Pinch grip, power grip and wrist twisting strengths of healthy older adults

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U.S.L. Nayak and J.M. Queiroga. Pinch Grip, Power Grip and Wrist Twisting Strengths of Healthy Older Adults. Gerontechnology 2004; 3(2): 77-88. Objectives of this cross-sectional study were to collect data on handgrip and wrist twisting strengths of healthy older adults and to arrive at regression equations that estimate pinch and power grip strengths of community-dwelling older adults in the United Kingdom. ***Methods.*** *The study sample comprised 65 males and 85 females within the age range of 55 to 85 years. A strain-gauge hand-held dynamometer was used to measure various pinch and power grip strengths. A torque meter was used to measure wrist twisting strength.* ***Results.*** *The correlation between pinch grip and power grip strengths was high (r>0.65) resulting in a linear regression equation. A multiple regression equation was developed, with power grip strength as the dependent variable and age, hand area, and mid arm circumference as predictor variables.* ***Conclusion.*** *Knowing a relationship between pinch grip and power grip strengths, and an equation to calculate the power grip strength, designers of food packaging can estimate pinch strengths of healthy older individuals living in the community. A torque value of 1.3 Newton-metre, as calculated in this paper, can be recommended as a removal torque for opening child-resistant bottle tops.*

Keywords: grip strength, wrist torque, older adults

Knowledge of hand function capabilities of older adults is useful to hand therapists, designers of hand prostheses, and designers of food and medication packaging. Muscular strength decreases with age[1,2] and a reduction in hand strength can affect the capacity to carry out activities of daily living (ADLs), thus influencing the quality of life. In addition to the natural ageing processes, various diseases compound problems in carrying out the ADLs. For example, rheumatic diseases may cause the hand to become deformed, making gripping difficult. Rantanen et al.[3] conducted a 25-year prospective study involving healthy males aged between 45 to 68 years and observed that reduction in handgrip strength, during the study period, correlated significantly to functional limitations and disability. Giampaoli et al.[4] followed 140 males aged between 71 and 91 years for four years and observed that the incidence of disability increased with decreasing grip strength. Disability was defined as needing help in performing various ADLs[5] and instrumental ADLs[6].

Pinch grip and power grip strengths have been used as indices of strength in hand therapy assessments[7,8]. Closing a hand with the thumb in opposition to all other fingers together generates a power grip. A key grip is produced by pressing the thumb pulp against the lateral aspect of the proximal interphalangeal joint of an index finger. By pressing the thumb pulp against the pulps of index (Pinch II), middle (Pinch III), ring (Pinch IV) and little fingers (Pinch V), other hand pinch grips can be generated.

Arthritis is the leading cause of disability and arthritic pain may make it harder to exert finger pressure. A reduced wrist rotation due to arthritis may increase the difficulty in generating twist and turning hand movements necessary to open child-resistant closures, jars and other food packaging that use 'peel-back' or 'tear-away' designs. The United Kingdom (UK) Department of Trade and Industry reports[9,10] clearly identified the need to produce data on pinch grip and wrist twisting strength reductions in older adults. A strong association between hand function and disability[3,4] suggested that in order to identify those older adults at risk of developing disability at a later stage in life, we needed accurate measurements of handgrip strength to establish normal ranges; since it had been highlighted by the various studies[11-14] that measurements can be influenced by grip position, procedures adopted and observer variations. It would be prohibitively expensive to measure grip strength of each and every older individual in the community. Consequently we needed a screening method to identify those people who showed a greater than normal decline in handgrip strength. Once identified, these individuals could then be contacted for an accurate measurement of handgrip strength using laboratory-based facilities. The grip strength measurements could then be used to identify those at risk of developing disability at a later stage in life and these people could undergo exercise interventions aimed at improving strength in all muscle groups. The following study was planned to measure accurately handgrip and pinch strengths of healthy older people and to arrive at regression equations to estimate handgrip strength of older adults in the community.

