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Relationships Between Anthropometry and Maximal Strength in Male Classic Powerlifters

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ABSTRACT

International Journal of Exercise Science 13(4): 1512-1531, 2020. Several studies have determined the influence of physical characteristics on strength. The present quantified the relationships between anthropometry and maximal strength. Male classic powerlifters (n=59) were measured before a championship. Two-tailed Pearson correlation analysis was used. Powerlifters that presented higher relative maximal strength (RMS) in the squat and bench generally had higher body weight (BW), body mass index (BMI), torso circumference (C), waist C/height, torso C/height ($r=0.26$ to 0.49, $p<0.05$), and smaller lower leg length (L)/height and forearm L/torso C ($r=-0.31$ to -0.45, $p<0.05$) ratios. Powerlifters with a higher % of their deadlift on their total generally presented a smaller BW, BMI, body fat percentage (BF%), waist and torso C, trunk L, waist C/height, torso C/height, trunk L/height, waist C/hip C, thigh L/ lower leg L, trunk L/thigh L ratios ($r=-0.26$ to -0.49, $p<0.05$) and higher lower leg L, lower leg L/height, reach/height, and forearm L/torso C ratios ($r=0.32$ to 0.51, $p<0.05$). Stepwise regressions revealed that a bigger torso positively predicted absolute maximal strength (AMS) in the squat ($\beta=0.41$, $p=0.04$), the bench ($\beta=0.77$, $p<0.01$), the deadlift ($\beta=0.88$, $p<0.01$) and the total ($\beta=0.89$, $p<0.01$), that a higher torso C/height ratio positively predicted RMS in the squat($\beta=0.48$, $p<0.01$), the bench ($\beta=-0.87$, $p<0.01$) and the total ($\beta=0.66$, $p<0.01$), and that reach/height positively predicted RMS in the deadlift ($\beta=0.37$, $p<0.01$) and it's % on the total ($\beta=0.31$, $p<0.01$), but negatively predicted RMS in the bench ($\beta=-0.25$, $p=0.02$) and its % on the total ($\beta=-0.24$, $p=0.04$) As all of the stronger correlations came from AMS, powerlifters should focus on increasing AMS (weight lifted) instead of RMS (Wilks pts).

KEY WORDS: Back squat, bench press, conventional deadlift, sumo deadlift, raw powerlifting

INTRODUCTION

Powerlifting is a sport of maximal strength (20) that includes 3 events: the back squat, the bench press and the deadlift (14). Participants have 3 attempts in each of these events to test their absolute maximal strength (AMS) by lifting a maximal load in a single repetition while respecting judging criteria. Participants must also attend the official weigh-in that takes place 2 hours before the competition to confirm the weight class in which they will be competing. The best completed attempt in each event is retained and summed up for the participant's final score, the total, which determines the final ranking for each weight class (14, 28). The total of the 3 events as well as the body weight of each participant is then inserted into a validated formula, the Wilks, in order to calculate participants relative maximal strength (RMS) and determine their ranking regardless of their weight class (60). Even though studies have attempted to develop new ways to evaluate the performance of powerlifters according to their body weight (3), body mass (8) or allometric (11, 33) and the International Powerlifting Federation (IPF) had voted the use of the new IPF formula, at the time this study was conducted, the Wilks score was still the formula utilized by the IPF and all of its underlying federations (27, 28). As well, a recent study published by Ferland et al. stated that the Wilks formula was more efficient than the IPF formula at determining the champion of champions between men's weight classes for both divisions (13).

As of 2012, the IPF has two distinct divisions: classic and equipped (27). The main distinction between these two divisions is the type of equipment competitors are permitted to use. The permitted personal equipment in the IPF's classic division are a lifting belt, knee sleeves and wrist wraps. In the equipped division, competitors are also permitted the use of supportive lifting suits for the squat and the deadlift, knee wraps, and a supportive t-shirt for the bench press (28). Powerlifters who compete in the classic division significantly lift less weight than the ones who compete in the equipped division (2, 13, 58).

At the time this study was conducted, several studies had determined the influence of various physical aspects of its competitors on powerlifting performance, namely on anthropometry (15, 30, 32, 38, 61), fat-free mass (4, 15, 16, 61), skeletal muscle mass (65) and bone mass (16). Granted, most of these studies had not been conducted on classic powerlifters, as most of them were carried out at a time when there was little to no differentiation between classic and equipped lifting. In addition, several other studies presented relationships between anthropometric characteristics and strength in the three powerlifting events (36), in the bench press only (35, 47, 50, 53) and in the 225 lbs NFL combine bench press test (23, 37) in other strength trained populations. Despite the results coming from these studies may not be applicable to classic powerlifting due to the differences in the various populations assessed.

