The Journal of Sports Medicine and Physical Fitness
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Title: THE ANTHROPOMETRIC PROFILE OF POWERLIFTERS: DIFFERENCES AS A FUNCTION OF BODYWEIGHT CLASS AND COMPETITIVE SUCCESS

Paper code: J Sports Med Phys Fitness-4696
Submission Date: 2013-06-24 18:59:05
Article Type: Original Article

Files:

1): Reply letter to comments on the manuscript
    Version: 1
    File format: application/msword

2): Manuscript
    Version: 3
    Description: Original manuscript
    File format: application/msword

3): Tables 2
    Version: 1
    Description: Table I,Table II, Table III, Table IV, Table V
    File format: application/msword

4): Figures 1
    Version: 1
    Description: Figure1, Figure2, Figure3, Figure 4, Figure5
    File format: application/msword

18th November 2013

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Title: J Sports Med Phys Fitness -4696- THE ANTHROPOMETRIC PROFILE OF POWERLIFTERS: DIFFERENCES AS A FUNCTION OF BODYWEIGHT CLASS AND COMPETITIVE SUCCESS

Authors: Lovera & Keogh

Dear Professor Oliaro,

We wish to thank the Reviewers for their thoughtful comments on our submitted manuscript. Underneath each of the Reviewer's comments we have attached our replies. Within the revised manuscript, we have also highlighted the altered sections in yellow. This has been done to highlight the changes to the revised manuscript or to the areas which we believed the reviewer(s) may have missed in the original submission. We hope that this will assist the reviewers and the editor in their re-examination of this manuscript.

Thanks
Marcos Lovera.

General comment (originality, scientific accuracy, strengths and/or weaknesses):

The paper is original and the authors have done a nice job with reporting the data accurately without "selling" it either way. The sample size has a small N, however, the did acknowledge the limitations well. Would like to have seen 1st, 2nd, 3rd place versus the rest or 1st and 2nd vs. the rest. This may have shown different findings.

Good paper with some corrections needed. Study is of medium priority to publish.

<u>Response</u>: First of all we are grateful about the positive comments you have given. We have tried to address your comments to increase the impact of the paper in relation to talent identification, coaching as well as the understanding of the relationship between anthropometry and strength and how this might apply to other aspects of exercise and sports science. In relation to your comments, we have tried to adjust all what it has been specified. We acknowledge the small "n" of 1 in the winners group of each bodyweight class as a potential limitation of the study. As a result, we have recalculated the results based on this suggested approach. When we initially compared the "top 2" vs "bottom 2" in each class, we found (as was to be expected) that the averages of both groups were a bit closer each other and therefore that we saw a tendency for less significant effects. This was magnified when we did "top 3" vs "bottom 3". The other issue with this approach was that in some groups in which the number of participants was < 4, that an athlete could be included in both the top and bottom groups. As such, we request the reviewer to be satisfied with the initial way that we presented the data in the initial manuscript.

Major corrections (main criticisms):

1. In the Abstract; in the results section, the value for proportional muscle mass needs to be reported.

<u>Response</u>: We have changed this in the abstract as suggested. (53.9 ± 2.2%).

2. Introduction is very wordy, find a way to shorten it and get to the point faster.

Response: We have attempted to improve this as suggested.

3. It is important to state whether these athletes are using gear (shirts, suits, wraps, etc..) or not. And if they are, what they are using. These tools can often change the biomechanics of each lift.

Response: We agree with that and we have now written this detail in the subject section of Methods as you request.

4. In the subject's section the lifter's ages and amount of years lifting were left out. Both could have significant implications to the results.

Response: We acknowledge this point and have now added this data into the table 1. Here it is in a short table for presenting the information.

Table 6. Amount of year of experience in weight lifting by categories of competition.

Categories	Years lifting		
56	1.8	±	1.8
60	8.4	±	15.1
67.5	5.7	±	3.8
75	10.5	±	10.0
82.5	9.5	±	10.3
90	10.5	±	7.8
100	11.0	±	9.7
110	20.0	±	19.8
125	8.0	±	2.0
+125	13.2	±	8.5
Winners	10.8	±	6.2
Non-Winners	9.3	±	10.0

5. Are these lifters steroid free?

Response: The International Powerlifting Federation (IPF) has adopted and implemented the WADA regulation. Worldwide doping controls are carried out in accordance with the World AntiDoping Code and the International Standard for Testing, developed by WADA in consultation with its stakeholders. Athletes who compete at the international and national level may be tested anytime, anywhere. The test can be conducted at a competition or away from a competition situation, such as at an athlete's home or training venue, with no advance notice. Therefore, we feel that most of the lifters were steroid free at the time of the competition, but obviously we can’t be 100% sure.

6. There is mention of a “ □12 week build-up involving three-four specific powerlifting training sessions per week for this competition ”. Was this the same for all of the athletes? This would include volume (intensity x sets) , amount of training sessions, time during the day, etc…

Response: Not all powerlifters or athletes in any other sport have identical training programs even if they are trying to achieve the same competitive goal. This statement in the initial manuscript reflected a general group average of the group data obtained from the participants whereby most lifters had a specific pre-competition training phase of 12 weeks leading into this competition.

7. Describe how a Wilks score is determined. It is different than simply making the total weight relative to the body weight.

Response: The Wilks score is a validated measure of powerlifting strength used by the IPF (International Powerlifting Federation) in all competitions to normalize lifters independently of their body weights in an attempt of having the “pound for pound” strongest lifter (1) . It is a more complicated approach than simply dividing through by body mass and takes into account the tendency for lifters of smaller-moderate body mass to have the greatest relative strength (kg lifted / kg body mass). Other powerlifting federations use other scores to determine their overall winners such as the Schwartz and Malone formulas so to achieve the same goal of determining the best overall lifter.

Minor corrections (page, paragraph, line where the author must make the corrections):

1. In the results section of the abstract, line 65 starting with “Most of these characteristics” need to be reworded and can easily be blended with the following

sentence.

Response: It has been reworded as suggest clarifying the idea.

2. On page 3, 18 starting with “this method…” seems to repeat itself.

Response: It has been reworded as suggest.

3. The Whole second paragraph in the introduction section may not be needed. It is definitely not needed to be known that these techniques are used in different training programs.

Response: It has been deleted as suggested.

4. The sentence in line 42 on page 4, starting with “like Olympic weight lifters…” needs to be reworded. It is too wordy and has a hard time conveying the point trying to be given.

Response: It has been rewritten as suggested.

5. Line 54 on page 4, starting with “Nevertheless, the astute….” this sentence can be removed or reworded. This article is not written to evaluate coaching.

Response: It has been rephrased as suggested.

6. The sentence starting on line 13 on page 7 starting with “all anthropometric measures…” is very confusing.

Response: It has been rephrasing as suggest simplifying the idea.

7. On page 7 line 34, in the sentence starting with “lengths… ” lengths of what? Body segments?

Response: It has been rephrased as suggest adding "body segmented lengths".

8. On page 7 line 47, in the sentence starting with "these tools…." This sentence is not needed. It should be reworked into the paragraph or removed.

Response: It has been deleted as suggested.

9. On page 12 line 48, the sentence starting with "Such results appear" needs to be removed or reworded, and mention of osteoporosis needs to be removed. This study does not focus on future problems of powerlifters.

Response: It has been deleted as suggested.

10. It should be noted earlier in the paper that the winners are based on their total of all three lifts, and not on their performance in individual lifts.

Response: It has been adding in the method section giving note how winners were selected by their total score.

Discretionary Revisions

1. On page 13, in line 13 The actual numbers are needed when talking about the differences between the two groups for each of the criteria that they were differing in.

Response: It has been added and completed as suggested.

