Grip strength as a function of age, height, body weight and Quetelet index

Article *in* Physiotherapy Theory and Practice · July 2009

DOI: 10.3109/09593989109106961

3 authors, including:

Joseph Balogun
Chicago State University
212 PUBLICATIONS **1,734** CITATIONS
SEE PROFILE

Sarafadeen A. Adenlola
Adex Physical Therapy PC
2 PUBLICATIONS **58** CITATIONS
SEE PROFILE

Physiotherapy Theory and Practice (1991) 7, 111-119

Grip strength as a function of age, height, body weight and Quetelet index

Joseph A. Balogun, Abideen A. Akinloye and Sarafadeen A. Adenlola

The primary aim of this study was to determine the viability of using physical characteristic parameters to predict grip strength. We measured the weight, height, Quetelet index (weight/height^2) and grip strength of 960 subjects (480 males and 480 females), ranging in age from 7 to 84 years. We analysed our data using linear-, multiple- and stepwise-regression models. We found that grip strength is positively related to: (1) age up to the third decade of life, and thereafter grip strength is inversely related to age; (2) both body weight and height at all ages; and (3) the Quetelet index during the first two decades of life. Furthermore, we found that grip strength can reliably be predicted from age, weight, height and the Quetelet index ($P<0.001$). Based on our findings, we recommend that grip strength normative data should be based on both body weight and age rather than age alone, as is the current practice.

INTRODUCTION

It is widely accepted that grip strength is a valid predictor of the functional integrity of the upper extremity (Helliwell et al, 1987; Spiegel et al, 1987). In clinical practice and in physical fitness programmes, grip strength is objectively measured by mechanical and electronic dynamometers (Kai-Nan et al, 1980; Myers et al, 1980; Solgaard et al, 1984), cable tensiometer (Nwuga, 1975) and modified sphygmomanometer (Helewa et al, 1981; Balogun et al, 1990a). The grip strength normative data of different populations have been published (Schmidt and Toews, 1970; Kellor et al, 1971; Lunde et al, 1972; Thorngren and Werner, 1979; Fraser and Benten, 1983; Ager et al, 1984; Mathiowetz et al, 1985a, 1986; Fullwood, 1986). Furthermore, the various physical factors affecting the measurement of grip strength have been identified (Teraoka, 1979; Pryce, 1980; Mathiowetz et al, 1985b; Balogun et al, 1990b).

Previous studies suggest that the dominant hand grip strength correlates fairly well with the strength of various muscle groups; and, as such, grip strength is considered fairly representative of total body strength (Myers et al, 1973; Balogun, 1987). However, researchers over the years have marvelled at the low correlation between physique and grip strength (Bechtol, 1954; Schmidt and Toews, 1970; Berger, 1982). Currently, the relationship between grip strength and physical characteristics indices (i.e. age, weight, height and body adiposity) is not well defined. More importantly, there is a dearth of information on which physical characteristic index is the major determinant of grip strength.

J.A. Balogun, A.A. Akinloye and S.A. Adenlola, Department of Medical Rehabilitation, Faculty of Health Sciences, Obafemi Awolowo University, Ile-Ife, Oyo State, Nigeria

(Reprint requests to JAB)

Accepted for publication January 1991

In a recent study, we compiled grip strength normative data for both males and females of different ages (Balogun et al, in press). In this report, we analysed our data further using linear-, multiple- and stepwise-regression models to (1) determine the relationship between grip strength and age, weight, height and the Quetelet index, and (2) identify which of the physical characteristic variables is the most viable predictor of grip strength.

METHODS

A total of 960 volunteers (480 males and 480 females; age range = 7–84 years) participated in our study. The physical characteristics of the subjects are presented in Table 1. The subjects were recruited from the community residential quarters, schools, shopping centres and churches in Oyo State, Nigeria. The informed consent of each subject was obtained prior to data collection. During a brief interview preceding measurement, we reviewed each subject's past medical history and obtained their biographical data (i.e. sex and age). Prospective subjects with injury or disease affecting the upper extremities were excluded from the study.

