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Hand-Grip Strength Cut-Points to Screen Older Persons at Risk for Mobility Limitation

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Abstract

Objectives—To determine optimal hand-grip strength cut-points for increased likelihood for mobility limitation among older people and to study whether these cut-points differ according to body mass index (BMI).

Design and setting—Cross-sectional analysis of data collected in the Finnish population-based Health 2000 Survey.

Participants and measurements—1 084 men and 1 562 women aged 55 years and older with complete data on anthropometry, hand-grip strength and self-reported mobility. Mobility limitation was defined as difficulties in walking 0.5-km or climbing stairs. Receiver Operating Characteristics analysis was used to estimate hand-grip strength cut-points for increased likelihood for mobility limitation.

Results—The overall hand-grip strength cut-points for increased likelihood for mobility limitation were 37 kg (sensitivity 62% and specificity 76%) for men and 21 kg (67% and 73%) for women. Hand-grip strength by BMI interaction on mobility limitation was significant among men ($p = 0.022$), while no such interaction was observed among women ($p = 0.156$). Among men, most optimal cut-offs were 33 kg (73% and 79%) for normal-weight men, 39 kg (67% and 71%) for overweight men and 40 kg (57% and 68%) for obese men. Among women, BMI-specific hand-grip strength cut-off values did not markedly increase accuracy over the overall cut-off value.

Conclusion—Hand-grip strength test is a useful tool to identify persons with increased risk for mobility limitation. Among men, the hand-grip strength cut-points for mobility increased along with BMI, while among women only one hand-grip strength threshold was identified.

Keywords

muscle strength; functional capacity; mobility; body mass index; ROC analysis

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INTRODUCTION

With increasing age, limitations in mobility-related tasks become more common (1,2). One important predictor of mobility is muscle strength (3,4). There is evidence that the association between strength and walking speed is curvilinear. A certain minimum level of strength is needed to walk at all. Thereafter, increases in strength may augment walking speed until a plateau is reached at another, higher level of strength (3,5,6). It has been shown that strength of the knee extensor muscles declines by 10-15% per decade until the age of 70-75 years thereafter accelerating to 25-40% per decade (7,8).

Leg strength measures may not be feasible in large studies or in clinical practice as they require a certain amount of participant practice and large and potentially cumbersome equipment. On the other hand, hand-grip strength is a simple, reliable and inexpensive surrogate of overall muscle strength and a valid predictor of physical disability and mobility limitation (9,10). However, the diagnostic thresholds in hand-grip strength that best identify persons at risk for mobility limitation are largely unknown (11). In the InCHIANTI study, hand-grip strength equally well identified people with poor mobility as did lower extremity muscle power and knee extension torque, and cut-points of 30 kg for men and 20 kg for women were recommended for use in clinical practice (11). However, the population used in the InCHIANTI study was distributed over a wide age range (20-102 years), included only a small proportion of heavier people, and persons with diagnosis of stroke, Parkinson's disease, peripheral neuropathy and cognitive impairment were excluded (11). Moreover, hand-grip cut-points were estimated for the whole population irrespective of the potential effect of body mass (11).

Excessive body adiposity is associated with increased risk for functional limitation (1,2).Obese persons need more muscle strength to move their body mass than normal-weight persons (12,13). Moreover, owing to their less centralized body mass, obese people are more vulnerable for balance problems and in consequence may need greater strength during walking (14). Therefore, hand-grip cut-points for increased risk for mobility limitation may need to be examined separately for normal-weight, overweight and obese persons among a representative older population. Difficulties in mobility are often the first sign of functional decline, identifying persons who could still benefit from preventive actions (15).

The purpose of this study was to determine optimal hand-grip strength cut-points for increased likelihood for mobility limitation in a representative sample of older people and to study whether these cut-points differ according to body mass index (BMI).

METHODS

Design and participants

The study is based on the Health 2000 Survey, a comprehensive nationwide health interview and examination survey carried out in Finland in 2000-2001 (16). The two-stage stratified cluster sample comprised 8 028 persons aged 30 years and older living in mainland Finland either in the community or in institutions. Participants aged 80 years or older were over-sampled (2:1) in relation to their proportion in the population. The present study targeted persons aged 55 years and older, and consisted of 3 392 persons (1 337 men and 2 055 women). Details of the study design have been described elsewhere (16).

