005). Therefore, individuals who compete in weightlifting devote a large portion of their training to improve these parameters. Muscular benefits from weightlifting are just one of many positives of engaging in such training. Individuals have also seen improvements in blood lipid levels, cardiovascular fitness, bone health, mental health, balance, blood pressure, and glycemic control (Erickson, Mercado, Goins, Lininger, & Riemann, 2018; Lavallee & Mansfield, 2013; Riemann, Mercado, Erickson, & Grosicki, 2020). An additional benefit of weightlifting is the resistance training aspect. Resistance training has been shown to decrease the prevalence of sarcopenia (muscle atrophy) in older individuals (Hunter, McCarthy, & Bamman, 2004). The training for Olympic weightlifting encompasses various components. Strength training forms the foundation, with exercises such as squats, deadlifts, and pulls aimed at developing lower body and upper body strength (Suchomel, Comfort, & Stone, 2015). Power training, including plyometrics and Olympic variations with lighter loads, focuses on enhancing explosive power and speed. Technical proficiency is crucial when considering weightlifting movement patterns in relation to performance outcomes (Comfort, Haigh, & Matthews, 2012). Flexibility and mobility are also essential aspects of weightlifting training. Adequate flexibility allows weightlifters to achieve optimal positions during the lifts, ensuring proper alignment and maximizing force production (Collegiate Strength and Conditioning Coaches Association, 2014). Stretching routines, mobility exercises, and specific drills targeting key areas like the hips, shoulders, and ankles aid in improving range of motion and joint stability. Masters Olympic weightlifters compete in Olympic-style weightlifting, similar to other age groups, in all official competitions. However, these athletes must be at least 35 years old to be classified as masters weightlifters. This age group extends up to the oldest age currently recognized (90 years). Despite peak performance typically occurring in the mid-twenties, masters athletes continue to achieve excellent results in weightlifting, demonstrating that age does not prevent the development of strength, power, and technical proficiency in Olympic weightlifting (Huebner et al., 2023). Masters athletes in Olympic weightlifting participate in training programs tailored to their specific needs and goals. The gender disparity in masters weightlifting is significant, with males being the majority. However, over a ten-year period, the number of women competing increased from 14% to 59% (Gava & Ravara, 2019). Research indicates minor gender differences in performance decline related to aging (Tayrose, Beutel, Cardone, & Sherman, 2015).

A recent increase in the number of masters athletes in the United States can be attributed to a growing population of more than 300 million people, an aging subpopulation of "baby boomers," and a culture enamored with sports (Baker, Horton, & Weir, 2010; Kontro et al., 2022; Kuster, 2002; Longo et al., 2009, 2011; Maron et al., 2001; McCarty, Marx, Maerz, Altchek, & Warren, 2008; Mehallo, Drezner, & Bytomski, 2006; Naal, Maffiuletti, Munzinger, & Hersche, 2007a; Naal et al., 2007b). As the population ages and interest in extending health and well-being increases, the number of Masters athletes has grown. Therefore, masters athletes provide a unique research cohort to under-stand the role of regular vigorous exercise in optimizing physical potential and health with advancing age (Fien et al., 2017; Ng, Hinton, Fan, Kanaya, & Shepherd, 2016; Totosy de Zepetnek et al., 2021).

Training programs for weightlifting focus on developing strength, power, technical proficiency, and flexibility. Anthropomorphic features, including body composition, somatotype, limb proportions, joint mobility, and body proportions, also contribute to weightlifting performance. While research may indicate that anthropometry is a useful tool in predicting general sports performance, few studies have investigated how anthropometric measures may influence weightlifting performance. Little research has been conducted on sex differences in anthropometric measures among competitive older adult weightlifting athletes. Understanding the unique physical characteristics of Olympic weightlifters aids in talent identification, training program design, and performance optimization. A first step in the analysis process is to develop a physical profile of these athletes. Due to the lack of research examining the physical characteristics of Masters Olympic weightlifters, a gap exists in the literature. Masters athletes provide a unique research cohort to understand the role of regular vigorous exercise in optimizing physical potential and health with advancing age Fien et al., 2017; Ng et al., 2016; Totosy de Zepetnek et al., 2021.

