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Age- and gender-specific normative data of grip and pinch strength in a healthy adult swiss population

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Abstract

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*** Submission Letter**

16-Apr-2008

Age and gender specific normative data of grip and pinch strength in a healthy adult Swiss population.

Dear Ladies and Gentlemen,

With this letter I would like to ask you to accept the attached full text article for review.

Yours sincerely,

Stephan Werle
Corresponding Author

AGE AND GENDER SPECIFIC NORMATIVE DATA OF GRIP AND PINCH STRENGTH IN A HEALTHY ADULT SWISS POPULATION

Approval for this study was obtained from the:

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SUMMARY

Assessment of hand strength is used in a wide range of clinical settings especially during treatment of diseases affecting the function of the hand. This investigation aimed to determine age- and gender-specific reference values for grip and pinch strength in a normal Swiss population with special regard to old and very old subjects as well as to different levels of occupational demand. Hand strength data were collected using a Jamar dynamometer and a pinch gauge with standard testing position, protocol and instructions.

Analysis of the data from 1023 tested subjects between 18 and 96 years revealed a curvilinear relationship of grip and pinch strength to age, a correlation to height, weight and significant differences between occupational groups. Hand strength values differed significantly from those of other populations, confirming the thesis that applying normative data internationally is questionable. Age and gender specific reference values for grip and pinch strength are presented.

Keywords: hand strength, grip strength, pinch, hand dominance, dynamometer, normative data

INTRODUCTION

Assessment of hand strength has proved to be reliable and valid (Hamilton et al., 1994; Mathiowetz et al., 1985) as an objective parameter to evaluate the functional integrity of the hand as part of the musculoskeletal system (Jones, 1989). Hand strength measurement is clinically used to determine the effectiveness of different treatment strategies in traumatic hand diseases as well as in diseases affecting hand function because of their systemic or local degenerative character. Particularly in rheumatoid arthritis grip strength is an indicator for the disease activity related joint destruction (Rhind et al., 1980). Assessing the outcome after treatment and estimating the manual work ability is not possible without having an objective index. In most cases baseline grip strength as a pre-injury or pre-illness muscle strength is not known. Referencing the opposite hand for comparison considers both hands to have similar pre-illness grip strength, which might be misleading (Desrosiers et al., 1995; Harth and Vetter 1994; Massy-Westropp et al., 2004; Mathiowetz et al., 1985; Petersen et al., 1989), possibly underestimates changing of contralateral strength during the illness period and is not useful for bilateral involvement.

For this reason, established normative data are used clinically to compare the patients to healthy population to decide about the return to pre-injury or pre-illness hand strength. Samples for normative studies must be large, random, and representative for the population’s heterogeneity to be statistically valid (Portney and Watkins 1993). In the existing large-scale investigations for normative data reliability is affected by the lack of an acceptable sample size (Crosby et al., 1994; Fraser and Benten 1983; Gilbertson and Barber-Lomax 1994; Harkonen et al., 1993), the small number of very old subjects (Ewald and Kohler 1991; Hanten et al., 1999; Massy-Westropp et al., 2004; Mathiowetz et al., 1985; Thorngren and Werner 1979), the focus on a special part of the population (Desrosiers et al., 1995; Harth and Vetter 1994; Schmidt and Toews 1970) or the deviation from standard protocol or type of dynamometer (Fraser and Benten 1983; Hanten et al., 1999; Schmidt and Toews 1970; Thorngren and Werner 1979). In addition, comparing the data of different populations indicates that there is a considerable variation and questions the reliability of applying norms internationally (Fraser and Benten 1983; Gilbertson and Barber-Lomax 1994).

To date, the clinically normative data published by Mathiowetz et al. (1985) was used. However, preliminary data from 150 volunteers revealed remarkable differences to these reference values. The main purpose of this study is to determine age- and gender-specific reference values for the Jamar dynamometer, introduced by Bechtol in 1954, and the pinch gauge, in a normal Swiss population and as a second purpose to compare them with normative data from other populations. In consideration of demographic development, special attention was paid to old and very old subjects as well as to different levels of demand on the hand.

METHODS

Sample characteristics

Approval for this study was obtained from the local Ethics Committee. The population was divided into 15 age groups per gender of five-year intervals except for the 18-19 and the 85+ age group. Recording of data was performed where the tester had access to large numbers of subjects in a supposedly broad socioeconomic and occupational range: shopping centres and malls, secondary schools, senior sports groups, and senior residences to realise a random approach.

An explanation about the purpose of the study was followed by a short interview to decide on inclusion: age, voluntary participation, country of residence (German speaking Switzerland) and exclusion (recent injury or prevalent disease involving the upper extremity distal to the shoulder, acute pain of the extremity distal to the shoulder, less than 6 month post-hospitalisation because of relevant surgery). As elbow function and position has proved to influence grip strength (Desrosiers et al., 1995), subjects with dysfunction of the elbow joint were also excluded.

The interview was restricted to asking for the date of birth, gender, height, weight, occupation, country of residence, nationality and handedness so as not to extend testing time and encourage voluntary participation.

Occupational demands on subjects was classified in five categories based on the Dictionary of Occupational Titles (Dictionary of Occupational Titles 1991): sedentary, light, medium, heavy, very heavy (Table 1). The following modification was made: medium for housewives; sedentary for students, apprentices, unemployed, invalids and pensioners not depending on daily help. Pensioners depending on daily help were classified as beyond sedentary (<S).

For subjects who were not sure which hand was dominant handedness was estimated by asking a series of questions from the Edinburgh Handedness Inventory (Oldfields 1971) and classified in the categories right-handed, left-handed, and ambidextrous.