Complete information about hand-grip strength test and mobility limitation was obtained from 2 748 persons. Persons who had a BMI under 20 kg/m^2 or who had experienced an unintentional weight loss of 10 kg or more during the past year due to undernourishment

and/or severe catabolism (n = 102) were excluded from the analyses, which reduced the final sample to 2 646 persons, 1 084 men and 1 562 women.

All the participants gave their written informed consent. The study was approved by the Ethical Committee for Epidemiology and Public Health in the Hospital District of Helsinki and Uusimaa in Finland.

Measures—The participants' weight and height were measured in light clothing without shoes. Weight to the nearest 100 g was obtained as a part of the bioimpedance analysis (InBody 3.0, Biospace Co., Seoul, South-Korea) and upright height by an unbending metal scale to the nearest 0.5 cm (Person-Check, Medizintechnik, KaWe, Kirchner & Wilhelm, Germany). Body mass index was calculated as weight divided by height squared (kg / m^2). Normal weight was defined as BMI of 20-24.9 kg/m^2, overweight as BMI of 25-29.9 kg/m^2 and obesity as BMI of 30 kg/m^2 or more (17). Body mass index is associated with walking limitation similarly as other obesity indicators such as abdominal fatness (18,19).

Prevalent chronic conditions were ascertained by the physician during the study center health examination (92% of the study population). For those who did not attend the health examination (8%), self-reported physician diagnosed chronic conditions were used in the analyses.

Hand-grip strength was used as a proxy of overall muscle strength. Measurement was performed with the dominant hand using a hand-held dynamometer (Good Strength, IGS01, Metitur Oy, Jyväskylä, Finland) with the participant in the seated position with elbow flexed at 110°. The participant was instructed to squeeze the handle as hard as possible for 3-5 seconds. The measurement was repeated after a recovery period of 30 seconds. If the two results differed by more than 10%, a third trial was carried out. The highest value of the stronger hand was used in the analyses. The reliability of the hand-grip test has been excellent with an intra-class correlation coefficient of 0.95 (20).

During the interview participants were asked: "Can you walk 0.5 km without resting?" and "Can you climb up one flight of stairs without resting?". The four response options were: without difficulty, with a little difficulty, with a lot of difficulty and unable to perform the activity. Participants were considered to have mobility limitation if they reported any difficulties in walking 500 meters or climbing one flight of stairs (21).

Statistical methods

Standard statistics were used for descriptive variables means, SDs and ranges. To examine whether hand-grip strength has a different effect on likelihood for mobility limitation among persons with different levels of BMI, the interaction between BMI and hand-grip strength on likelihood for mobility limitation was examined in an age-adjusted logistic regression model. Among men, a significant hand-grip strength by BMI interaction was found (p for interaction = 0.022), while no such interaction was observed among women (p for interaction = 0.156). To improve congruence in the results, both BMI-specific and overall hand-grip strength cut-points were estimated for men and women.

Receiver Operating Characteristics (ROC) analysis was performed to estimate optimal hand-grip strength cut-points, corresponding to the perfect scenario of 100% sensitivity and 100% specificity for increased likelihood for mobility limitation. The best cut-point for balancing the sensitivity and specificity of the test was defined as that yielding the minimal value for equation: $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$ (22). The effect of impaired hand-grip strength on likelihood for mobility limitation was examined using an age-adjusted logistic regression model.

The analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL, USA). The complexity of the sampling design was taken into account in the analyses (16). A difference was considered statistically significant when $P < 0.05$.

RESULTS

The mean age of the study population was 67 years (range 55-99) and three out of four participants had at least one physician-diagnosed chronic condition. Forty-five percent of participants had physician-diagnosed arterial hypertension, 37% low back syndrome, 24% heart disease, 24% osteoarthritis of knee or hip, 17% pulmonary disease, 13% mental disease and 10% cancer. In women, the mean (±SD) BMI was 28.1 kg/m^2 (±4.7) and hand-grip strength 23 kg (±7). For men, the corresponding values were 27.6 kg/m^2 (±4.0) and 41 kg (±11). Thirty-five percent of women and 25% of men reported difficulty in walking 0.5-km or climbing stairs and were categorized as having mobility limitation.