This study uniquely examines anthropomorphic profiles of Masters Olympic weightlifters, a population underr epresented in sport science, offering insights into adaptations and informing training, performance, and health strat egies specific to aging athletes. Therefore, the purpose of this study was to develop an anthropomorphic profile of elite master's Olympic weightlifters.

2. MATERIALS AND METHODS

Athletes who competed in the 2022 World Masters Weightlifting Championships, held in Orlando, Florida, USA, were eligible to participate in this study. Data collection occurred on-site during the December 2022 event. Recruitment was conducted via email through National Masters Chairs, the Masters Weightlifting Facebook page, and word-of-mouth at the competition venue. Athletes in the adaptive category and those with incomplete anthropometric data were excluded. All participants provided written informed consent in accordance with the Declaration of Helsinki. The study protocol was approved by the Michigan State University Institutional Review Board (STUDY00007906).

2.1. Measurements

Anthropomorphic data were collected on-site in the athlete's lounge, which was used by athletes after weigh-in and by technical officials during their breaks in competition. Participants were asked to self-report their age. Participant height was determined using a stadiometer (Detecto, Webb City, MO). All other information was collected using a Fit3D ProScanner. Key measurements used in this research included: body fat percentage, lean body mass, fat mass, waist-to-hip ratio, body mass index, body shape index, surface body shape index, neck circumference, bust circumference, chest circumference, waist circumference, hip circumference, bicep – left and right circumference, forearm – left and right circumference, shoulder to wrist length – left and right, inseam – left and right.

Participants stood on the center of a rotating platform holding the handles of the apparatus located on either side of their body while the Fit3D ProScanner camera measured over 450 anthropometric measurements in 40 seconds. Participants were instructed to tie up any hair that covered their neck, look forward and remain as still as possible. Body circumfer-ences were used to estimate %BF via the Fit3D ProScanner beta- software (December 2022). Previous research has determined the Fit3D ProScanner to be valid and reliable (Totosy de Zepetnek et al., 2021).

The Sinclair Total is calculated by taking an athlete's total (combined max snatch and clean & jerk) and multiplying that number by the Sinclair Coefficient. Sinclair formula, which was officially approved by the International Weightlifting Federation and used for the determination of the best athletes in international and national competitions since 1979 (Sinclair, 1985).

The Sinclair-Meltzer-Faber Formula (SMF) is used at the International Masters Weightlifting Association (IMWA) World and Continental Championships to compute the best lifter in each age group and the best overall lifter in the championship for men. The formula uses the 2020 Sinclair Body Weight Coefficients and the Meltzer-Faber Age Coefficients, which remain static unless and until changes are approved by the IMWA Congress and/or Executive Board.

The Sinclair-Huebner-Meltzer-Faber Formula (SHMF) is used at IMWA World and Continental Championships to determine the best lifter in each age group and the overall best female lifter in the championship. The formula utilizes the 2020 Sinclair Body Weight Coefficients and the Huebner, Meltzer, Faber Age Coefficients.

The SMF for men and SHMF for women results of participant performance. To compare athletic ability and determine an overall best lifter, a body weight adjustment is applied to the total weight lifted to compare performances made by lifters of different body weights. This scaled total is then multiplied by "age coefficients" to consider performance decline due to aging, to arrive at a standardization of the total by body weight and age.

2.2. Statistical Analysis

Continuous variables were summarized with medians and quartiles or means and standard deviations, as appropriate, and categorical variables with frequencies and percentages. Wilcoxon or Pearson tests were used to compare these variables, as appropriate. Scatter plots with smoothing B-splines were used to visualize the association of anthropomorphic parameters (body fat, waist-to-hip ratio, etc.) with age. Linear regression was conducted to determine the association between anthropomorphic variables and athlete performance. All analyses were conducted using R v. 4.3.0 (https://www.R-project.org/).