Measurement procedure

Grip strength data were collected by one tester using a Jamar dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, U.S.A.) and pinch strength using a pinch gauge (Baseline, Fabrication

Enterprises INC, Irvingston, NY10533, U.S.A.), both purchased new prior to the study commencing and calibrated by the manufacturer. Standard grip strength testing position as, recommended by the American Society of Hand Therapists (ASHT) (Fess and Moran 1981), was used with subjects seated upright against the back of a chair (without armrests) with feet flat on the floor (Balogun et al., 1991; Teraoka 1979), shoulder adducted and neutrally rotated, elbow flexed 90 degrees (Balogun et al., 1991; Desrosiers et al., 1995; Ferraz et al., 1992; Fess and Moran 1981), forearm in neutral position (Richards and Palmiter-Thomas 1996), wrist slightly extended (0 to 15), between 0 and 15 degrees ulnar deviation (Hazelton et al., 1975; Pryce 1980). Measuring pinch strength, following grip strength testing, the same arm and upper extremity posture was used, suggested by the ASHT (Mathiowetz et al., 1984).

Precision grip testing was restricted to pinch strength being its most common parameter so as not to extend testing time. For measuring pinch strength the gauge was placed between the thumb pad and the radial side of the middle phalanx of the index finger, while the thumb's IP-joint position was self selected. Any deviation from standard testing position, lead to an interruption followed by a repetition after a short rest. The hand to be tested first was chosen by the subject. The Jamar dynamometers 2nd (smallest) handle position was exclusively used for grip strength testing as recommended by the ASHT.

Sincerity of effort, measuring hand strength, being a relevant problem in clinical practice (Gülke et al., 2007), we consider not to influence the evaluation of normative data due to the voluntary participation.

Standard instructions were spoken at a constant volume, since verbal instructions (Davis 1974) and the volume of a verbal command (Johansson et al., 1983) can influence performance on evaluation tests. The current study uses the mean of three trials for analysis to allow comparison with normative data from previous large-scale investigations. A pretrial was not needed since there is apparently no learning effect when three consecutive trials are taken (Mathiowetz 1990). In the current study a rest of about 15s, needed to alternate hands and to record the previous score, was provided according to previous research (Hanten et al., 1999; Harth and Vetter 1994; Mathiowetz 1990). The duration of isometric contraction was not timed, but the tester made sure that the maximum force was reached rather by a moderate increase than by a sudden one.

Statistics

Raw data was automatically entered into the data files using the Remark Office OMR (Gravic Inc. Philadelphia U.S.) followed by statistical analysis with the Statistical Package for the Social Sciences 11.0 (SPSS Inc. Chicago U.S.) computer software.
Results were reported as means +/- standard deviation (SD) and standard error of mean (SEM) for men and women for each age group on dominant and non-dominant hands. T-test for paired samples was used to define the stronger hand in both right and left-handed subjects. An ANOVA-Test was used to detect differences between age groups and right and left hands.

RESULTS

Sample characteristics

From October 2006 to April 2007, 1023 subjects (516 men and 507 women), from a German speaking population and 11 different cantons of Switzerland, including urban, suburban and rural areas, participated. Age ranged between 18 and 96 years. When stratified for age and gender subgroups, a minimum of 29 subjects (mean 34.1 ranging from 29 to 48) were tested for each subgroup, which was considered to be an adequate sample size. The study group represents a wide occupational and socioeconomic background with 13% foreigners from 27 foreign nationalities. Occupational demand was distributed as shown in Table 1. There were no subjects in the very heavy work group.

Main findings

Grip and pinch strength data, presented in Tables 2 and 3, follow a curvilinear relationship to age with grip strength increasing with age, peaking between 35-39 years in men and 40-44 in women and declining thereafter (Fig. 1). Average pinch strength peaked between 35 and 44 years in men and 55-59 years in women. There was a high correlation for grip (0.961, p=0.001) and pinch (0.941, p=0.001) strength between right and left hands. The standard deviations ranged from 13% (in the 18 to 19 age group) to 30% (in the 80 to 84 age group) and from 12% (in the 65 to 69 age group) to 29% (in the 85+ age group) for male and female grip strength respectively. Standard deviations of male pinch strength ranged from 14% (in the 35 to 39 age group) to 34% (in the 80 to 84 age group) and of female pinch strength from 13% (in the 25 to 29 age group) to 40% (in the 85+ age group).

A subanalysis of the subjects aged 18 to 69 revealed smaller variations:

The standard deviations of these subgroups ranged from 13% to 18% (mean 15%) and from 12% to 19% (mean 16%) for male and female grip strength respectively. The same effect for pinch strength was found with standard deviations of male pinch strength ranging from 14% to 19% (mean 16%) and of female pinch strength from 13% to 21% (mean 18%).

Repeated testing of grip strength showed a fatigue effect with a mean difference of 1.3 kg for the right and 1.53 kg for the left hand between the first and third grip strength trial. There was a trend towards a smaller difference in pinch strength (0.07kg, p=0.06) for the right but no difference for the left hand between first and third trial.

Stratified findings

The results of grip and pinch strength were stratified for hand dominance in the following way. A remarkable percentage of 4.4% (men 3.9% and women 4.9%) of the whole study group claimed to be ambidextrous. Most of these people reported to had been left-handed children, forced to switch to right-handedness in the context of former educational demands.

These 4.4% were excluded from analysing hand dominance related grip strength.

The 75 (7.3%) left-handed subjects had 11% higher mean dominant grip and 7.5% greater mean dominant pinch strength values than the right-handed subjects (100%) and reached a 5.4% greater grip strength with their dominant hand compared to the non-dominant side (100%), which was significant (p=0.01). Right-handers showed the same relationship with significant (p=0.01) greater dominant grip and pinch strength (2.8% and 5% respectively) compared to their non-dominant hands (100%). Due to the fact that both, right and left-handed individuals had higher grip and higher or equal pinch strength in their dominant hands, further analysis and listing of the normative data (Table 2, 3) was done comparing dominant and non-dominant hands regardless of handedness.