Furthermore, the largest peak moment in all three planes were produced at the hip joint during the powerlifting squat (57) and that greater loads can be lifted with a low bar squat as it targets the stronger hip musculature (17). In addition, the sticking point in the bench press does not seem to be affected by a change in the moment arm (12), a narrow grip bench press produces greater barbell velocity (18) and a wider grip bench press shows similar muscle activation except for the biceps brachii (48). Finally, physical proportions will affect performance in the deadlift as the conventional deadlift may be more suitable for individuals with a shorter torso and the sumo deadlift may be more suitable for individuals with a longer torso (7) and no direct or specific cross over exists between the back squat and the conventional deadlift (19). Authors believe that these previously mentioned studies indirectly reinforce the importance of anthropometry in powerlifting performance.

Thus, the goal of this study was to quantify the relationships between body composition, anthropometric values and physical proportions, and maximal strength in classic powerlifting. The hypothesis of this study was that various correlations between anthropometric characteristics of powerlifters and relative and absolute maximal strength in the squat, the bench press, the deadlift and the total would be revealed. The results of the present study could help practitioners understand the impact of the presented physical characteristics on strength as previous investigations support that it can enhance physical and athletic performances (1, 9, 21, 24, 25, 31, 43, 54-56, 66).

METHODS

Participants

Ethics approval was obtained through the university's institutional review board committee (2790_e_2018). Participants were asked to read and sign two copies of the written informed consent form, before proceeding into data collection. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (41).

Participants (n=59) were all male from three age categories: sub-junior (18 yrs of age; n=1), junior (18 to 23 yrs old; n=18) and open (23 to 40 yrs old; n=40) classic powerlifters participating in the Quebec Powerlifting Federation (QPF) provincial championship. The QPF being affiliated to the Canadian Powerlifting Union (CPU) and IPF (6, 27, 45) has its anti-doping program ran by the Canadian Center for Ethics in Sports (CCES) which falls under the World Anti-Doping Agency (WADA) regulations (1, 5). Therefore, participants were all competing under strict drug-testing regulations. Sample includes subjects from all federated weight classes: -59 kg, -66 kg, -74 kg, -83 kg, -93 kg, -105 kg, -120 kg et 120 kg+. Participants' characteristics are presented in tables 1 to 3.

Table 1. Participants maximal strength per weight class.

Weight Class	Number of Participants	Bodyweight Kg	Squat Kg	Bench Kg	Deadlift Kg	Total Kg
-59 kg	1	54.6	170	113	190	473
-66 kg	1	62.9	155	100	185	440
-74 kg	10	71.6 ±3.1	185.3 ±22.5	126.6 ±20.9	220.5 ±31.4	532.3 ±64.9
-83 kg	14	80.6 ±2.1	205.7 ±24.1	136.6 ±21.0	237.7 ±16.7	580.0 ±55.7
-93 kg	15	90.5 ±3.66	230.2 ±26.4	148.3 ±19.6	257.8 ±33.0	636.3 ±74.2
-105 kg	7	100.7 ±4.1	255.1 ±21.1	165.7 ±20.6	263.6 ±25.4	684.4 ±58.1
-120 kg	10	114.6 ±4.0	258.1 ±31.8	170.5 ±22.1	278.9 ±37.9	707.4 ±82.0
120+ kg	1	132.5	317.5	205	280	802.5
Total	59					

Means±SD.

Table 2. Participants' characteristics (n=59).

Measure	Mean ± SD
Age	26.2 ± 4.8 yrs
Height	174.2 ± 6.8 cm
BW	89.9 ± 16.5 kg
BMI	29.5 ± 4.6
BF%	20 ± 7.3 %
LBW	71.1 ± 9.7 kg
Hip C	102.9 ± 14.3 cm
Waist C	91.2 ± 12.3 cm
Torso C	109.6 ± 9.7 cm
Arm L	33.2 ± 1.9 cm
Forearm L	26.7 ± 1.3 cm
Thigh L	41.9 ± 2.6 cm
Lower Leg L	42.1 ± 2.4 cm
Trunk L	39.2 ± 3.4 cm
Reach	180.9 ± 7.5 cm
Hip C/Height	0.59 ± 0.07
Waist C/Height	0.52 ± 0.07
Torso C/Height	0.63 ± 0.05
Trunk L/Height	0.22 ± 0.02
Thigh L/Height	0.24 ± 0.01
Lower Leg L/Height	0.24 ± 0.01
Reach/Height	1.04 ± 0.02
Waist C/Hip C	0.89 ± 0.07
Forearm L/Reach	0.15 ± 0.00
Forearm L/Torso C	0.25 ± 0.02
Forearm L/Height	0.15 ± 0.01
Forearm L/Arm L	0.80 ± 0.04
Thigh L/Lower Leg L	1.0 ± 0.07
Trunk L/Thigh L	0.94 ± 0.08

Means±SD. BW: Body Weight; BMI: Body Mass Index; BF%: Body Fat Percentage; LBW: Lean Body Weight, C: Circumference, L: Length

Table 3. Participants' competition results (n=59).