3. RESULTS

Of the 820 eligible athletes, 172 (21.0%) from 17 countries completed the physical assessment portion of the study. Four were excluded due to missing anthropomorphic data, resulting in a final sample of 104 females (ages 35–70) and 64 males (ages 35–90). While competition performance (SMF/SHMF) did not significantly differ between participants and non-participants, those who participated were generally older. This was likely due to the timing of data collection, which occurred primarily during the first 7 of the 10 championship days, before the youngest age groups (35 and 40) competed.

3.1. Descriptive Characteristics of Participants

Age, height and weight for female and male participants, as well as the combined sample are shown in Table 1. Female participants were younger, not as tall and weighed less than male participants.

Table 1. Descriptive characteristics of participants.

Variable	F *N=104*	M *N=64*	Combined *N=168*
Age (Years)	51.78 ± 9.42	55.38 ± 13.60	53.15 ± 11.29
Height (cm)	160.81 ± 7.21	171.41 ± 8.92	164.85 ± 9.42
Weight (kg)	68.1 ± 16.1	85.0 ± 14.6	74.5 ± 17.6

Table 2. Performance and scaled performance.

Variable	N	F	M	Combined
Snatch (kg)	164	49.4 ± 13.9	83.2 ± 25.2	62.2 ± 25.0
Clean and jerk (kg)	164	63.3 ± 16.2	105.1 ± 29.2	78.2 ± 29.5
Competition total (kg)	157	112.8 ± 29.9	188.4 ± 53.5	139.7 ± 53.9
SMF/SHMF	157	203.0 ± 28.4	315.6 ± 28.8	

3.2. Performance Outcomes and Scaled Performance Outcomes

Table 2 presents a total of 164 athletes snatch and clean and jerk totals, while 157 athletes posted totals (Snatch and clean and jerk performance totals combined). Female athletes recorded a lower mean snatch, clean and jerk, competition total and scaled performance values when compared to the male participants.

Table 3. Results of body composition analysis.

Variable	N	F	M
Body fat %	165	28.79 ± 6.27	23.79 ± 6.46
Lean body mass	165	105.9 ± 17.3	142.2 ± 21.4
Fat mass	165	45.1 ± 20.5	45.7 ± 17.6
Waist-to-hip ratio	167	0.84 ± 0.04	0.92± 0.06
Body mass index	168	26.21 ± 5.48	28.80 ± 3.51

3.3. Body Composition Analysis

Table 3 presents the results of body composition analysis. Female participants were determined to have higher body fat percentages, lower lean body mass, slightly lower fat mass, lower waist-hip ratio and lower body mass index scores when compared to male participants.

Table 4. Body shape indices of participants.

Variable	N	F	M
Body shape index	165	0.079± 0.004	0.078 ± 0.004
Surface body shape index	165	0.112 ± 0.007	0.108 ± 0.006

3.4. Body Shape Indices

Table 4 presents Body Shape Indices of the participants. A Body Shape Index (ABSI) based on WC adjusted for height and weight.

$$\mathrm{ABSI} \equiv \frac{\mathrm{WC}}{\mathrm{BMI}^{2/3}\mathrm{height}^{1/2}}.$$

Body shape index mean scores for female and males athletes were very similar, while sur-face body shape index scores differed more substantively. Female participants displayed a higher surface body index, a comparison between torso mass to all other body mass, score when compared to male participants.

Table 5. Circumference and length measurements of participants.