Dominant and non-dominant grip as well as pinch strength correlated significantly (0.964 and 0.942 respectively, p=0.001).

Difference between dominant and non-dominant grip strength was significant (mean difference 1.15 kg, 95% CI, ranging from 0.93 kg to 1.36 kg). The same relation was found for pinch strength (mean 0.34 kg, 95% CI, from 0.29 kg to 0.39 kg). Of the whole study group

35% achieved higher grip scores with their non- dominant hand of grip and 28% of pinch strength.

In people aged 75 and older measurements led to the following results: These age and gender subgroups consisted of at least 29 subjects each (mean 31, ranging from 29 to 35). Pinch strength as well as grip strength showed a gradual decline with advancing age in both, male and female people. Comparison of the subgroup specific standard deviations shows a sudden increase in people aged 70 and older for both men and women. Women reached lower mean values as men with 64% of the mean male grip strength and 68% of the mean male pinch strength irrespective of side and hand dominance.

Both, height ranging from 140 to 198 cm (mean 169 cm), and weight ranging from 40 to 125 kg (mean 71.1 kg) was found to correlate with both grip and pinch strength ($p=0.001$). Subject BMI ranged from 16.4 to 49.8 kg/m2 (mean 24.7).

Measured differences for grip and pinch strength between all five occupational groups were significant ($p=0.001$) with grip and pinch strength increasing with level of occupational demand (Fig. 2).

DISCUSSION

Measured hand strength in our population differed significantly from those of the referenced study by Mathiowetz et al. (1985) confirming the data of our preliminary measurements and the current literature. We measured significantly higher grip values in each age group (mean difference 4.7 kg, 95% CI: 3.6 to 5.9 kg) and significantly lower pinch strength values (mean difference 1.1 kg, 95% CI: 0.9 to 1.3 kg), although values correlated well.

In this context, statistical analysis of the data shows a high accordance to data of previous hand strength evaluations referring to the curvilinear relationship to age with a characteristic peak of grip and pinch strength (Fig. 1) (Desrosiers et al., 1995; Gilbertson and Barber-Lomax 1994; Hanten et al., 1999; Harth and Vetter 1994; Massy-Westropp et al., 2004; Mathiowetz et al., 1985), the percentage of left-handed participants (Desrosiers et al., 1995; Ewald and Kohler 1991; Hanten et al., 1999; Harth and Vetter 1994; Massy-Westropp et al., 2004; Mathiowetz et al., 1985), and the influence of gender, height and weight on grip and pinch strength (Crosby et al., 1994; Desrosiers et al., 1995; Gilbertson and Barber-Lomax 1994; Hanten et al., 1999; Harth and Vetter 1994; Mathiowetz et al., 1985). It becomes apparent that these characteristics do not vary between different populations, suggesting a cultural independent age and gender related distribution of hand strength.

A lot of parameters such as age, gender, height and weight, occupation and leisure activities (Crosby et al., 1994; Harth and Vetter 1994), temperature (Wiles and Edwards 1982), warm-up (Marion and Niebuhr 1992) and time of day (Bechtol 1954; Ferraz et al., 1992) are considered to potentially influence hand strength. Crosby et al. (1994), analysing the influence of the level of the Jamar dynamometer, found an important part of the participants (39%) reached maximum grip force on a level other than level 2, which possibly leads to higher standard deviations while only testing on level 2. However, repeated testing on more than one level in clinical practice would considerably extend testing time. Additional measuring of height, weight or even hand width of a tested person could help to estimate the amount and direction of the deviation of the normative mean, as these parameters have proved to correlate positively with hand strength ($r=0.7335$) (Everett and Sills 1952). Furthermore, significant differences for grip and pinch strength between all five occupational groups were found in the data.

The actual number of observations in our investigation would be too small to define reference data adjusted for weight/height (BMI) and specific occupational demand although a more precise prediction of grip strength would be possible with further separation for these parameters. A study design, focused on a sufficient age-gender sample size for each occupational demand subgroup, would be necessary, which was not the purpose of this study. However, taking the influence of occupational demand level on hand strength into account can help to estimate amount and direction of deviation from the normative value. As in clinical practice, time-consuming classification of patient occupation is uncommon.

Focusing on hand dominance in current large scale investigations, the difference between the strength scores of right and left-dominant people varies from -2.8% to 18% and -6.5% to 4.4% for grip and pinch strength respectively (Crosby et al., 1994; Ewald and Kohler 1991; Hanten et al., 1999; Harth and Vetter 1994; Mathiowetz et al., 1985). The reason for these different findings was possibly the small part of left-handers in all of the current large-scale studies with a mean of 50 left-handed, ranging from 22 to 120 (Crosby et al., 1994; Desrosiers et al., 1995; Ewald and Kohler 1991; Hanten et al., 1999; Harth and Vetter 1994; Massy-Westropp et al., 2004; Mathiowetz et al., 1985). Such sample sizes are probably not large enough to sufficiently discuss influenced hand strength in this special part of the population multifactorially and the percentage of 7.3% left-handed in our study group is too small to establish reference values for left-dominant people.

A special problem is the definition of handedness. An important part of our participants had difficulties deciding on handedness. Especially the differentiation between left and equal handedness was not clear. The use of defined criteria as recommended by Oldfields (1971) is essential to decide on hand dominance. Concerning the relationship between dominant and non-dominant hands, previous research found different relationships for right and left-handed people. Left-dominant participants had lower grip strength in the dominant hand (Harth and Vetter 1994; Mathiowetz et al., 1985) or no significant difference at all (Crosby et al., 1994; Hanten et al., 1999), while right-handers had both, higher grip and pinch strength in their dominant side compared to their non-dominant side (Crosby et al., 1994; Hanten et al., 1999; Harth and Vetter 1994; Massy-Westropp et al., 2004; Mathiowetz et al., 1985). The fact that right-handers as well as left-handers in our study group had higher strength values on their dominant side, allows for the inclusion of the left dominant participants and to present reference values separated in dominant and non-dominant hands regardless of handedness.