To estimate optimal hand-grip strength cut-points for increased risk for mobility limitation, Receiver Operating Characteristic (ROC) curves calculated. The overall hand-grip strength cut-points were 37 kg (sensitivity 62% and specificity 76%) for men and 21 kg (67% and 73%) for women. According to the ROC curve, the optimal hand-grip cut-points for increased likelihood for mobility limitation were 33 kg (73% and 79%) for normal-weight men, 39 kg (67% and 71%) for overweight men and 40 kg (57% and 68%) for obese men (figure 1). Among women, the corresponding hand-grip cut-points were almost similar across the BMI categories: 20 kg (74% and 72%), 21 kg (69% and 74%) and 23 kg (69% and 65%) (figure 2). Body mass index-specific cut-points improved the sensitivity and specificity of hand-grip test in identifying people with mobility limitation particularly in men but not so much in women (table 1).

Hand-grip strength below the BMI-specific cut-off value was associated with almost three-fold greater odds for mobility limitation in men (OR 2.73, 95% CI 1.91-3.88) and women (OR 2.73, 95% CI 2.10-3.54) compared to those with normal hand-grip strength.

DISCUSSION

Based on a representative population-based study, we determined optimal hand-grip strength cut-points for increased likelihood for mobility limitation for older men and women. Hand-grip strength cut-points increased, along with increasing BMI, from 33 kg for normal-weight men to 39 kg for overweight men and further to 40 kg for obese men. Among women, one threshold of 21 kg appeared to be sufficient at any level of BMI.

To the best of our knowledge, only one previous study has attempted to determine diagnostically relevant hand-grip strength cut-points for poor mobility (11). In the InCHIANTI study, the hand-grip cutoff values identifying persons at risk for mobility limitation were 30 kg for men and 20 kg for women (11). In turn, in our representative sample of adults aged 55 years and older comparable hand-grip cut-point was determined for older women, while our analysis suggested substantially higher cut-points than InCHIANTI for older men with various BMIs. In the InCHIANTI study, the inclusion of young adults (age ranged from 20 to 102 years), the small proportion of obese people (average BMI ranged from 23 to 28 kg/m^2) and the exclusion of persons with neurological or cognitive impairments may have underestimated the true muscle strength thresholds for impaired mobility in older age (11). In the Health 2000 Survey, the representativeness of data was improved using supplementary data collection, carried out to increase participation in the health examination, as well as inclusion of institutionalized persons (20).

In men, the most accurate hand-grip strength cut-points for mobility limitation were markedly higher in the higher BMI categories. However among women, BMI-specific cut-points provided only limited accuracy over the overall hand grip strength cut-points. There may be several explanations for this. First of all, earlier studies have shown that among obese women the correlation between hand-grip strength and leg strength, an important determinant of mobility, is lower than among normal weight women suggesting than among obese women grip strength may not be a good indicator of total body strength (23). In addition, there is some longitudinal evidence suggesting that women lose upper extremity strength at a lower rate than lower extremity strength while in men the strength decline in upper and lower extremities is more parallel (7). This suggests that there may be more women than men with poor lower extremity performance who have relatively good grip strength. Thirdly, the correlation between hand-grip strength and body fatness is weaker in women than men (24). The data presented indicate that a general, rather than a specific BMI cut point for grip strength is associated with mobility limitation among women.

While a certain minimum level of muscle strength is needed for locomotion at all, the evidence for the hypothesized curvilinear association between strength and mobility is equivocal (4-6). A linear relationship between muscle strength and mobility is likely to be present among weaker and frailer adults, while a plateau is reached at a certain higher level of strength (3,5,6). For example, improved muscle strength is associated with improved function among frail institutionalized old adults (25), while no functional benefit has been observed among stronger community-living older persons (26). Thus, hand-grip strength as a determinant of functional performance may need to be interpreted with caution among young-old community-living adults. In addition, this study showed that the discrimination value of the hand-grip test decreased among obese people. Although more research is needed before a multidimensional easy-to-use diagnostically valid risk assessment scale for disability can be constructed, this study clearly supports the inclusion of hand-grip strength as a component of such a scale.