Variable	N	F	M
Neck circumference (cm)	166	35.86 ± 3.29	41.99 ± 3.63
Bust circumference (cm)	167	98.60 ± 11.30	109.84 ± 8.78
Chest circumference (cm)	167	98.96 ± 9.46	112.16 ± 7.78
Waist circumference (cm)	167	87.5 ± 10.4	96.9 ± 11.4
Hip circumference (cm)	168	103.75 ± 11.09	103.99 ± 6.79
Bicep - left circumference (cm)	168	31.72 ± 4.39	35.31 ± 3.16
Bicep - right circumference (cm)	168	31.90 ± 4.36	36.00 ± 3.59
Forearm - left circumference (cm)	168	25.41 ± 2.52	29.28 ± 2.12
Forearm – right circumference (cm)	168	26.32 ± 2.26	30.36 ± 2.07
Shoulder to wrist length - left (cm)	168	52.24 ± 3.45	57.09 ± 3.79
Shoulder to wrist length - right (cm)	167	52.90 ± 3.39	57.80 ± 4.20
Inseam - left (cm)	168	70.88 ± 4.78	72.15 ± 4.99
Inseam - right (cm)	168	70.89 ± 4.76	72.19 ± 4.99

3.5. Circumference and Length Measures

Circumference measures (cm) of various body parts are reported in Table 5. Female partic-ipants displayed lower circumference and length measurements when compared to male participants. The closest circumference measurement between the two groups was hip circumference (0.24 cm difference).