Statistical accuracy as well as low range of the values within each age and gender subgroup, all were essential preconditions to offer hand strength values as normative data. Low standard errors of means (SEM) support the high accuracy of our values. In contrast, the high maximum of standard deviations (29.6% for grip and 40.1% for pinch strength for the whole study group) questions the use as normative data. Exclusion of the people/subjects aged 70 years and older leads to a remarkable decrease of these variations in the age groups below with maximum values of 19% and 21% (grip and pinch strength respectively).

One possible reason for accuracy limitations of values in the elderly population might be prevalent diseases or conditions affecting hand strength with a supposedly increasing prevalence with age, which were not detected by the preceding interview or which were unknown to the participants themselves. Especially in elderly subjects, large differences of activity levels result in a wide range of strength values leading to higher standard deviations. We found a 59% in higher mean grip strength (mean grip strength of dominant hand in pensioners not depending on daily help 33.8 kg vs. 21.3 kg in pensioners depending on daily help) and a 54 % higher mean pinch strength (mean grip strength of dominant hand in pensioners not depending on daily help 7.1kg vs. 4.62kg in pensioners depending on daily help) in the sedentary subgroup

This study suggests that high standard deviation values in elderly participants are at least partially influenced by the characteristics of the dynamometers. As strength values decrease with age, differences between the elderly individuals, expressed as standard deviations in percent, increased due to the limited precision of strength reading on a 2kg and 0.5kg step scale (Jamar dynamometer and pinch gauge respectively). These characteristics of hand strength in the elderly, with an ongoing decline of the mean and especially higher standard deviations, underlines the necessity of further separating the population aged 75 and older to provide normative data, one of the purposes of this study.
The standard deviations of the population aged 18 to 69 were considered low enough not to make their use as reference data in clinical practice questionable. However, using the data of the elderly/older age group/ people, a wider range of the values, increasing with advancing age even within these groups, was taken into account.
An essential requirement of instruments measuring grip strength is reliability of measuring consistently and predictably (Fess 1986). Evaluation of isometric grip and pinch strength reveals high inter-rater and test-retest reliability on healthy and disabled subjects (Hamilton et al., 1994) under the precondition of frequent calibration (Harkonen et al., 1993). Those findings demonstrate the validity of the method and are considerable prerequisites for the comparability of normative data between populations. As grip and pinch strength measurement, using standard testing instruments and protocol, proved to be reliable and valid. The different findings compared to

previous research were not considered to be a result of a methodical error but really existing differences. Under those preconditions, these results confirm significant differences between populations. However, as the purpose of this study was not to investigate the influence of cultural and socio-economic characteristics on hand strength, the discussion of these influences would be speculative.

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TABLES AND FIGURES

Table 1

Variables	Women (n=507)	Men (n=516)	Total (n=1023)
Continuous			
Weight in kg	64.1 (±12.3)[a]	78 (±11.8)	71.1 (±13.9)
	40-120	48-125	40-145
Height in cm	163.7 (±6.7)	175.1 (±7.1)	169.4 (±8.9)
	140-188	155-198	140-198
BMI in kg/m^2	24 (±4.6)	25.4 (±3.6)	24.7 (±4.2)
	16.4-49.8	17.4-41.6	16.4-49.8
Categorical			
Dominance			
Right	450 (88.8%)[b]	453 (87.8%)	903 (88.3%)
Left	32 (6.3%)	43 (8.3%)	75 (7.3%)
Ambidextrous	25 (4.9%)	20 (3.9%)	45 (4.4%)
Level of current occupation*			
<S (beyond sedentary work)	51 (10.1%)[c]	56 (10.9%)	107 (10.5%)
S (sedentary work)	210 (41.4%)	248 (48.1%)	458 (44.8%)
L (light work)	110 (21.7%)	81 (15.7%)	191 (18.7%)
M (medium work)	133 (26.2%)	105 (20.3%)	238 (23.3%)
H (heavy work)	3 (0.6%)	26 (5%)	29 (2.8%)
VH (very heavy work)	0 (0%)	0 (0%)	0 (0%)

[a] M (SD) Range
[b] n
* Frequencies of occupational demand. Modified after the Dictionary of Occupational Demand (Dictionary of Occupational Titles 1991), explanation in the text.
[c] n