In the current study, we decided to assess mobility difficulties based on self-reports of difficulties in walking 500 m and climbing stairs rather than performance based measures of mobility. Self-reports may better reflect the immediate experience about the day-to-day reality in mobility of the participants, while performance-based measures of function reflect motor performance distinct from the impact of contextual factors and may thus be more easily compared between different studies. Even though some criteria for walking speed exist to identify people with impaired walking (e.g. 1.2 m/s, (27)), there is no consensus yet about which cut-off values to use to best identify impaired mobility in older people. The current study focused on mobility impairment in the context of the participants' everyday lives, as performance based measures such as gait speed and hand grip strength may not reflect the impact of contextual factors that influence daily functioning.

The strengths of this study include the large sample of older adults with a representative proportion of persons aged 80+ and frail persons (ensured by over-sampling and a supplementary examination carried out at home or in an institution), and objective assessment of muscle strength and BMI. This study has its limitations. First, a hand-grip strength test was used as a proxy for leg strength, which is crucial for mobility. However, hand-grip strength has shown a moderately high correlation with the isometric strength of lower extremity muscle groups, and the age-related loss of hand-grip strength is comparable with that of knee extensor strength (11,28). Furthermore, hand-grip strength and knee extensor strength show a similar association with poor mobility (11). Second, the cross-sectional design does not permit the conclusion that impaired muscle strength precedes mobility limitation. However, there is evidence that impaired muscle strength predicts impaired function in older age (9,29). Nevertheless, the validity of estimated hand-grip cut-

points should be verified in a longitudinal study. Third, the validity of BMI as the approximate of body fatness may be compromised since changes in body composition and fat distribution with aging are not well captured by standard anthropometry (19). On the other hand, the measure of BMI is easy and quick to perform and it has associated with walking limitation similarly as other obesity indicators such as abdominal fatness (18,19).

In conclusion, in this study we determined BMI-specific hand-grip strength cut-points for increased likelihood for mobility limitation. Moreover, this population-based study showed that the need of muscle strength for mobility-related activities increases along with body mass index, particularly in men. A simple hand-grip strength test with BMI-specific cut-points appears to be a good candidate for clinical assessment of risk for mobility limitation. The grip strength cut-points determined in this study should be verified in a prospective study design.

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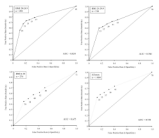

Figure 1.
Receiver Operating Characteristics (ROC) curves for identifying mobility limitation according to different cut-points for hand-grip strength (kg) in men. Area under the curve (AUC) is indicated in the figure. The AUC is significantly different from 0.5, $p < 0.001$ for all. Mobility limitation was considered if person reported any difficulties in walking 500 meters or climbing one flight of stairs.

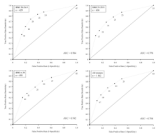

Figure 2.
Receiver Operating Characteristics (ROC) curves for identifying mobility limitation according to different cut-points for hand-grip strength (kg) in women. Area under the curve (AUC) is indicated in the figure. The AUC is significantly different from 0.5, $p < 0.001$ for all. Mobility limitation was considered if person reported any difficulties in walking 500 meters or climbing one flight of stairs.

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Table 1

Sensitivity and specificity of hand-grip test to identify mobility limitation in the different body mass index (BMI) groups using an overall and BMI-specific cut-point

	Overall cut-point			BMI-specific cut-point		
Gender	**Cut-point, kg**	**Sensitivity, %**	**Specificity, %**	**Cut-point, kg**	**Sensitivity, %**	**Specificity, %**
Men (n = 1 084)						
All	37	62	76			
BMI 20-24.9	37	79	66	33	73	79
BMI 25-29.9	37	62	78	39	67	71
BMI 30 or more	37	47	80	40	57	68
Women (n = 1 562)						
All	21	67	73			
BMI 20-24.9	21	79	68	20	74	72
BMI 25-29.9	21	69	74	21	69	74
BMI 30 or more	21	57	78	23	69	65

Note: Mobility limitation was considered if person reported any difficulties in walking 500 meters or climbing one flight of stairs.