We measured each subject's weight and height using a portable stadiometer. Subsequently, we measured their right- and left-hand grip strength in random order using a hand dynamometer (Harpenden® Dynamometer, British Indicators Ltd). Standardised instructions and procedures were employed (Balogun et al, 1990b). The measurements were taken in the standing position with the elbow joint held in full extension; the shoulder joint was adducted and neutrally rotated, while the forearm was held in the neutral position. The handle of the dynamometer was adjusted (i.e. the grip size) so that the uppermost part of the dynamometer rested comfortably on the thenar eminence of each subject. Subsequently, the subjects were instructed 'to squeeze the handle of the dynamometer as hard as possible' and to 'hold it in place for 5 seconds'. Verbal encouragement was offered during the test by commanding the subjects to 'pull, pull, pull'. Each hand was tested twice and the higher reading for each was recorded for data analysis. The subjects were given feedback on their performance during both trials.

Following data collection, we computed the Quetelet index of each subject using standard formulae:

$$\text{Quetelet index} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$$

The Quetelet index provides a measure of weight adjusted for height and it is an objective measure of body adiposity (Khosia and Lowe, 1967).

Statistical analysis

We computed the Pearson product–moment correlation coefficient (r) to determine the relationship between physical characteristic indices (age, height, weight and Quetelet index) and grip strength. Multiple- and stepwise-regression models were employed to determine the combined and individual contribution of the physical indices to the prediction of grip strength. Multiple-regression analysis explains the variance of a criterion (dependent) variable by estimating the contributions to the total variance by a number of predictor (independent) variables.

Table 1
Physical characteristics of the subjects (N=960)

Variable	Range		$\bar{x} \pm$ SD
	Minimum	Maximum	
Age (years)	7.0	84.0	39.2±22.1
Weight (kg)	16.0	97.0	52.7±14.6
Height (cm)	104.0	194.0	155.9±15.8
Quetelet index (kg/m²)	12.8	36.2	21.2± 3.7

In the present study, grip strength (y, kg) was the dependent variable, and age (x_1, years), height (x_2, cm), body weight (x_3, kg) and Quetelet index (x_4, kg/m^2) were the independent variables. The multiple-regression equation for this study can be represented mathematically as follows:

$$y = k + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

where k is the regression constant and b is the beta weight for the corresponding independent variables. The multiple correlation coefficient (R) of a regression equation provides the relative importance of the independent variables in making predictions. The coefficient of determination (R^2) is an index of the contribution of the combination of independent variables to the total variability in predicting the dependent variable.

The stepwise-regression procedure selects the independent (predictor) variables in the order of their relative strengths in predicting the dependent variable. In this study, the tolerance level was set at a probability of 0.01 ($F \geq 4.00$). We evaluated the predictability of the regression equations using the analysis of variance (ANOVA) procedure. The above statistical analyses were performed on an IBM 370 computer using the SPSS statistical package.

RESULTS

We classified the subjects into eight age groups using 10-year intervals and plotted the mean anthropometric indices for the different age groups (Fig. 1). The graph revealed that height, body weight and Quetelet index increases with chronological age, but they attain their maximum values at different ages. Height, body weight and Quetelet index peaked at 20–29 years, 40–49 years and 50–59 years respectively. The mean grip strength scores for the males and females in the different age groups are plotted in Figs 2 and 3 respectively. The grip strength of both sexes increased with chronological age but also peaked at different ages. The grip strength peaked between 30 and 39 years in the males (Fig. 1) and between 20 and 29 years in the females (Fig. 2), after which a progressive decline was found in both the right and left upper extremities.

The relationship between physical characteristics and grip strength is presented in Table 2. The analyses revealed that grip strength is positively correlated ($P<0.05$) with age up to the third decade of life, and thereafter grip strength is inversely related to age ($P>0.05$). Furthermore, consistent positive correlations ($P<0.001$) were obtained between grip strength and weight and between grip strength and height irrespective of age. On the contrary, grip strength is only significantly related ($P<0.001$) to the Quetelet index during the first two decades of life.

