Grip Strength and Leg Extensor Power in 19 to 72-year-old Danish men and women. The Health2006 Study.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000192
Article Type:	Research
Date Submitted by the Author:	26-May-2011
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Subject Heading:	Sports & exercise medicine
Keywords:	Epidemiology < TROPICAL MEDICINE, Strength isometric isokinetic, Measurement

Grip strength and leg extensor power in 19 to 72-year-old Danish men and women. The Health2006 Study.

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Word count: 2.814 (excl. Title page, Abstract, references, figures, tables, Acknowledgements, Competing interests & Exclusive licence)

Keywords: Muscular fitness, Population-based study, Epidemiology

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Abstract (wordcount: 199)

Aim: To assess muscular fitness, by hand grip strength (HGS) and leg extensor power (LEP) and to explore the association with leisure time physical activity (LTPA).

Study population: A population-based sample of 19- to 72-year-old men and women were invited for the health survey "Health2006". Response rate was 43.8% (N=3,471), 55% were women, mean age was 49±13 yrs.

Methods: Height, weight, waist circumference, HGS and LEP were measured and participants answered a self-administered questionnaire. LEP was measured in a subsample (n=438). Gender-stratified multiple linear regression analyses were applied.

Results: A large inter-individual variation was found in HGS and LEP. Both measures declined with age and women had markedly lower HGS and LEP than men at all ages. LTPA was positively associated with HGS in men (p=0.0002) and women (p<0.0001) in the total sample, while in the subsample it was significant in men only (p=0.004); the association between LTPA and LEP was sigificant in women only (p=0.02). Data were adjusted for age, height and waist circumference.

Conclusion: In this large population-based study sample, muscular fitness declined with age and LTPA was associated with HGS in both genders. Findings emphasize the importance of maintaining a physically active lifestyle at any age.

Article summary

Article focus:

-Muscle strength and power play an important role, not only for sport performance, but also in relation to various prevalent chronic conditions and for function and disability in older people.

-Hand grip strength is a simple and frequently used measure of general muscle strength and function in large study populations, whereas muscle power is an understudied area in large population-based studies.

-Behavior, in particular physical activity is related to muscle performance

Key messages:

-The present study demonstrates that measurement of leg extensor power can be implemented and performed in large study populations along with the measurement of hand grip strength.

-Among 19- to 72-year old Danish men and women there was a large inter-individual variation in hand grip strength and leg extensor power. Strength and power declined across groups of increasing age and women were markedly weaker than men at any age.

-Self-reported leisure time physical activity level was significantly associated with hand grip strength, which emphasizes the importance of maintaining a physically active lifestyle at any age.

Strengths and limitations of this study:

-Strengths include the large population-based study sample and the inclusion of hand grip strength and leg extensor power in the same study.

- The cross-sectional design is a major limitation, as it does not allow for causal inferences.

INTRODUCTION

Apart from being an active tissue that burns lipid, stores ingested glucose, and significantly contributes to basal metabolic rate, skeletal muscle plays an obvious role in locomotion [1]. Accordingly, muscular fitness has been defined as '*muscular strength and power and other properties of muscle that contribute to its mass and quality'* [1]. Maximal hand grip strength has been described as the simplest method for assessing general muscle strength and function [2]. It is a strong and consistent predictor of morbidity and mortality in middle aged and elderly persons [3-5] and of disability in older populations [6,7]. Skeletal muscle function is additionally regarded as a useful indicator of malnutrition, and measurement of hand grip strength has been used as a screening tool for nutritional risk at hospital admission [8]. Muscle power is the product of force generated and speed of movement, and has been described as the ability of the neuromuscular system to produce the greatest possible force as fast as possible [9]. Muscle power is an understudied area in population-based studies, although muscle power is required in the movements of sport, work, and daily living and has been viewed as an exceedingly important testing variable [10]. In sports muscle power may be more related to functional performance than muscle strength [11], and improvement in muscle power is important for improving athletic performance [12]. In middle aged and older individuals the decline in muscle power is approximately twice as large as the decline in isometric strength [13,14], primarily because the loss of force is magnified by the loss of velocity due to the selective loss of type II fibres. Reduced muscle power is related to mobility limitation and decreased functional performance [15-17] and the relationship appears to be stronger than the relationship between functional performance and muscle strength [16,17]. In addition, muscle power is related to balance [18] and leg extensor power has been identified as a predictor of falls in elderly populations over 65 years of age [19,20]. To our knowledge leg extensor power has not previously been measured in large population samples and hence there are no reference values available for leg extensor power in general population samples.

The aim of the present study was to describe muscular fitness, by means of hand grip strength (HGS) and leg extensor power (LEP), in a large population-based sample of 19 to 72-year-old Danish men and women and to explore the associations of leisure time physical activity (LTPA) with HGS and LEP, respectively.

METHODS

Study population

The Health2006, a population-based cross-sectional study, was initiated at the Research Centre for Prevention and Health (RCPH) in June 2006 and was terminated in May 2008 [21]. Participants were recruited through the Danish Civil Registration office as a random sample of men and women between 19 and 72 years of age and living in 11 municipalities of the Western part of the Capital Region of Denmark. Out of 7,931 invited men and women, 3,471 choose to participate, corresponding to a response rate of 43.8%. All participants gave written informed consent before taking part in the study and the study was approved by the local ethics committee (KA20060011).

Physical measurements

Participants underwent an extensive health examination when visiting the RCPH, including measurement of height, weight, and waist circumference. Height was measured without shoes to the nearest cm, weight was measured in light clothing without shoes to the nearest 0.1 kg and body mass index (BMI) was calculated as kg/m^2. Waist circumference was measured midway between the lower rib margin and the iliac crest to the nearest cm, without any pressure to the body surface and with an unstretched tape meter.

Muscular fitness was assessed by two different measures of muscle performance in the upper and the lower extremity, respectively. Hand grip strength was measured in the dominant hand using a Jamar® dynamometer [22] and following a standardized protocol. The participant was seated in upright position with the arm along the side; the arm bent 90 degrees at the elbow and the forearm and wrist in neutral position. The width of the handle was adjusted to fit the hand size. Hand grip strength was measured three times in the dominant hand with brief pauses between each measurement and the best of three measurements was considered the maximum hand grip strength. Participants were given verbal encouragement during measurements in order to ensure full activation and generation of maximal muscle power.

Maximum single leg extensor power (LEP) was measured using a Nottingham leg extensor powerrig® [23] as previously described [13]. The subjects were in a seated position and a single explosive leg extension accelerated a flywheel from rest. The final speed of the flywheel was used to calculate the average power of the leg extensors. The subjects familiarised themselves with the procedure by two warm up trials followed by a minimum of five and a maximum of 10 maximal trials with approximately 30 second pause between them. The right leg was measured, unless the participant had a knee or ankle problem of the right leg, in which case the left leg was measured. All measurements were carried out by the same four trained nurses and lab technicians.

Questionnaire

Information on sociodemografic variables, physical activity and functional limitation was measured by self-report questionnaire. Participants were asked to categorise their usual physical activity level during leisure time as one of the following: 1) mainly sedentary, 2) lightly active, 3) moderately active or 4) vigorously active [24]. For the analyses categories 3 and 4 were combined, because of few participants in category 4. Functional limitation was measured as being limited in climbing several flights of stairs because of one's health: (very limited, slightly limited, not limited. Education was determined as number of years school education ($\leq$ 7 years, 8-9 years, 10 years or > 10 years) and employment status was assessed in three categories (currently employed, formerly employed, never employed).

Statistical analysis

Baseline characteristics were calculated for men and women separately and presented as means (±SD) and percentages unless otherwise stated. Students t-tests were used for comparison of mean HGS in those who were right- and left-handed, respectively. Men and women were analysed separately throughout, but we used tests for interactions to compare sex differences formally. Linear regression models were performed with HGS and LEP, respectively, as outcome variables and the following explanatory variables: leisure time physical activity level, age, height and waist circumference. Age, height and waist circumference were entered as continuous variables. Age and waist were entered in a quadratic form, whereas height was entered in a linear form. Least squares (LS) means were estimated from the regression models with a mean estimate for age, height and waist circumference for men and women separately. We used F-tests to test for interaction between age and LTPA level in all the models, in order to explore whether age-related decline in muscle strength and power differed by level of LTPA. All statistical analyses were performed using SAS, version 9.2 (SAS statistical software, version 9.2, SAS Institute, Inc.; Cary; NC, USA).

RESULTS

Among participants 55% were women (n=1,918) and mean age was 49.4±13 yrs (median 50, range: 19-72). Characteristics of the study population are presented in table 1. Among non-responders, there were significantly more men (54% men among non-responders vs.45% men among participants, p<0.001) and non-responders were markedly younger than participants (mean age 45.7±15 yrs, p< 0.001). Overall non-response was inversely correlated with age and especially in the youngest age group, participation rate was very low.

Table 1. Sociodemografic characteristics, muscle performance, body composition, physical activity level and functional limitation among men and women in the Health2006 study population (N=3,471).

	Men (N=1,553) Mean	(SD)	Women (N=1,918) Mean	(SD)
Age, *years*	50	(13)	49	(13)
Grip Strength, *kilograms*	49.2	(8.0)	31.1	(6.1)
Leg extensor power, *watt**	286	(92)	160	(56)
BMI	26.5	(4.1)	25.4	(5.1)
Waist circumference, *cm*	95	(12)	83	(13)
Height, *cm*	179	(6.8)	166	(6.4)
	N	**%**	**N**	**%**
Physical activity (leisure)				
Sedentary	283	(18)	354	(18)
Moderate activity	873	(57)	1212	(64)
High/vigorous activity	378	(25)	340	(18)
School education#				
≤7 years	171	(11)	122	(6)
8-9 years	316	(21)	304	(16)
10 years	437	(28)	582	(31)
>10 years	484	(32)	668	(36)
Employment status				
Employed	1162	(76)	1358	(72)
Formerly employed	341	(22)	499	(26)
Never employed	26	(2)	30	(2)
Limited in stair-climbing				
Yes, very limited	32	(2)	50	(3)
Yes, slightly limited	174	(11)	344	(18)
No	1321	(87)	1497	(79)

*Legrig data from 438 participants only: 183 men/ 255 women.
Information on school education was missing for 19 men/33 women, 126(8%) men/209(11%) women reported ‘other’ school education.

In the entire study population, 10% of participants (n=331), were left-handed. Mean grip strength among the left-handed was significantly higher than among the right-handed (40.5 ±11.3 kg vs. 39.0 ±11.8 kg, p=0.02). Mean handgrip strength in men and women across groups of different age, height, waist circumference and LTPA level is presented in table 2. Grip strength varied according to age and gender as expected. Men were markedly stronger than women at all ages and maximum strength was observed midlife (40-49 years of age in men and 30-39 years of age in women), and thereafter HGS decreased with increasing age in both genders (table 2). HGS increased with increasing height, whereas there was a significant inverse relationship between HGS and waist circumference in both genders. Finally, physical activity level was positively associated with HGS in both genders.

Table 2
Mean handgrip strength in men and women of different age groups, socioeconomic position, leisure time physical activity level and body composition (N=3,471).