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1. Vanderburgh, P.M. and A.M. Batterham. Validation of the Wilks powerlifting formula. *Med Sci Sports Exerc*. 31:1869-1875. 1999.

THE ANTHROPOMETRIC PROFILE OF POWERLIFTERS: DIFFERENCES AS A FUNCTION OF BODYWEIGHT CLASS AND COMPETITIVE SUCCESS

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Acknowledgements: The authors would like to acknowledge the support of José Luis Inguanti, the President of the Argentine Powerlifting Federation who supported the idea of the project and allowed us work positively into the tournament. Also to all competitors from the Argentine Championship who voluntarily participated in this project. And as well as the participating anthropometrists who worked professionally in the evaluation process.

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Abstract

Aim. This study sought to better understand the relationship between anthropometric profile and maximal strength, as assessed in the sport of powerlifting as relatively little research has examined how differences in anthropometry may contribute to bodyweight-related differences in performance or between more and less successful lifters in the same bodyweight class.

Methods. To address this aim, 63 male powerlifters from an Argentine National Tournament were assessed for 31 anthropometric variables taken using ISAK (International Society for the Advancement of Kinanthropometry) protocols. Body fractionation (adipose, muscle, bone, residual and skin tissue masses) was determined using the validated Kerr & Ross five way fractionation model of body composition that has yet to be used with powerlifters.

Results. Results indicated that the powerlifters showed very elevated values of mesomorphy, muscle girths, muscle mass, bone breadths, and all this accompanied by a medium to low stature. Most of these characteristics were more pronounced in the heavier divisions. The winners had significantly larger proportional muscle mass (53.9 ± 2.2%), muscle to bone mass ratio (5.3 ±1.0) and crural index (1.21 ±0.12) than the non-winners. **Conclusion.** These comparisons reveal some potential key anthropometric determinants of high level powerlifting performance. These results further support the view that while powerlifters have unique anthropometric profiles, more successful powerlifters typically have higher degrees of muscle mass expressed per unit height and/or bone mass but similar segment lengths and segment length ratios to their less successful peers.

Keywords: powerlifting, anthropometry, ISAK, body composition, proportionality.

INTRODUCTION

Kinanthropometry is a discipline which uses a variety of direct measures such as skinfolds, muscular girths, bony breadths and segment lengths to indirectly determine body composition, proportions and somatotype in order to gain insight into the determinants of sports performance [1]. Regular kinanthropometric profiling can be useful for talent identification and monitoring of training and nutritional strategies. One of the more advanced methods used by International Society for the Advancement of Kinanthropometry (ISAK) practitioners is the five-way fractionation model of body composition [2, 3]. The five-way model provides data on components of lean body mass, muscle, and bone; is based on mathematical equations instead of multiple-regression equations and considers the dimensionality of tissues. This method has therefore been proposed to be more accurate than other models [4], especially when assessing larger athletes [5-7]. Otherwise, the five-way model has only been applied to a few sport studies, and only one of these studies has used it on relatively large muscular rugby players [4].

Research suggests that the anthropometric characteristics of powerlifters contribute to their impressive displays of strength [5, 7-10]. Specifically, powerlifters have been shown to be highly mesomorphic, have large girths and bony breadths and relatively short segment lengths [5, 7, 11, 12]. High levels of mesomorphy, muscle mass, girths and/or cross-sectional area aid powerlifting performance by increasing the muscular force and torque potential of the lifter [9, 10]. Like Olympic weightlifters [13], having short limbs may enhance the performance of these powerlifts (particularly in the squat and bench press). This is due to the tendency for shorter limbs to decrease the distance the bar has to be lifted and hence the amount of muscular work performed, and to improve the mechanical advantage by reducing the resistance moment arms. Nevertheless, it should be recognised that limb proportions that are disadvantageous for one of the powerlifts e.g. bench press can be advantageous for another lift e.g. deadlift [5].

A small number of studies describing the powerlifting anthropometric profile have grouped athletes into somewhat arbitrarily defined light, middle and heavy weight classes [7, 10] in an attempt to determine the effect of body mass on powerlifters' anthropometry and performance. However, no study has yet presented anthropometric data for athletes across all the weight classes during a competition. Normative anthropometric data for each bodyweight class would assist all involved in talent identification and coaching in powerlifting. Further, relatively little research has examined anthropometric differences between powerlifters of varying levels of performance [5]. Keogh et al. [5] found that a group of stronger lifters (Wilks score > 410), had significantly more muscle mass and larger girths (in both absolute and Phantom-normalized terms) than a weaker group (Wilks score < 370). However, no studies have yet compared the anthropometric profile of class winners to non-winners during competition. Such an analysis may provide further insights into the anthropometric determinants of powerlifting performance.

Therefore, the two objectives of this study are: First, to describe the anthropometric characteristics of each man's body weight class in the Powerlifting Argentine National Tournament population. Second, to compare the winners of each bodyweight class to all other competitors in their class in an attempt to gain further insight into the anthropometric determinants of success in powerlifting. By using the five-compartment model in these analyses, we hope to demonstrate the improved accuracy of this approach over that used in previous anthropometric research of large, muscular athletes such as powerlifters. Such data may be of interest to athletes and coaches and of general interest to those in the field of strength and conditioning, sports nutrition and talent identification.

MATERIALS AND METHODS

Experimental Approach to the Problem

The present study used a cross-sectional design to compare the anthropometric characteristics of nationally-ranked male powerlifters: 1) across all weight classes; and 2) winners and non-winners of each weight class in order to gain further insight into the importance of anthropometric profile in powerlifting performance. Dependent anthropometric measures spanned body composition, muscular girths, bone breadths and segment lengths variables, with most of these expressed in absolute and proportional terms. Student T-tests were used to identify any significant differences between the winners and non-winner groups.

Subjects

The subjects included in this study were 63 male volunteers out of 90 competitors from an Argentine National Powerlifting Tournament. Within these 63 subjects, 8 winners of the 10 body weight divisions were included, the only exceptions being the winners of the <82.5 kg and <125 kg classes who did not wish to participate in this study. As all the participants were assessed at the National championships, they had typically all completed a specific ~12 week build-up involving three-four specific powerlifting training sessions per week for this competition. Like their British counterparts [14], many of the Argentinian lifters would have utilized similar training techniques and periodization structures, however no two athletes would have likely used the exact training program during this time.This competition was the primary competition or one of two primary competitions for each athlete that calendar year. During competition, all lifters used approved lifting equipment including squat and deadlift suits, bench press shirts, knee wraps and wrist wraps in accordance with International Powerlifting Federation (IPF) regulations. Regarding the AntiDoping test, the IPF has adopted and implemented the WADA regulation. Worldwide doping controls are carried out in accordance with the World AntiDoping Code and the International Standard for Testing, developed by WADA in consultation with its stakeholders.

Procedure

The anthropometric evaluation was carried out by ten Level 2 and 3 International Society for the Advancement of Kinanthropometry (ISAK) anthropometrists utilizing standard ISAK (International Society for the Advancement of Kinanthropometry, 2001) protocols. All volunteers signed an informed consent form. The form was approved by the Argentinean powerlifting federation authorities and oversaw by the University of San Martin Ethics Committee who approved the study. The anthropometric measures assessed were weight, stature, sitting height, arm span, segment lengths, bone breadths, muscle girths and skinfolds. These assessments were performed 2 hours before the start of the competition at the IPF official weight-in. Body weight was evaluated with a CAM weigh machine (C.A.M, SRL, Buenos Aires). Stature and sitting height were assessed with wall-mounted stadiometers (Rosscraft SRL, Buenos Aires), 50 cm high wooden boxes and a 90º angle square which was set on the subjects' head. The arm span was assessed with a millimetred Rosscraft horizontal stadiometer. Body segment lengths were assessed using a Rosscraft segmometer. Campbell 20 calipers were used to assess large bone breadths and Campbell 10 calipers for small bone breadths. Girths were assessed using metallic non-extendible tapes (Lufkin w606pm and Rosscraft, Canada). Skinfolds were assessed using a Harpenden caliper (Batty, UK).