Measure	Mean ± SD
Squat kg	223.6 ± 39.1 kg
Bench kg	147.2 ± 27.0 kg
Deadlift kg	249 ± 35.9 kg
Total kg	619.8 ± 95.8 kg
Squat Wilks	145.3 ± 17.0 pts
Bench Wilks	95.7 ± 13.1 pts
Deadlift Wilks	162.4 ± 17.3 pts
Total Wilks	403.4 ± 41.3 pts
% Squat	36 ± 1.8 %
% Bench	23.7 ± 1.7 %
% Deadlift	40.3 ± 2.2 %

Protocol

The experimental approach of this descriptive quantitative research was designed to quantify the relationships between anthropometric characteristics and maximal strength. The investigation research design consisted of collecting various body composition and anthropometric values during an official competition weigh-in and to put them into comparison with the results of the competition. The independent variables being the various anthropometric characteristics and the dependent variables being the competition results (weight lifted in kg, Wilks points and % of each lift on the total).

An announcement of the research project which included the researchers' contact information was made through the QPF's Facebook page. This announcement was made to inform the potential participants of the research project and the presence of the research team at the official weigh-in as it is sanctioned to be «carried out in a room with the door closed, with only the competitor, the coach or manager and the two/three referees present» (28).

The research team was present at the official weigh-in of the provincial championship, as participants would get weighed by an official referee and then given the opportunity to participate in the research project, without feeling any pressure or slowing down the official weigh-in procedures. Authors would like to mention that female classic powerlifters were excluded from this study as the research team was present in the official weigh-in room of the championship and, as they were are all males, their presence in the female weigh-in room would have been unethical as well as prohibited (28).

During data collection, participants had to be in their underwear only (no socks). Data collection began by having subjects standing still as anthropometric measurements were taken with a flexible, yet non-stretchable 3 m measuring tape (as recommended by the ACSM) (44) to the nearest 0.1 cm in the following order: hip circumference was measured at its largest girth, muscles relaxed and arms to the side; waist circumference was measured at belly button height, muscles relaxed and arms to the side; chest circumference was measured at its largest girth (around nipple height) arms to the side, excluding the shoulders; arm length was measured in a straight line (not following the musculature) from lateral posterior apex of the acromion process to the apex of the olecranon, arms to the side, and hands in a neutral position; forearm length was measured from the apex of the olecranon to the styloid process of the ulna, arms to the side, and hands in a neutral position; thigh length was measured from the lateral apex of the greater trochanter to lateral epicondyle space of the knee; lower leg length was measured from the lateral epicondyle space of the knee to the lateral apex of the malleolus; trunk length was measured from the centre of the belly button to the top of the sternal extremity of the collarbone; reach (wingspan) was measured from tip to tip of the middle fingers, arms abducted to 90°. Height was measured with a stadiometer (Seca 217, Hambourg, Germany) feet together heels against the stadiometer, chin tucked with lungs full of air. All these measurements were taken by the same investigator while he was being assisted by a colleague as instructions were given verbally to the participants. This was done in order to get rid of the inter-tester reliability effect as previous research recommended that anthropometric intra-reliability should be above 95% (59) and that measurements should be carried out, when possible, by one observer (59) as the number of observers increases unreliability (34) and intra-observer reliability is above 95% (62). All limb measurements were taken once, due to the competition weigh in time constraints, on the right side of the participants.

The anatomical landmark selection was primarily based on their impact on powerlifter's external leverages as it is commonly known that physical characteristics, such as a shorter torso, femur, lower leg reduce the moment arm in the back squat, that a bigger torso or shorter arms reduce stroke distance in the bench press and that a shorter torso and longer arms reduce the moment lever in the deadlift. Thus, the goal of these anthropometric measurements was to verify some of those common beliefs. The anatomical landmark's selection was also based on simplicity of identification allowing the investigators to take measurements quickly as well as for the practitioners to be able to reproduce these measurements and calculate their client's ratios. Furthermore, in order to measure limb lengths precisely with the straightest lines possible, it was important for the researcher to utilize the best anatomical landmarks available. Consequently, all anatomical landmark selections were based on Frank H. Netter's Atlas of human anatomy (42) and the ACSM's guidelines for exercise testing and prescription (44). Finally, the anthropometric measurements and the methods used in this study were the same as the ones used in the other study published by Ferland et al. on "Physical Characteristics and Maximal Strength in Men Practicing the Back Squat, the Bench Press and the Deadlift" as the goal of this study is to present results that are specific to male classic powerlifters (15).

After anthropometric measurements were taken, participants stood on a validated bio-impedance scale (In-Body 270, Seoul, Korea) (29) where their age in years was asked verbally before starting the analysis for measurement of lean body weight, fat mass and body fat percentage. No particular instructions were given to the participants prior to the bio-impedance scale analysis (BIA) regarding food and water consumption as they were not contacted individually before the data collection and researchers did not want to interfere with the competition's results. Hydration status was not monitored in any kind of manner and information about participants' weight loss procedures was not collected, as it is practically impossible to control for all confounding factors and to know what athletes do prior competition that could affect performance. These previously mentioned factors are considered limitations to the BIA analysis, although authors believe that all participants were measured under similar competition settings. All participant measurements were taken and recorded within approximately 4-minutes in order to respect the championship's weigh-in schedule and procedures.