	Handgrip Strength (kilograms)			
	Men		Women	
	N	Mean (sd)	N	Mean (sd)
Age group				
19-29 years	104	50.5 (8.2)	183	32.4 (5.1)
30-39 years	218	52.7 (7.7)	280	34.4 (5.8)
40-49 years	382	52.9 (7.1)	486	33.7 (5.4)
50-59 years	383	48.9 (7.0)	476	30.2 (5.5)
60-72 years	461	44.4 (6.8)	480	26.7 (4.8)
		P<0.0001		***P>0.0001***
Height				
Women <160 / Men <175 cm	423	44.6 (6.9)	327	27.6 (5.2)
Women 160-164/ Men 175-179 cm	368	48.3 (7.0)	427	29.7 (5.4)
Women 165-170/ Men 180-185 cm	447	51.5 (7.4)	620	31.8 (6.0)
Women>170/ Men >185 cm	269	53.3 (7.9)	463	33.8 (6.0)
		P<0.0001 [a]		***P>0.0001*** [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	740	49.4 (7.7)	850	31.4 (5.7)
Overweight (Women 80-88/men 94-102)	547	49.4 (8.1)	490	30.7 (6.3)
Obese (Women >88/men>102)	349	48.6 (8.3)	577	30.9 (6.4)
		P=0.005 [a]		***P=0.01*** [a]
Physical activity level (Leisure time)				
Sedentary	281	48.4 (8.2)	347	30.6 (6.1)
Moderate activity	870	49.0 (7.9)	1203	30.9 (6.0)
High/vigorous activity	377	50.3 (7.7)	337	32.3 (6.0)
		P=0.0007 [a]		***P=0.0001*** [a]

[a] P-values adjusted for age (age-adjusted F-test).

Measurement of LEP was implemented during the last months of the Health2006 study and hence LEP is only available in a sub group of 438 participants, 183 men and 255 women. Only 3 participants out of the 438 participants performed the test with the left leg. Mean leg extensor power in men and women across groups of different age, height, weight circumference and LTPA level is presented in table 3. LEP decreased with increasing age (table 3), and the age-related decline in LEP (men 32% decline, women 38% decline) was relatively greater than the age-related decline in HGS (men 16% decline, women 22% decline) from 40-49 years of age to the oldest age-group. A large inter-individual variation in HGS and LEP was seen in all age groups, but overall men in the oldest age group were stronger than women at any age. LEP increased with increasing height and unlike HGS, LEP was significantly higher in overweight and obese men and women than in participants of normal weight, as defined by waist circumference. Finally, physical activity level was not associated with LEP in these age-adjusted analyses (table 3).

Table 3
Mean leg extensor power in men and women of different age groups, socioeconomic position, leisure time physical activity level and body composition (N=438).

	Leg extensor power (Watts)			
	Men		Women	
	N	Mean (sd)	N	Mean (sd)
Age group				
19-29 years	16	340 (95)	25	193 (48)
30-39 years	20	309 (90)	40	183 (66)
40-49 years	45	342 (93)	54	184 (45)
50-59 years	35	274 (68)	71	155 (50)
60-72 years	67	234 (73)	65	119 (41)
		P<0.0001		***P<0.0001***
Height				
Women <160 / Men <175 cm	40	237 (72)	41	135 (50)
Women 160-164/ Men 175-179 cm	49	272 (53)	53	143 (50)
Women 165-170/ Men 180-185 cm	51	310 (88)	88	163 (53)
Women>170/ Men >185 cm	39	324 (99)	55	192 (59
		P=0.018 [a]		***P<0.0001*** [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	83	276 (89)	109	151 (51)
Overweight (Women 80-88/men 94-102)	58	302 (88)	59	169 (55)
Obese (Women >88/men>102)	46	283 (102)	87	166 (62)
		P=0.0002 [a]		***P<0.0001*** [a]
Physical activity level (Leisure time)				
Sedentary	33	292 (108)	52	148 (57)
Moderate activity	107	284 (94)	157	160 (56)
High/vigorous activity	41	286 (75)	44	172 (55)
		P=0.76 [a]		***P=0.25*** [a]

[a] P-values adjusted for age (age-adjusted F-test).

In figure 1 the LEP values are plotted against age and a regression line illustrates the ages-related decline in LEP in men and women, respectively. Similarly, HGS is regressed against age in figure 2 and 3. Overall LEP and HGS was significantly correlated (r=0.75, p< 0.0001) (data not shown). When adjusted for age, height and waist circumference, leisure time physical activity level (LTPA) was significantly associated with HGS in men (p=0.0002) and women (p<0.0001) (data not shown). However, in the sub sample where both HGS and LEP measurements were available, LTPA was significantly associated with HGS in men only (figure 4), whereas LTPA was significantly associated with LEP in women only (figure 5). No significant interaction between age and LTPA was found neither in the analysis with HGS, nor with LEP.

DISCUSSION

The present population-based study of 19 to 72-year-old Danish men and women documented that both measures of muscle performance decreased with age, but the age-related decline in LEP was relatively greater than the equivalent age-related decline in HGS. This difference may likely be attributed to age-related loss of velocity due to selective loss of type II fibres, as suggested by others [13].

In agreement with a large previous study [25], grip strength in the oldest men (60-72-year old) was higher than grip strength among women of any age. We observed the same phenomenon for LEP. In everyday life this implies that especially older women are disadvantaged with respect to activities of daily living that require high muscle strength and power, e.g. when doing heavy house work, opening jars, quickly crossing a road, or attempting to avoid falling [19,20]. This is well in accordance with the fact that women live with more disability than men throughout life.

The gender difference and the relationship between age and LEP in this study correspond very well with previous findings in small volunteer study samples of men and women [23] and in non-trained healthy men [14]. Scatter plots and regression lines illustrating the age-related decline in LEP are remarkably similar, considering the difference in study populations.

Grip strength reference values vary significantly among different populations and with the type of hand grip dynamometer used [26]. However, the reported HGS values and the age-related decline after 45 years of age correspond well with findings in a longitudinal study of +45 year-old Danish men and women, although they used a Smedley® dynamometer [25]. Interestingly, Frederiksen et al found that the decline reached a horizontal plateau in the oldest women (90+), when adjustment was made for selective drop-out by the weakest participants [25]. The oldest participants in our study were 72 years of age and accordingly we did not observe a similar horizontal plateau.

We found that waist circumference was negatively associated with HGS in both genders, whereas it was positively associated with LEP. This difference may be explained by the fact that a large body, whether fat or muscle, demands great strength and power of the lower extremities when moving about, whereas a large waist circumference not necessarily requires great strength of the upper extremities.

In the present study, HGS was significantly associated with physical activity in both men and women in the entire study sample. Previous studies in large populations of older and middle aged people have similarly documented that HGS is associated with physical activity [25,27], which in itself predicts better survival, less disability and less morbidity.

In the subsample HGS was significantly associated with physical activity in men only, while the association between physical activity level and LEP was significant in women only. However, LEP was only measured in a relatively small subsample and results should therefore be interpreted cautiously. The findings could be due to the great variation in HGS and LEP (Figures 1, 2 and 3) and thus lack of statistical power. Moreover, the measurement of LTPA was self-reported and rather crude and we were unable to distinguish between different types of LTPA. Certain types of physical activity may primarily involve leg power, e.g. running or bicycling, whereas arm- and handgrip strength may be involved in other types of activity, e.g. tennis or badminton. Likewise different types of occupations may require specific types of muscle work in the upper- or the lower extremities. However, we did not have detailed information on participants' occupation to explore this in the analyses.

Frederiksen et al found that genetic effects accounted for 52% of the variation in HGS and the genetic effect was constant across age groups [27]. Likewise, the results from twin studies suggest that one-third to one-half of the individual variation in LEP among older people is accounted for by genetic effects [28]. This suggests that muscle strength and power may be results of interactions between environmental and genetic effects [9,27]. Lately birth cohort studies have reported strong associations between birth weight and HGS in midlife, suggesting that environmental influences during gestation may also affect adult grip strength [29,30] possibly through number of muscle fibres established at birth. As a result some people may have poorer 'starting values' and thus are at increased risk for muscle impairments or sarcopenia, but behaviour, in particular physical activity, also has a key role in maintaining muscle performance at an adequate level, especially in old age [31]. This emphasizes the importance of maintaining a physically active lifestyle at any age throughout life.

The present study has several strengths and limitations that should be addressed. Strengths include the large population-based sample of adult men and women and the inclusion of hand grip strength and leg extensor power measurement in the same study. The standardised measurement of muscle strength and power performed by the same four trained nurses and lab technicians is also a strength of the present study. A major limitation of our study is the relatively low response rate that may potentially threaten generalizability of results. Especially in the younger age groups the response rate was low. However, the age and gender distribution of grip strength and leg power values, correspond very well with findings from other studies. We consider this an indication that our results have not been severely biased by the low-participation rate. Finally, the cross sectional design of our study, does not allow for causal inferences on the association between physical activity and HGS or LEP, or on the relationship with age.

In conclusion, we found that men had markedly higher HGS and LEP than women at all ages. HGS and LEP declined with age in both genders and the LTPA level was associated with HGS in both genders, but with LEP in women only. Studies on leg extensor power in larger study populations are needed in order to obtain reference values, which the present study does not have sufficient data to provide. Larger study samples and reference values are necessary for further exploration of the significance of muscle strength and power in relation to functional capacity, well-being and other health outcomes.

Perspectives

As demonstrated in the present study measurement of LEP can be implemented and performed in population-based studies along with measurement of HGS. A growing amount of research-based evidence suggests that muscle strength and power play an important role, not only for sport performance, but also in relation to various prevalent chronic conditions, and disability in older people. Consequently, age-related reference values for muscle strength and power in sedentary and physically active people would be useful. This also emphasizes the need for feasible methods for collecting valid data on muscle strength and power in large population-based study samples.

Acknowledgements

Funding sources: Timber Merchant Vilhelm Bang’s Foundation, The Danish Heart Foundation, The Danish Board of Health, The Danish Environmental Protection Agency, The Copenhagen County Research Foundation, Aase and Einar Danielsen’s Foundation, The Velux Foundation, ALK-Abelló

A/S (Hørsholm, Denmark), The Danish Scientific Research Council, and the Health Insurance Foundation (Helsefonden).

Competing interests

The authors declare that there are no competing interests.

Exclusive license

Contributorship statement

AL, TJ and MAa were responsible for conception and design of the study. NB provided advice on methodology of datacollection. NB and MAa undertook analysis and interpretation of data. MAa produced first draft of the article and NB, BT, AL and TJ critically revised the manuscript. All authors approved the final version of the manuscript.

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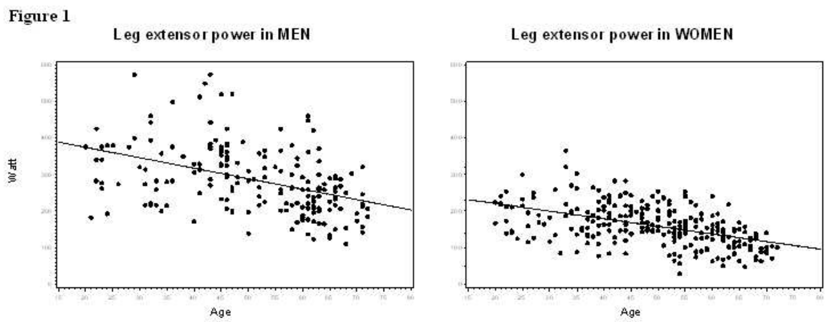

Figure 1
Leg extensor power (W) plotted against age in men (n=183) and women (n=255).
Regression lines y= -2.8581 (age) + 431.47 and y=-2.0936 (age) + 262.93 in men and women, respectively.

232x78mm (96 x 96 DPI)

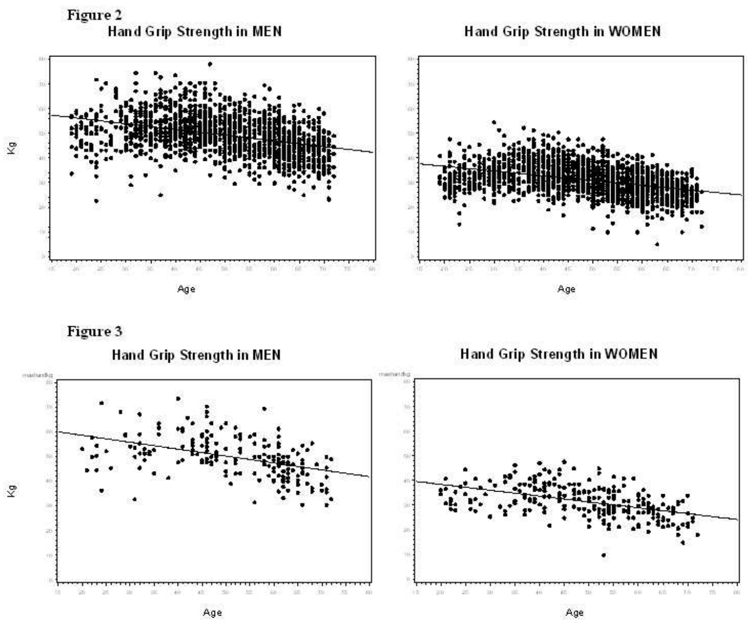

Figure 2
Hand grip strength (Kg) plotted against age in men (n=1548) and women (n=1905).
Regression lines y= -0.2318 (age) + 60.814 and y=-0.1934 (age) + 40.471 in men and women, respectively.