METHODS AND MATERIALS

Subjects

Subjects for this study were selected at random, using the Thousand Elders database that was established by the Centre for Applied Gerontology as a sampling frame[15]. This is a nation-wide panel of volunteer people aged 55 years and above, who belong to various socio-economic backgrounds. Prior to the beginning of the study, subjects were informed about its purpose and methods to measure grip strength. Those who agreed to take part signed a consent form and filled-in a health status questionnaire. The ethical approval for the study was obtained from the South Birmingham (UK) Local Research Ethics Committee.

Subjects presenting with any impairment affecting upper limb function due to osteoarthritis or who had upper limb fractures within the previous two years were not included in the present study. Subjects who had been admitted to a hospital during the previous three months were also excluded. Subjects affected by neuromuscular disorders or with a history of a malignant disease were also not included.

A total of 444 members of the Thousand Elders were approached. Of these, 288 agreed to take part in the study, 55 said no, and 101 did not send any reply back. After examining the brief health status questionnaire that was sent to them, out of the 288 subjects 90 were excluded, as they did not meet required criteria for inclusion in the study. The remaining 198 subjects were interviewed by the second author of this article. After the interview another 48 subjects were excluded since 35 of them presented with some kind of inflammatory disease or musculoskeletal disorder, six had a history of malignant disease in the last five years, one had respiratory failure, and six were above the age of 85 years. Consequently the final study sample included 150 subjects (all Caucasian origin), 65 males and 85 females, in the age range of 55 to 85 years.

Measures

Cognitive functional status

The cognitive functional status of subjects was assessed, using the 'Mini-Mental State' Examination (MMSE) questionnaire which was an established method of screening for cognitive impairment[16].

Nutritional status

The Mini Nutritional Assessment (MNA) questionnaire was used to identify those subjects at risk of malnutrition[17].

Health-related quality of life

Subject's perception of health-related quality of life was assessed, using the EuroQol questionnaire[18]. Information on the number of medications taken per day was also collected. No blood samples were taken from subjects for biochemical analyses.

Anthropometric measurements

The following anthropometric measurements were obtained from subjects. Weight in kilograms (kg) was measured, without shoes and in light clothing, to the nearest 0.5 kg, using an electronic weighing scale (Hanson Electronic Limited, UK). Height of subjects, without shoes, was measured in meters (m) to the nearest 0.5 centimetre (cm), using a stadiometer fixed to the wall. Body mass index (BMI) was calculated using the equation: BMI = weight/(height x height). Hand length in cm was measured for the dominant hand, to the nearest 0.1 cm, from the distal crease of the wrist to the tip of the middle finger using a tape measure. Hand width from the base of the thumb was also measured in cm. The hand area (HA) (cm^2) was calculated by multiplying the hand length with the hand width measurements. Mid arm circumference (MAC) of the dominant arm was measured to the nearest 0.1cm with a measuring tape placed gently but firmly around the arm.

Strength measurements

Power grip, key grip, and pinch grip strengths of the index, middle, ring and little fingers were all measured in Newton (N) using a hand assessment and treatment system (HATS), which used temperature-compensated strain gauges (Figure 1). This instrumentation was designed to give digital readouts and was developed by the Centre for Rehabilitation Robotics of Staffordshire University, UK[19]. The sampling frequency used for data collection was 40Hz. The strength measurement accuracy was within 5% according to the testing procedures set by the UK National Physical Laboratory[19].

To minimise effects of the body position on grip strength measurements, the standard protocol suggested by the American Society of Hand Therapists[20] was used. According to them, a subject should be seated in a straight back chair (without arm rests) with the feet flat on the floor, the shoulder adducted and in neutral rotation and flexion. The elbow should be flexed to 90^0 with the forearm and wrist in neutral position. The power grip strength of the dominant hand was obtained by subjects squeezing the dynamometer handle maximally, by contracting the finger flexor muscles (with the thumb in opposition to four fingers). The dynamometer handle bar was adjusted to obtain comfortable grip for individual subjects. The key grip was obtained by keeping the pinch gauge between the thumb pad and radial side of the middle phalanx of the index finger and by pressing while the remaining fingers in a flexed position. Pinch II strength was measured by pressing firmly the pinch gauge that was positioned between the tip

Figure 1. Hand assessment and treatment system

of the index finger and the thumb. Similarly other pinch strength measurements were obtained. Subjects were asked to build up their maximum strength and to hold it for about five seconds so that the maximum value could be recorded. To avoid fatigue effects, only one measurement for each grip position was obtained with a rest period of one-minute interval between each strength measurement.