We derived separate multiple-regression equations for the male and female subjects because of the dichotomy in age at which grip strength peaked for both sexes. We used the ages at which they attained their maximum grip strength as 'anchor points'. For the male subjects, we derived different regression equations for those aged below 40 years (male grip strength peaked between 30 and 39 years) and another for those older than 40 years. Similarly, we derived two equations for the females; one for those below 30 years of age (female grip strength peaked between 20 and 29 years) and the other for those older than 30 (Table 3). The results of the multiple-regression analyses showed that in both sexes the four independent (predictor) variables contributed significantly ($P<0.001$) to the prediction of right- and left-hand grip strength (Table 3). The combined contribution of the four independent variables to the prediction of grip strength ranged from 51 to 85%. The remaining unexplained variance can be attributed to random variation (e.g. noise and other physical factors not measured in the present study.

The results of the stepwise-regression analysis for the male subjects aged under 40 years of age and for the females aged under 30 years of age are presented in Tables 4 and 5 respectively. Over 80% of the total variance in grip strength of both sexes is accounted for by weight; however, height contributed less than 1% for the males and about 2% for the females. In both sexes, the contribution of age and the Quetelet

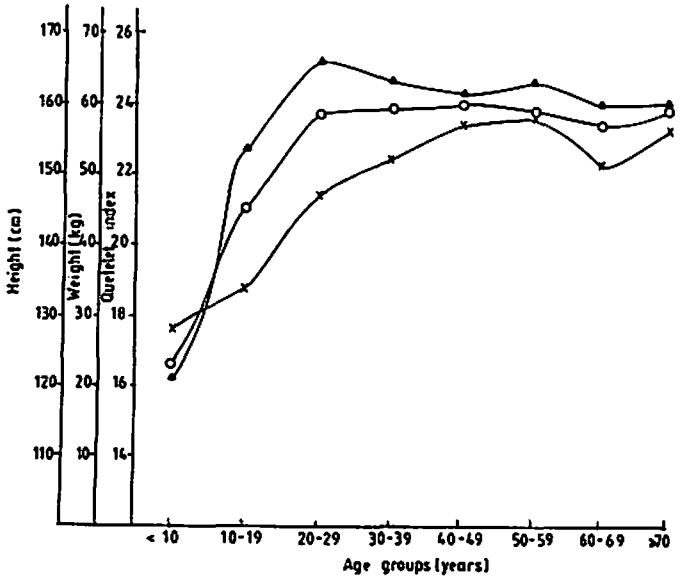

Fig. 1 The anthropometric indices of the subjects in the different age groups. ▲, height (cm); O, weight (kg); ×, Quetelet index.

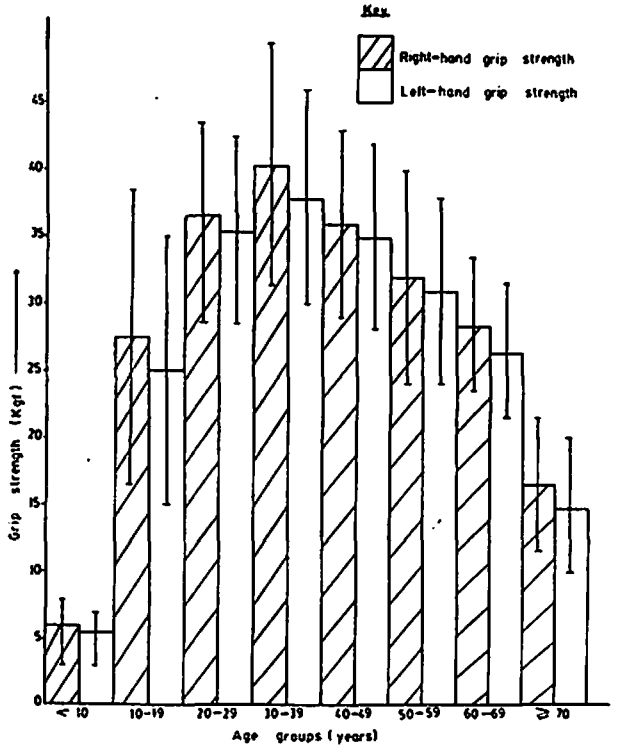

Fig. 2 The right- and left-hand grip strength of males.