Figure 3
Hand grip strength (Kg) plotted against age in men (n=183) and women (n=255).
Regression lines y=-0.2795 (age) +64.117 and y=-0.2363 (age) +43.218 in men and women, respectively.

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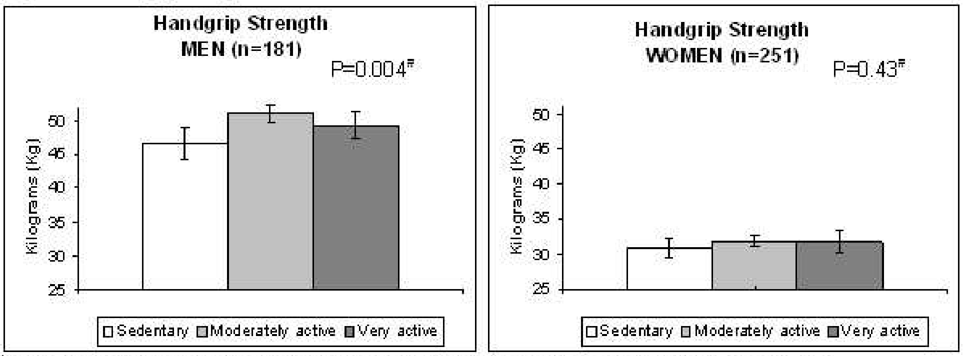
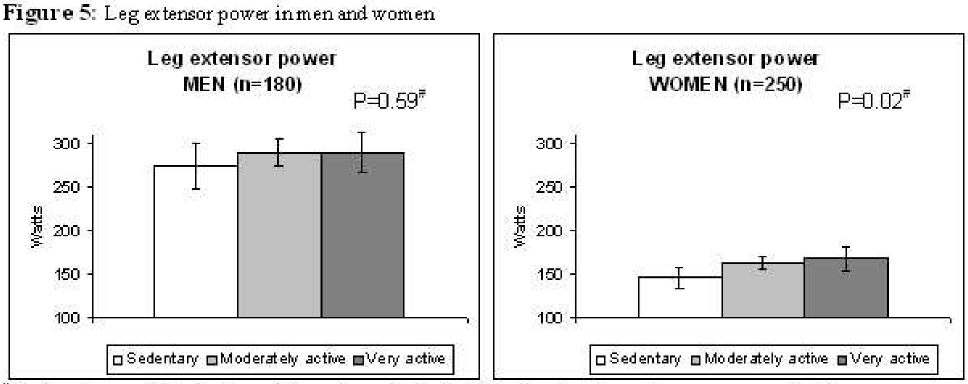
Figure 4: Handgrip strength in men and women



#P-value for association between leisure time physical activity level and handgrip strength, adjusted for age, height and waist circumference.

Figure 5: Leg extensor power in men and women



#P-value for association between leisure time physical activity level and leg extensor power, adjusted for age, height and waist circumference.

Figure 4
Handgrip strength in men and women, respectively, across categories of leisure time physical activity, presented as LS means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.

Figure 5
Leg extensor power in men and women, respectively, across categories of leisure time physical activity, presented as LS means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.

164x158mm (96 x 96 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies*** (Grip Strength and Leg extensor power in 19 to 72-year-old Danish men and women. The Health2006 Study.)

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
	OK	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8* OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
	OK	(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13* OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14* OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15* OK	Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Grip Strength and Lower Limb Extension Power in 19 to 72-year-old Danish men and women. The Health2006 Study.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000192.R1
Article Type:	Research
Date Submitted by the Author:	01-Jul-2011

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Primary Subject Heading:	Sports & exercise medicine
Keywords:	Epidemiology < TROPICAL MEDICINE, Strength isometric isokinetic, Measurement

Grip strength and lower limb extension power in 19 to 72-year-old Danish men and women. The Health2006 Study.

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Word count: 2.738 (excl. Title page, Abstract, references, figures, tables, Acknowledgements, Competing interests & Exclusive licence)

Keywords: Muscular fitness, Population-based study, Epidemiology

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Abstract (wordcount: 198)

Aim: To assess muscular fitness, by hand grip strength (HGS) and lower limb extension power (LEP) and to explore the association with age, leisure time physical activity (LTPA) and body composition.

Study population: A population-based sample of 19- to 72-year-old men and women were invited for the health survey "Health2006". Response rate was 43.8% (N=3,471), 55% were women, mean age was 49±13 yrs.

Methods: Height, weight, waist circumference, HGS and LEP were measured and participants answered a self-administered questionnaire. LEP was measured in a subsample (n=438). Gender-stratified multiple linear regression analyses were applied.

Results: A large inter-individual variation was found in HGS and LEP. Both measures declined with age and were highly correlated (r=0.75, p<0.0001). LTPA was positively associated with HGS in men (p=0.0002) and women (p<0.0001) in the total sample, while in the subsample it was significant in men only (p=0.004); the association between LTPA and LEP was significant in women only (p=0.02). Data were adjusted for age, height and waist circumference.

Conclusion: In this large population-based study sample, muscular fitness declined with age and LTPA was associated with HGS in both genders. The findings emphasize the importance of maintaining a physically active lifestyle at any age.

Deleted: women had markedly lower HGS and LEP than men at all ages.

INTRODUCTION

Apart from being an active tissue that burns lipid, stores ingested glucose, and significantly contributes to basal metabolic rate, skeletal muscle plays an obvious role in locomotion [1]. Accordingly, muscular fitness has been defined as '*muscular strength and power and other properties of muscle that contribute to its mass and quality'* [1]. Maximal hand grip strength has been described as the simplest method for assessing general muscle strength and function [2]. It is a strong and consistent predictor of morbidity and mortality in middle aged and elderly persons [3-5] and of disability in older populations [6,7]. Skeletal muscle function is additionally regarded as a useful indicator of malnutrition, and measurement of hand grip strength has been used as a screening tool for nutritional risk at hospital admission [8]. Muscle power is the product of force generated and speed of movement, and has been described as the ability of the neuromuscular system to produce the greatest possible force as fast as possible [9]. Muscle power is an understudied area in population-based studies, although muscle power is required in the movements of sport, work, and daily living and has been viewed as an exceedingly important testing variable [10]. In sports muscle power may be more related to functional performance than muscle strength [11], and improvement in muscle power is important for improving athletic performance [12]. In middle aged and older individuals the decline in muscle power is approximately twice as large as the decline in isometric strength [13,14], primarily because the loss of force is magnified by the loss of velocity due to the selective loss of type II fibres. Reduced muscle power is related to mobility limitation and decreased functional performance [15-17] and the relationship appears to be stronger than the relationship between functional performance and muscle strength [16,17]. In addition, muscle power is related to balance [18] and lower limb extension power has been identified as a predictor of falls in elderly populations over 65 years of age [19,20]. To our knowledge lower limb extension power has not previously been measured in large population samples.

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The aim of the present study was to describe muscular fitness, by means of hand grip strength (HGS) and lower limb extension power (LEP), in a large population-based sample of 19 to 72-year-old Danish men and women. Furthermore, to explore the associations of HGS and LEP, respectively, with age, leisure time physical activity (LTPA) and body composition.

METHODS

Study population

The Health2006, a population-based cross-sectional study, was initiated at the Research Centre for Prevention and Health (RCPH) in June 2006 and was terminated in May 2008 [21]. Participants were recruited through the Danish Civil Registration office as a random sample of men and women between 19 and 72 years of age and living in 11 municipalities of the Western part of the Capital Region of Denmark. Pregnant women were not included. Out of 7,931 invited men and women, 3,471 choose to participate, corresponding to a response rate of 43.8%. All participants gave written informed consent before taking part in the study and the study was approved by the local ethics committee (KA20060011).

Physical measurements

When visiting the RCPH the participants underwent an extensive health examination, which has been described in detail elsewere [22], including measurement of height, weight, and waist circumference. Height was measured without shoes to the nearest cm, weight was measured in light clothing without shoes to the nearest 0.1 kg and body mass index (BMI) was calculated as kg/m^2. Waist circumference was measured midway between the lower rib margin and the iliac crest to the nearest cm, without any pressure to the body surface and with an unstretched tape meter.

Muscular fitness was assessed by two different measures of muscle performance in the upper and the lower extremity, respectively. Hand grip strength was measured in the dominant hand using a Jamar® dynamometer [23] and following a standardized protocol. The participant was seated in upright position with the arm along the side; the arm bent 90 degrees at the elbow and the forearm and wrist in neutral position. The width of the handle was adjusted to fit the hand size. Hand grip strength was measured three times in the dominant hand with brief pauses between each measurement and the best of three measurements was considered the maximum hand grip strength. High inter-rater and test-retest reliability have previously been demonstrated for these standardized measurement procedures [24] .

Maximum single lower limb extension power (LEP) was measured using a Nottingham Leg Extensor Power Rig ® [25] as previously described [13]. The subjects were in a seated position and a single explosive leg extension accelerated a flywheel from rest. The final speed of the flywheel was used to calculate the average power of the leg extensors. The subjects familiarised themselves with the procedure by two warm up trials followed by a minimum of five and a maximum of 10 maximal trials with approximately 30 second pause between them. Participants were given verbal encouragement during measurements in order to ensure full activation and generation of maximal muscle power. The right leg was measured, unless the participant had a knee or ankle problem of the right leg, in which case the left leg was measured. High test-retest reliability of the LEP measurement has been reported using the Nottingham Leg Extensor Power Rig® and following the standardised measurement protocol [25].

All measurements were carried out by the same four trained nurses and lab technicians.

Questionnaire

Information on sociodemografic variables, physical activity and functional limitation was measured by self-report questionnaire. Participants were asked to categorise their usual physical activity level during leisure time as one of the following: 1) mainly sedentary, 2) lightly active, 3) moderately active or 4) vigorously active [26]. For the analyses categories 3 and 4 were combined, because of few participants in category 4. Functional limitation was measured as being limited in climbing several flights of stairs because of one's health: (very limited, slightly limited, not limited. Education was determined as number of years school education (≤ 7 years, 8-9 years, 10 years or > 10 years) and employment status was assessed in three categories (currently employed, formerly employed, never employed).

Statistical analysis

Baseline characteristics were calculated for men and women separately and presented as means (±SD) and percentages unless otherwise stated. Data from men and women were analysed separately throughout, but we used tests for interactions to compare gender differences formally. Pearson's correlation coefficient was used to determine the correlation between HGS and LEP. Univariate associations between age group and HGS and LEP, respectively, were assessed in general linear regression models. Likewise, we explored the association of HGS and LEP, respectively, with height, waist circumference and LTPA in general linear regression analyses adjusting for age. We determined regression coefficients and regression lines of the association between age and HGS and LEP, respectively, in a linear regression model. Finally the associations between LTPA and muscular fitness were estimated in multiple linear regression models with HGS and LEP, respectively, as outcome variables and LTPA as the primary explanatory variable. Age, height and waist circumference were included as co-variates and were entered as continuous variables. Age and waist were entered in a quadratic form, whereas height was entered in a linear

Deleted: Students t-tests were used for comparison of mean HGS in those who were right- and left-handed, respectively.

form. Least squares (LS) means were estimated from the regression models with a mean estimate for age, height and waist circumference for men and women separately. We used F-tests to test for interaction between age and LTPA level in all the models, in order to explore whether age-related decline in muscle strength and power differed by level of LTPA. All statistical analyses were performed using SAS, version 9.2 (SAS statistical software, version 9.2, SAS Institute, Inc.; Cary; NC, USA).