Wrist twisting strength or torque (in Newton-metre, Nm) was measured using a commercially available torque gauge (AFG 1000N, Mecmesin Limited, West Sussex, UK). Basically, it was a jar-shaped measuring unit linked to a digital strain indicator. The main body of the unit was 90 mm long with a diameter of 44 mm. At one end of the unit a 50 mm diameter plastic lid was fixed to which a torque was applied. The lid thickness was 10 mm with a slightly rough texture. Subjects, while seated, were instructed to hold the jar-shaped unit with the non-preferred hand (power grip position) and apply the twisting movement on the lid with the preferred hand (spherical grip position). They were instructed to exert their maximum possible torque and to hold it for about five seconds. No verbal encouragement was given during testing and only one measurement was obtained. All strength and torque measuring instruments were calibrated at the beginning of the study. All measurements were taken during the mornings only.

Data analyses
All data were analysed using the statistical package SPSS Version 11.5 (SPSS Inc, Chicago, ILL). Pearson product-moment correlation test gave correlation between power grip and various pinch grip strengths and a linear regression equation was obtained for each correlation, but separately for males and females. Correlation between power grip strength and age, including various anthropometric measurements, was carried out to identify predictor variables for inclusion in a stepwise, multiple regression equation to estimate power grip strength for a population other than the study sample.

RESULTS
The sample
The study sample comprised 65 males (mean age = 73.14, standard deviation (SD) = 6.6) and 85 females (mean age = 70.18, SD = 8.0) in the age range of 55 to 85 years.

Overall health status
No subjects showed any signs of cognitive impairment. The mean MMSE score for males was 28.8 (±1.2) and for females 28.9 (±1.2) (out of 30). All subjects were well nourished, according to their MNA score. They all scored 12 points or more (out of 14) in the screening part of the MNA questionnaire. Therefore no further assessment was needed. All subjects reported to have a good quality of life. When they were asked to characterise their general health state with a number on a scale ranked from 0 to 100 (100 denoting the best possible health state), the mean score for males was 85 (±9.5) and for females 87 (±11).

Past medical history
The past medical history of the subjects was obtained in order to assess their health status. Of these, 47 % were not on any prescribed medication. Antihypertensive drugs were the most common medication taken by a quarter of the sample and the remainders took medication mainly for mild osteoarthritis in the knees, urinary incontinence, and mild asthma. The presence of the drugs taken by the subjects did not have any significant effect on their power grip strength. Independent Student's t-test results between the medication (53%) and non-medication (47%) groups are $t = -0.572$, $df = 148$ and $p = 0.568$. The Chi-squared results (Pearson c^2 =

0.594, df = 1 and p = 0.441) showed no significant differences between males (46%) and females (54%) with respect to medication intake.

Anthropometric and strength measurements

Tables 1 and 2 give mean, standard deviation, and percentile values for anthropometric and strength measurements for males and females. Independent Student's t-tests for the entire male and female groups indicate significant differences for all strength measurements, weight, height, and hand area, except for the body mass index (BMI) (t = -0.31, df = 148, p = 0.758) and mid arm circumference (MAC) (t = 1.25, df = 148, p = 0.213). Figure 2 shows variations in the power grip strength (PGS) for males and females. Figure 3 highlights wrist twisting strength (torque) variations for males and females.