Body composition was calculated with the five-way fractionation model. This method divides the body mass into 5 anatomically defined components, adipose, muscle, bone, residual and skin tissue masses [2, 3]. In addition, the difference between the ‘‘structured body mass’’ which is defined as the sum of the mass of these 5 separate components and the recorded body weight on the scale expressed as a percentage of body mass to provide information on the percentage error of the model. The Health-Carter model [15] was used for Somatotyping analysis, estimated by the anthropometric method. Proportionality was evaluated through the Phantom stratagem [1, 16, 17], with the Phantom z-score data expressed as group means and standard errors of the mean. Through the Phantom stratagem all variables were first adjusted to the Phantom height of 170.18 cm and then transformed the new values into z-scores allowing a proportional and more accurate comparison among people of deferent heights. A number of derived indices were also calculated; the BMI (body mass index) in kg · m^{-2}; sum of 6 skinfolds in mm (∑ 6 skf.); muscle-to-bone ratio as kg muscle · kg bone $^{-1}$; cormic index as cm sitting height · cm stature $^{-1}$ in percentage; brachial index as cm radiale-stylion length · cm acromiale-radiale length $^{-1}$ in percentage; and crural index as cm tibiale laterale height · cm trochanterion-tibiale laterale length^{-1} in percentage. The results obtained in the competition were taken for each competitor from the original electronic record of the competition results. Winners within each bodyweight class are based on their total score obtained from the sum of their best three lifts. The overall winner of the competition is decided by each lifters' Wilks score which is a validated system used by the IPF to normalize strength across the bodyweight classes[18].

Statistics

Data is presented for each of the bodyweight classes as means and standard deviations (mean ± sd). The reliability of all measures was high, with all anthropometric variables having intraclass correlations greater than 0.90 and the technical error of measurement was found to be less than 2% for all skinfolds and less than 1% for all bone breadths and limb girths and lengths. D'Agostino-Pearson tests for normal distribution were made for the whole sample and for each weight class of competition, accepting normality in all breadths, lengths, girths and almost all basic assessments excluding weight. Proportional differences between groups were realized by the Phantom method and compared through Z-score [1, 17]. Differences in the means for the winners and non-winners groups were estimated by a student T-test with statistical significance set at $P < 0.05$. All statistics were calculated using SPSS (version 15.0, USA) and the Med Calc (version 9.5.2.0).

RESULTS

Descriptive characteristics of powerlifters sample.

No significant difference in age (Winners: 30.7 ± 6.8 years vs Non-Winners: 33.6 ± 14.9 years) or training experience (Winners: 10.8 ± 6.2 years vs Non-Winners: 9.3 ± 10.0 years) was found between the winners and non-winners. Table 1 presents information on the amount of years of training experience and the results obtained in the competition. In general, the weight lifted across the three exercises by the competitors increased with bodyweight class.

Insert table I about here

Table 2-4 provide details on the anthropometric profile of the different weight classes. Specifically, Table 2 contains general demographic and absolute anthropometric variables such as height, mass, segment lengths and bony breadths data. Table 3 presents data for absolute girths and skinfolds, whereas Table 4 provides information on body segment ratio indexes and body fractionation. In general, most of the absolute anthropometric characteristics such as muscle mass, skinfolds, muscle girths, bony breadths and somatotype tended to increase with bodyweight.

Insert Tables 2-4 about here

Figure 1 illustrates the mean somatotypes for each bodyweight class and a comparison of the winners and non-winners. It is apparent that all sub-groups showed a meso-endomorph tendency.

Insert Figure 1 about here

Figure 1. Somatoplot by categories of competition.

Differences between the winner group and the rest of the powerlifters.

Table 5 presents the comparison between the group of winners and the non-winners (rest of the lifters) in body composition, BMI, muscle to bone ratio, sitting height/stature, brachial and crural indexes, as well as their competition results. The winners' group had a significantly greater percentage of muscle mass (+ 2.7%, P= 0.0337), muscle-to-bone ratio (+0.6, P=0.0363) and crural index (+0.10, P=0.0427) than the non-winners. The winners had significantly greater squat and bench press strength (+54 kg, P=0.0137 and +40 kg, P=0.0142 respectively), and a non-significant tendency for greater dead lift strength (+33.7 kg, P=0.0640).

Insert Table 5 about here

Figures 2-5 displays the differences between the powerlifters who won their bodyweight class (Winners) compared to the non-winners via their Z phantom scores [17]. No significant differences were observed in any of these proportional variables, although there was a non-significant trend for the winners to have a superior flexed arm girth (P=0.0555) and tibiale laterale (P=0.0965) length.

Insert Figures 2-5 about here.

Figure 2. Comparison of the segment Lengths of the Winners and the Non-winners powerlifters through the phantom (mean ± standard error).

Figure 3. Comparison of the Breadths of the Winners and the Non-winners powerlifters through the phantom (mean ± standard error). A-P chest deph = anterior – posterior chest deph.

Figure 4. Comparison of the Girths of the Winners and the Non-winners powerlifters through the phantom (mean ± standard error).

Figure 5. Comparison of the Skinfolds of the Winners and the Non-winners powerlifters through the phantom (mean ± standard error).

DISCUSSION

The results of the present study add to our understanding of the role of anthropometric characteristics in maximal strength performance by providing some normative powerlifting data for different bodyweight classes and by describing the differences in the anthropometric profile of winners of each weight class vs non-winners. As this was the first study to use the five-way body fractionation model with powerlifters, the results of this study also have methodological implications for the assessment of these anthropometric qualities, especially for large muscular athletes.

Although based on somewhat small sample sizes per weightclass, the results of the weight class comparison provided some interesting trends. The muscle, bone and adipose masses increased on average by 4.7 kg, 0.6 kg and 1.7 kg, respectively between bodyweight divisions. The amount of muscle mass demonstrated by the powerlifters of the highest divisions was very impressive, with values between 60 and 70 kg common. The bone mass values of the heaviest divisions (-125 and +125 kg) were also very high, averaging 12.5 ± 0.7 kg with Z-phantom scores of 1.78, indicating that such athletes were almost two standard deviations above the mean for their height adjusted bone mass. An analysis of the muscle to bone ratio was also conducted to determine if the greater muscle mass of the heavyweight lifters was merely a result of their increased bone mass, as has been suggested previously [19, 20]. However, results indicated a substantially greater muscle to bone ratio for the heavier than lighter lifters. This result would appear consistent with the increase in mesomorphy observed for the heavyweight lifters, reflecting their greater ability to accumulate muscle mass per unit of height or bone mass than the lighter lifters.