RESULTS

Among participants 55% were women (n=1,918) and mean age was 49.4±13 yrs (median 50, range: 19-72). Characteristics of the study population are presented in table 1. Among non-responders, there were significantly more men (54% men among non-responders vs.45% men among participants, p<0.001) and non-responders were markedly younger than participants (mean age 45.7±15 yrs, p< 0.001). Overall non-response was inversely correlated with age and especially in the youngest age group, participation rate was very low.

Table 1. Sociodemografic characteristics, muscle performance, body composition, physical activity level and functional limitation among men and women in the Health2006 study population (N=3,471).

	Men (N=1,553) Mean (SD)		Women (N=1,918) Mean (SD)	
Age, *years*	50	(13)	49	(13)
Grip Strength, *kilograms*	49.2	(8.0)	31.1	(6.1)
Lower limb extension power, *watt**	286	(92)	160	(56)
BMI	26.5	(4.1)	25.4	(5.1)
Waist circumference, *cm*	95	(12)	83	(13)
Height, *cm*	179	(6.8)	166	(6.4)
	N	**%**	**N**	**%**
Physical activity (leisure)				
Sedentary	283	(18)	354	(18)
Moderate activity	873	(57)	1212	(64)
High/vigorous activity	378	(25)	340	(18)
School education#				
≤7 years	171	(11)	122	(6)
8-9 years	316	(21)	304	(16)

10 years	437	(28)	582	(31)
>10 years	484	(32)	668	(36)
Employment status				
Employed	1162	(76)	1358	(72)
Formerly employed	341	(22)	499	(26)
Never employed	26	(2)	30	(2)
Limited in stair-climbing				
Yes, very limited	32	(2)	50	(3)
Yes, slightly limited	174	(11)	344	(18)
No	1321	(87)	1497	(79)

*Legrig data from 438 participants only: 183 men/ 255 women.
Information on school education was missing for 19 men/33 women, 126(8%) men/209(11%) women reported ‘other’ school education.

In the entire study population, 10% of participants (n=331), were left-handed. Mean handgrip strength in men and women across groups of different age, height, waist circumference and LTPA level is presented in table 2. Grip strength varied according to age and gender as expected. Maximum strength was observed midlife (40-49 years of age in men and 30-39 years of age in women), and thereafter HGS decreased with increasing age in both genders (table 2). HGS increased with increasing height, whereas there was a significant inverse relationship between HGS and waist circumference in both genders. Finally, physical activity level was positively associated with HGS in both genders.

Deleted: Mean grip strength among the left-handed was significantly higher than among the right-handed (40.5 ±11.3 kg vs. 39.0 ±11.8 kg, p=0.02).

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Table 2
Mean handgrip strength in men and women of different age groups, leisure time physical activity level and body composition (N=3,471).

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	Handgrip Strength (kilograms)			
	Men		**Women**	
	N	**Mean (sd)**	**N**	**Mean (sd)**
Age group				
19-29 years	104	50.5 (8.2)	183	32.4 (5.1)
30-39 years	218	52.7 (7.7)	280	34.4 (5.8)
40-49 years	382	52.9 (7.1)	486	33.7 (5.4)
50-59 years	383	48.9 (7.0)	476	30.2 (5.5)
60-72 years	461	44.4 (6.8)	480	26.7 (4.8)
		P<0.0001		***P<0.0001***
Height				
Women <160 / Men <175 cm	423	44.6 (6.9)	327	27.6 (5.2)
Women 160-164/ Men 175-179 cm	368	48.3 (7.0)	427	29.7 (5.4)
Women 165-170/ Men 180-185 cm	447	51.5 (7.4)	620	31.8 (6.0)
Women>170/ Men >185 cm	269	53.3 (7.9)	463	33.8 (6.0)
		P<0.0001 [a]		***P>0.0001*** [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	740	49.4 (7.7)	850	31.4 (5.7)

Overweight (Women 80-88/men 94-102)	547	49.4 (8.1)	490	30.7 (6.3)
Obese (Women >88/men>102)	349	48.6 (8.3)	577	30.9 (6.4)
		P=0.005 [a]		*P=0.01* [a]
Physical activity level (Leisure time)				
Sedentary	281	48.4 (8.2)	347	30.6 (6.1)
Moderate activity	870	49.0 (7.9)	1203	30.9 (6.0)
High/vigorous activity	377	50.3 (7.7)	337	32.3 (6.0)
		P=0.0007 [a]		*P=0.0001* [a]

[a] P-values adjusted for age (age-adjusted F-test).

Measurement of LEP was implemented during the last months of the Health2006 study and hence LEP is only available in a sub group of 438 participants, 183 men and 255 women. Only 3 participants out of the 438 participants performed the test with the left leg. Mean leg extensor power in men and women across groups of different age, height, waist circumference and LTPA level is presented in table 3. LEP decreased with increasing age (table 3). A large inter-individual variation in HGS and LEP was seen in all age groups. LEP increased with increasing height and unlike HGS, LEP was significantly higher in overweight and obese men and women than in participants of normal weight, as defined by waist circumference. Finally, physical activity level was not associated with LEP in these age-adjusted analyses (table 3).

Deleted:), and the age-related decline in LEP (men 32% decline, women 38% decline) was relatively greater than the age-related decline in HGS (men 16% decline, women 22% decline) from 40-49 years of age to the oldest age-group

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Table 3
Mean lower limb extension power in men and women of different age groups, leisure time physical activity level and body composition (N=438).

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	Lower limb extension power (Watts)			
	Men		Women	
	N	Mean (sd)	N	Mean (sd)
Age group				
19-29 years	16	340 (95)	25	193 (48)
30-39 years	20	309 (90)	40	183 (66)
40-49 years	45	342 (93)	54	184 (45)
50-59 years	35	274 (68)	71	155 (50)
60-72 years	67	234 (73)	65	119 (41)
		P<0.0001		*P<0.0001*
Height				
Women <160 / Men <175 cm	40	237 (72)	41	135 (50)
Women 160-164/ Men 175-179 cm	49	272 (53)	53	143 (50)
Women 165-170/ Men 180-185 cm	51	310 (88)	88	163 (53)
Women>170/ Men >185 cm	39	324 (99)	55	192 (59
		P=0.018 [a]		*P<0.0001* [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	83	276 (89)	109	151 (51)

Overweight (Women 80-88/men 94-102)	58	302 (88)	59	169 (55)
Obese (Women >88/men>102)	46	283 (102)	87	166 (62)
		P=0.0002 [a]		***P<0.0001*** [a]
Physical activity level (Leisure time)				
Sedentary	33	292 (108)	52	148 (57)
Moderate activity	107	284 (94)	157	160 (56)
High/vigorous activity	41	286 (75)	44	172 (55)
		P=0.76 [a]		***P=0.25*** [a]

[a] P-values adjusted for age (age-adjusted F-test).

In figure 1 the LEP values are plotted against age and a regression line illustrates the ages-related decline in LEP in men and women, respectively. Similarly, HGS is regressed against age in figure 2 and 3. Overall LEP and HGS were significantly correlated (r=0.75, p< 0.0001) (data not shown). When adjusted for age, height and waist circumference, leisure time physical activity level (LTPA) was significantly associated with HGS in men (p=0.0002) and women (p<0.0001) (data not shown). However, in the sub sample where both HGS and LEP measurements were available, LTPA was significantly associated with HGS in men only (figure 4), whereas LTPA was significantly associated with LEP in women only (figure 5). No significant interaction between age and LTPA was found neither in the analysis with HGS, nor with LEP.

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DISCUSSION

The present population-based study of 19 to 72-year-old Danish men and women documented that both measures of muscle performance decreased with age as expected. The relationship between age and LEP in this study correspond very well with previous findings in small volunteer study samples of men and women [25] and in non-trained healthy men [14]. Scatter plots and regression lines illustrating the age-related decline in LEP are remarkably similar, considering the difference in study populations.

Deleted: , but the age-related decline in LEP was relatively greater than the equivalent age-related decline in HGS. This difference may likely be attributed to age-related loss of velocity due to selective loss of type II fibres, as suggested by others [13].In agreement with a large previous study [25], grip strength in the oldest men (60-72-year old) was higher than grip strength among women of any age. We observed the same phenomenon for LEP. In everyday life this implies that especially older women are disadvantaged with respect to activities of daily living that require high muscle strength and power, e.g. when doing house work, opening jars, quickly crossing a road, or attempting to avoid falling [19,20]. This is well in accordance with the fact that women live with more disability than men throughout life. ¶
The gender difference and t

Grip strength reference values vary significantly among different populations and with the type of hand grip dynamometer used [27]. However, the reported HGS values and the age-related decline after 45 years of age correspond well with findings in a longitudinal study of +45 year-old Danish men and women, although they used a Smedley® dynamometer [28]. Interestingly, Frederiksen et al found that the decline reached a horizontal plateau in the oldest women (90+), when adjustment was made for selective drop-out by the weakest participants [28]. The oldest participants in our study were 72 years of age and accordingly we did not observe a similar horizontal plateau.

We found that waist circumference was negatively associated with HGS in both genders, whereas it was positively associated with LEP. This difference may be explained by the fact that a large body, whether fat or muscle, demands great strength and power of the lower extremities when moving about, whereas a large waist circumference not necessarily requires great strength of the upper extremities.

In the present study, HGS was significantly associated with physical activity in both men and women in the entire study sample. Previous studies in large populations of older and middle aged people have similarly documented that HGS is associated with physical activity [28,29], which in itself predicts better survival, less disability and less morbidity.

In the subsample HGS was significantly associated with physical activity in men only, while the association between physical activity level and LEP was significant in women only. However, LEP was only measured in a relatively small subsample and results should therefore be interpreted cautiously. The findings could be due to the great variation in HGS and LEP (Figures 1, 2 and 3) and thus lack of statistical power. Moreover, the measurement of LTPA was self-reported and rather crude and we were unable to distinguish between different types of LTPA. Certain types of physical activity may primarily involve leg power, e.g. running or bicycling, whereas arm- and handgrip strength may be involved in other types of activity, e.g. tennis or badminton. Likewise different types of occupations may require specific types of muscle work in the upper- or the lower extremities. However, we did not have detailed information on participants' occupation to explore this in the analyses.

Frederiksen et al found that genetic effects accounted for 52% of the variation in HGS and the genetic effect was constant across age groups [29]. Likewise, the results from twin studies suggest that one-third to one-half of the individual variation in LEP among older people is accounted for by genetic effects [30]. This suggests that muscle strength and power may be results of interactions between environmental and genetic effects [9,29]. Lately birth cohort studies have reported strong associations between birth weight and HGS in midlife, suggesting that environmental influences during gestation may also affect adult grip strength [31,32] possibly through number of muscle fibres established at birth. As a result some people may have poorer 'starting values' and thus are at increased risk for muscle impairments or sarcopenia, but behaviour, in particular physical activity, also has a key role in maintaining muscle performance at an adequate level, especially in old age [33]. This emphasizes the importance of maintaining a physically active lifestyle at any age throughout life.

It seems worth noting, that overall HGS and LEP were highly correlated in the present study. This supports the use of HGS as a single, simple and inexpensive method for assessing general muscle strength and function

The present study has several strengths and limitations that should be addressed. Strengths include the large population-based sample of adult men and women and the inclusion of hand grip strength and leg extensor power measurement in the same study. The standardised measurement of muscle strength and power performed by the same four trained nurses and lab technicians is also a strength of the present study. A major limitation of our study is the relatively low response rate that may potentially threaten generalizability of results. Especially in the younger age groups the response rate was low. However, the age and gender distribution of grip strength and leg power values, correspond very well with findings from other studies. We consider this an indication that our results have not been severely biased by the low-participation rate. Finally, the cross sectional design of our study, does not allow for causal inferences on the association between physical activity and HGS or LEP, or on the relationship with age.