Table 1: Anthropometric and strength measurements of males, n = 65, BMI = Body mass index, HA = Hand area, MAC = Mid arm circumference, PGS = Power grip strength, SD = Standard deviation

Variable	Mean	SD	5th %ile	50th %ile	95th %ile
Age (years)	73.14	6.62	62.30	73.00	82.00
Weight (kg)	79.64	12.37	61.90	77.00	102.61
Height (m)	1.74	0.075	1.62	1.72	1.87
BMI (kg/m²)	26.29	3.26	21.30	26.10	33.07
HA (cm²)	224.73	18.2	193.87	223.10	255.84
MAC (cm)	30.39	2.97	25.38	30.50	35.46
PGS (N)	352.18	83.18	190.80	348.25	492.95
Key grip (N)	94.4	19.66	63.76	98.10	130.96
Pinch II (N)	60.97	16.7	39.24	58.86	96.63
Pinch III (N)	54.26	14.7	34.34	53.95	85.35
Pinch IV (N)	35.77	12.0	19.62	34.33	57.39
Pinch V (N)	23.17	8.6	14.71	24.52	34.34
Torque (Nm)	3.68	0.92	1.94	3.79	5.07

Correlation coefficients

Pearson correlation coefficients between the PGS and age, weight, and anthropometric measurements are given in Table 3. The statistically significant variables were then used in a multiple linear regression analysis to identify predictor variables for estimating the power grip strength (PGS).

Table 2: Anthropometric and strength measurements of females, n = 85, BMI = Body mass index, HA = Hand area, MAC = Mid arm circumference, PGS = Power grip strength, SD = Standard deviation

Variable	Mean	SD	5th %ile	50th %ile	95th %ile
Age (years)	70.18	8.0	58.3	68.0	83.0
Weight (kg)	67.47	10.83	53.3	67.2	92.85
Height (m)	1.59	0.066	1.49	1.59	1.72
BMI (kg/m²)	26.47	3.61	20.45	26.29	33.04
HA (cm²)	175.4	13.3	152.25	176.47	199.1
MAC (cm)	29.74	3.3	25.06	29.1	37.6
PGS (N)	201.16	55.67	127.53	196.2	315.88
Key grip (N)	62.67	13.12	44.15	63.76	88.29
Pinch II (N)	40.39	10.12	24.53	39.24	58.86
Pinch III (N)	37.28	9.34	24.52	34.33	53.95
Pinch IV (N)	24.53	7.86	14.7	24.52	42.67
Pinch V (N)	15.55	5.3	9.8	14.71	24.5
Torque (Nm)	2.37	0.79	1.32	2.20	3.8

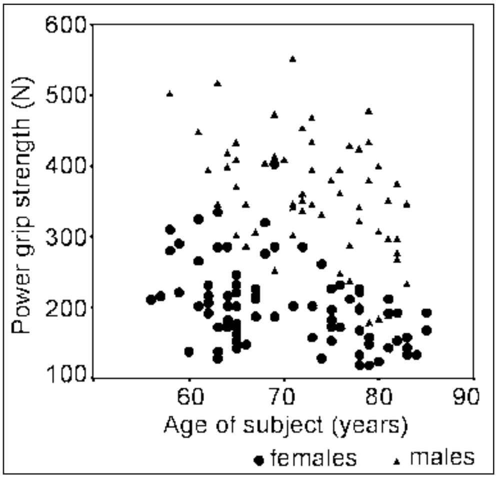

Figure 2: Powergrip strength variation with age

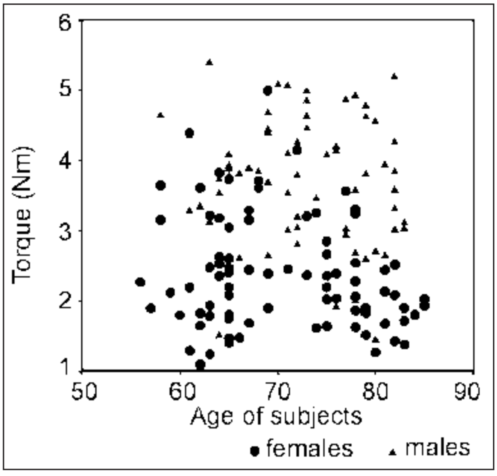

Figure 3: Torque variation with age

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Multiple regression analysis

