THE USE OF ANTHROPOMETRIC VARIABLES TO PREDICT BENCH PRESS AND SQUAT STRENGTH IN WELL-TRAINED STRENGTH ATHLETES

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The ability of anthropometric variables to predict the strength of 42 powerlifters in a relatively simple bench press (BP) and complex squat (SQ) exercise was assessed. Powerlifters were measured for 42 anthropometric dimensions using International Society for the Advancement of Kinanthropometry protocols. Correlation and multiple linear regression analyses were performed, with independent variables entered in stepwise order. The prediction of bench press strength (r^2 = 0.71; SEE = 20 kg; CV = 14%) by flexed upper arm girth and arm length-height index appeared somewhat greater than the prediction of SQ strength (r^2 = 0.49, SEE = 33.4 kg, CV = 17%) by musculoskeletal size. These results suggest that the ability of anthropometric measures to predict strength may decrease with exercise complexity in well-trained strength athletes and that anthropometric characteristics place upper limits on BP and SQ strength.

KEY WORDS: anthropometry, powerlifting, prediction, strength, weight-training

INTRODUCTION: Muscular strength is an important determinant of success in many sports and is also required for many activities of daily living (Komi, 2003). While muscular strength can be determined using numerous methods, it is frequently measured by a one repetition maximum (1RM). The ability to lift a 1RM load requires the production of a muscular torque that exceeds the load torque. The muscular torque is equal to the muscular force(s) multiplied by the muscle's moment arm, while the load torque is equal to the product of the load force(s) and the moment arm of the load.

Anthropometric profiling can be used to give an indication of the ability of the muscles to produce force as well as the moment arm of the load. The ability of a muscle to produce force is proportional to its cross-sectional area (Komi, 2003) and therefore increases with greater levels of fat-free mass (FFM) (Brechue & Abe, 2002). Therefore, standard anthropometric measures such as body mass, FFM, mesomorphy and trunk/limb girths may all give some indication to the strength of a person. The moment arm of the load is the perpendicular distance from the line of pull of the load to the joint about which rotation is occurring. This means that the moment arm of the load and hence the load torque becomes greater as the lifter's limb length increases. Powerlifters and Olympic weightlifters therefore typically have proportionally shorter limbs than the general population (Hume et al., 2003; Norton et al., 1996).

The association of certain anthropometric characteristics with strength-based sporting activities has resulted in a number of studies investigating the relationship and predictive ability of standard anthropometric measures to muscular strength (Ballmann et al., 1999; Hart et al., 1991; Kroll et al., 1990; Mayhew et al., 1991; Mayhew et al., 1993). The results of this literature appear somewhat equivocal, with anthropometric variables explaining 26%-69% of the common variance in bench press (BP) and squat (SQ) strength with an accuracy of 10%-17%. This variation in results may reflect differences in the training status and familiarity of the subjects with the strength tests, the complexity of the strength tests, the contraction mode used and the anthropometric variables measured and derived.

The present study therefore sought to examine the effect of exercise complexity on the ability of anthropometric variables to predict strength in well-trained strength athletes (powerlifters) who were extremely familiar with the lifting of 1 RM loads in the SQ, BP and deadlift (DL) exercises. In the confines of the present study, the BP was considered a relatively simple exercise whereas the SQ was considered to be more complex in nature. The SQ was considered more complex than the BP because the SQ is performed in a standing rather than supine posture and because it requires the activation of a greater number of agonist and stabiliser muscles. It was hypothesised that the anthropometric variables would explain a relatively high level of common variance and that they would be moderately good predictors of muscular strength in both lifts; although these relationships were expected to be stronger in the BP than SQ exercise. The common variance explained and the predictive ability of the anthropometric variables was also expected to be greater than that reported in studies that utilised novice or lower-level strength athletes.