In conclusion, we found that HGS and LEP declined with age in both genders and the LTPA level was associated with HGS in both genders, but with LEP in women only. Studies on lower limb extension power in larger study populations are needed in order to obtain reference values, which the present study does not have sufficient data to provide. Larger study samples and reference values are necessary for further exploration of the significance of muscle strength and power in relation to functional capacity, well-being and other health outcomes.

Deleted: men had markedly higher HGS and LEP than women at all ages.

Perspectives

As demonstrated in the present study measurement of LEP can be implemented and performed in population-based studies along with measurement of HGS. A growing amount of research-based evidence suggests that muscle strength and power play an important role, not only for sport performance, but also in relation to various prevalent chronic conditions, and disability in older people. Consequently, age-related reference values for muscle strength and power in sedentary and physically active people would be useful. This also emphasizes the need for feasible methods for collecting valid data on muscle strength and power in large population-based study samples.

Acknowledgements

Funding sources: Timber Merchant Vilhelm Bang's Foundation, The Danish Heart Foundation, The Danish Board of Health, The Danish Environmental Protection Agency, The Copenhagen County Research Foundation, Aase and Einar Danielsen's Foundation, The Velux Foundation, ALK-Abelló A/S (Hørsholm, Denmark), The Danish Scientific Research Council, and the Health Insurance Foundation (Helsefonden).

Competing interests

The authors declare that there are no competing interests.

Exclusive license

Contributorship statement

AL, TJ and MAa were responsible for conception and design of the study. NB provided advice on methodology of datacollection. NB, BT and MAa undertook analysis and interpretation of data. MAa produced first draft of the article and NB, BT, AL and TJ critically revised the manuscript. All authors approved the final version of the manuscript.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies*** (Grip Strength and Leg extensor power in 19 to 72-year-old Danish men and women. The Health2006 Study.)

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
	OK	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8* OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
	OK	(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13* OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14* OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15* OK	Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Figure 1

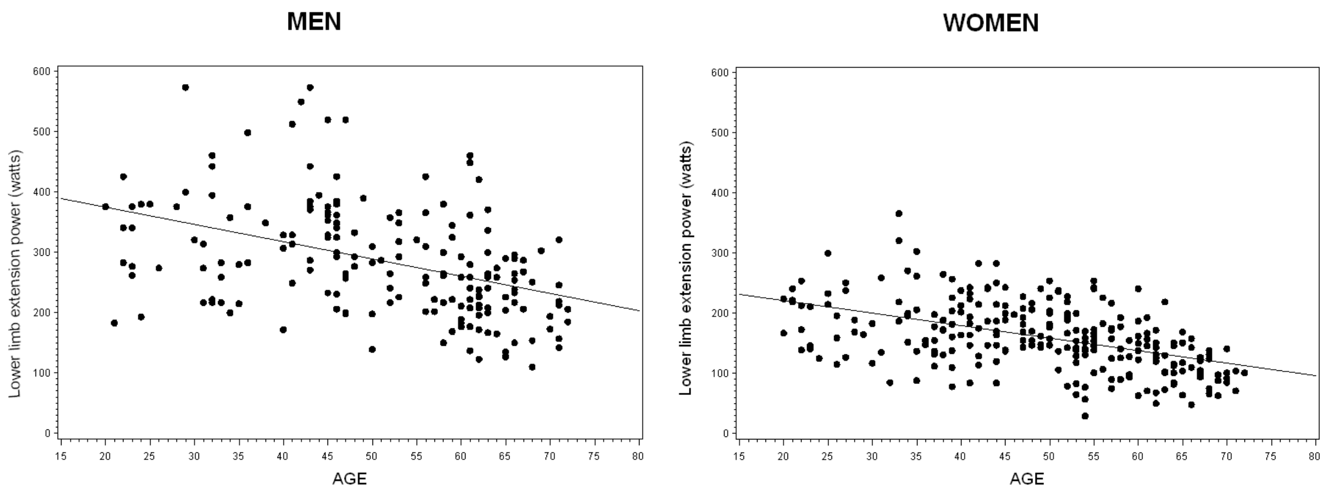

MEN
WOMEN
Lower limb extension power (watts)
Lower limb extension power (watts)
AGE
AGE

Figure 2

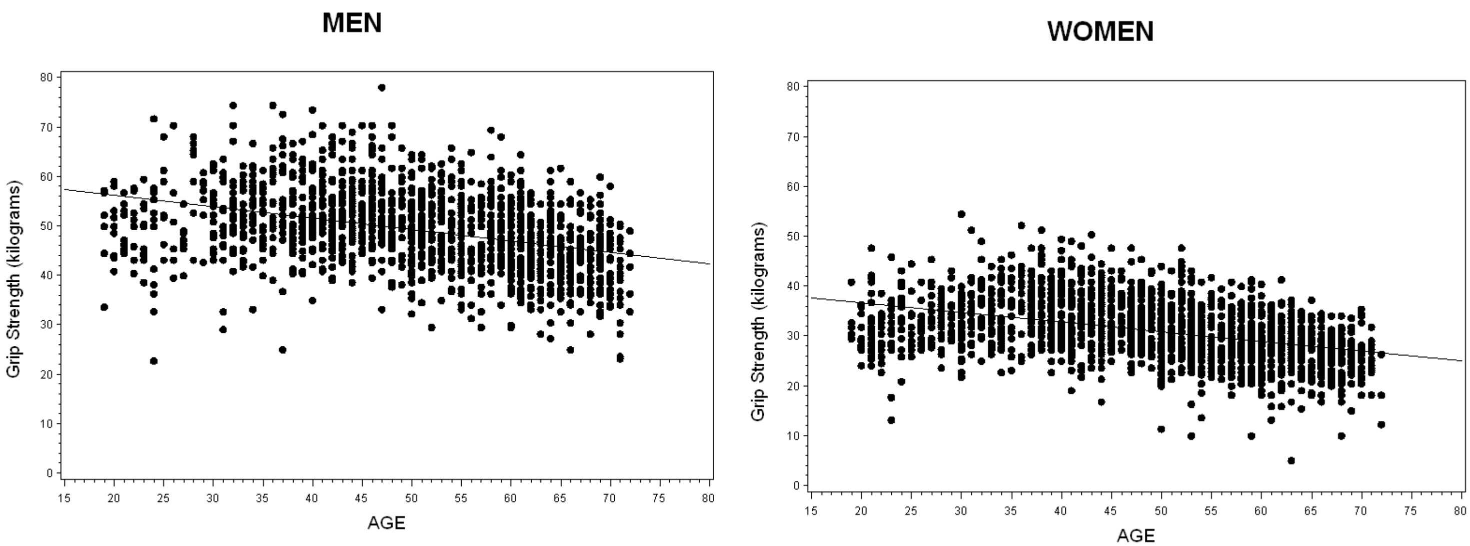


Figure 3

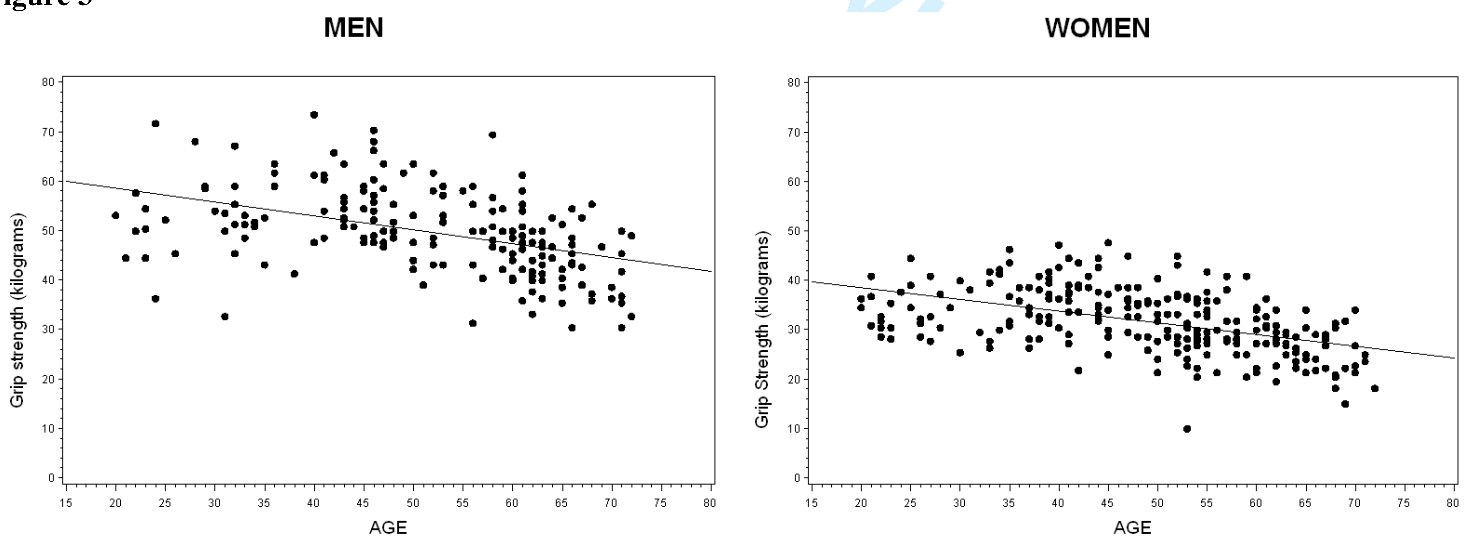
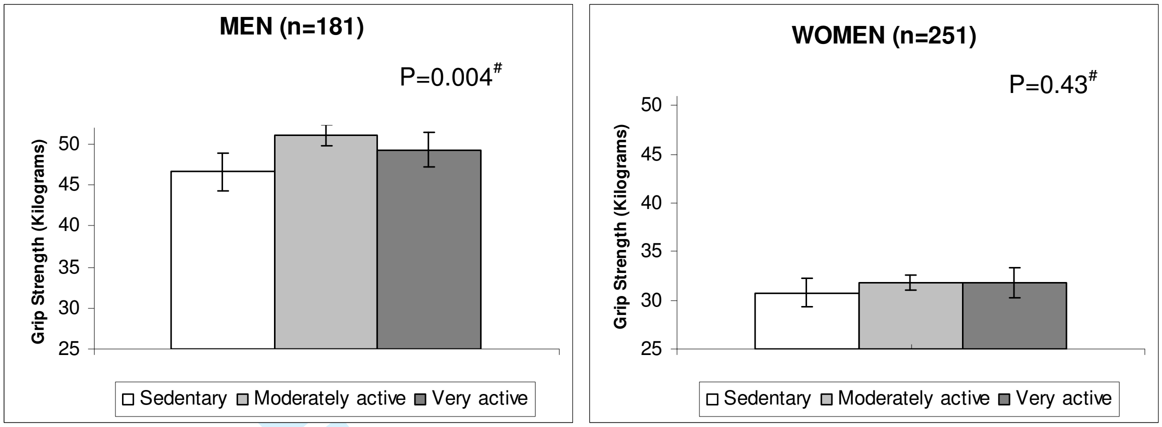
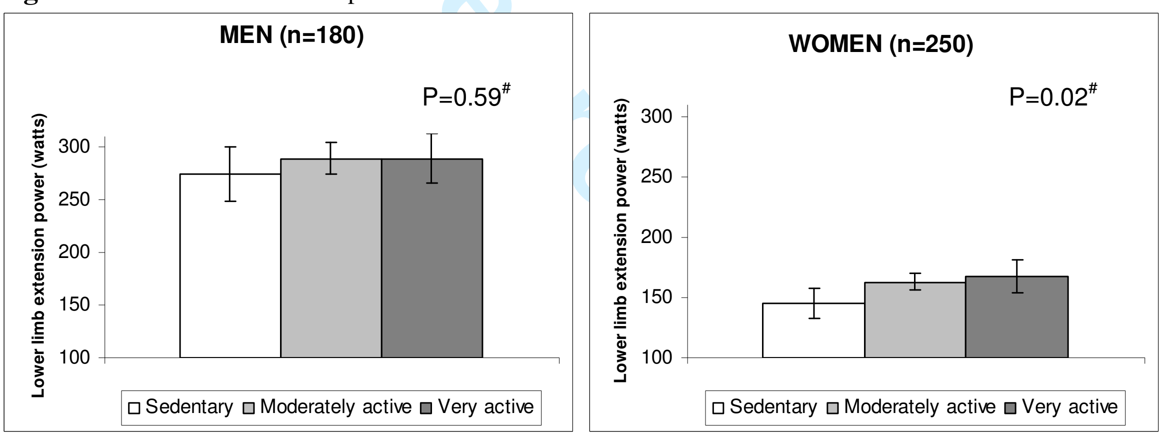


Figure 4: Handgrip strength in men and women.