Table 4 gives regression coefficients from a stepwise, multiple regression analysis for the entire sample. The Table also gives the adjusted R^2 to indicate contribution by individual predictor variables to the final regression model. The regression equation is PGS = 132.457 + 1.782 x HA – 2.957 x age - 85.562 x gender + 3.57 x MAC (eq 1) PGS is power grip strength in Newton; HA is hand area in cm^2 ; the gender value for males = 0 and for females = 1, and MAC is mid arm circumference in cm. The value of $R^2 = 0.685$ and the adjusted $R^2 = 0.676$.

The analysis of variance results for the model were $F_{4,145} = 78.88$ and $p = 0.000$. The data were further analysed to determine relationships between the PGS and key grip and various pinch grips. The regression equations were obtained with the PGS as a predictor variable and other grip strengths as dependent variables (Table 5). For males the regression equation to estimate the key grip strength is given by Key grip strength = 38.62 + 0.16 x (PGS). (eq 2)
The Pearson correlation coefficient between the key grip strength and the power grip strength is given by $r = 0.67$ ($p = 0.000$). For females the regression equation is Key grip strength = 31.48 + 0.16 x (PGS). (eq 3)
The Pearson correlation between the two grips is $r = 0.658$ ($p = 0.000$).
In a similar manner we can estimate other pinch grips, using the PGS as a predictor variable and the appropriate regression coefficients given in Table 5.

Wrist twisting strength

The mean torque value for all males, for a lid diameter of 50mm, is 3.68 (±0.92) Nm (Table 1) and for all females 2.37 (±0.79) Nm (Table 2). The t-test results showed that males had significantly higher torque strength than females ($t = 9.388$, $df = 148$, $p<0.001$).
For males, the 5th percentile value for torque is 1.94 Nm, 50th percentile value is 3.79 Nm and the 95th percentile value is 5.07 Nm. The corresponding torque values for female subjects are 1.32 Nm, 2.2 Nm and 3.8 Nm.

Table 3: Pearson correlation between PGS and potential predictor variables. BMI = Body mass index, HA = Hand area, MAC = Mid arm circumference, PGS = Power grip strength, n = number of subjects

Variables	Males (n = 65)		Females (n = 85)	
	r	p	r	p
Age	-0.39	0.001	-0.408	0.000
Weight	0.348	0.005	0.353	0.001
Height	0.372	0.002	0.457	0.000
BMI	0.182	0.147	0.118	0.282
HA	0.371	0.002	0.491	0.000
MAC	0.428	0.000	0.188	0.084

Table 4: Stepwise Regression model to predict Power grip strength. Dependent variable: Power grip strength. HA = Hand area (cm2), Age in years, Gender coded male = 0 and female = 1, MAC = Mid arm circumference (cm)

Variable	Coefficient b	Standard error se(b)	Adjusted R square	t	p
Constant	132.457	94.65		1.4	0.164
HA	1.782	0.39	0.596	4.56	0.000
Age	-2.957	0.648	0.629	-4.56	0.000
Gender	-85.562	18.47	0.667	-4.63	0.000
MAC	3.57	1.58	0.676	2.26	0.025