AMS and RMS were tested during competition. Participants would lose study eligibility if they did not complete at least one attempt in each of the 3 competition lifts, as their final result would not represent a complete performance. As this competition was a qualifying event for the national championship from which competitors only had to reach a certain standard to qualify, participants were asked if they were giving their 100% on that given day in the consent form. Any participants that were not going for a maximum effort on all of the three lifts, whether it would be for personal reasons or because of a limiting injury were not eligible in this study. Participants had the possibility to contact researchers at any given time after data collection if they wanted to be removed from the study, without having to give any explanation. No information was collected on the training regimen of the subjects. Following the provincial championship, the results of the participants were received through e-mail from the competition director. Wilks score for each event and percentage of each event on the total were calculated from these results.

Statistical Analysis

The statistical analysis was performed on a total of 59 participants, without any being removed for lack of completion or voluntary withdrawal. Participants' characteristics are presented as means accompanied with their respective standard deviation. The Shapiro-Wilk test for normality was compiled for each variable. Correlations between independent variables (participant characteristics, n=29) and dependent variables (competition results, n=11) were calculated using a 2-tailed Pearson correlation analysis. As the literature is not consistent with the interpretation of the size of a correlation coefficient (39, 40, 51), this rule of thumb was put into place: strong relationship cut-off was set at $r \geq 0.6$, moderate at $r \geq 0.3$ and weak at $r < 0.3$. Forward stepwise linear regression analysis was performed to determine the ability of each participant's characteristic to predict competition results. In this current study, the research protocol was directed towards male powerlifters of 18 to 40 yrs old, competing in all 3 events, in a drug-tested (1, 5) sanctioned competition under what is considered to be the strictest regulations (6, 27, 28, 45), utilizing the validated Wilks coefficient to calculate relative maximal strength (13, 60). The stepwise forward algorithm allowed to begin with a null model of prediction and to pursue until no independent variable could be removed or added (22). Statistical significance was set at $p \leq 0.05$ for both analyses. All statistical analyses were conducted using IBM SPSS Statistics for Windows version 25.

Wilks formula:

$$\text{Wilks Points} = \text{Weight lifted in kg} * \left(\frac{500}{a + bx + cx^2 + dx^3 + ex^4 + fx^5}\right)$$

Constants for the Wilks formula are presented on the Wikipedia website (63).

RESULTS

The two-tailed Pearson correlation analysis revealed multiple correlations between subject's characteristics and performance. Results show that all of the stronger correlations and the greatest number of significant correlations came from AMS measures (Total=84, Strong n=29, Moderate n= 46, Weak n= 9) rather than RMS measures (Total=31, Strong n=0, Moderate n= 25 and Weak n= 6) and percentages of each lift on the total (Total= 35, Strong n=0, Moderate n= 30 and Weak n=5). All correlation results are presented in results Table 4.

The stepwise forward regression analysis revealed multiple performance predictors between subjects' characteristics and performance. The most important stepwise regression results revealed that a bigger torso positively predicted AMS in the squat (β=0.41, p=0.04), the bench press (β=0.77, p<0.01), the deadlift (β=0.88, p<0.01) and the total (β=0.89, p<0.01), that a higher torso C/height ratio positively predicted RMS in the squat (β=0.48, p<0.01), the bench press (β=-0.87, p<0.01) and the total (β=0.66, p<0.01), and that reach/height positively predicted RMS in the deadlift (β=0.37, p<0.01) and % of it on the total (β=0.31, p<0.01), but negatively predicted RMS in the bench press (β=-0.25, p=0.02) and % of it on the total (β=-0.24, p=0.04). All stepwise regression analysis results are presented in Table 5 and 6.

Table 4. Relationships between powerlifters' anthropometric characteristics and performance (n=59).