#P-value for association between leisure time physical activity level and handgrip strength, adjusted for age, height and waist circumference.

Figure 5: Lower limb extension power in men and women



#P-value for association between leisure time physical activity level and leg extensor power, adjusted for age, height and waist circumference.

Figure legends

Figure 1
Lower limb extension power (watts) plotted against age in men (n=183) and women (n=255). Regression lines y= -2.8581 (age) + 431.47 and y=-2.0936 (age) + 262.93 in men and women, respectively.

Figure 2
Hand grip strength (Kg) plotted against age in men (n=1548) and women (n=1905). Regression lines y= -0.2318 (age) + 60.814 and y=-0.1934 (age) + 40.471 in men and women, respectively.

Figure 3
Hand grip strength (Kg) plotted against age in men (n=183) and women (n=255). Regression lines y=-0.2795 (age) +64.117 and y=-0.2363 (age) +43.218 in men and women, respectively.

Figure 4
Handgrip strength in men and women, respectively, across categories of leisure time physical activity, presented as least squares (LS) means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.

Figure 5
Lower limb extension power in men and women, respectively, across categories of leisure time physical activity, presented as least squares (LS) means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.

Grip Strength and Lower Limb Extension Power in 19 to 72-year-old Danish men and women. The Health2006 Study.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000192.R2
Article Type:	Research
Date Submitted by the Author:	05-Aug-2011

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Primary Subject Heading:	Sports & exercise medicine
Keywords:	Epidemiology < TROPICAL MEDICINE, Strength isometric isokinetic, Measurement

Grip strength and lower limb extension power in 19 to 72-year-old Danish men and women. The Health2006 Study.

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Word count: 2.742 (excl. Title page, Abstract, references, figures, tables, Acknowledgements, Competing interests & Exclusive licence)

Keywords: Muscular fitness, Population-based study, Epidemiology

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Abstract (wordcount: 198)

Aim: To assess muscular fitness, by hand grip strength (HGS) and lower limb extension power (LEP) and to explore the association with age, leisure time physical activity (LTPA) and body composition.

Study population: A population-based sample of 19- to 72-year-old men and women were invited for the health survey "Health2006". Response rate was 43.8% (N=3,471), 55% were women, mean age was 49±13 yrs.

Methods: Height, weight, waist circumference, HGS and LEP were measured and participants answered a self-administered questionnaire. LEP was measured in a subsample (n=438). Gender-stratified multiple linear regression analyses were applied. Data were adjusted for age, height and waist circumference.

Results: A large inter-individual variation was found in HGS and LEP. Both measures declined with age and were highly correlated (r=0.75, p<0.0001). LTPA was positively associated with HGS in men (p=0.0002) and women (p<0.0001) in the total sample, while in the subsample it was significant in men only (p=0.004); the association between LTPA and LEP was significant in women only (p=0.02).

Conclusion: In this large population-based study sample, muscular fitness declined with age and LTPA was associated with HGS in both genders. The findings emphasize the importance of maintaining a physically active lifestyle at any age.

Deleted: Data were adjusted for age, height and waist circumference.¶

INTRODUCTION

Apart from being an active tissue that burns lipid, stores ingested glucose, and significantly contributes to basal metabolic rate, skeletal muscle plays an obvious role in locomotion [1]. Accordingly, muscular fitness has been defined as '*muscular strength and power and other properties of muscle that contribute to its mass and quality'* [1]. Maximal hand grip strength has been described as the simplest method for assessing general muscle strength and function [2]. It is a strong and consistent predictor of morbidity and mortality in middle aged and elderly persons [3-5] and of disability in older populations [6,7]. Skeletal muscle function is additionally regarded as a useful indicator of malnutrition, and measurement of hand grip strength has been used as a screening tool for nutritional risk at hospital admission [8]. Muscle power is the product of force generated and speed of movement, and has been described as the ability of the neuromuscular system to produce the greatest possible force as fast as possible [9]. Muscle power is an understudied area in population-based studies, although muscle power is required in the movements of sport, work, and daily living and has been viewed as an exceedingly important testing variable [10]. In sports muscle power may be more related to functional performance than muscle strength [11], and improvement in muscle power is important for improving athletic performance [12]. In middle aged and older individuals the decline in muscle power is approximately twice as large as the decline in isometric strength [13,14], primarily because the loss of force is magnified by the loss of velocity due to the selective loss of type II fibres. Reduced muscle power is related to mobility limitation and decreased functional performance [15-17] and the relationship appears to be stronger than the relationship between functional performance and muscle strength [16,17]. In addition, muscle power is related to balance [18] and lower limb extension power (LEP) has been identified as a predictor of falls in elderly populations over 65 years of age [19,20]. To our knowledge LEP has not previously been measured in large population samples.

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The aim of the present study was to describe muscular fitness, by means of hand grip strength (HGS) and lower limb extension power (LEP), in a large population-based sample of 19 to 72-year-old Danish men and women. Furthermore, to explore the associations of HGS and LEP, respectively, with age, leisure time physical activity (LTPA) and body composition.

METHODS

Study population

The Health2006, a population-based cross-sectional study, was initiated at the Research Centre for Prevention and Health (RCPH) in June 2006 and was terminated in May 2008 [21]. Participants were recruited through the Danish Civil Registration office as a random sample of men and women between 19 and 72 years of age and living in 11 municipalities of the Western part of the Capital Region of Denmark. Pregnant women were not included. Out of 7,931 invited men and women, 3,471 choose to participate, corresponding to a response rate of 43.8%. All participants gave written informed consent before taking part in the study and the study was approved by the local ethics committee (KA20060011).

Physical measurements

When visiting the RCPH the participants underwent an extensive health examination, which has been described in detail elsewere [22], including measurement of height, weight, and waist circumference. Height was measured without shoes to the nearest cm, weight was measured in light clothing without shoes to the nearest 0.1 kg and body mass index (BMI) was calculated as kg/m^2.

Waist circumference was measured midway between the lower rib margin and the iliac crest to the nearest cm, without any pressure to the body surface and with an unstretched tape meter.

Muscular fitness was assessed by two different measures of muscle performance in the upper and the lower extremity, respectively. Hand grip strength was measured in the dominant hand using a Jamar® dynamometer [23] and following a standardized protocol. The participant was seated in upright position with the arm along the side; the arm bent 90 degrees at the elbow and the forearm and wrist in neutral position. The width of the handle was adjusted to fit the hand size. Hand grip strength was measured three times in the dominant hand with brief pauses between each measurement and the best of three measurements was considered the maximum hand grip strength. High inter-rater and test-retest reliability have previously been demonstrated for these standardized measurement procedures [24] .

Maximum single lower limb extension power (LEP) was measured using a Nottingham Leg Extensor Power Rig ® [25] as previously described [13]. The subjects were in a seated position and a single explosive lower limb extension accelerated a flywheel from rest. The final speed of the flywheel was used to calculate the average power of the lower limb extensors. The subjects familiarised themselves with the procedure by two warm up trials followed by a minimum of five and a maximum of 10 maximal trials with approximately 30 second pause between them. Participants were given verbal encouragement during measurements in order to ensure full activation and generation of maximal muscle power. The right lower limb was measured, unless the participant had a knee or ankle problem of the right lower limb, in which case the left lower limb was measured. High test-retest reliability of the LEP measurement has been reported using the Nottingham Leg Extensor Power Rig® and following the standardised measurement protocol [25].

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All measurements were carried out by the same four trained nurses and lab technicians.

Questionnaire

Information on sociodemografic variables, physical activity and functional limitation was measured by self-report questionnaire. Participants were asked to categorise their usual physical activity level during leisure time as one of the following: 1) mainly sedentary, 2) lightly active, 3) moderately active or 4) vigorously active [26]. For the analyses categories 3 and 4 were combined, because of few participants in category 4. Functional limitation was measured as being limited in climbing several flights of stairs because of one's health: (very limited, slightly limited, not limited) [27]. Education was determined as number of years school education (≤ 7 years, 8-9 years, 10 years or > 10 years) and employment status was assessed in three categories (currently employed, formerly employed, never employed).

Statistical analysis

Baseline characteristics were calculated for men and women separately and presented as means (±SD) and percentages unless otherwise stated. Data from men and women were analysed separately throughout, but we used tests for interactions to compare gender differences formally. Pearson's correlation coefficient was used to determine the correlation between HGS and LEP. Univariate associations between age group and HGS and LEP, respectively, were assessed in general linear regression models. Likewise, we explored the association of HGS and LEP, respectively, with height, waist circumference and LTPA in general linear regression analyses adjusting for age. We determined regression coefficients and regression lines of the association between age and HGS and LEP, respectively, in a linear regression model. Finally the associations between LTPA and muscular fitness were estimated in multiple linear regression models with HGS and LEP, respectively, as outcome variables and LTPA as the primary explanatory variable. Age, height and waist circumference were included as co-variates and were entered as continuous variables. Age and waist were entered in a quadratic form, whereas height was entered in a linear form. Least squares (LS) means were estimated from the regression models with a mean estimate for age, height and waist circumference for men and women separately. We used F-tests to test for interaction between age and LTPA level in all the models, in order to explore whether age-related decline in muscle strength and power differed by level of LTPA. All statistical analyses were performed using SAS, version 9.2 (SAS statistical software, version 9.2, SAS Institute, Inc.; Cary; NC, USA).

RESULTS

Among participants 55% were women (n=1,918) and mean age was 49.4±13 yrs (median 50, range: 19-72). Characteristics of the study population are presented in table 1. Among non-responders, there were significantly more men (54% men among non-responders vs.45% men among participants, p<0.001) and non-responders were markedly younger than participants (mean age 45.7±15 yrs, p< 0.001). Overall non-response was inversely correlated with age and especially in the youngest age group, participation rate was very low.

Table 1. Sociodemografic characteristics, muscle performance, body composition, physical activity level and functional limitation among men and women in the Health2006 study population (N=3,471).

Variable	**Men (N=1,553) Mean (SD)**		**Women (N=1,918) Mean (SD)**	
Age, *years*	50	(13)	49	(13)
Grip strength, *kilograms*	49.2	(8.0)	31.1	(6.1)
Lower limb extension power, *watt**	286	(92)	160	(56)
BMI, *kg/m^2*	26.5	(4.1)	25.4	(5.1)
Waist circumference, *cm*	95	(12)	83	(13)
Height, *cm*	179	(6.8)	166	(6.4)
	N	**%**	**N**	**%**
Physical activity (leisure)				
Sedentary	283	(18)	354	(18)
Moderate activity	873	(57)	1212	(64)
High/vigorous activity	378	(25)	340	(18)

School education#				
≤7 years	171	(11)	122	(6)
8-9 years	316	(21)	304	(16)
10 years	437	(28)	582	(31)
>10 years	484	(32)	668	(36)
Employment status				
Employed	1162	(76)	1358	(72)
Formerly employed	341	(22)	499	(26)
Never employed	26	(2)	30	(2)
Limited in stair-climbing				
Yes, very limited	32	(2)	50	(3)
Yes, slightly limited	174	(11)	344	(18)
No	1321	(87)	1497	(79)

*Lower limb extension power data from 438 participants only: 183 men/ 255 women.
Information on school education was missing for 19 men/33 women,
126(8%) men/209(11%) women reported 'other' school education.