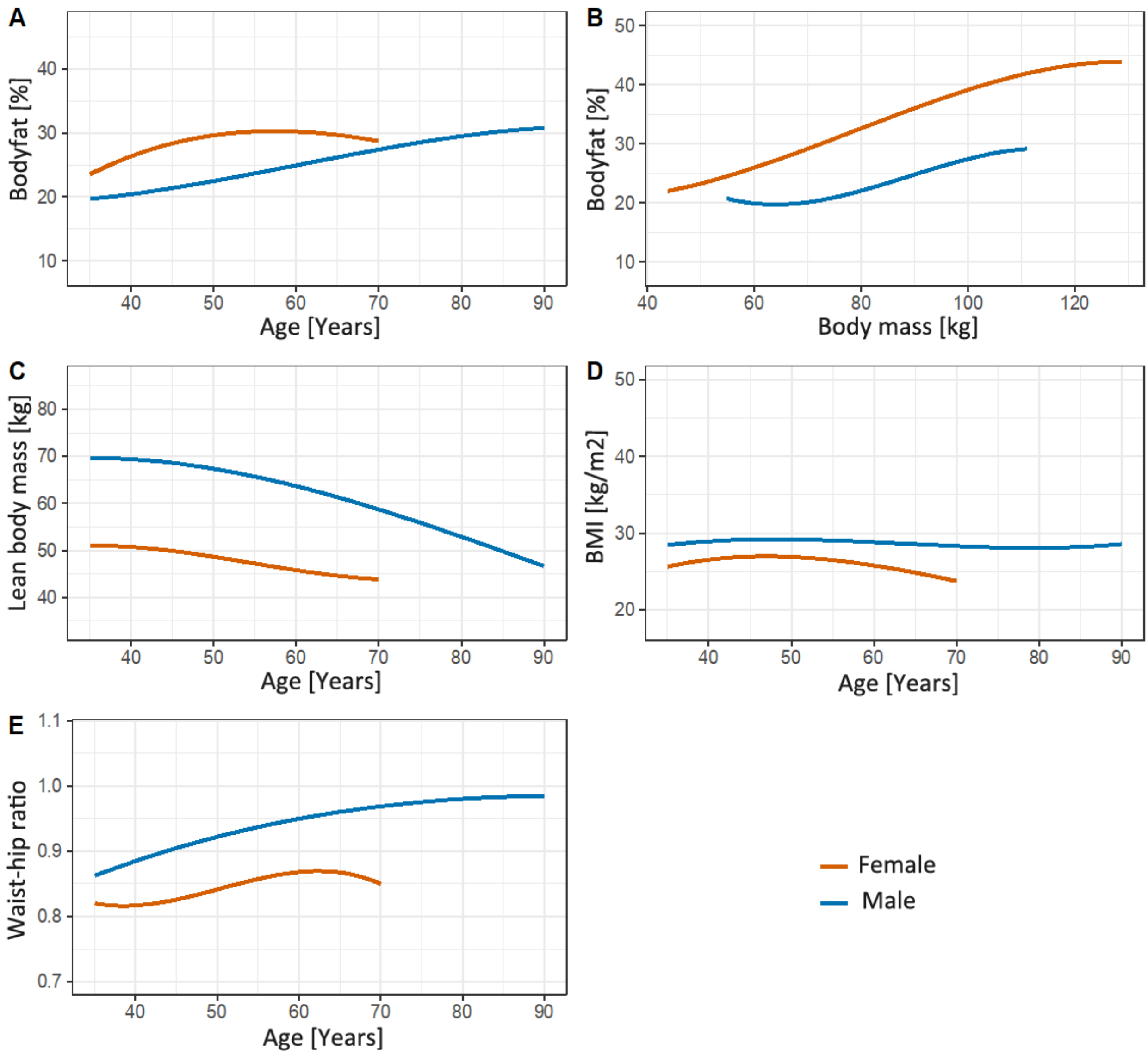

Figure 1. A through E articulate the association of age or body mass with an-thropometric measurements (A) Body fat [%] Across age in years, (B) Body fat % across body mass [kg], (C]) Lean body mass across age in years, (D) Body mass index across age in years, and (E) Waist-hip ratio across age. Smoothing spline curves with 95% confidence bands are shown. The color red represents female participants and the color blue represents male participants.

Figure 1 illustrates the association of age or body mass with anthropometric measurements (A) Body fat [%] Across age in years, (B) Body fat % across body mass [kg], (C]) Lean body mass across age in years, (D) Body mass index across age in years, and (E) Waist-hip ratio across age. Smoothing spline curves with 95% confidence bands are shown. The color red represents female participants and the color blue represents male participants.

Table 6. Linear regression coefficients for anthropometric variables for weight lifted [kg] for total weightlifting performance.

	Male		Female	
Variable	Coefficient (SE)	P-value	Coefficient (SE)	p-value
Height	1.08 (0.24)	<0.001	0.046 (1.02)	<0.001
Body fat	0.97 (0.22)	0.001	0.68 (0.16)	<0.001
Lean mass	0.82 (0.40)	0.044	-0.15 (0.22)	0.496
Biceps left	0.73 (0.24	0.004	0.167 (0.24)	0.489
Biceps right	0.62 (0.27)	0.027	0.29 (0.21)	0.178

Table 6 presents the linear regression coefficients for anthropometric variables for weight lifted [kg] for total weightlifting performance.

Table 7. Linear regression coefficients for anthropometric variables for weight lifted [kg] for snatch performance.

Variable	Male		Female	
	Coefficient (SE)	P-value	Coefficient (SE)	P-value
Height	0.48 (0.12)	<0.001	0.19 (0.05)	<0.001
Body fat	0.46 (0.11)	<0.001	0.30 (0.8)	<0.001
Lean mass	0.36 (0.19)	0.071	-0.08 (0.11)	0.484
Biceps left	0.32 (0.12)	0.008	<0.01 (0.12)	0.977
Biceps right	0.25 (0.14)	0.075	0.07 (0.10)	0.536

Table 7 presents linear regression coefficients for anthropometric variables for weight lifted [kg] for snatch performance.

Table 8. Linear regression coefficients for anthropometric variables for weight lifted [kg] for clean and jerk performance.

Variable	Male		Female	
	Coefficient (SE)	P-value	Coefficient (SE)	P-value
Height	0.63 (0.14)	<0.001	0.27 (0.06)	<0.001
Body fat	0.52 (0.13)	<0.001	0.38 (0.86)	<0.001
Lean mass	0.48 (0.23)	0.041	-0.07 (0.12)	0.543
Biceps left	0.40 (0.14)	0.006	0.16 (0.13)	0.216
Biceps right	0.37 (0.16)	0.024	0.23 (0.12)	0.056

Table 8 presents Linear regression coefficients for anthropometric variables for weight lifted [kg] for clean and jerk performance.