	S	B	D	T	SW	BW	DW	TW	%S	%B	%D
Age	**.31**	**.41**	**.28**	**.35**	**.30**	**.43**	.21	**.35**	-.00	**.34**	**-.26**
Height	**.34**	**.27**	**.37**	**.36**	.00	-.07	-.08	-.05	.13	-.03	-.08
BW	**.78**	**.70**	**.64**	**.76**	**.37**	**.26**	.00	.24	**.38**	.17	**-.43**
BMI	**.76**	**.70**	**.57**	**.72**	**.43**	**.34**	.02	**.30**	**.40**	.22	**-.49**
BF%	**.54**	**.45**	**.33**	**.47**	**.29**	.16	-.09	.13	**.41**	.11	**-.47**
LBW	**.67**	**.62**	**.66**	**.70**	**.28**	.22	.09	.23	.20	.12	-.25
Hip C	**.58**	**.44**	**.63**	**.60**	**.31**	.14	.24	**.27**	.19	-.09	-.08
Waist C	**.72**	**.65**	**.56**	**.69**	**.34**	.24	-.03	.21	**.37**	.17	**-.43**
Torso C	**.78**	**.77**	**.69**	**.79**	**.44**	**.42**	.15	**.38**	**.26**	**.26**	**-.41**
Arm L	.04	.04	.22	.11	-.19	-.14	.02	-.11	-.20	-.08	.22
Forearm L	**.34**	**.27**	**.45**	**.38**	.09	.00	.12	.09	.05	-.12	.05
Thigh L	**.34**	.23	**.33**	**.33**	.04	-.09	-.08	-.05	.18	-.09	-.08
Lower Leg L	-.06	-.11	.15	.00	-.23	**-.27**	.01	-.18	-.16	-.24	**.32**
Trunk L	**.53**	**.46**	**.36**	**.48**	.18	.09	-.17	.03	**.35**	.13	**-.38**
Reach	**.35**	**.26**	**.48**	**.40**	.05	-.05	.10	.05	.02	-.14	.09
Hip C/Height	**.54**	**.42**	**.58**	**.56**	**.35**	.17	**.27**	**.31**	.18	-.08	-.08
Waist C/Height	**.67**	**.61**	**.49**	**.63**	**.37**	**.28**	-.01	.24	**.37**	.20	**-.45**
Torso C/Height	**.69**	**.71**	**.57**	**.69**	**.48**	**.49**	.19	**.43**	.22	**.30**	**-.41**
Trunk L/Height	**.46**	**.40**	.24	**.39**	.22	.15	-.16	.07	**.36**	.18	**-.42**
Thigh L/Height	.17	.09	.13	.15	.05	-.07	-.05	-.02	.14	-.10	-.04
Lower Leg L/Height	**-.41**	**-.41**	-.15	**-.34**	**-.33**	**-.31**	.09	-.20	**-.35**	**-.30**	**.51**
Reach/Height	.05	.00	**.27**	.12	.07	.02	**.37**	.19	-.22	-.24	**.36**
Waist C/Hip C	**.32**	**.38**	.08	**.27**	.13	.20	-.24	.02	**.27**	**.32**	**-.46**
Forearm L/Reach	.08	.08	.08	.09	.08	.07	.06	.08	.05	-.01	-.03
Forearm L/Torso C	**-.64**	**-.67**	**-.49**	**-.63**	**-.42**	**-.45**	-.10	**-.36**	-.23	**-.36**	**.46**
Forearm L/Height	.09	.07	.20	.13	.10	.07	.24	.16	-.07	-.13	.15
Forearm L/Arm L	**.30**	.22	.19	**.26**	**.31**	.16	.10	.22	**.28**	-.03	-.20
Thigh L/Lower Leg L	**.37**	**.31**	.18	**.30**	.24	.14	-.08	.11	**.31**	.12	**-.34**
Trunk L/Thigh L	**.29**	**.28**	.13	.25	.16	.15	-.10	.07	.23	.19	**-.32**

Bold indicates significant correlations at p<0.05

S: Squat, B: Bench, D: Deadlift, T: Total, SW: Squat Wilks, BW: Bench Wilks, DW: Deadlift Wilks, TW: Total Wilks, %S: Percentage Squat, %B: Percentage Bench, %D: Percentage Deadlift, BW: Body Weight, BMI: Body Mass Index, BF%: Bodyfat Percentage, LBW: Lean Body Weight, C: Circumference, L: Length

Table 5. Stepwise linear regression analysis formulas in order to predict powerlifting performance (included participants: n=59).

Squat kg = Torso C*1.67 + BW*0.951 – 44.888
(R=0.797, p<0.001, SEE=24.02)

Bench kg = Torso C*2.139 – 87.26
(R=0.767, p<0.001, SEE=17.49)

Deadlift kg = Torso C*3.264 + Waist C/Hip C*-185.551+55.994
(R=0.757, p<0.001, SEE=23.84)

Total kg = Torso C*8.766 – Waist C/Hip C*317.859 + Forearm L/Arm L*380.762 – 365.626
(R=0.824, p<0.001, SEE=55.78)

Squat Wilks = Torso C/Height*159.962 + 44.64
(R=0.479, p<0.001, SEE=15.08)

Bench Wilks = Torso C/Height*299.938 - Waist C/Height*171.154 + Age*0.927 – Reach/Height*162.786 + 141.212
(R=0.684, p<0.001, SEE=9.87)

Deadlift Wilks = Reach/Height*315.303 – 164.951
(R=0.371, p=0.004, SEE=16.18)

Total Wilks = Torso C/Height*532.076 – Waist C/Hip C*212.934 = 257.228
(R=0.527, p<0.001, SEE=35.75)

Squat % = BF%*0.001 + 0.34
(R=0.413, p=0.001, SEE=0.02)

Bench % = Forearm L/Torso C*-0.37 – Hip C/Height*-0.08 + Age*0.001 – Reach/Height*0.2 + 0.556
(R=0.582, p<0.001, SEE=0.01)

Deadlift % = Leg L/Height*0.548 - BMI*0.003 + Reach/Height*0.335 + Hip C/Height*0.083 - 0.047
(R=0.702, p<0.001, SEE=0.02)

Significance was set at p<0.05 level.
*Authors recommend using the prediction formulas only to predict weight lifted in kg
BF%: Bodyfat Percentage, BW: Body Weight, C: Circumference, L: Length

Table 6. Stepwise linear regression analysis results (included participants: n=59).