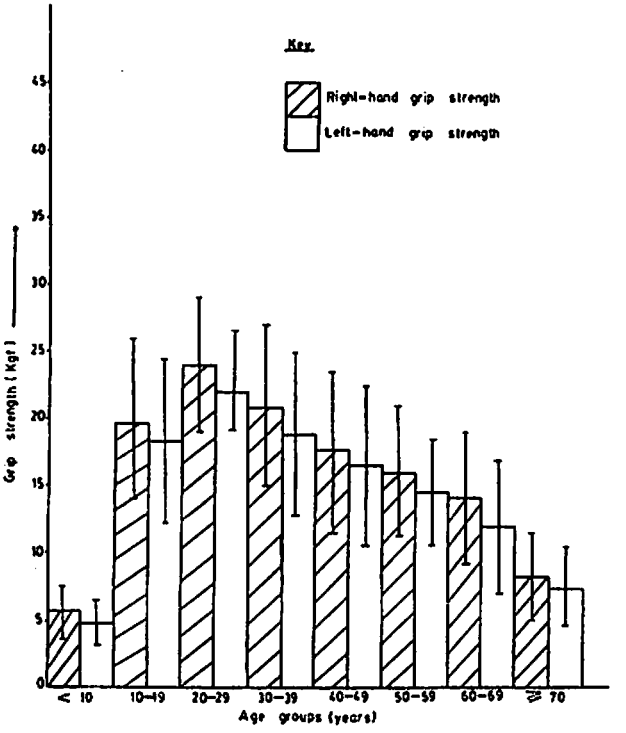

Fig. 3 The right- and left-hand grip strength of females.

index to the prediction of grip strength is less than 1% (Tables 4 and 5). The above findings reveal that body weight is the most viable predictor of grip strength of adolescents and young adults.

The stepwise-regression analysis for the male and female subjects' (aged 40+ and 30+ respectively) grip strength is presented in Tables 6 and 7. Age accounted for the greatest variance in grip strength in both sexes: 60% of the total variance among the males and about 40% among the females. Weight and height were the other viable predictors of grip strength among the male and female subjects respectively. The predictive value of the Quetelet index among both sexes was less than 1%. The above findings revealed that age is the most viable predictor of grip strength of elderly subjects.

DISCUSSION

One of the aims of this *ex post facto* study was to determine the relationship between grip strength and the physical characteristics of subjects of different ages. We found that grip strength is positively correlated ($P<0.001$) with both body weight and height for all age groups. These findings are in agreement with the results of previous related studies. Bookwalter (1950) found that body weight is linearly related to grip strength up to 250 lb. Everett and Sills (1952) reported a positive relationship between grip strength and height. Schmidt and Toews (1970) measured the grip strength of 1208 normal subjects and found that their grip strength increased as body weight and height increased up to 215 lb and 75 inches respectively. Based on their find-

Table 2
Relationship[a] between physical characteristics and grip strength

Age group	Physical characteristics			
	Age	Height	Weight	Quetelet index
⩽10 years (n=120)				
right hand	0.42***	0.51***	0.58***	0.34***
left hand	0.32***	0.48***	0.57***	0.37***
10–19 years (n=120)				
right hand	0.59***	0.80***	0.81***	0.51***
left hand	0.63***	0.80***	0.84***	0.56***
20–29 years (n=120)				
right hand	0.18*	0.55***	0.56***	0.08
left hand	0.17*	0.54***	0.57***	0.12
30–39 years (n=120)				
right hand	0.04	0.71***	0.55***	0.05
left hand	0.09	0.70***	0.54***	0.05
40–49 years (n=120)				
right hand	−0.05	0.58***	0.36***	0.05
left hand	−0.03	0.60***	0.34***	0.01
50–59 years (n=120)				
right hand	−0.14	0.62***	0.38***	0.01
left hand	−0.15*	0.65***	0.40***	0.01
60–69 years (n=120)				
right hand	−0.04	0.67***	0.43***	−0.02
left hand	−0.06	0.65***	0.42***	−0.01
⩾70 years (n=120)				
right hand	−0.10	0.44***	0.47***	0.11
left hand	−0.11	0.43***	0.54***	0.10
7–84 years (n=960)				
right hand	0.00	0.70***	0.60***	0.30***
left hand	−0.01	0.69***	0.60***	0.29**

[a] Pearson product-moment correlation coefficient.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$.