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In the entire study population, 10% of participants (n=331), were left-handed. Mean handgrip strength in men and women across groups of different age, height, waist circumference and LTPA level is presented in table 2. Grip strength varied according to age and gender as expected. Maximum strength was observed midlife (40-49 years of age in men and 30-39 years of age in women), and thereafter HGS decreased with increasing age in both genders (table 2). HGS increased with increasing height, whereas there was a significant inverse relationship between HGS and waist circumference in both genders. Finally, physical activity level was positively associated with HGS in both genders.

Table 2
Mean handgrip strength in men and women of different age groups, leisure time physical activity level and body composition (N=3,471).

Variable	Handgrip strength (kilograms)			
	Men		Women	
	N	Mean (sd)	N	Mean (sd)
Age group				
19-29 years	104	50.5 (8.2)	183	32.4 (5.1)
30-39 years	218	52.7 (7.7)	280	34.4 (5.8)
40-49 years	382	52.9 (7.1)	486	33.7 (5.4)
50-59 years	383	48.9 (7.0)	476	30.2 (5.5)
60-72 years	461	44.4 (6.8)	480	26.7 (4.8)
		P<0.0001		***P<0.0001***
Height				
Women <160 / Men <175 cm	423	44.6 (6.9)	327	27.6 (5.2)
Women 160-164/ Men 175-179 cm	368	48.3 (7.0)	427	29.7 (5.4)
Women 165-170/ Men 180-185 cm	447	51.5 (7.4)	620	31.8 (6.0)
Women>170/ Men >185 cm	269	53.3 (7.9)	463	33.8 (6.0)

		P<0.0001 [a]		*P>0.0001* [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	740	49.4 (7.7)	850	31.4 (5.7)
Overweight (Women 80-88/men 94-102)	547	49.4 (8.1)	490	30.7 (6.3)
Obese (Women >88/men>102)	349	48.6 (8.3)	577	30.9 (6.4)
		P=0.005 [a]		*P=0.01* [a]
Physical activity level (Leisure time)				
Sedentary	281	48.4 (8.2)	347	30.6 (6.1)
Moderate activity	870	49.0 (7.9)	1203	30.9 (6.0)
High/vigorous activity	377	50.3 (7.7)	337	32.3 (6.0)
		P=0.0007 [a]		*P=0.0001* [a]

[a] P-values adjusted for age (age-adjusted F-test).

Measurement of LEP was implemented during the last months of the Health2006 study and hence LEP is only available in a sub group of 438 participants, 183 men and 255 women. Only 3 participants out of the 438 participants performed the test with the left lower limb. Mean LEP in men and women across groups of different age, height, waist circumference and LTPA level is presented in table 3. LEP decreased with increasing age (table 3). A large inter-individual variation in HGS and LEP was seen in all age groups. LEP increased with increasing height and unlike HGS, LEP was significantly higher in overweight and obese men and women than in participants of normal weight, as defined by waist circumference. Finally, physical activity level was not associated with LEP in these age-adjusted analyses (table 3).

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Table 3
Mean lower limb extension power in men and women of different age groups, leisure time physical activity level and body composition (N=438).

Variable	**Lower limb extension power (Watts)**			
	Men		**Women**	
	N	Mean (sd)	N	Mean (sd)
Age group				
19-29 years	16	340 (95)	25	193 (48)
30-39 years	20	309 (90)	40	183 (66)
40-49 years	45	342 (93)	54	184 (45)
50-59 years	35	274 (68)	71	155 (50)
60-72 years	67	234 (73)	65	119 (41)
		P<0.0001		*P<0.0001*
Height				
Women <160 / Men <175 cm	40	237 (72)	41	135 (50)
Women 160-164/ Men 175-179 cm	49	272 (53)	53	143 (50)

Women 165-170/ Men 180-185 cm	51	310 (88)	88	163 (53)
Women>170/ Men >185 cm	39	324 (99)	55	192 (59
		P=0.018 [a]		***P<0.0001*** [a]
Waist circumference				
Normal (Women <80 cm/men <94 cm)	83	276 (89)	109	151 (51)
Overweight (Women 80-88/men 94-102)	58	302 (88)	59	169 (55)
Obese (Women >88/men>102)	46	283 (102)	87	166 (62)
		P=0.0002 [a]		***P<0.0001*** [a]
Physical activity level (Leisure time)				
Sedentary	33	292 (108)	52	148 (57)
Moderate activity	107	284 (94)	157	160 (56)
High/vigorous activity	41	286 (75)	44	172 (55)
		P=0.76 [a]		***P=0.25*** [a]

[a] P-values adjusted for age (age-adjusted F-test).

In figure 1 the LEP values are plotted against age and a regression line illustrates the ages-related decline in LEP in men and women, respectively. Similarly, HGS is regressed against age in figure 2 and 3. Overall LEP and HGS were significantly correlated (r=0.75, p< 0.0001) (data not shown). When adjusted for age, height and waist circumference, leisure time physical activity level (LTPA) was significantly associated with HGS in men (p=0.0002) and women (p<0.0001) (data not shown). However, in the sub sample where both HGS and LEP measurements were available, LTPA was significantly associated with HGS in men only (figure 4), whereas LTPA was significantly associated with LEP in women only (figure 5). No significant interaction between age and LTPA was found neither in the analysis with HGS, nor with LEP.

DISCUSSION

The present population-based study of 19 to 72-year-old Danish men and women documented that both measures of muscle performance decreased with age as expected. The relationship between age and LEP in this study correspond very well with previous findings in small volunteer study samples of men and women [25] and in non-trained healthy men [14]. Scatter plots and regression lines illustrating the age-related decline in LEP are remarkably similar, considering the difference in study populations.

Grip strength reference values vary significantly among different populations and with the type of hand grip dynamometer used [28]. However, the reported HGS values and the age-related decline after 45 years of age correspond well with findings in a longitudinal study of +45 year-old Danish men and women, although they used a Smedley® dynamometer [29]. Interestingly, Frederiksen et al found that the decline reached a horizontal plateau in the oldest women (90+), when adjustment was made for selective drop-out by the weakest participants [29]. The oldest participants in our study were 72 years of age and accordingly we did not observe a similar horizontal plateau.

We found that waist circumference was negatively associated with HGS in both genders, whereas it was positively associated with LEP. This difference may be explained by the fact that a large body, whether fat or muscle, demands great strength and power of the lower extremities when moving about, whereas a large waist circumference not necessarily requires great strength of the upper extremities.

In the present study, HGS was significantly associated with physical activity in both men and women in the entire study sample. Previous studies in large populations of older and middle aged people have similarly documented that HGS is associated with physical activity [29,30], which in itself predicts better survival, less disability and less morbidity.

In the subsample HGS was significantly associated with physical activity in men only, while the association between physical activity level and LEP was significant in women only. However, LEP was only measured in a relatively small subsample and results should therefore be interpreted cautiously. The findings could be due to the great variation in HGS and LEP (Figures 1, 2 and 3) and thus lack of statistical power. Moreover, the measurement of LTPA was self-reported and rather crude and we were unable to distinguish between different types of LTPA. Certain types of physical activity may primarily involve lower limb power, e.g. running or bicycling, whereas arm- and handgrip strength may be involved in other types of activity, e.g. tennis or badminton. Likewise different types of occupations may require specific types of muscle work in the upper- or the lower extremities. However, we did not have detailed information on participants' occupation to explore this in the analyses.

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Frederiksen et al found that genetic effects accounted for 52% of the variation in HGS and the genetic effect was constant across age groups [30]. Likewise, the results from twin studies suggest that one-third to one-half of the individual variation in LEP among older people is accounted for by genetic effects [31]. This suggests that muscle strength and power may be results of interactions between environmental and genetic effects [9,30]. Lately birth cohort studies have reported strong associations between birth weight and HGS in midlife, suggesting that environmental influences during gestation may also affect adult grip strength [32,33] possibly through number of muscle fibres established at birth. As a result some people may have poorer 'starting values' and thus are at increased risk for muscle impairments or sarcopenia, but behaviour, in particular physical activity, also has a key role in maintaining muscle performance at an adequate level, especially in old age [34]. This emphasizes the importance of maintaining a physically active lifestyle at any age throughout life.

It seems worth noting, that overall HGS and LEP were highly correlated in the present study. This supports the use of HGS as a single, simple and inexpensive method for assessing general muscle strength and function [2].

The present study has several strengths and limitations that should be addressed. Strengths include the large population-based sample of adult men and women and the inclusion of hand grip strength and lower limb extension power measurement in the same study. The standardised measurement of muscle strength and power performed by the same four trained nurses and lab technicians is also a

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strength of the present study. A major limitation of our study is the relatively low response rate that may potentially threaten generalizability of results. Especially in the younger age groups the response rate was low. However, the age and gender distribution of grip strength and lower limb extension power values, correspond very well with findings from other studies. We consider this an indication that our results have not been severely biased by the low-participation rate. Finally, the cross sectional design of our study, does not allow for causal inferences on the association between physical activity and HGS or LEP, or on the relationship with age.

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In conclusion, we found that HGS and LEP declined with age in both genders and the LTPA level was associated with HGS in both genders, but with LEP in women only. Studies on LEP in larger study populations are needed in order to obtain reference values, which the present study does not have sufficient data to provide. Larger study samples and reference values are necessary for further exploration of the significance of muscle strength and power in relation to functional capacity, well-being and other health outcomes.

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Perspectives

As demonstrated in the present study measurement of LEP can be implemented and performed in population-based studies along with measurement of HGS. A growing amount of research-based evidence suggests that muscle strength and power play an important role, not only for sport performance, but also in relation to various prevalent chronic conditions, and disability in older people. Consequently, age-related reference values for muscle strength and power in sedentary and physically active people would be useful. This also emphasizes the need for feasible methods for collecting valid data on muscle strength and power in large population-based study samples.

Acknowledgements

Funding sources: Timber Merchant Vilhelm Bang's Foundation, The Danish Heart Foundation, The Danish Board of Health, The Danish Environmental Protection Agency, The Copenhagen County Research Foundation, Aase and Einar Danielsen's Foundation, The Velux Foundation, ALK-Abelló A/S (Hørsholm, Denmark), The Danish Scientific Research Council, and the Health Insurance Foundation (Helsefonden).

Competing interests

The authors declare that there are no competing interests.

Exclusive license

Contributorship statement

AL, TJ and MAa were responsible for conception and design of the study. NB provided advice on methodology of datacollection. NB, BT and MAa undertook analysis and interpretation of data. MAa produced first draft of the article and NB, BT, AL and TJ critically revised the manuscript. All authors approved the final version of the manuscript.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***
(Grip Strength and Leg extensor power in 19 to 72-year-old Danish men and women. The Health2006 Study.)