Results of the present study revealed that the winners had a significantly greater muscle mass, muscle to bone ratio and crural index than the non-winners. In contrast, proportionality comparisons via the Phantom showed no significant differences between the winners and non-winners. As this might have reflected a lack of statistical power due to the small sample size of winners (n=8), an inspection of non-significant trends ($0.0500 < p < 0.1000$) was also performed. These non-significant trends also included the potential that the winners may have had greater flexed arm girth as well as tibiale laterale length. Such results therefore appear quite consistent with Keogh et al. [5] who found that stronger powerlifters had bigger girths per unit height and greater muscle mass than weaker powerlifters, but that relatively few differences in segment lengths, either in absolute or relative terms were apparent. The results of the present study and that of Keogh et al. [5] therefore suggest that the ability to accumulate large amounts of muscle mass per unit height is crucial for powerlifting success and that between-athlete differences in segment length proportions do not play a substantial role in differentiating the performance (overall total) of national level powerlifters. The lack of differences in segment lengths found in the current study appears somewhat in contrast to earlier studies [19-21] where significant correlations were reported between segment lengths and strength in the three separate powerlifts. This potential discrepancy may reflect a number of factors. For example, it may reflect the relative lack of lifting experience and strength and heterogeneity of body mass and height in these other studies compared to those recruited in the current study and that of Keogh et al. [5]. Further, the significant correlations between segment lengths and strength reported in these other studies were typically reported for the three specific lifts rather than overall performance. This is not overly surprising as the proportions advantageous for one lift e.g. the deadlift may prove disadvantageous for another lift such as the bench press. This is important to remember as the overall powerlifting score is the total sum of the weight lifted across the squat, bench press and deadlift exercises. Therefore, the potentially inverse relationship existing between certain segment ratios and the different lifts may mean that, for the upper limbs, relatively normal segment length proportions offer the best overall potential for the bench press and deadlift. Alternately, for the lower limbs length proportions, a higher crural index (shank : thigh ratio) could offer a significant advantage for the squat as the relative reduction in the thigh length would reduce the work required and resistance moment arms in this exercise. It should also be acknowledged that other factors than anthopometric profile influence strength and could differ between the winners and non-winners. Examples of these may include morphological factors such as muscle fiber type, muscle pennation angle and muscle insertion point as well as a range of factors influencing the neural activation of the agonist and antagonist muscles [21].

The five-way fractionation model as used in this study provides accurate information on adipose, muscle and bone mass [4] which are the main morphological aspects for sports successes and general health [22] as well as the residual tissue. This method also allows the calculation of a prediction error. This error is the difference between the structured weight by the sum of 5 calculated tissue types and the weight on the scale and is expressed as a percentage. For the population of these powerlifters the prediction error was 3.6 ± 2.4% (2.9kg), which is considered acceptable as it is below 5% of the stipulated fidelity limit. This result is also comparable to the 3.4 ±4.1% (3.0 kg) found in quite heavily muscled rugby players reported by Holway and Garavaglia [4] using the same technique. In contrast, Keogh et al. [7] reported a mean error of 16.7 kg (13.7%) for the body mass of heavyweight powerlifters using the Drinkwater & Ross [23] method. The greater accuracy of the five way fractionation method than the Drinkwater and Ross [23] approach used in previous powerlifting studies [5-7] comes from its use of mathematical equations that were directly validated from cadavers. As a result, it would appear that all future studies using ISAK or similar anthropometric methods for determining the body composition of large muscular athletes like powerlifters should use the five way model in preference to that of Drinkwater & Ross [23]. The small prediction error found in the current study and that of Holway and Garavaglia [4] would also suggest that this method could be accurately used to better monitor changes in the 5 compartments body composition of large strength trained athletes.

Nevertheless, this study still had a number of methodological limitations. The first obviously is the small number (n = 8) of winners of each of the 8 classes in which the winner consented to participate and the fact that some of the extreme weight classes had very low numbers. This was to be expected and reflects a normal distribution whereby most of the lifters compete in the moderate weightclasses and most competitors are non-winners rather than winners. As some powerlifters cut weight to make their weightclass it is also likely that the training anthropometric profile may have differed to the profiles we determined within 2 hours prior to the competition. Nevertheless, no powerlifting competition is actually won or lost based directly on what is lifted in training, rather it is the athlete who lifts best at the competition who wins.

CONCLUSION

This study describes anthropometric and body composition data from the majority of lifters at the Argentinian Powerlifting Championship in order to examine how anthropometric measures may differ as a function of weight class and success within each class. These comparisons revealed that an increase in muscle mass, muscle to bone ratio and mesomorphy may all be key determinants of powerlifting performance. In contrast, the influence of segment lengths and proportions on performance was less clear. But in spite of this, a higher crural index, which means a much longer shank relative to the thigh, may represent an important factor in the performance of the lifters. Such information may assist in talent identification and monitoring of training in powerlifting; and provide useful normative values for powerlifters of different weight classes. The greater accuracy of the five-way fractionation model found in the current study than that reported previously for other powerlifting anthropometry studies, suggests that the five-way model should be used when assessing the anthropometry of large, muscular athletes. We would therefore promote semi-regular anthropometric monitoring of powerlifters using the 5 way fractionation model as it may identify anthropometric limitations for each lifter and allow more specific training for body parts that limit performance in the three lifts. Finally, future studies in this area should use similar methodologies to that of the current study, but strive to substantially increase sample size by obtaining data from larger higher-level international competitions or by pooling data from a number of smaller competitions. Such data will provide a greater normative database, which will further enhance the representativeness and usefulness of this information.

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TITLES OF TABLES

Table I. Results obtained in the competition by categories of competition (mean ± sd).

Table II. Powerlifting anthropometric data by categories of competition (mean ± sd).

Table III. Powerlifting anthropometric data by categories of competition (mean ± sd).

Table IV. Powerlifting body composition, somatotype and indexes by categories of competitions (mean ± sd).

Table V. Comparison of the winners sample and the rest of the powerlifters.

TITLES OF FIGURES

1. Somatoplot of all mean by categories of competitions; -56 (n=2), -60 (n=7), -67-5 (n=9), -75 (n=9), -82.5 (n=14), -90 (n=6), -100 (n=7), -110 (n=2), -125(n=3), +125 (n=4). And winners (n=8) and others (n=55) are also provided.
2. Lengths comparison of winners (n=8) and non-winners (n=55) through the phantom. Values are means and standards error Zp-scores.
3. Breadths comparison of winners (n=8) and non-winners (n=55) through the phantom. Values are means and standards error Zp-scores.
4. Girths comparison of winners (n=8) and non-winners (n=55) through the phantom. Values are means and standards error Zp-scores.
5. Skinfolds comparison of winners (n=8) and non-winners (n=55) through the phantom. Values are means and standards error Zp-scores.

Table 1. Results obtained in the competition by categories of competition (mean ± sd).

CATEGORIES	+125 n = 4	-125 n = 3	-110 n = 2	-100 n = 7	-90 n = 6	-82.5 n = 14	-75 n = 9	-67.5 n = 9	-60 n = 7	-56 n = 2
Squat (kg)	297.5 ± 37.7	253.3 ± 30.6	223.8 ± 118.8	235.7 ± 44.8	248.3 ± 42.6	197.2 ± 17.6	208.2 ± 38.2	164.7 ± 51.4	155.0 ± 20.9	110.0 ± 0.0
Bench Press (kg)	218.8 ± 18.4	151.7 ± 33.3	162.5 ± 60.1	163.9 ± 17.8	165.0 ± 31.9	127.2 ± 19.6	121.7 ± 31.8	111.4 ± 30.1	88.3 ± 19.5	73.8 ± 12.4
Dead Lift (kg)	282.5 ± 17.1	240.0 ± 52.0	217.5 ± 102.5	237.1 ± 50.4	256.5 ± 28.7	222.5 ± 20.0	198.3 ± 24.0	188.9 ± 45.3	174.2 ± 19.3	148.8 ± 5.3
Sum (kg)	798.8 ± 57.2	645 ± 106.4	603.8 ± 281.1	636.8 ± 110.2	669.6 ± 97.0	546.9 ± 41.4	546.4 ± 77.4	465.0 ± 121.7	417.5 ± 55.7	332.5 ± 17.7
Winners sum (kg)	870.0	850.0	802.5	752.5	805.0	752.5	675.0	607.5	485.0	345.0
Non-Winners sum (kg)	775.0 ± 39.1	635.0 ± 105	405.0	616.7 ± 105.7	643 ± 79.1	546.9 ± 41.4	521 ± 50.3	447.2 ± 116.9	404.0 ± 50.2	320
Age of training experiece (years)	13.2 ± 8.5	8.0 ± 2.0	20.0 ± 19.8	11.0 ± 9.7	10.5 ± 7.8	9.5 ± 10.3	10.5 ± 10.0	5.7 ± 3.8	8.4 ± 15.1	1.8 ± 1.8

Table II. Powerlifting anthropometric data by categories of competition (mean ± sd).