Table 3
Summary of the analysis of variance and coefficient of determination (R^2) for the grip strength multiple-regression equation

Analysis	Mean square	F ratio	R^2
Males aged under 40			
right hand	12 117.2	284.8*	0.83
left hand	11 132.5	324.9*	0.85
Females aged under 30			
right hand	4 165.5	297.0*	0.84
left hand	2 732.2	208.2*	0.83
Males aged 40 or more			
right hand	3 231.2	90.1*	0.62
left hand	3 420.0	105.32*	0.65
Females aged 30 or more			
right hand	1 608.0	77.3*	0.52
left hand	1 430.9	74.8*	0.51
Combined data (i.e. for both sexes and for all ages)			
right hand	23 846.2	466.5*	0.66
left hand	22 111.7	457.5*	0.66

* $P<0.001$.

Table 4
Summary of the grip strength multiple- and stepwise-regression analyses for males aged under 40, showing the contribution of the predictor variables

	Right hand			Left hand		
Parameter	R^2	$\%R^2$ change	Beta coefficient	R^2	$\%R^2$ change	Beta coefficient
Constant			−33.59			−41.82
Weight	0.815	81.5	0.33	0.835	83.5	0.27
Height	0.823	0.8	0.26	0.841	0.6	0.26
Age	0.829	0.6	0.20	0.846	0.6	0.18
Quetelet index	0.829	0.0	0.31	0.847	0.0	0.58
SEE*			6.52			5.85

*SEE, standard error of estimate for the multiple-regression equation (kgf).

Table 5
Summary of the grip strength multiple- and stepwise-regression analyses for females aged under 30, showing the contribution of the predictor variables

	Right hand			Left hand		
Parameter	R^2	$\%R^2$ change	Beta coefficient	R^2	$\%R^2$ change	Beta coefficient
Constant			−27.39			−49.19
Weight	0.814	81.4	0.34	0.807	80.7	0.02
Height	0.835	2.1	0.21	0.823	1.6	0.34
Age	0.835	0.0	0.02	0.826	0.0	−0.01
Quetelet index	—	—	—	0.826	0.3	0.85
SEE*			3.74			3.62

*SEE, standard error of estimate for the multiple-regression equation (kgf).

ings, they concluded that 'in general, taller persons have greater grip strength'. In a study of 57 female students, Lunde et al (1972) also found that grip strength is positively related to height and weight, but that it is more strongly correlated to weight than height. More recently, Balogun et al (1990b) obtained positive correlations between grip strength (the measurements were taken in different testing postures and elbow joint angles), body weight and height.

In the present study, grip strength was positively related to the Quetelet index (an estimate of adiposity) during the first two decades of life. This finding is in disagreement with the earlier findings of Balogun (1987), who measured the grip strength and body fat composition of 50 female college students (age range = 19–30 years) using a Jamar dynamometer and skinfold caliper respectively. He found a negative relationship ($P<0.05$) between grip strength and body fat. The inconsistency between the two studies may be due to the different methods used to quantify adiposity, and the narrow age range in Balogun's (1987) study.

The primary purpose of this study was to determine the viability of using physical characteristic indices to predict grip strength. We found that age, body weight, height and the Quetelet index combined contributed significantly to the prediction of right- and left-hand grip strength. Our findings are consistent with the results of two studies that used the multiple-regression analysis model (Schmidt and Toews, 1970; Lunde et al, 1972). Using height, body weight and age as predictor variables, Schmidt and Toews (1970) derived multiple-regression equations to predict the grip strength of both hands. However, they did not indicate the coefficient of determination of their regression equation. In the other study, Lunde et al (1972) used body weight and height in their regression equation and reported a multiple-regression coefficient of