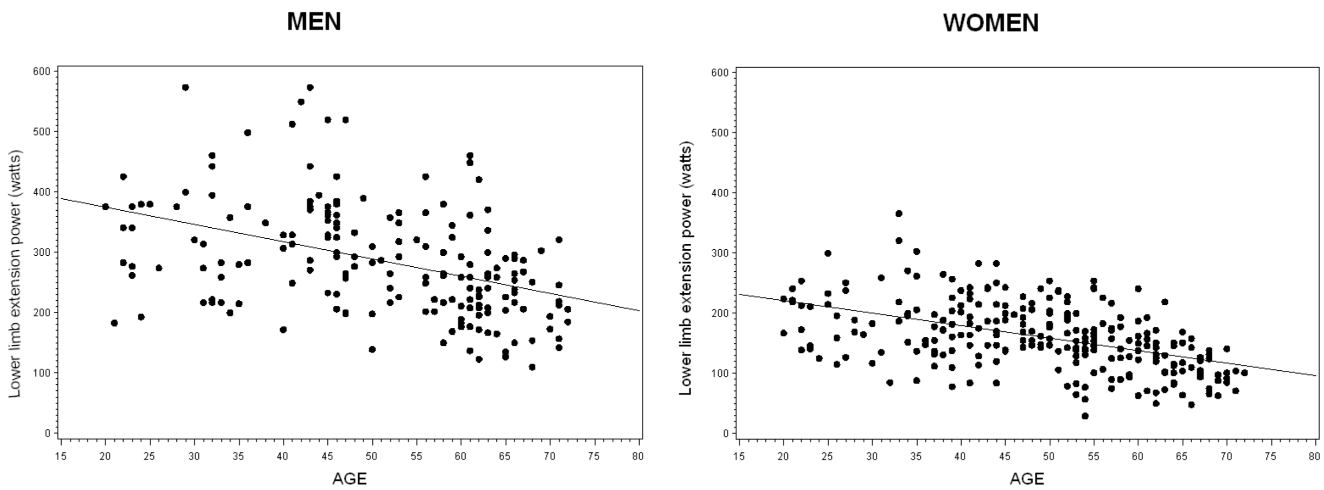
	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
	OK	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2 OK	Explain the scientific background and rationale for the investigation being reported
Objectives	3 OK	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4 OK	Present key elements of study design early in the paper
Setting	5 OK	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6 OK	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7 OK	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8* OK	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9 OK	Describe any efforts to address potential sources of bias
Study size	10 OK	Explain how the study size was arrived at
Quantitative variables	11 OK	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
	OK	(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13* OK	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14* OK	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15* OK	Report numbers of outcome events or summary measures
Main results	16 OK	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17 OK	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18 OK	Summarise key results with reference to study objectives
Limitations	19 OK	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20 OK	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21 OK	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22 OK	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Figure 1


MEN
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Lower limb extension power (watts)
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Figure 2

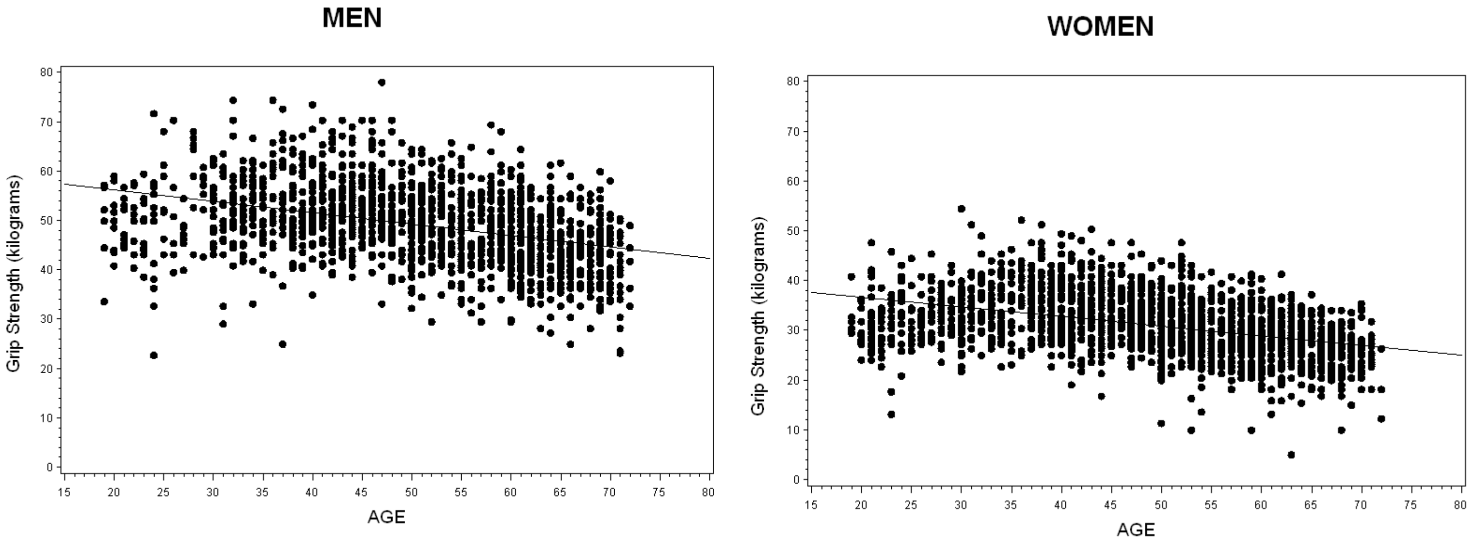


Figure 3

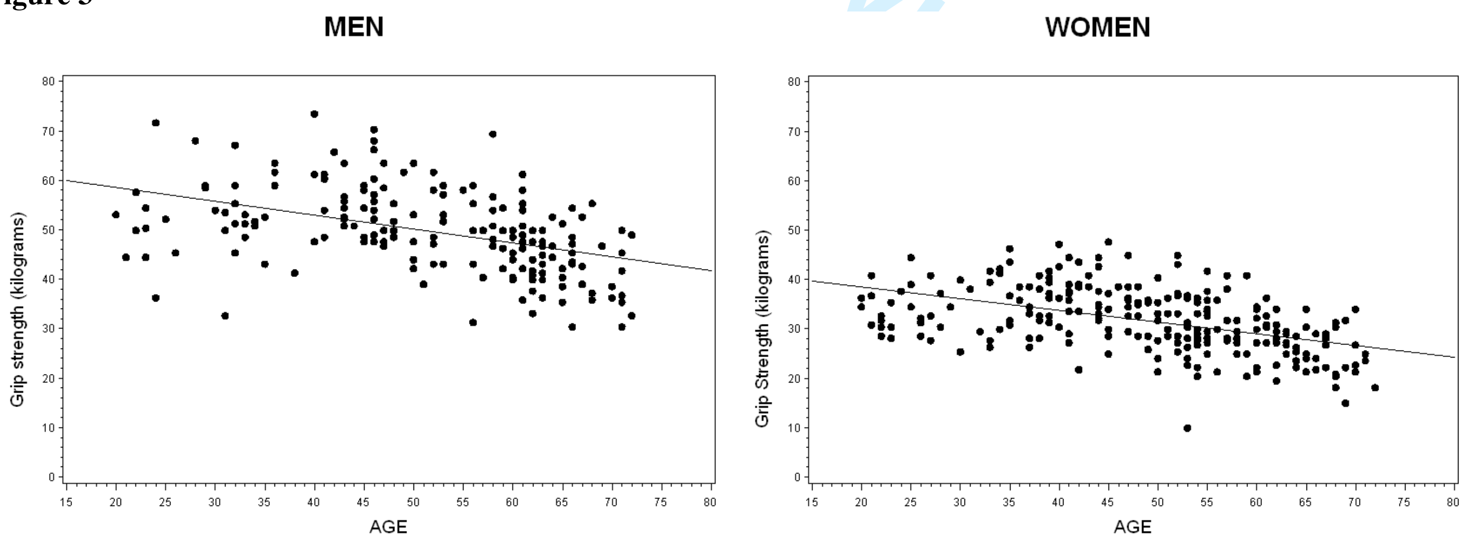
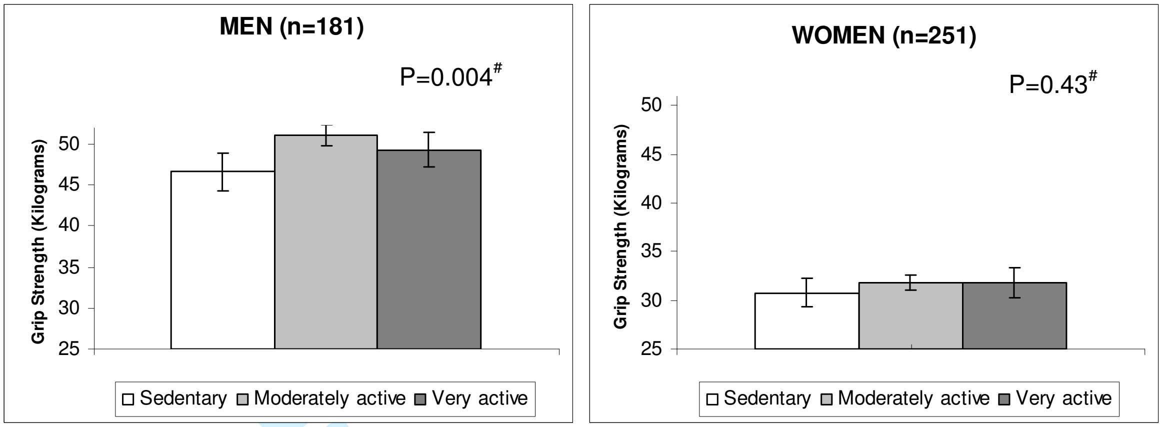
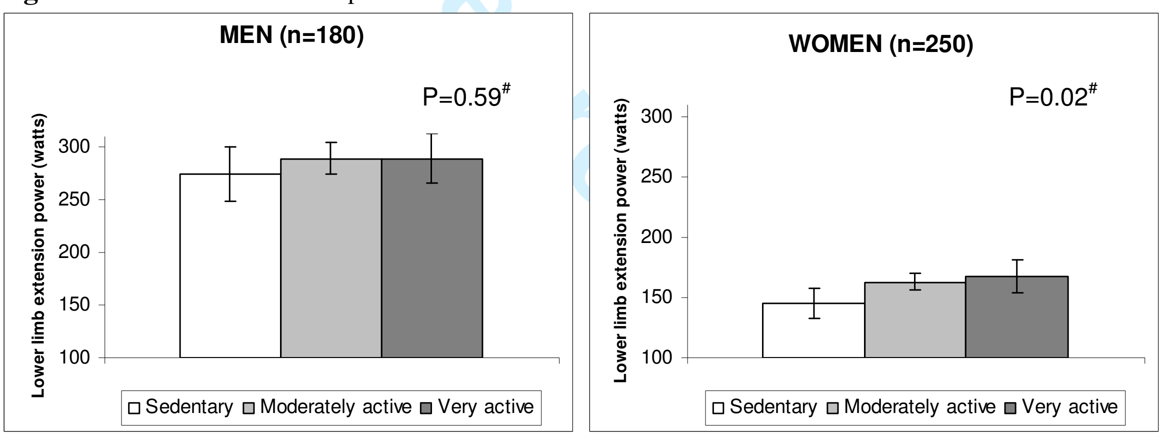


Figure 4: Handgrip strength in men and women.



#P-value for association between leisure time physical activity level and handgrip strength, adjusted for age, height and waist circumference.

Figure 5: Lower limb extension power in men and women



#P-value for association between leisure time physical activity level and leg extensor power, adjusted for age, height and waist circumference.

Figure legends

Figure 1
Lower limb extension power (watts) plotted against age in men (n=183) and women (n=255). Regression lines y= -2.8581 (age) + 431.47 and y=-2.0936 (age) + 262.93 in men and women, respectively.

Figure 2
Hand grip strength (Kg) plotted against age in men (n=1548) and women (n=1905). Regression lines y= -0.2318 (age) + 60.814 and y=-0.1934 (age) + 40.471 in men and women, respectively.

Figure 3
Hand grip strength (Kg) plotted against age in men (n=183) and women (n=255). Regression lines y=-0.2795 (age) +64.117 and y=-0.2363 (age) +43.218 in men and women, respectively.

Figure 4
Handgrip strength in men and women, respectively, across categories of leisure time physical activity, presented as least squares (LS) means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.

Figure 5
Lower limb extension power in men and women, respectively, across categories of leisure time physical activity, presented as least squares (LS) means with 95% confidence intervals. LS means are estimated in a linear regression model with a mean estimate for age, height and waist circumference.