CATEGORIES	+125 n = 4	-125 n = 3	-110 n = 2	-100 n = 7	-90 n = 6	-82.5 n = 14	-75 n = 9	-67.5 n = 9	-60 n = 7	-56 n = 2
Basics										
Age (years)	35.3 ± 2.7	37.4 ± 18.0	40.4 ± 16.8	35.1 ± 10.6	32.7 ± 9.4	32.8 ± 13.7	35.9 ± 15.3	33.6 ± 20.5	29.0 ± 16.4	16.1 ± 2.6
Body mass (kg)	131.3 ± 6.5	119.5 ± 4.3	108.7 ± 1.3	96.0 ± 3.6	88.0 ± 1.8	79.3 ± 1.8	73.7 ± 0.7	65.9 ± 2.1	59.2 ± 1.0	54.5 ± 0.7
Stature (cm)	180.3 ± 10.3	184.1 ± 3.4	167.6 ± 9.8	171.9 ± 6.2	174.1 ± 5.6	170.5 ± 6.2	168.6 ± 4.2	165.3 ± 5.3	162.7 ± 8.3	162.3 ± 3.4
Sitting height (cm)	98.8 ± 3.6	97.3 ± 2.4	90.7 ± 4.7	92.2 ± 2.0	91.1 ± 4.1	91.4 ± 3.2	89.4 ± 1.7	88.9 ± 2.8	87.3 ± 3.8	84.5 ± 0.1
Arm Span (cm)	182.1 ± 12.5	192.0 ± 6.6	174.3 ± 13.7	177.9 ± 9.8	182.2 ± 5.2	174.7 ± 8.1	174.3 ± 6.2	169.9 ± 9.6	165.9 ± 6.3	169.8 ± 5.2
Lengths (cm)										
Acromiale-Radiale	33.6 ± 3.2	35.5 ± 1.3	32.9 ± 1.6	34.3 ± 2.1	34.3 ± 1.4	32.7 ± 1.8	32.6 ± 1.7	31.8 ± 1.5	31.6 ± 1.2	30.3 ± 0.4
Radiale-stylion	27.3 ± 1.3	27.9 ± 1.8	24.7 ± 1.3	25.3 ± 1.8	26.3 ± 0.8	25.3 ± 1.2	26.0 ± 1.2	24.7 ± 2.2	24.6 ± 1.6	25.3 ± 1.4
Troch - T.Laterale	44.7 ± 4.5	44.7 ± 1.6	39.5 ± 5.0	44.4 ± 5.0	42.8 ± 2.9	41.3 ± 3.1	41.9 ± 3.8	40.2 ± 4.1	41.6 ± 2.5	36.1 ± 0.1
Tibiale Laterale	48.1 ± 3.3	49.7 ± 2.5	46.5 ± 1.2	46.2 ± 2.2	48.9 ± 3.7	47.1 ± 3.3	47.5 ± 2.4	45.6 ± 1.9	44.3 ± 4.1	49.1 ± 1.3
Breadths (cm)										
Biacromial	45.0 ± 2.3	45.9 ± 1.6	43.3 ± 3.7	41.7 ± 0.9	41.9 ± 0.7	41.0 ± 1.6	39.6 ± 1.3	39.0 ± 1.4	38.7 ± 1.9	37.4 ± 3.4
Transverse chest	37.2 ± 1.8	36.0 ± 2.4	32.7 ± 4.7	32.0 ± 1.3	30.1 ± 2.9	30.2 ± 1.4	28.1 ± 1.4	27.0 ± 2.2	26.5 ± 1.8	26.6 ± 1.2
A-P chest depth	26.8 ± 1.7	25.2 ± 1.9	22.9 ± 3.3	22.4 ± 1.5	20.0 ± 1.4	20.2 ± 2.1	19.6 ± 1.4	18.0 ± 2.0	16.1 ± 1.8	17.0 ± 2.0
Biiliocristal	33.8 ± 1.9	34.1 ± 1.9	32.6 ± 1.3	31.2 ± 2.9	28.6 ± 0.6	27.8 ± 1.2	27.5 ± 1.5	26.6 ± 1.1	26.1 ± 1.4	27.3 ± 0.4
Humerus	7.8 ± 0.3	8.0 ± 0.4	7.2 ± 0.5	7.3 ± 0.2	7.2 ± 0.4	7.0 ± 0.3	6.9 ± 0.6	6.8 ± 0.4	6.9 ± 0.3	6.8 ± 0.5
Femur	10.3 ± 0.4	10.6 ± 1.0	10.7 ± 0.1	9.5 ± 0.5	9.9 ± 1.0	9.3 ± 0.6	9.7 ± 0.6	9.5 ± 0.3	9.4 ± 0.4	9.6 ± 0.4

Troch - T.Laterale = Trochanterion - Tibiale Laterale; A-P chest depth = Anterior - posterior chest depth

Table III. Powerlifting anthropometric data by categories of competition (mean ± sd).