4. DISCUSSION

1. The aim of the present study was to determine the anthropometric profile of Masters Olympic weightlifters. Competitive Olympic weightlifters possess distinctive characteristics that enable them to excel in a sport that demands a unique combination of strength, power, technique, and mental resilience. These athletes embody dedication to training, exceptional physical attributes, and a deep understanding of the sport's intricacies. Competitive Olympic weightlifters exhibit remarkable levels of strength and power. Their training programs are designed to develop maximum force production, enabling them to lift heavy loads in explosive movements. These athletes typically display high levels of muscle mass due to the emphasis on resistance training. Research by Storey et al. (2012) has shown that weightlifters have a higher proportion of lean muscle mass compared to non-weightlifting athletes, which contributes to their ability to generate forceful movements during the lifts.

The anthropometric characteristics of male weightlifters have been extensively documented (Storey & Smith, 2012). However, the investigation of the anthropometric characteristics of master's weightlifters, particularly female master's weightlifters, is limited. When comparing the characteristics of master's weightlifters to those of younger competitive weightlifters and the general population, differences are observed.

4.1. Performance

The decline in performance associated with age is understandable due to potential changes in skeletal muscle structure and function, bone mineral density, cardiovascular structure and function, and endocrine function. Borges, Reaburn, Driller, & Argus, 2016. As articulated by Huebner, Meltzer, and Perperoglou (2019), there is a fractional decline in male and female masters weightlifting performance after the age of 35. The age-related performance decline in female weightlifters mirrors that of men, except for an accelerated decline during a 10-year period from the late 40s to late 50s, coinciding with the transition into menopause. However, the decline in masters athlete weightlifting performance does not significantly differ from that observed in other sports. Similar patterns of performance decline have been observed across age groups and sexes in sports such as running, swimming, triathlon, and cycling. Baker & Tang, 2010.

4.2. Physical Characteristics

When examining the physical characteristics of masters Olympic weightlifters, comparisons to the general public are warranted. Although the sample used in this research was international in nature, viable data from the Centers for Disease Control and Prevention in the United States Fryar, Carroll, Gu, Afful, & Ogden, 2021 can be used to determine if there are differences in physical characteristics found in a general population and Olympic weightlifters of the same age (30–80+ years).

Regarding height, female Olympic weightlifters in this research were slightly taller (160.81cm ± 7.21) than the general population (160.13cm ± 0.38). Males reported being slightly shorter than the general population (171.41cm ± 8.92 and 172.8cm ± 0.41, respectively). It is interesting that female participants in this research are taller than the general population, understanding that shorter body dimensions coincide with a greater mean skeletal muscle cross-sectional area, which is advantageous for weightlifting performance.3 This may be an artifact of the convenience sample used in this research. As masters Olympic weightlifters are studied in greater numbers, perhaps this information will shift.

When comparing the weight of masters Olympic weightlifters to the general population, both female and male weightlifting groups weighed less than the general population (Fe-male 68.1kg ± 16.1 and Male 85.0kg ± 14.6 masters Olympics weightlifters compared to Female 76.6kg ±1.1 Male 90.98kg ± 1.03 general population). Body Mass Index scores for participants in this research were also lower than those of the general public. As reported by the Center for Disease Control and Prevention (CDC), the average BMI for females is 30.0 ± .41 and for males 29.48 ± .30. Whereas for female Olympic weightlifters displayed BMIs of 26.21 ± 5.48 for females and 28.80 ± 3.51 for males. Waist circumference measures were also less in the weightlifters, 87.5 ± 10.4cm± 9.46 for females weightlifters compared to 99.67cm ±.95 and 96.9 ± 11.4cm± 7.78 compared to 105.13 cm±.79.