Table 6
Summary of the grip strength multiple- and stepwise-regression analyses for males aged 40 or more, showing the contribution of the predictor variables

	Right hand			Left hand		
Parameter	R^2	$\%R^2$ change	Beta coefficient	R^2	$\%R^2$ change	Beta coefficient
Constant			93.94			68.86
Weight	0.559	55.9	−0.59	0.594	59.4	−0.61
Height	0.610	5.1	0.75	0.645	5.1	0.58
Age	0.615	0.5	−1.43	0.653	0.7	−0.98
Quetelet index	0.617	0.2	−0.27	0.653	0.0	−0.12
SEE*			5.99			5.70

*SEE, standard error of estimate for the multiple-regression equation (kgf).

Table 7
Summary of the grip strength multiple- and stepwise-regression analyses for females aged 30 or more, showing the contribution of the predictor variables

	Right hand			Left hand		
Parameter	R^2	$\%R^2$ change	Beta coefficient	R^2	$\%R^2$ change	Beta coefficient
Constant			9.87			−14.98
Weight	0.399	39.9	−0.29	0.398	39.8	−0.27
Height	0.508	10.9	0.11	0.508	11.0	0.26
Age	0.515	0.7	0.44	0.512	0.4	0.19
Quetelet index	0.521	0.6	−0.91	0.513	0.1	−0.35
SEE*			4.56			4.37

*SEE, standard error of estimate for the multiple-regression equation (kgf).

0.32 and 0.27 for the right and left hands respectively. The coefficient of determination (0.10 and 0.07 for the right and left hands respectively) of their regression equation is much lower than the values obtained in the present study. A comparison of the standard error of estimate for the multiple-regression equation published by Schmidt and Toews (1970) was made difficult because grip strength in their study was measured in pounds as compared to the metric unit (kgf) used in the present study.

Clinical relevance

Grip strength normative data are used by physical therapists to (1) determine the severity of injury to the upper extremities, (2) establish treatment goals and (3) make clinical decisions regarding job placement and restrictions. Grip strength normative data are based on age (Schmidt and Toews, 1970; Kellor et al, 1971; Lunde et al, 1972; Thorngren and Werner, 1979; Fraser and Benten, 1983; Ager et al, 1984; Mathiowetz et al, 1985a, 1986; Balogun et al, in press). We found that body weight is the most viable predictor of grip strength among adolescents and young adults; however, among the elderly, age is the most viable predictor of grip strength. The above findings have practical implications. The findings suggest that practising physical therapists must take into consideration the body weight of their clients when comparing their grip strength values with population norms based on age. More specifically, grip strength data should be based on both body weight and age criteria rather than using the age criterion alone.

In addition to gripping, the major functions of the hand include manipulation and expression. During the activities of daily life, many tasks are performed that require the use of grip and pinch forces, which are just a fraction of the maximum

isometric grip force. Similarly, manual dexterity is required in everyday tasks. Thus, physical therapists assessing patients with upper extremity disabilities should evaluate grip strength in conjunction with range of hand motion, manipulation skills and skin sensation (Bear-Lehman and Abreu, 1989).

CONCLUSIONS

The results of the present study revealed that grip strength is positively related to: (1) age up to the third decade of life, and thereafter grip strength is inversely related to age; (2) both body weight and height at all ages; and (3) the Quetelet index during the first two decades of life. Furthermore, we found that grip strength can be predicted with good confidence ($P<0.001$) from physical characteristic indices. Based on our findings, we recommend that grip strength normative data should be based on body weight and age criteria rather than age alone, as is the current practice.