CATEGORIES	+125 n = 4	-125 n = 3	-110 n = 2	-100 n = 7	-90 n = 6	-82.5 n = 14	-75 n = 9	-67.5 n = 9	-60 n = 7	-56 n = 2
Girths (cm)										
Head	61.0 ± 2.8	59.6 ± 1.9	57.4 ± 2.1	58.1 ± 0.7	57.5 ± 1.2	57.1 ± 0.9	56.0 ± 1.3	55.9 ± 1.7	55.8 ± 1.9	53.9 ± 0.9
Arm (relaxed)	45.9 ± 0.4	39.4 ± 2.6	42.0 ± 1.1	39.0 ± 2.9	37.1 ± 1.0	34.5 ± 2.4	33.3 ± 1.7	31.8 ± 1.8	29.3 ± 1.8	26.1 ± 2.2
Arm (flexed)	48.6 ± 0.4	42.5 ± 1.2	44.7 ± 2.6	41.7 ± 2.1	40.5 ± 1.3	37.7 ± 2.3	36.0 ± 1.6	35.1 ± 2.2	32.4 ± 1.6	30.2 ± 2.8
Forearm (maximum)	35.9 ± 0.9	34.1 ± 1.4	32.8 ± 0.8	31.3 ± 1.3	31.1 ± 0.8	29.6 ± 1.0	28.3 ± 1.0	27.2 ± 1.0	26.2 ± 1.0	24.8 ± 0.6
Chest (mesosternale)	129.7 ± 1.6	125.0 ± 1.6	123.2 ± 0.4	114.8 ± 3.4	110.0 ± 3.8	103.3 ± 5.5	102.0 ± 3.7	97.1 ± 3.6	93.1 ± 4.0	86.2 ± 3.7
Waist (minimum)	112.3 ± 3.3	107.6 ± 6.4	105.5 ± 9.9	96.2 ± 3.7	89.2 ± 4.1	84.0 ± 4.8	81.7 ± 3.0	74.7 ± 1.9	71.1 ± 4.0	70.3 ± 9.7
Gluteal (hips)	118.2 ± 2.4	114.0 ± 1.0	116.0 ± 4.5	103.2 ± 3.3	99.8 ± 1.3	97.2 ± 2.1	94.2 ± 2.8	89.4 ± 1.0	85.0 ± 0.9	84.1 ± 1.9
Thigh (1 cm gluteal)	72.7 ± 1.1	69.3 ± 1.9	72.6 ± 0.8	64.6 ± 1.8	62.0 ± 2.2	59.1 ± 2.3	57.4 ± 2.7	53.9 ± 1.6	51.0 ± 1.5	48.2 ± 0.0
Thigh (mid thonch-T.L)	66.6 ± 1.7	63.0 ± 0.4	65.8 ± 3.2	60.0 ± 3.2	58.5 ± 3.4	56.2 ± 3.2	53.8 ± 3.9	51.7 ± 2.1	47.9 ± 1.5	46.2 ± 0.4
Calf (maximum)	43.5 ± 1.0	42.2 ± 1.7	42.1 ± 2.1	38.2 ± 2.8	38.6 ± 1.5	37.4 ± 2.7	35.5 ± 1.5	34.4 ± 0.9	33.6 ± 1.1	33.3 ± 0.9
Skinfolds (mm)										
Triceps	8.6 ± 1.3	14.5 ± 6.5	15.7 ± 5.8	9.5 ± 3.8	6.4 ± 1.9	6.6 ± 2.1	8.1 ± 3.1	7.4 ± 2.2	6.8 ± 1.3	6.8 ± 0.6
Subescapular	22.4 ± 3.8	27.5 ± 13.3	17.6 ± 4.5	19.0 ± 10.3	11.5 ± 3.0	12.7 ± 4.2	11.3 ± 2.2	9.2 ± 2.4	8.4 ± 1.3	5.4 ± 1.1
Supraspinale	8.6 ± 1.3	14.5 ± 6.5	15.7 ± 5.8	9.5 ± 3.8	6.5 ± 1.9	6.6 ± 2.1	8.1 ± 3.1	7.4 ± 2.2	6.8 ± 1.3	6.8 ± 0.6
Abdominal	26.4 ± 5.3	31.7 ± 3.6	25.8 ± 11.6	16.8 ± 7.5	12.9 ± 7.5	12.9 ± 4.5	15.7 ± 3.7	9.6 ± 4.0	9.9 ± 3.0	5.9 ± 0.4
Front thigh	15.6 ± 2.9	14.2 ± 3.9	14.4 ± 0.8	11.5 ± 5.4	8.5 ± 1.3	8.5 ± 2.9	11.3 ± 3.0	10.2 ± 4.4	8.7 ± 1.7	6.5 ± 1.0
Medial Calf	10.6 ± 5.2	17.1 ± 8.4	17.0 ± 4.5	9.1 ± 5.9	8.9 ± 2.3	6.7 ± 2.1	8.3 ± 3.1	7.4 ± 1.4	6.2 ± 1.7	5.5 ± 2.7
Σ 6 Skinfolds	102.3 ± 15.5	132.1 ± 48.9	107.4 ± 38.5	79.9 ± 28.4	58.5 ± 13.9	55.6 ± 13.3	63.8 ± 16.2	50.4 ± 10.9	46.3 ± 9.0	36.2 ± 3.2

Thigh (mid thonch-T.L) = Thigh middle thronchaterion - tibiale laterale; Σ 6 Skinfolds = Sum of 6 skinfolds

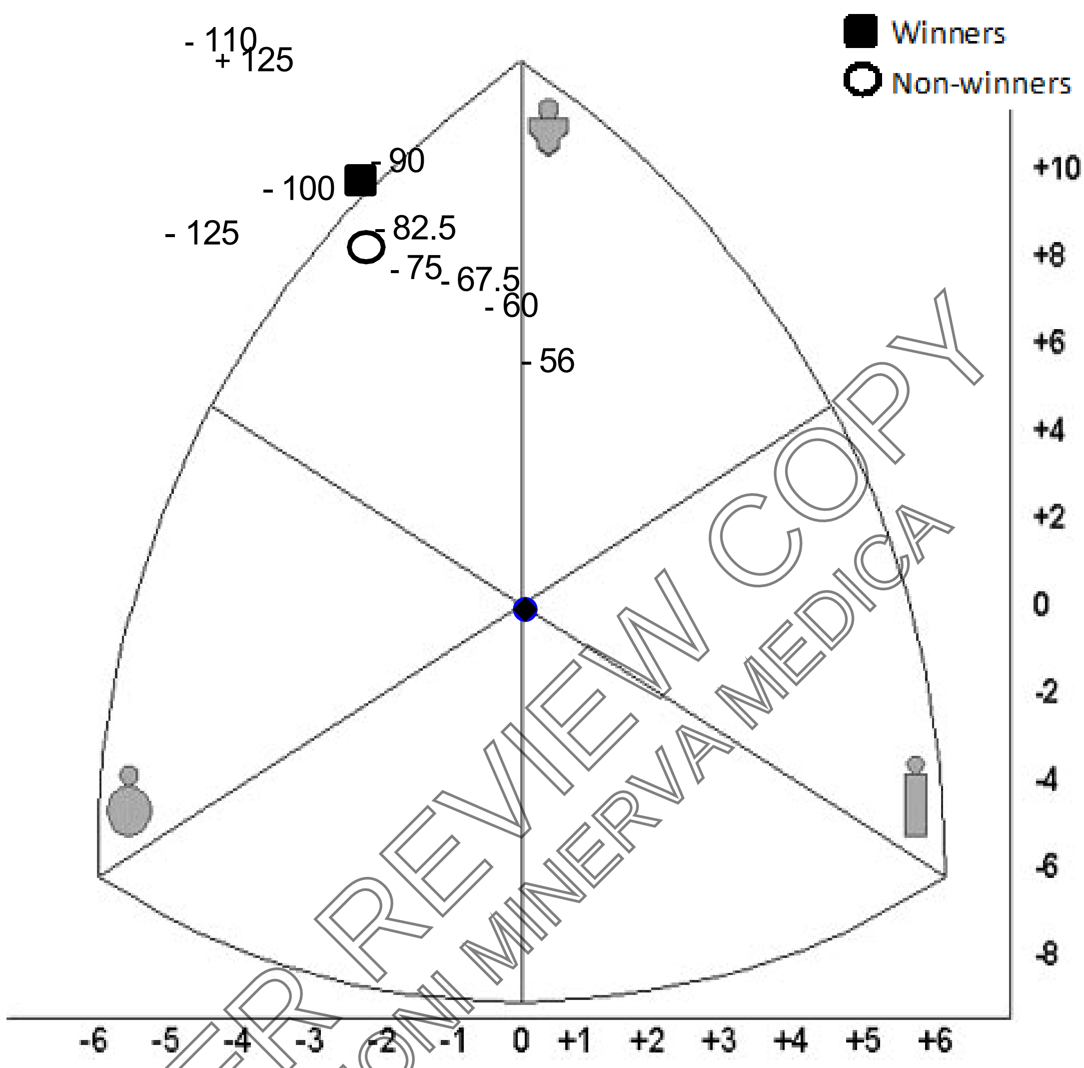
Table IV. Powerlifting body composition, somatotype and indexes by categories of comepetition (mean ± sd).