Body Mass Index (BMI) is a commonly used measure to estimate body fat based on an individual's height and weight. Although it serves as a general screening tool for identifying potential weight-related health risks, BMI has limitations, particularly for elite athletes such as Olympic weightlifters. The formula does not differentiate between fat mass and fat-free mass (FFM), which can lead to misclassification. Olympic weightlifters typically undergo rigorous training to develop maximal strength and power, often leading to increased muscle mass. Consequently, their BMI may be elevated despite low levels of body fat, making it an unreliable indicator of health in this population.

Research has indicated that BMI alone may not accurately reflect the health or body composition of Olympic weightlifters. A study by Storey et al. (2012) found that Olympic weightlifters have a higher proportion of lean muscle mass and lower body fat percentage compared to non-weightlifting athletes. This means that despite having a higher BMI due to increased muscle mass, they may have a healthier body composition and a lower risk of certain health conditions. In contrast, the general population's BMI distribution is more representative of the broader population. For most people, BMI can provide a reasonably accurate assessment of their weight-related health risks. However, it is essential to note that even in the general population, BMI has limitations. It does not account for factors such as muscle mass, bone mineral density, and fat distribution, which can vary widely among individuals. Relying solely on BMI to assess health can lead to misclassification. Some individuals with a "normal" BMI may have a higher percentage of body fat and lower muscle mass, a condition known as normal-weight obesity, which is associated with an increased risk of metabolic disorders (Romero-Corral et al., 2008).

While BMI can be a useful tool for assessing weight-related health risks in the general public, it may not provide an accurate assessment of health for Olympic weightlifters and other elite athletes. These athletes often have higher BMIs due to their increased muscle mass, which may not be indicative of an unhealthy body composition. The results of this research indicate that the subjects (both female and male) averaged a BMI in the overweight category according to the Centers for Disease Control and Prevention (25.0 to Kyle, Genton, Slosman, and Pichard (2001) indicate the limitation of using BMI as an indicator of fatness or leanness. Individual body composition compartments, i.e., FFM and fat mass, should therefore be measured to evaluate changes in body composition with aging. This is especially important in subjects in whom increased fat mass might mask decreases in FFM that might not be observed when assessment is limited to determining BMI only. Furthermore, it has been reported that although BMI is ideally suited for population-level studies, describing obesity by BMI can result in inaccurate assessment of adiposity because the numerator in the calculation of BMI does not distinguish lean muscle from fat mass. Romero-Corral et al., 2008 also note that a person with central obesity (with excessive visceral fat) can have a normal BMI and yet have a high mortality risk. BMI does not account for sex differences in fat distribution or age-related decline in muscle mass. Gurunathan & Myles, 2016 emphasizes the importance of considering additional health measures, such as body fat percentage, muscle mass, and other health markers, when evaluating the well-being of elite athletes.

In terms of body composition, competitive Olympic weightlifters often exhibit a meso-morph somatotype. Body composition plays a significant role, with weightlifters having a higher proportion of lean muscle mass and a lower body fat percentage compared to non-weightlifting athletes Storey et al., 2012. This lean body composition enhances the strength-to-weight ratio, allowing weightlifters to generate more force while maintaining agility and speed. This body type, characterized by a muscular and athletic physique with broad shoulders and a narrow waist, is advantageous for generating power and strength Suchomel et al., 2015. These physiological attributes contribute to the athletes' ability to lift heavy loads explosively. The relationship between body composition metrics (body fat percentage, lean body mass, BMI, and waist-to-hip ratio) and performance outcomes presents a complex picture. For example, the relatively higher body fat percentage in females might not directly correlate with decreased performance, suggesting that for Masters athletes, the quality of mass (lean vs. fat) and its distribution plays a more crucial role in performance than merely the quantity of fat mass. The lean body mass findings support the hypothesis that maintaining muscle mass is critical for sustaining performance levels in aging athletes.