TABLE 2

	Men (n=496)							Women (n=482)						
Age[a]	n	Hand[b]	Mean	SD[c]	SEM	Min	Max	n	Hand	Mean	SD	SEM	Min	Max
18-19	33	D	51.2	6.6 (12.9)	1.15	33.7	64.0	31	D	32.0	4.8 (15.1)	0.87	22.7	42.7
		ND	48.3	7.7 (15.8)	1.33	28.7	63.3		ND	30.7	4.1 (13.3)	0.73	24.0	38.0
20-24	29	D	53.9	8.7 (16.2)	1.62	40.7	79.0	31	D	33.4	5.4 (16.2)	0.97	23.7	42.3
		ND	51.2	8.5 (16.6)	1.58	34.3	72.7		ND	31.5	4.8 (15.3)	0.87	19.0	38.3
25-29	30	D	53.0	7.5 (14.1)	1.36	40.7	74.3	30	D	34.3	5.7 (16.5)	1.04	22.0	45.0
		ND	50.4	7.5 (14.9)	1.37	40.0	73.3		ND	33.6	6.1 (18.1)	1.1	23.3	45.7
30-34	28	D	55.0	7.1 (12.9)	1.33	42.0	68.0	30	D	33.8	5.9 (17.3)	1.07	20.3	45.7
		ND	52.5	7.3 (13.9)	1.38	40.0	68.3		ND	32.6	4.6 (14.2)	0.85	22.3	40.0
35-39	41	D	55.9	7.9 (14.1)	1.23	36.0	73.0	42	D	35.8	6.7 (18.7)	1.03	18.7	50.0
		ND	53.6	8.7 (16.2)	1.36	37.3	73.3		ND	34.6	5.9 (17.0)	0.91	18.7	49.7
40-44	37	D	54.2	8.1 (15.0)	1.33	40.0	78.0	39	D	34.0	6.0 (16.7)	0.96	24.3	51.3
		ND	53.4	8.5 (15.9)	1.39	36.7	83.7		ND	34.7	5.3 (15.4)	0.85	25.3	45.7
45-49	31	D	51.8	8.3 (16.0)	1.49	30.7	64.0	40	D	34.1	5.3 (15.5)	0.83	24.3	47.7
		ND	60.0	7.2 (14.5)	1.3	32.3	62.7		ND	33.6	5.5 (16.2)	0.86	24.0	47.3
50-54	40	D	50.8	9.1 (17.8)	1.43	26.3	73.3	34	D	33.7	4.5 (13.2)	0.77	24.0	42.0
		ND	59.2	8.9 (18.0)	1.4	28.3	72.3		ND	33.7	4.6 (13.7)	0.79	22.7	42.7
55-59	30	D	53.6	8.6 (16.1)	1.58	35.7	72.0	28	D	31.9	4.9 (15.3)	0.92	25.3	48.0
		ND	51.1	8.0 (15.6)	1.45	37.7	69.0		ND	31.5	5.9 (18.6)	1.11	25.0	55.3
60-64	33	D	47.9	6.4 (13.3)	1.11	33.7	62.7	30	D	28.7	5.5 (19.1)	1.0	13.3	37.0
		ND	47.6	6.5 (13.7)	1.14	30.7	58.7		ND	28.3	5.3 (18.7)	0.96	15.3	35.3
65-69	46	D	43.0	6.8 (15.8)	1.0	25.3	57.0	34	D	29.5	3.6 (12.2)	0.62	23.3	36.7
		ND	42.3	6.4 (15.2)	0.95	24.0	54.0		ND	27.8	4.5 (16.1)	0.77	20.0	36.7
70-74	33	D	41.7	8.9 (21.3)	1.54	22.7	61.0	27	D	26.4	6.8 (25.6)	1.3	10.3	40.7
		ND	40.8	8.6 (21.2)	1.5	21.3	61.3		ND	26.0	5.5 (21.1)	1.06	14.3	38.0
75-79	28	D	36.8	9.7 (26.5)	1.84	17.0	54.3	26	D	25.0	4.5 (17.9)	0.88	16.7	34.7
		ND	36.6	8.9 (24.2)	1.67	19.3	52.7		ND	23.7	4.8 (20.1)	0.93	14.3	30.7
80-84	29	D	30.7	9.1 (29.5)	1.68	12.3	54.0	32	D	19.2	5.2 (27.3)	0.93	9.3	30.3
		ND	29.4	8.7 (29.6)	1.62	11.3	47.0		ND	19.7	5.1 (25.7)	0.9	9.7	29.0
>85	28	D	22.4	6.2 (27.6)	1.17	11.3	36.3	28	D	16.9	4.8 (28.1)	0.9	9.3	27.0
		ND	23.2	5.9 (25.3)	1.11	9.7	34.3		ND	16.7	4.9 (29.4)	0.93	7.7	25.7

[a] years
[b] D dominant hand, ND non-dominant hand
[c] absolute value (%)