References

Ager C L, Olivett B L, Johnson C L 1984 Grasp and pinch strength in children 5–12 years old. American Journal of Occupation Therapy 38: 107–113

Balogun J A 1987 Assessment of physical fitness of female physical therapy students. Journal of Orthopaedic and Sports Physical Therapy 8: 525–532

Balogun J A, Akomolafe C T, Amusa L O 1990a Reproducibility and criterion-related validity of the modified sphygmomanometer for isometric testing of grip strength. Physiotherapy Canada 42: 290–295

Balogun J A, Akomolafe C T, Amusa L O 1990b Grip strength: Effects of testing posture and elbow position. Archives of Physical Medicine and Rehabilitation 71

Balogun J A, Adenlola S A, Akinloye A A (in press) Grip strength normative data for the Harpenden dynamometer. Journal of Orthopaedic and Sports Physical Therapy

Bear-Lehman J, Abreu B C 1989 Evaluating the hand: Issues in reliability and validity. Physical Therapy 69: 1025–1033

Bechtol C O 1954 Grip test: The use of a dynamometer with adjustable handle spacing. Journal of Bone and Joint Surgery 36A: 820–824

Berger R A 1982 Applied exercise physiology. Lea and Febiger, Philadelphia

Bookwalter K W 1950 Grip strength norms for males. Research Quarterly 21: 249–276

Everett P W, Sills F D 1952 Relationship of grip strength to stature, samototype components and anthropometric measurements of hand. Research Quarterly 26: 161–166

Fraser C, Benten J 1983 A study of adult hand strength. British Journal of Occupational Therapy 10: 294–299

Fullwood D 1986 Australian norms for hand and finger strength of boys and girls, aged 5–12 years. Australian Occupational Therapy Journal 33: 26–36

Helewa A, Goldsmith C H, Smythe H A 1981 The modified sphygmomanometer – An instrument to measure muscle strength: A validation study. Journal of Chronic Diseases 34: 353–361

Helliwell P, Howe A, Wright V 1987 Functional assessment of the hand: Reproducibility, acceptability and utility of a new system for measuring strength. Annals of Rheumatic Diseases 46: 203–208

Kai-Nan A N, Chao E Y, Askew L J 1980 Hand strength measurements. Archives of Physical Medicine and Rehabilitation 61: 366–372

Kellor M, Frost J, Silberberg N, Iverson I, Cummings R 1971 Hand strength and dexterity. American Journal of Occupational Therapy 25: 77–83

Khosia T, Lowe C R 1967 Indices of obesity derived from body weight and height. British Journal of Preventive and Social Medicine 21: 122–128

Lunde B K, Brewer W D, Garcia P A 1972 Grip strength of college women. Archives of Physical Medicine and Rehabilitation 53: 491–493

Mathiowetz V, Kashman V, Volland G, Weber K, Dowe M, Rogers S 1985a Grip and pinch strength: Normative data for adults. Archives of Physical Medicine and Rehabilitation 66: 59–74

Mathiowetz V, Rennels C, Donahoe L 1985b Effects of elbow position on grip and key pinch strength. Journal of Hand Surgery 10A: 694–697

Mathiowetz V, Wiemer D M, Federman S M 1986 Grip and pinch strength: Norms for 6 to 19 years old. American Journal of Occupational Therapy 40: 705–800

Myers C L, Golding L A, Sinning W E 1973 The Y's way to physical fitness, 1st edn. Rodale Press, Emmaus, Penn.

Myers D B, Greenan D M, Palmar D G 1980 Hand grip function in patients with rheumatoid arthritis. Archives of Physical Medicine and Rehabilitation 61: 369–372

Nwuga V C 1975 Grip strength and grip endurance in physical therapy students. Archives of Physical Medicine and Rehabilitation 56: 296–300

Pryce J C 1980 The wrist position between neutral and ulnar deviation that facilitates the maximum power grip strength. Journal of Biomechanics 13: 501–511

Schmidt R T, Toews J V 1970 Grip strength as measured by the Jamar dynamometer. Archives of Physical Medicine and Rehabilitation 51: 321–327

Solgaard S, Kristiansen S, Jensen J S 1984 Evaluation of instruments for measuring grip strength. Acta Orthopaedica Scandinavica 55: 569–572

Spiegel J S, Paulus H E, Ward N B 1987 What are we measuring? An examination of walk time and grip strength. Journal of Rheumatology 14: 80–86

Teraoka T 1979 Studies on the peculiarity of grip strength in relation to body positions and aging. Kobe Journal of Medical Sciences 25: 1–17

Thorngren K G, Werner C O 1979 Normal grip strength. Acta Orthopaedica Scandinavica 50: 255–259