When examining the results of a regression analysis, the performance in total and the clean and jerk was significantly related to height, body fat percentage, lean mass, and biceps measures. Snatch performance was also related to each of these characteristics, except for the right biceps measure. This may be an anomaly, considering that the left biceps measure showed a significant relationship with both movements and the total performance.

Regarding female athletes, height and body fat were significantly related to total performance, snatch, and clean and jerk. These findings are consistent with other published research indicating that physical characteristics such as height can significantly influence performance. Storey et al., 2012. Additionally, body composition, particularly body fat percentage, is well documented as having a significant relationship with sport performance. Storey and Smith, 2012 suggests that female body fat percentages may play a crucial role in performance, especially in strength-based sports.

Although limb length did not display a significant relationship with weightlifting performance in this group of athletes, the significance of biceps measures in males suggests that skeletal muscle cross-sectional area may play a more prominent role in their performance compared to female athletes. This could be due to the greater emphasis on upper body strength in male athletes, which correlates with larger muscle mass and potentially greater force production Brown & Lee, 2017.

The participation of athletes aged 35 to 90 highlights the broad age range of Masters athletes engaged in weightlifting, suggesting not only a sustained interest but also capability in high-performance activities beyond what is typically considered the prime age for such physical feats. Notably, the older age of participants, especially given the collection's timing, underscores a potential selection bias or a reflection of a more committed, experienced cohort. This observation aligns with literature suggesting that while physiological capacities naturally decline with age, Masters athletes can maintain relatively high levels of performance, possibly due to prolonged training and adaptation effects. Strength, power, technical proficiency, mental resilience, discipline, and body composition contribute to success in lifting heavy loads with precision and efficiency.

Many of masters athletes are experienced competitors who continue their athletic pursuits after their sports careers have ended, while others are individuals who return to sport after extended periods of inactivity or simply participate and train sporadically (Garhammer, 1980; Huebner et al., 2023). A recent increase in the number of masters athletes in the United States can be attributed to a growing population of more than 300 million people, an aging subpopulation of "baby boomers," and a culture enamored with sports (Collegiate Strength and Conditioning Coaches Association, 2014; Comfort et al., 2012; Erickson et al., 2018; Gava & Ravara, 2019; Huebner et al., 2023; Hunter et al., 2004; Komi, 2005; Lavallee & Mansfield, 2013; Riemann et al., 2020; Suchomel et al., 2015; Tayrose et al., 2015). Therefore, master's athletes provide a unique research cohort to understand the role of regular vigorous exercise in optimizing physical potential and health with advancing age (Kuster, 2002; Storey et al., 2012; Storey & Smith, 2012). One of the first steps in the analysis process is to develop a physical profile of these athletes. Therefore, the purpose of this study was to develop an anthropomorphic profile of elite master's Olympic weightlifters. The greatest strength of this study is the sample size. Very few, if any, studies examining masters Olympic weightlifters have included such a robust number of participants. The main limitation of this research is its cross-sectional nature. While differences between sexes, ages, and other variables could be described, true age-related or other differences could not be quantified. However, the data indicated the favorable anthropometry and potential health characteristics of the masters Olympic weightlifting athletes compared to data reported for age-matched individuals. It is unclear how the athletes who participated in the study may differ from those who did not participate and if there was any recruitment, selection, or participation bias whereby higher-performing masters athletes would be more likely to participate than their lower-performing peers. Thus, this may impact the overall generalizability of the results.

5. CONCLUSION

Understanding the physical and performance profiles of Masters athletes provides valuable insights for designing age- and sex-specific training programs that optimize health and performance outcomes. For instance, the data underline the importance of resistance and strength training in preserving lean muscle mass and reducing fat mass, crucial factors for both competitive success and general health. As the sport of Masters Olympic Weightlifting is diverse in its weight and age categories, this process may warrant subsequent collection efforts to build an even more robust data set with the intent of deepening analyses.

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Institutional Review Board Statement: The Ethical Committee of the Michigan State University, USA has granted approval for this study on 15 August 2022 (Ref. No. STUDY00007906).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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