normative data of grip and pinch strength

TABLE 3

	Men (n=496)							Women (n=482)						
Age[a]	n	Hand[b]	Mean	SD[c]	SEM	Min	Max	n	Hand	Mean	SD	SEM	Min	Max
18-19	33	D	9.5	1.8 (18.9)	0.31	5.2	13.5	31	D	6.9	1.2 (17.8)	0.22	4.7	10.3
		ND	9.1	1.7 (19.2)	0.3	6.5	13.5		ND	6.5	1.2 (17.8)	0.21	4.7	9.3
20-24	29	D	9.8	1.4 (14.1)	0.26	7.7	12.3	31	D	6.5	1.3 (19.9)	0.23	3.8	8.7
		ND	9.2	1.4 (15.0)	0.26	7.3	12.5		ND	6.2	1.2 (19.4)	0.22	4.0	8.5
25-29	30	D	10.1	1.4 (14.1)	0.26	7.8	13.7	30	D	6.8	0.9 (13.3)	0.16	4.8	8.3
		ND	9.5	1.6 (16.2)	0.28	6.0	12.8		ND	6.6	1.0 (15.3)	0.18	5.2	8.8
30-34	28	D	9.9	1.5 (15.4)	0.29	6.5	13.0	30	D	6.9	1.2 (17.8)	0.22	4.2	10.0
		ND	9.3	1.7 (18.1)	0.32	6.0	13.2		ND	6.7	1.1 (15.5)	0.19	4.2	8.7
35-39	41	D	10.4	1.5 (14.0)	0.23	8.0	13.5	42	D	7.1	1.4 (19.6)	0.22	4.5	12.3
		ND	10.1	1.6 (16.0)	0.25	7.5	13.5		ND	6.7	1.3 (18.8)	0.19	4.0	8.8
40-44	37	D	10.3	1.5 (14.8)	0.25	7.3	13.5	39	D	7.2	1.0 (13.9)	0.16	5.0	9.5
		ND	10.0	1.7 (16.8)	0.28	7.5	13.5		ND	6.9	1.0 (14.7)	0.16	5.0	8.8
45-49	31	D	9.8	1.7 (17.7)	0.31	6.2	13.0	40	D	7.1	1.3 (17.7)	0.2	4.5	9.5
		ND	9.2	1.6 (17.4)	0.29	6.5	12.3		ND	6.8	1.1 (16.5)	0.18	4.7	9.2
50-54	40	D	9.7	1.5 (15.4)	0.24	6.8	12.3	34	D	6.9	1.0 (14.0)	0.17	5.0	8.8
		ND	9.5	1.5 (15.3)	0.23	7.0	13.5		ND	6.6	0.9 (14.2)	0.16	4.8	8.5
55-59	30	D	10.3	1.5 (14.5)	0.27	8.0	13.2	28	D	6.8	1.4 (20.1)	0.26	5.0	12.5
		ND	9.7	1.5 (15.5)	0.28	6.5	12.5		ND	6.6	1.4 (21.1)	0.26	5.3	12.5
60-64	33	D	9.8	1.5 (15.2)	0.26	7.3	13.5	30	D	6.7	1.4 (21.4)	0.26	3.2	9.3
		ND	9.3	1.6 (16.7)	0.27	7.0	13.0		ND	6.4	1.3 (20.6)	0.24	3.5	8.3
65-69	46	D	8.7	1.5 (16.9)	0.22	5.7	13.3	34	D	6.3	1.1 (17.4)	0.19	4.5	9.3
		ND	8.4	1.5 (18.1)	0.23	5.8	11.5		ND	6.0	1.2 (19.8)	0.20	4.3	10.0
70-74	33	D	8.3	1.9 (22.8)	0.33	3.2	11.8	27	D	5.7	1.6 (28.5)	0.31	3.2	9.8
		ND	7.9	1.8 (22.2)	0.3	4.0	11.3		ND	5.5	1.6 (29.1)	0.31	3.0	8.3
75-79	28	D	8.2	2.4 (30.0)	0.46	1.8	12.8	26	D	5.1	1.2 (23.6)	0.23	2.5	7.0
		ND	7.8	2.2 (27.4)	0.41	2.5	11.5		ND	4.5	1.4 (28.2)	0.25	2.2	6.8
80-84	29	D	6.4	2.1 (33.5)	0.4	2.0	10.7	32	D	4.3	1.3 (29.1)	0.22	1.3	7.2
		ND	6.5	2.2 (33.8)	0.4	1.7	11.0		ND	3.9	1.2 (31.0)	0.22	1.3	6.2
>85	28	D	5.4	1.8 (32.7)	0.33	1.8	8.2	28	D	3.1	1.3 (40.1)	0.24	1.2	6.7
		ND	5.5	1.4 (25.2)	0.26	2.5	8.0		ND	2.8	1.1 (39.1)	0.21	0.8	5.3

[a] years
[b] D dominant hand, ND non-dominant hand
[c] absolute value (%)

Fig. 1a

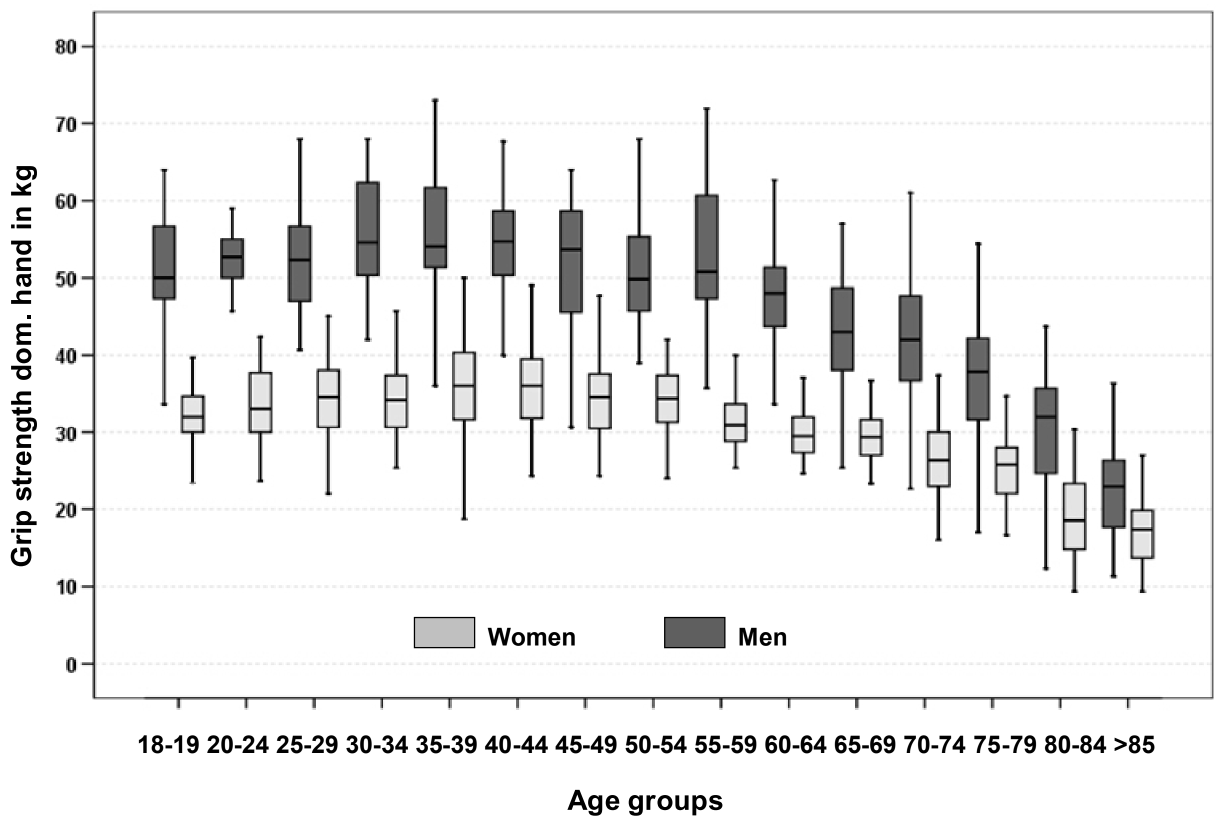

80
70
60
50
40
30
20
10
0
Grip strength dom. hand in kg
Women
Men
18-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65-69 70-74 75-79 80-84 >85
Age groups