METHODS: Forty-two male powerlifters (age 34.2 ± 10.8 years old) of at least national standard were measured for 42 anthropometric dimensions. The maximum load lifted in competition for the BP, SQ and DL were also recorded. None of the powerlifters were injured at the time of the competition or had tested positive to anabolic steroids. The Auckland University of Technology Ethics Committee approved this study. All powerlifters received verbal and written information about the study and gave written informed consent prior to their participation.

Double measures for each of the 42 anthropometric dimensions (triple measures for skinfolds) were obtained using the International Society for the Advancement of Kinanthropometry (ISAK) protocols (Norton et al., 1996). All measures were taken by accredited ISAK Level II and III anthropometrists. These measures included eight skinfolds (using a Slimguide calliper 10 g/mm^2 constant pressure), 13 limb/body girths (using a Lufkin metal tape), 11 limb/body lengths (using an anthropometer), four breadths and widths (all on the right side of the body) and body mass (using Seca scales). Selected anthropometric measures were used to determine somatotype following the methods described by Heath & Carter (1967). Body fat was calculated using the equations of Sloan and Weir (1970). Fat free mass (FFM) was calculated by subtracting the body fat mass from the total body mass. Musculoskeletal size was measured by dividing FFM by height (Slaughter & Lohman, 1980). The arm length-height index (arm length/height), brachial index (forearm length/upper arm length), Brugsch index (chest circumference/height), Cormic index (sitting height/height), crural index (tibia length/femur length) and acromio-iliac index (bi-iliac/bi-acromial breadth) were also calculated.

Results for the anthropometric and strength measures were expressed as mean and standard deviation. Relationships between the strength and anthropometric variables were examined using Pearson-product correlations. Multiple linear regression analysis was used to predict BP and SQ strength, with the anthropometric variables entered in stepwise order. Only those anthropometric variables that were theoretically related to BP and SQ strength based on a qualitative model were entered in each analysis. All statistical analyses were conducted using SPSS Ver 12.0. Statistical significance was accepted at a level of $p < 0.05$.

RESULTS AND DISCUSSION: The 1 RM loads lifted by the powerlifters during competition (BP: 144 ± 35 kg; SQ 219 ± 51 kg; DL 233 ± 35 kg) were indicative of their high levels of muscular strength. The anthropometry of the powerlifters appeared consistent with previous studies (Bale & Williams, 1987; Brechue & Abe, 2002; Hume et al., 2003). Typically, the powerlifters were endo-mesomorphic in nature, with large muscular trunk and limb girths as well as relatively short limbs. The mean values of selected anthropometric variables and their correlations to BP and SQ strength are shown in Table 1.

The anthropometric variables that were most highly correlated to BP and SQ strength were those that related to FFM, muscular girths and somatotype. Similar results have been reported for BP, SQ and isometric bicep curl strength (Ballmann et al., 1999; Hart et al., 1991; Kroll et al., 1990; Mayhew et al., 1991; Mayhew et al., 1993). In contrast, the limb length, limb length ratios and bony breadths were typically not significantly related to BP or SQ strength. The lack of any significant correlation between the strength and limb lengths/limb length ratios was in contrast to previous results for bicep curl (Kroll et al., 1990) and SQ strength (Mayhew et al., 1993). This may have reflected the current sample which appeared more heterogenous in regards to body mass (54-163 kg) and height (147-189 cm) than previous studies. Heavyweight powerlifters are generally taller than their lightweight counterparts and as a result have longer limbs (Hume et al., 2003). Therefore, the tendency for a longer limb decreasing strength by increasing the moment arm and torque of the load may be offset by an increase in the girth and cross-sectional area of the agonist muscles. The relations between strength and limb lengths may possibly be increased by using a more homogenous sample in terms of body mass and height.

Table 1 The relationship between selected anthropometric variables and strength as measured in the BP and SQ.