Performance Measures	Characteristics	R^2	B	β	P-Value
Squat kg		0.635			<0.001
	Torso C		1.67	0.414	0.039
	BW		0.951	0.402	0.045
Bench kg		0.588			<0.001
	Torso C		2.139	0.767	<0.001
Deadlift kg		0.573			<0.001
	Torso C		3.264	0.882	<0.001
	Waist C/Hip C		-185.551	-0.379	<0.001
Total kg		0.678			<0.001
	Torso C		8.766	0.887	<0.001
	Waist C/Hip C		-317.859	-0.243	0.011
	Forearm L/Arm L		380.762	0.163	0.047
Squat Wilks		0.230			<0.001
	Torso C/Height		159.962	0.479	<0.001
Bench Wilks		0.468			<0.001
	Torso C/Height		299.938	1.172	<0.001
	Waist C/Height		-171.154	-0.865	<0.001
	Age		0.927	0.340	0.003
	Reach/Height		-162.786	-0.254	0.022
Deadlift Wilks		0.138			0.004
	Reach/Height		315.303	0.371	0.004
Total Wilks		0.277			<0.001
	Torso C/Height		532.076	0.657	<0.001
	Waist C/Hip C		-121.394	-0.376	0.010
% Squat		0.171			0.001
	BF%		0.001	0.413	0.001
% Bench		0.338			<0.001
	Forearm L/Torso C		-0.370	-0.423	0.003
	Hip C/Height		-0.080	-0.340	0.012
	Age		0.001	0.298	0.017
	Reach/Height		-0.200	-0.243	0.036
% Deadlift		0.493			<0.001
	Lower Leg L/Height		0.548	0.254	0.028
	BMI		-0.003	-0.558	<0.001
	Reach/Height		0.335	0.311	0.003
	Hip C/Height		0.083	0.269	0.034

Significance was set at p<0.05 level.
BF%: Bodyfat Percentage, BW: Body Weight, C: Circumference, L: Length

DISCUSSION

The main finding of this study is that several relationships between classic powerlifters' anthropometric characteristics and performance measures exist and that they could explain how certain individuals can perform better in the different powerlifting events.

As all of the stronger correlations with anthropometric characteristics came from AMS, these results suggest that powerlifters should focus on increasing AMS (weight lifted) instead of focusing on increasing RMS (Wilks pts). In fact, body weight (BW), body mass index (BMI), body fat percentage (BF%), lean body weight (LBW), hip, waist and torso circumference (C), hip C/height, waist C/height and torso C/height all presented higher correlation coefficients with AMS rather than with RMS. Thus, powerlifters should be warned to not only focus on increasing RMS and to stop trying to remain in a lower weight class but should also consider utilizing training techniques that stimulate muscular hypertrophy in order to increase all of the previously mentioned physical characteristics. Hypertrophy training should build up more training volume and include sets of 6 to 12 repetitions at a moderate velocity while varying exercises and the exercise's parameters (grip, stance, etc.), maintain moderate (60-90s) too long (3 min +) rest intervals and avoid going to failure too frequently (52). Similar results were found in a study published by Reya et al. which highlighted that lean body mass, agonist cross-sectional area, brachial index and strength of shoulder and elbow flexors were the greatest predictors of bench press AMS in elite competitive powerlifters (46). Let's not forget to mention that the strong relationships between body weight and weight lifted (r=0.64-0.78) also confirm the utility of weight classes.

The results presenting stronger correlations with anthropometric characteristics in AMS rather than RMS also show that anthropometric characteristics have a stronger relationship with absolute weight lifted (AMS), but a smaller one with relative weight lifted (RMS). These results could mean that these anthropometric characteristics are a good predictor of how strong a powerlifter can possibly become but are much less predictive how competitive he can be in his weight class or relative to his body weight (Wilks pts).

Meanwhile, the present study's data agrees with previous research. In fact, an early study conducted on male novice high-school powerlifters also presented strong significant ($p<0.01$) correlations between AMS in the bench press and torso C (r=0.70) as well as AMS in the deadlift and body mass (r=0.65) and torso C (r=0.65) (38). Furthermore, this study also presented results of a multiple regression analysis which showed that age, body mass, 6 skin folds (mm), arm cross-sectional area and forearm length (L) predicted 68.9% of AMS in the bench press (38). As well, age, body mass, 6 skin folds and thigh C explained 62.4% of AMS in the deadlift (38).