Table 5: Pinch grip strengths regression coefficients. PGS = Power grip strength

Dependent variable	Predictor variables		Coefficient b	Standard error se(b)	t	p
Key grip	Constant	males	38.62	8.0	4.83	0.000
		females	31.48	4.1	7.75	0.000
	PGS	males	0.16	0.02	7.17	0.000
		females	0.16	0.02	7.96	0.000
Pinch II	Constant	males	21.93	7.69	2.85	0.006
		females	23.14	3.67	6.31	0.000
	PGS	males	0.11	0.02	5.22	0.000
		females	0.09	0.02	4.88	0.000
Pinch III	Constant	males	19.11	6.66	2.87	0.006
		females	17.1	3.1	5.55	0.000
	PGS	males	0.10	0.02	5.42	0.000
		females	0.10	0.02	6.8	0.000
Pinch IV	Constant	males	7.26	5.45	1.33	0.187
		females	7.68	2.61	2.95	0.004
	PGS	males	0.08	0.02	5.38	0.000
		females	0.08	0.01	6.7	0.000
Pinch V	Constant	males	8.83	4.36	2.02	0.047
		females	7.24	1.98	3.67	0.000
	PGS	males	0.04	0.01	3.38	0.001
		females	0.04	0.01	4.36	0.000

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DISCUSSION

This cross-sectional study was designed to obtain accurate measurement of variations in power, key- and other pinch grips of independent, community-dwelling older adults within the age range of 55 to 85 years. A new hand function assessment system incorporating strain gauge technology has been used. The advantage of the present system over Jamar™[20] and other systems is that the present system uses an automatic data acquisition hardware and software protocol to give digital data for computer storage and readouts. This should eliminate any observer errors that can occur in reading a dial. The present electronic system does not suffer from calibration drift problems, as experienced by some hydraulic instruments[19].

Grip strength comparison

The stringent inclusion criteria adopted have resulted in having a study sample comprising 150 healthy individuals from a sampling frame of 444 older adults. The present study was compared with that published on the UK population. The study published by Bassey and Harris[21] used a strain gauge dynamometer to measure the power grip strength of 920 older adults aged 65 years and over. The mean value for the PGS for males was 332 N (±91), whereas the present study gives a value of 345 N (±79) for males aged 65 - 85 years. For females it was 191 N (±62) and the present study gives 192 N (±52). A close agreement can be seen between the two studies. No pinch grip data were reported by the authors[21].

The present data were also compared with those published by Gilbertson and Barber-Lomax[22]. The results are presented in Table 6. A small disagreement seen could well be due to different type of instrumentation used in the measurements. They[22] used Jamar™ hydraulic dynamometer to measure power grip strength and a hydraulic pinch gauge (B+L Engineering, Sante Fe Springs, California) to measure key grip. They used three trials for each measurement, whereas in the present study only one trial was used. The number of trials necessary to obtain maximum grip strength has varied among different studies. Some have used one trial[23,24], others two or three trials[3,4,25] for grip strength measurements. Crosby et al.[26] included two trials in their study and found that the repeat testing was unnecessary. Since there were a lot of pinch grip measurements in the present study, it was decided to use one trial to avoid any fatigue effects.

Table 6: Comparison between the present grip strength results and the published results[22]. PGS = Power grip strength. Mean and standard deviations (in parentheses) are given

	Males		Females	
Variable	Present	Published	Present	Published
Sample size	65	50	85	50
PGS (N)	352.18 (83.2)	386.11 (53.7)	201.16 (55.7)	244.4 (48.1)
Key grip (N)	94.4 (19.7)	95.2 (14.9)	62.7 (13.1)	66.6 (16.6)
Pinch II (N)	61.0 (16.8)	64.0 (14.1)	40.4 (10.1)	43.9 (11.9)

The results from the present study indicated that males were heavier ($t = 6.413$, $df = 148$, $p = 0.000$) and were taller ($t = 12.318$, $df = 148$, $p = 0.000$) than females. However, the body mass index was not found to be significantly different. ($t = -0.308$, $df = 148$, $p = 0.758$). These results are similar to those published by Skelton et al.[27].

Various factors contribute to declines in hand power grip strength in older adults[25,28,29]. Some of these are body weight, skeletal size, physical activity level, chronic diseases, depressed mood, and loss of muscle mass. The inclusion criteria used in the selection of the subjects for this study have eliminated older adults with chronic diseases and people who suffered from depression. The antihypertensive medication taken by the subjects has not contributed significantly to the power grip strength. The recent work of Syddall et al.[30] in identifying grip strength as a single marker of frailty, suggested the existence of correlation between grip strength and ageing markers which included haemoglobin and alkaline phosphatase. Since no blood samples were taken during the present study, it was not possible to include these ageing markers into the regression model.