CATEGORIES	+125 n = 4	-125 n = 3	-110 n = 2	-100 n = 7	-90 n = 6	-82.5 n = 14	-75 n = 9	-67.5 n = 9	-60 n = 7	-56 n = 2
Indexes										
Sitting height/Stature	0.54 ± 0.01	0.53 ± 0.02	0.54 ± 0.00	0.54 ± 0.01	0.52 ± 0.02	0.54 ± 0.01	0.53 ± 0.01	0.54 ± 0.01	0.54 ± 0.02	0.52 ± 0.01
Brachial	0.82 ± 0.08	0.79 ± 0.07	0.75 ± 0.00	0.74 ± 0.04	0.77 ± 0.04	0.78 ± 0.03	0.80 ± 0.05	0.78 ± 0.06	0.78 ± 0.03	0.84 ± 0.03
Crural	1.08 ± 0.10	1.11 ± 0.09	1.19 ± 0.12	1.06 ± 0.18	1.15 ± 0.15	1.15 ± 0.11	1.14 ± 0.14	1.15 ± 0.14	1.06 ± 0.08	1.36 ± 0.04
BMI (kg/St^2)	40.6 ± 3.9	35.3 ± 1.4	38.8 ± 4.0	32.6 ± 2.0	29.1 ± 1.6	27.4 ± 2.3	26 ± 1.5	24.2 ± 1.8	22.5 ± 2.1	20.7 ± 1.1
Muscle to Bone ratio	5.5 ± 0.4	4.6 ± 0.5	6.3 ± 1.6	4.8 ± 0.6	5.2 ± 0.7	4.9 ± 0.5	4.7 ± 0.6	4.3 ± 0.4	4.0 ± 0.6	3.5 ± 0.3
Masses (%)										
Adipose tissue	20.3 ± 2.0	26.0 ± 5.6	21.0 ± 2.8	20.1 ± 4.0	18.7 ± 3.1	19.1 ± 2.3	21.6 ± 2.8	20.3 ± 2.4	20.7 ± 2.2	20.0 ± 2.8
Muscle mass	52.3 ± 1.8	47.0 ± 6.0	53.0 ± 5.6	51.4 ± 3.9	54.3 ± 5.5	52.7 ± 2.6	50.7 ± 2.4	51.3 ± 2.6	50.2 ± 3.4	48.5 ± 3.5
Residual mass	13.7 ± 1.0	12.6 ± 1.1	13.0 ± 1.4	13.0 ± 1.1	11.6 ± 1.6	12.1 ± 1.0	11.7 ± 1.5	11.2 ± 1.2	10.4 ± 1.4	12.0 ± 0.0
Bone mass	9.7 ± 0.5	10.0 ± 0.0	9.0 ± 1.0	10.8 ± 1.0	10.6 ± 0.8	11.0 ± 0.8	10.7 ± 1.0	11.8 ± 0.6	12.8 ± 1.0	14.0 ± 0.0
Skin mass	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.3 ± 0.5	4.8 ± 0.4	5.0 ± 0.0	5.0 ± 0.0	5.2 ± 0.4	5.7 ± 0.5	6.0 ± 0.0
Error %, Method vs Scale	3.12 ± 3.0	6.74 ± 4.1	1.21 ± 1.4	2.70 ± 1.8	2.67 ± 2.3	3.13 ± 1.7	3.88 ± 2.6	4.85 ± 2.3	3.93 ± 2.5	2.61 ± 1.8
Masses (Kg)										
Adipose tissue	26.5 ± 3.6	31.3 ± 7.8	23.2 ± 2.9	19.36 ± 4.0	16.4 ± 2.8	15.2 ± 1.8	15.8 ± 2.1	13.4 ± 1.7	12.2 ± 1.5	10.9 ± 1.5
Muscle mass	68.7 ± 3.2	56.2 ± 5.1	57.7 ± 6.8	49.48 ± 4.4	47.8 ± 3.1	41.9 ± 2.6	37.5 ± 2.2	33.8 ± 2.1	29.8 ± 2.0	26.2 ± 2.2
Residual mass	18.2 ± 1.8	15.0 ± 1.4	13.8 ± 1.6	12.54 ± 0.9	10.4 ± 1.4	9.68 ± 0.8	8.73 ± 1.2	7.3 ± 0.7	6.29 ± 0.8	6.57 ± 0.1
Bone mass	12.5 ± 0.9	12.3 ± 0.5	9.4 ± 1.3	10.39 ± 1.1	9.26 ± 0.8	8.62 ± 0.7	7.98 ± 0.8	7.82 ± 0.5	7.57 ± 0.7	7.49 ± 0.0
Skin mass	5.09 ± 0.2	4.66 ± 0.2	4.51 ± 0.3	4.21 ± 0.1	4.09 ± 0.2	3.9 ± 0.2	3.67 ± 0.1	3.55 ± 0.2	3.35 ± 0.2	3.29 ± 0.2

Table V. Comparison of the winners sample with the rest of powerlifters.

	Winners (n=8)		Non-winners (n=55)			T-test
	mean	sd	mean	sd	difference	p
Masses (%)						
Adipose tissue	18.9	1.2	20.6	3.0	-1.71	0.1203
Muscle mass	53.9	2.2	51.2	3.4	2.67	**0.0337**
Residual mass	11.8	1.7	12.0	1.8	-0.25	0.7686
Bone mass	10.6	1.7	11.2	1.3	-0.58	0.2454
Skin mass	5.0	0.9	4.9	5.7	0.1	0.9609
Error %, Method vs Scale	4.2	2.7	3.5	2.4	0.68	0.4506
Masses (Kg)						
Adipose tissue	16.4	5.8	16.9	5.6	-0.5	0.8150
Muscle mass	46.7	15.1	41.9	10.2	4.8	0.2480
Residual mass	10.5	4.8	10.0	3.1	0.5	0.6937
Bone mass	8.8	2.1	9.0	1.6	-0.2	0.7520
Skin mass	4.1	0.7	3.9	0.5	0.2	0.3197
Indexes						
BMI (kg/St^2)	29.8	7.7	28.1	5.2	1.7	0.5879
Muscle to Bone ratio	5.3	1.0	4.7	0.7	0.6	**0.0363**
Sitting height/Stature	0.53	0.01	0.53	0.01	0.00	1.0000
Brachial	0.80	0.06	0.78	0.05	0.03	0.3007
Crural	1.21	0.12	1.11	0.13	0.10	**0.0427**
Competition scores						
Squat (kg)	254.1	78.1	199.4	51.7	54.7	**0.0137**
Bench Press (kg)	169.7	53.6	129.7	39.2	40.0	**0.0142**
Dead Lift (kg)	244.7	55.3	211.0	45.1	33.7	0.0640
Sum (kg)	668.4	180.2	543.9	130.6	124.6	**0.0230**

Figure 1. Somatoplot by categories of competition.



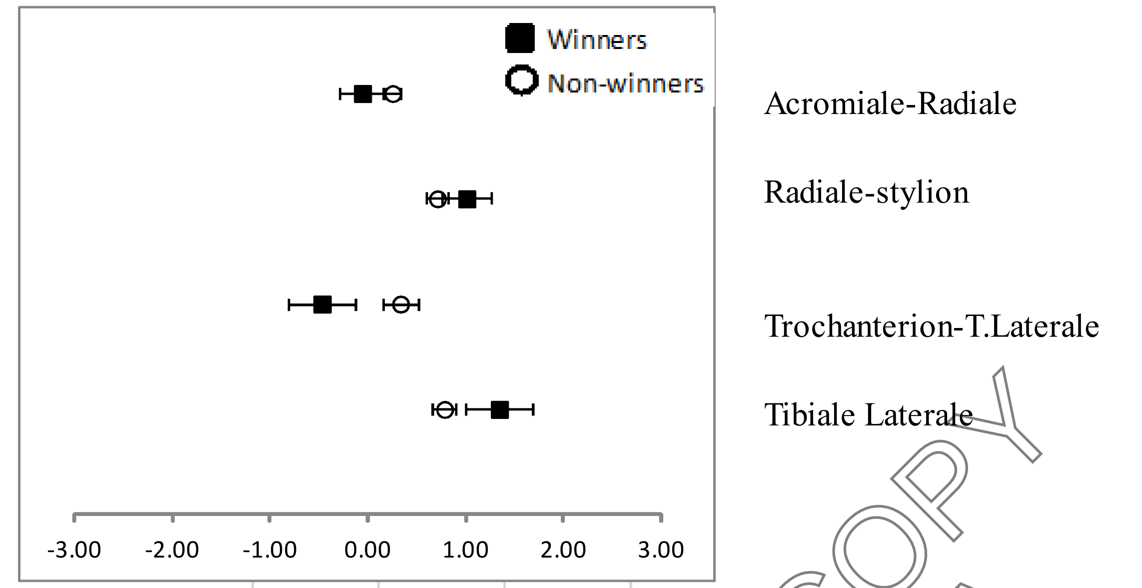


Figure 2. Comparison of the segment lengths of the Winners and the Non-winners powerlifters through the Phantom (mean ± standard error)