A more recent study conducted by Keogh et al., also presented similar results to the present and the studies cited above, as they compared the anthropometric profile of weaker (-370 Wilks) to stronger (410+ Wilks) male IPF affiliated equipped powerlifters. Their effect size analysis revealed that the stronger group had more powerlifting experience, greater muscle mass, normalized muscle mass and a higher torso C/height ratio (30). In addition, an even more recent study published by Lovera and Keogh, which was directed on male IPF affiliated equipped powerlifters, also presented similar results when comparing winners to the other participants by showing that winners displayed significantly greater muscle mass (32). As well, a study conducted by another group, also directed on IPF affiliated equipped male powerlifters, presented similar results to the present and the others cited above by indicating that absolute skeletal muscle mass was significantly ($p<0.001$) strongly correlated with AMS in the squat ($r=0.93$), the bench press ($r=0.88$), the deadlift ($r=0.84$) and the total ($r=0.94$). As well, their results indicated that thigh length/height ratio did not correlate with any of the RMS measures (65). Overall, the results from these previous studies support the ones presented in the current by confirming the importance of age, body mass, muscle mass, body fat percentage, forearm L, torso C and body mass in AMS in the bench press and the deadlift.

The results of the present study also display anthropometric measurements that are not possible to modify with training as they are partly genetically predisposed. These measurements include forearm L, thigh L, trunk L, reach, trunk L/height, reach/height, forearm L/arm L, thigh L/lower leg L and trunk L/thigh L. It is important to notice that all of these measurements were significantly positively correlated with maximal strength except for lower leg L/height which was significantly negatively correlated with it. Perhaps these various measurements should allow coaches to partially predict their client's genetic powerlifting potential.

Percentage of the powerlifter's deadlift (%D) on the total presented a different trend than all other performance measures as it was significantly ($p<0.05$) negatively correlated with age, BW, BMI, BF%, waist and torso C, trunk L, waist C/height, torso C/height, trunk L/height, waist C/hip C, thigh L/lower leg L, trunk L/thigh L ratios and significantly ($p<0.05$) positively correlated with lower leg L as well as lower leg L/height, reach/height, and forearm L/torso C ratios. These relationships suggest that a powerlifter considered as a «deadlift specialist» would generally be younger, lighter, thinner, less muscular, have a smaller waist and torso circumference, shorter trunk and thighs and longer lower legs, reach and forearms. It is important to specify that powerlifters presenting these characteristics are not necessarily stronger than their peers at the deadlift, but that they present a higher % of their deadlift on their total, which could also mean that they do not perform as well at the squat and the bench press. This was partially confirmed as correlations with age, BW, BMI, BF%, Waist and Torso C, Trunk L, waist C/height, torso C/height, trunk L/height, waist C/hip C, thigh L/lower leg L and trunk L/height were all significantly positively correlated with most AMS performance measures, but significantly negatively correlated with the % of the powerlifter's deadlift on the total. This was also confirmed with age, BW, BMI, torso C, waist C/height and torso C/height ratios being all significantly positively correlated with squat and bench RMS (Wilks pts).

RMS in the squat and the bench press was significantly positively correlated with age, BW, BMI, torso C, waist C/height, torso C/height and significantly negatively correlated with lower leg L/height and forearm L/torso C and none of the anthropometrical characteristics were significantly correlated with RMS in the deadlift. These results add to the possibility of the ideal body type of a powerlifter that is strong in the squat is closely related to ideal one for the bench press, but not for the deadlift.

There were no significant correlations between thigh L/height and any of the powerlifting performance measures. The current results could help abolish the non-scientific belief that shorter femurs according to body height help with squat performance. From the results tables, it can be observed that it is lower leg L/height that is significantly negatively correlated with powerlifting performance. Thus, it can be hypothesized that shorter lower legs relative to body height could permit greater knee flexion and let the knees travel more forward as it could help to be more upright in the squat (reducing the moment arm, when measured horizontally from the centre of the barbell to the centre of the hip joint) consequently permitting a mechanical advantage. Shorter lower legs in the bench press could permit a greater arch and more leg drive as the feet could be placed more under the bench through greater knee flexion. Shorter lower legs in the deadlift could help participants start with their trunk in a relatively more vertical position and execute a leg-lift as described by Hales et al. (19). On the other hand, lower leg L/height was significantly negatively correlated with % of the powerlifters' deadlift on their total, which could mean that for the deadlift specialist, longer lower legs could contribute to opening the knee joint and permit the hamstrings to be at a better angle of pull as well as reducing the moment arm as long as the hips start from a higher position and the powerlifter executes what would be considered a back-lift, as described by Hales et al. (19).

Furthermore, by looking at the results from the correlation table (Table 4), one could hypothesize that the powerlifter with greater AMS would have bigger hips, a bigger waist, a bigger torso, longer forearms, longer thighs, a longer trunk, a longer reach, higher hip C/height, waist C/height, torso C/height, trunk L/height, waist C/hip C, forearm L/arm L, thigh L/ lower leg L and trunk L/thigh L ratios, but smaller lower leg L/height and forearm L/torso C ratios when compared to his fellow competitors.