The regression model may be improved further by the addition of a hand activity score (HAS). A questionnaire is needed to quantify the customary activities that involve predominantly hand function. These activities could be, for example, 'playing piano', 'ironing', 'gardening', 'bowling' and so on. The score would be similar to an effort score as discussed by Bassey[28] and can be incorporated as a predictor variable in the estimation of the PGS, since these hand activities are thought to improve the forearm muscle mass and finger joint movements.

It is postulated that in a new regression model with age, HA, MAC and HAS as predictor variables can be used to estimate the PGS of independent, community-dwelling older adults. The predictor variable values can be obtained by means of a postal survey among older adults or collected by hospital/social services department domiciliary staff during their routine home visits. The value of HA can be obtained by measuring a hand-print of the dominant hand of a person. From the PGS calculations one can identify those older adults at risk of developing disability in later life (PGS below the normal value). These people can then be contacted to obtain accurate measurements of their PGS using laboratory equipment. A suitable muscle exercise programme can then be devised to improve their handgrip strength that is believed to delay the onset of disability[31-33].

The Pearson correlation coefficient between the key grip strength and the PGS is 0.67 ($p = 0.000$) for males and 0.66 ($p = 0.000$) for females. The linear regression equations (equations 2 and 3) can be used to estimate the key grip strength once we know the PGS. A similar analysis can be carried out to determine other pinch strengths for males and females.

Wrist twisting strength comparison

Since females are weaker in muscular strength than males, designers of packaging should use torque data for females, in particular the 5th percentile value. In this way a vast majority of older adults (males and females) can open vacuum-sealed jars used for food and child-resistant bottle closures for medication. The 5th percentile torque value for females given by our study is 1.32 Nm, whereas, a torque value of 2.0 Nm has been quoted in the literature by Voorbij and Steenbekkers[34] for Dutch older adults. This value is rather too high, since from Figure 3 it can be seen that about 22% of our study sample had the wrist twisting torque below this value.

The wrist twisting data from the present study were also compared with that published by Peebles and Norris[35]. From their data, mean opening torque, needed to separate a lid of 45mm diameter from an aluminium jar, was calculated for males and females in the age range of 51 to 80 years. The mean torque value for males (sample = 17) is 3.78 Nm (SD = 1.03) and for females (sample = 26) the mean torque is 2.43 Nm (SD = 0.74). In the present study, the mean torque value for males (sample = 65, lid dia. = 50mm) is 3.68 Nm (SD = 0.92) and for females (sample = 85) it is 2.37 Nm (SD = 0.79). A close comparison can be seen for the torque values from the two studies.

It is interesting to see from Peebles and Norris[35] that a mean value for opening torque exerted by male children under the age of 5 years (sample = 7) on a 45mm diameter lid is 0.81 (SD = 0.48), whereas Rohles et al.[36] give a value of 0.8 Nm for the torque exerted by 4-year old children on a 35mm diameter screw top which is used on child-resistant bottles[37]. The 5th percentile female value for the torque as given by the present study is 1.32 Nm, which is greater than that can be generated by male children under the age of 5 years. Consequently it can be recommended that designers should consider the value of 1.3 Nm as a removal torque on medication containers to render them child-resistant[38,39].

CONCLUSIONS

The present study has demonstrated that knowing age and hand measurements, one can estimate the power grip strengths of older adults living in the community. The main points of the study are

(i) Power grip strength of healthy older adults living in a community can be estimated using a multiple regression equation with age and hand measurements as predictor variables.

(ii) Key grip and pinch grip strength can be estimated using a linear equation with power grip strength as a predictor variable.

(iii) A removal torque of 1.3 Nm can be used as a guide for the design of screw tops for child-resistant bottles.

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