Anthropometric Variable	Mean ± SD	Bench Press	Squat
Height (cm)	172 ± 8	0.12	0.07
Body mass (kg)	91 ± 21	0.49**	0.61**
Sum of eight skinfolds (mm)	110 ± 51	0.41**	0.49**
Body fat (%)	15 ± 5	0.41**	0.49**
Fat-free mass (kg)	77 ± 13	0.55**	0.64**
Musculoskeletal Size (kg FFM.cm^{-1})	0.45 ± 0.07	0.55**	0.68**
Endomorphy	3.8 ± 1.8	0.36	0.45**
Mesomorphy	8.5 ± 2.0	0.46**	0.55**
Ectomorphy	0.7 ± 0.8	-0.55**	-0.54**
Anterior posterior chest depth (cm)	22 ± 4	0.44**	0.39**
Bi-acromial breadth (cm)	42 ± 2	0.44**	0.34*
Bi-illiac breadth (cm)	29 ± 3	0.26	0.31
Acromio-iliac index (%)	143 ± 9	-0.03	-0.17
Chest girth (cm)	111 ± 10	0.63**	0.61**
Flexed upper arm girth (cm)	41 ± 5	0.71**	0.72**
Upper thigh girth (cm)	64 ± 7	0.46**	0.57**
Mid-thigh girth (cm)	60 ± 7	0.52**	0.59**
Upper arm length (cm)	33 ± 2	0.09	-0.05
Forearm length (cm)	27 ± 2	-0.14	-0.22
Total arm length (cm)	80 ± 4	-0.06	0.05
Thigh length (cm)	42 ± 4	-0.07	0.08
Arm length-height index (%)	46 ± 2	-0.10	-0.14
Brachial index (%)	81 ± 5	-0.23	-0.32*
Brugsch Index (%)	65 ± 6	0.56**	0.57**
Cormic Index (%)	56 ± 8	0.11	0.07
Crural index (%)	90 ± 5	0.17	0.12

* Significantly correlated at a level of $p < 0.05$.
** Significantly correlated at a level of $p < 0.01$.

Portions of this data have been presented previously (Keogh et al., 2004).Multiple linear regression was used to predict BP and SQ strength. The regression equations for the BP and SQ exercises are shown below.

Bench press (kg) = (7.05 x Flexed Upper arm girth) – (3.92 x Arm length-height index) + 38.4. ($r^2 = 0.71$, SEE = 19.7 kg, CV = 14%).

Squat (kg) = (535.76 x Musculoskeletal Size) – 21.44. ($r^2 = 0.49$, SEE = 36.4 kg, CV = 17%).

The results of the linear regression analyses indicated that approximately 70% and 50% of the common variance of the powerlifters' BP and SQ strength was explained by the anthropometric variables and that these anthropometric variables allowed their strength to be predicted with moderate accuracy (14%-17%). These results were consistent with the hypothesis that the common variance explained and the ability of anthropometric variables to predict strength would be greater in the simple BP than complex SQ exercise. This may reflect the fact that factors not assessed in the current study such as skill (technique) and "core" stability are more important in the SQ than BP.

While some studies have reported similar levels of accuracy of BP and SQ strength prediction (Hart et al., 1991; Mayhew et al., 1993), the present study was able to explain a greater proportion of the variance in BP strength than previous studies. As the athletes in the current study were considerably stronger than those in previous studies, this suggests that anthropometric variables are a major determinant of BP strength in highly strength-trained athletes. This indicates that anthropometric variables place an upper limit on the level of maximum strength, with this especially pronounced in more simple movements. These results suggest that well-trained strength athletes who wish to further increase their strength in the SQ and especially the BP exercise may need to perform some hypertrophy training for the specific muscles groups required in these lifts.

CONCLUSIONS: Standard anthropometric variables can be used to predict the strength (BP more so than SQ) of well-trained strength athletes with reasonable precision. As the predictive ability of these anthropometric variables appears to increase with the simplicity of the exercise and the strength of the athletes, it suggests that certain anthropometric variables are important determinants of BP and SQ performance. By comparing their predicted and actual 1 RM, each lifter may be able to determine if they need to prioritise hypertrophic or specific skill training to further improve their strength.

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