FIG. 1b

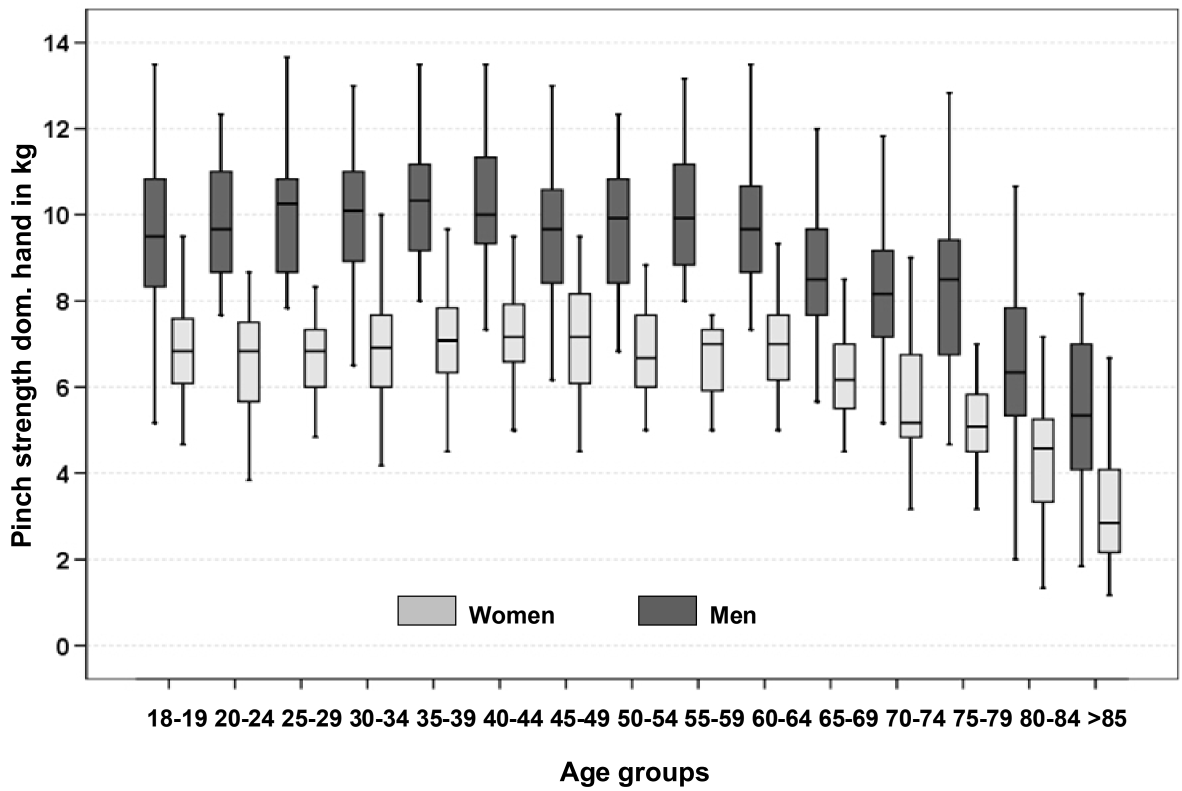
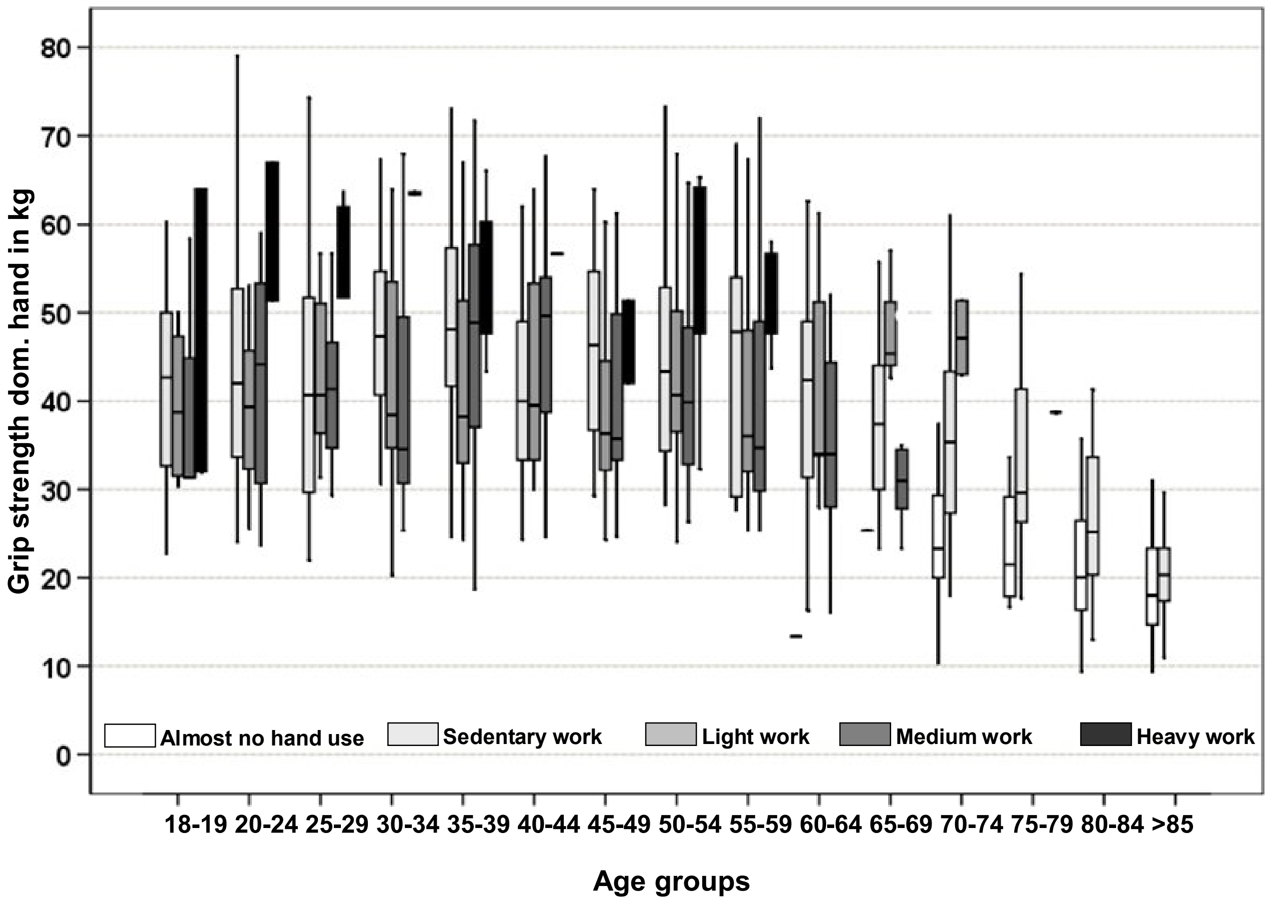
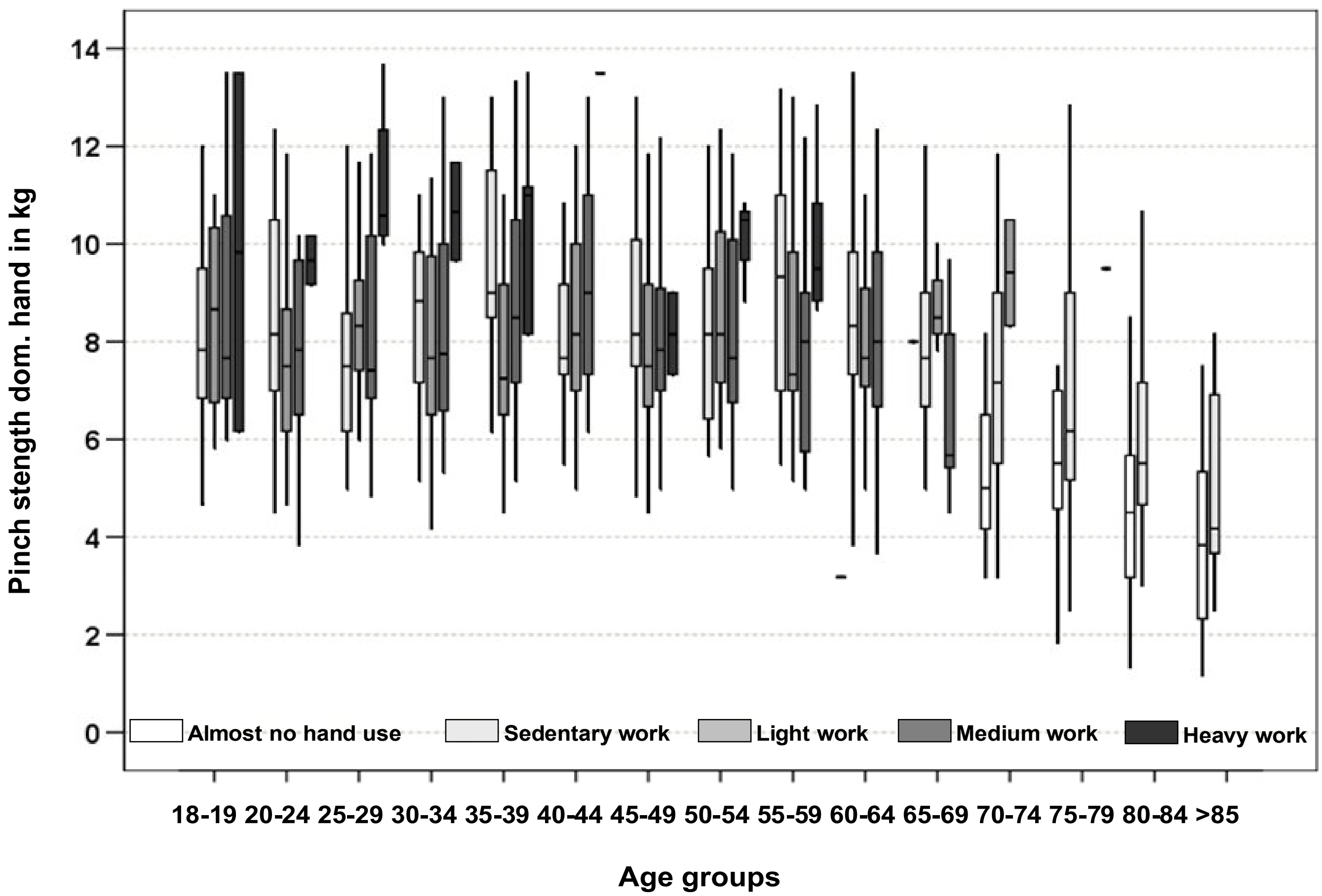

14
12
10
8
6
4
2
0
Pinch strength dom. hand in kg
Women
Men
18-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65-69 70-74 75-79 80-84 >85
Age groups

FIG. 2a



Differences significant (p=0.001)

FIG. 2b



Differences significant (p=0.001)