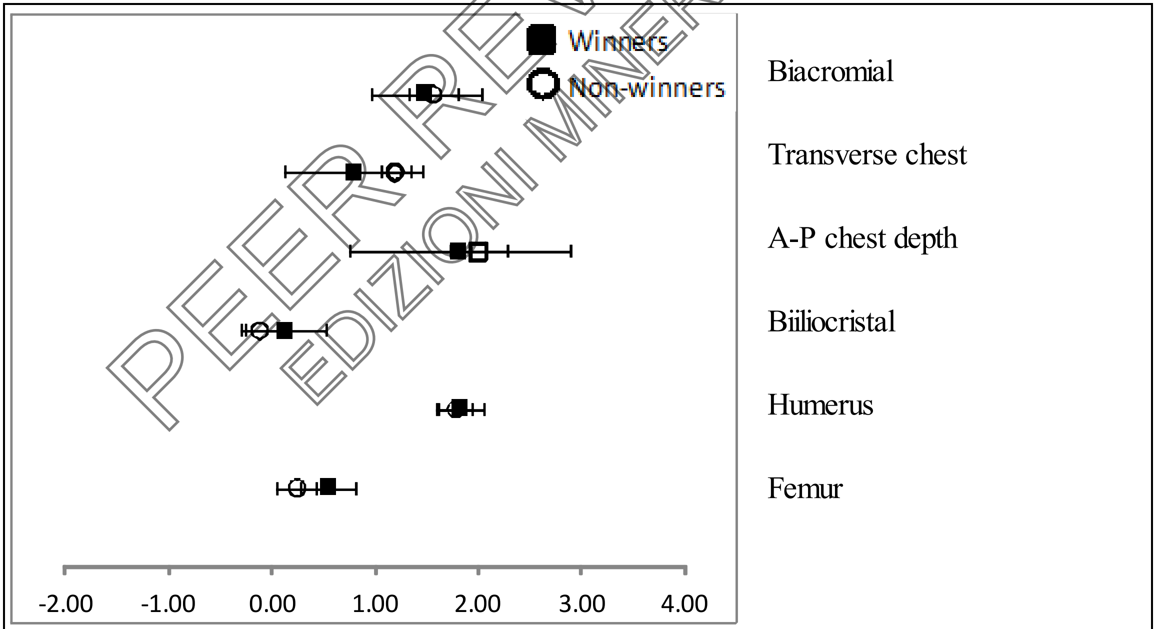


Figure 3. Comparison of the Breadths of the Winners and the Non-winners powerlifters through the Phantom (mean ± standard error). A-P chest deph = Anterior - Posterior chest deph

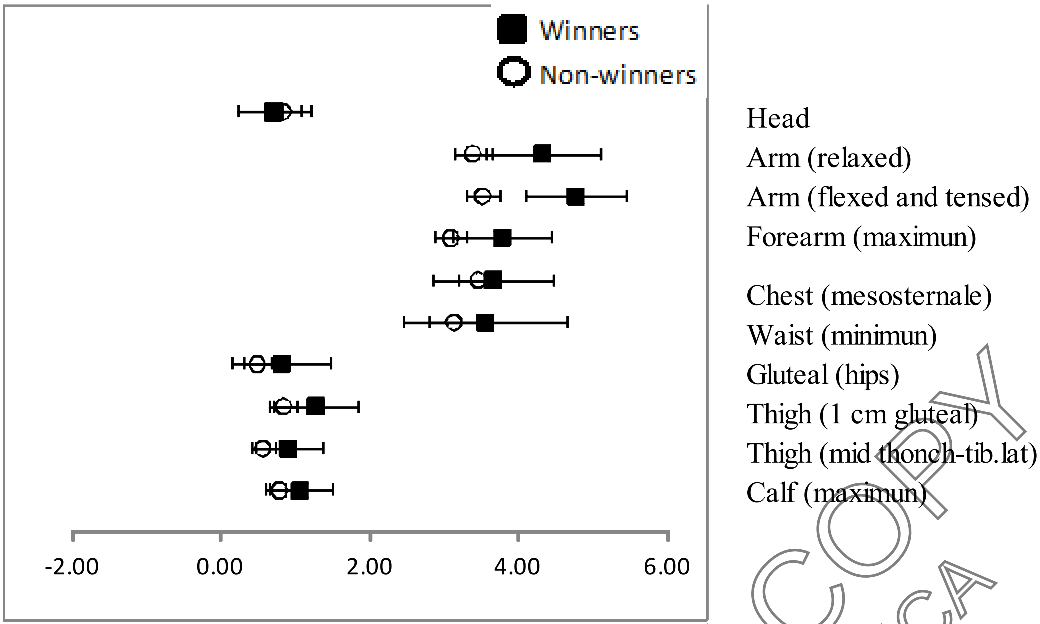


Figure 4. Comparison of the Girths of the Winners and the Non-winners powerlifters through the Phantom (mean ± standard error)

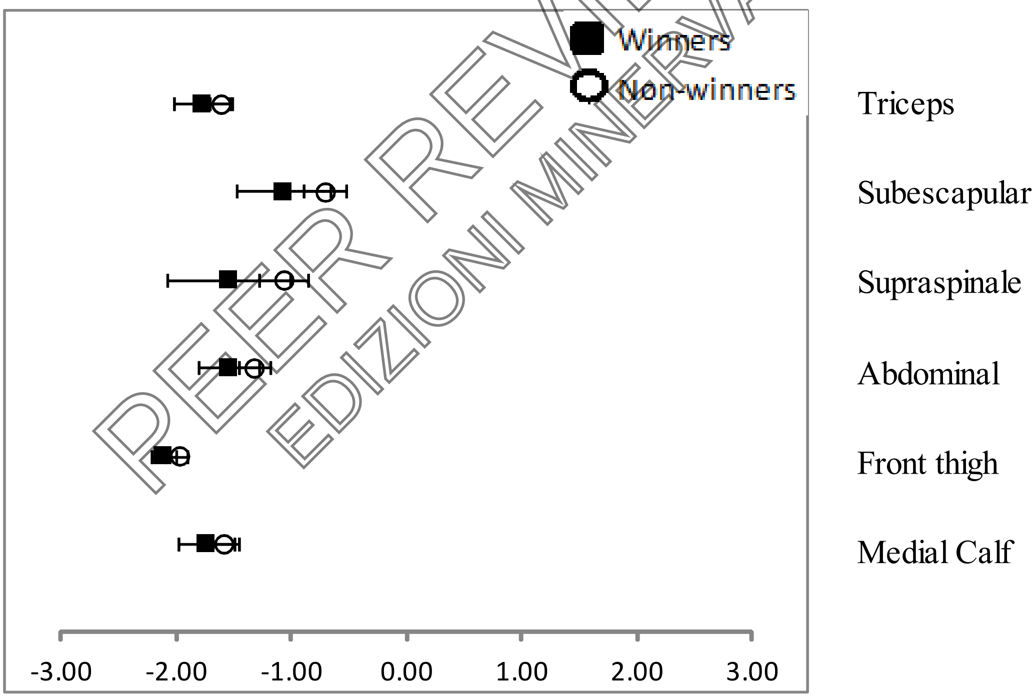


Figure 5. Comparison of the Skinfolds of the Winners and the Non-winners powerlifters through the Phantom (mean ± standard error)