Results from the stepwise analysis, as used in previously published research on the topic (15, 38), show that torso C significantly predicted ($p<0.05$) and positively affected AMS in the squat, the bench, the deadlift and the total. As well, Torso C/height significantly positively predicted RMS in the squat, the bench and the total. These results could be explained by the fact that a thicker torso could possibly improve the powerlifter's internal leverages as well as permit him to gain more lean muscle mass. Furthermore, reach/height significantly positively predicted RMS in the deadlift and % of the deadlift on the total and significantly negatively predicted RMS in the bench and % of the bench on the total. These significant relationships could mean, respectively, that longer arms relative to body height help improve leverages for the deadlift as the individual can place his hips closer to the bar in order to reduce the moment arm when measured from the centre of his hips to the centre of the barbell, but that it decreases the powerlifters advantage in the bench press as it increases stroke distance.

Limitations to this study include the fact that cofounding factors such as participants' hydration level, nutrient intake, lifting experience, training status and training routine were not monitored. Authors understand that these factors could have affected the anthropometric and BIA measurements thereby increasing the discrepancy between participants. However, despite the hydration status could affect circumferences and bodyweight, it does not affect segment lengths. Furthermore, the anthropometric measurements used in this study had not been previously validated, even though other anthropometric measurement techniques were considered, but discarded due to the competition time constraint as well as the need for a greater redundancy in material/equipment.

Another limit of this study is that limb circumferences and muscle thickness were not measured among subjects due to time constraints as measurements were taken at the official weigh-in of a championship. Fortunately, the present study is inline with another study directed on equipped male USAPL powerlifters (13 national level, 4 world and 3 national champions) that utilized muscle thickness instead of segment, ratios as herein, to quantify the relationship between physical characteristics and AMS in powerlifting. This study, in fact, presented significant correlations ($p<0.01$) between various muscle thicknesses (forearm, biceps, triceps, chest, abdomen, subscapularis, quadriceps, hamstrings, tibialis anterior and calves) and squat (r=0.79 - 0.91), bench press (r=0.63 - 0.85) and deadlift (r=0.70 - 0.90) AMS. The strongest correlation observed between muscle thickness and AMS were with the subscapularis muscle for all three lifts (squat, r=0.91, bench r=0.85 and deadlift r=0.90). This study also presented strong correlations between AMS and fat-free mass/height (r=0.86 - 0.95) (4).

The present study's results also confirm the results from previous work published by Ferland et al. showing that lean body tissue is related to most absolute and relative maximal strength measures in male and female classic powerlifters (r=0.61-95, $p<0.05$) (16) and also confirms most of the anthropometric characteristics related to relative and absolute maximal strength in the three powerlifting events in powerlifters and NCAA football players (15).

Furthermore, two studies published by Mayhew et al. presented the relationships between anthropometric characteristics (including muscle thickness) and strength in non-powerlifter populations. The first study showed that arm circumference and arm muscle cross-sectional area as well as thigh circumference presented strong relationships with strength in the three powerlifting events in highly trained football players (36) and the second showed that selected upper arm cross-sectional area, body fat percentage and chest circumference (torso) were the best items to predict bench press strength in college males (35). Another study published by Vigotsky et al. also presented significant relationships between parallel back squat strength and fat-free mass normalized to height as well as anthropometry (61).

Thus, many investigators have shown that physical characteristics are correlated with powerlifting maximal strength outcomes. However, the present study adds to the body of knowledge by presenting the significance of new physical proportions on strength that is more in line with biomechanical leverage advantages and not just solely based on physiological muscle adaptations.

Conclusion: Ultimately, this research was able to reveal multiple correlations between body composition, anthropometric values and physical proportions and maximal strength in classic powerlifting as well as to quantify the ability of certain of those characteristics to predict maximal strength. The hypothesis of this study was that various correlations between anthropometric characteristics of powerlifters and relative and absolute maximal strength in the squat, the bench press, the deadlift and the total would be revealed. Results from the 2-tailed Pearson correlation analysis did reveal multiple significant relationships between physical characteristics and relative and absolute maximal strength in the squat, the bench, the deadlift and the total. Therefore, the hypothesis is accepted.

The results of the present study should be utilized by powerlifting coaches as they could reproduce the simple anthropometric assessments presented in the methodology to have a better understanding of their trainees' physical strength and weaknesses. Nonetheless, it is important for practitioners to remember that these results are specific to weigh-in high-level competitive testing environment, and that results related to body composition testing should be viewed within that specific lens. The present results may not be generalizable to other testing environments where variables that can impact BIA results may fundamentally alter the results of similar comparisons of body composition and sport performance as shown in previously published research (10, 26, 49).

Some of the assumptions made in the discussion indicate that there is a need for future research to be directed towards powerlifters' anthropometry and its effect on biomechanics. Other future research could be directed towards female classic powerlifters as well as on classic powerlifter's internal leverages, such as: muscle thickness, muscle pennation angle, tendon length, and tendon to bone insertion.

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