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

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OBJECTIVES: To determine optimal hand-grip strength cut points for likelihood of mobility limitation in older people and to study whether these cut points differ according to body mass index (BMI).

DESIGN: Cross-sectional analysis of data.

SETTING: Data collected in the Finnish population-based Health 2000 Survey.

PARTICIPANTS: One thousand eighty-four men and 1,562 women aged 55 and older with complete data on anthropometry, hand-grip strength and self-reported mobility.

MEASUREMENTS: Mobility limitation was defined as difficulty walking 0.5 km or climbing stairs. Receiver operating characteristic analysis was used to estimate hand-grip strength cut points for likelihood of mobility limitation.

RESULTS: The overall hand-grip strength cut points for likelihood of mobility limitation were 37 kg (sensitivity 62%; specificity 76%) for men and 21 kg (sensitivity 67%; specificity 73%) for women. The effect of the interaction between hand-grip strength and BMI on mobility limitation was significant in men ($P = .02$), but no such interaction was observed in women ($P = .16$). In men, the most-optimal cutoff points were 33 kg (sensitivity 73%; specificity 79%) for normal-weight men, 39 kg (sensitivity 67%; specificity 71%) for overweight men, and 40 kg (sensitivity 57%; specificity 68%) for obese men. In women, BMI-specific hand-grip strength cutoff values was not markedly more accurate than the overall cutoff value.

CONCLUSION: The hand-grip strength test is a useful tool to identify persons at risk of mobility limitation. In men, hand-grip strength cut points for mobility increased with BMI, whereas in women, only one hand-grip strength threshold was identified. **J Am Geriatr Soc 58:1721–1726, 2010.**

Key words: muscle strength; functional capacity; mobility; body mass index; ROC analysis

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DOI: 10.1111/j.1532-5415.2010.03035.x

Limitations in mobility-related tasks become more common with older age.[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 10% to 15% per decade until the age of 70 to 75, thereafter accelerating to 25% to 40% per decade.[7,8]

Leg strength measures may not be feasible in large studies or in clinical practice because they require a certain amount of participant practice and large and potentially cumbersome equipment, whereas hand-grip strength is a simple, reliable, 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 Invecchiare in Chianti (InCHIANTI) Study, hand-grip strength identified people with poor mobility as well as 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 studied in the InCHIANTI Study was distributed over a wide age range (20–102) and included only a small proportion of heavier people, and persons with diagnoses 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 greater risk of functional limitation.[1,2] Obese persons need more muscle

0002-8614/10/$15.00

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 to balance problems and in consequence may need greater strength to walk.[14] Therefore, hand-grip cut points for risk of mobility limitation may need to be examined separately for normal-weight, overweight, and obese persons in 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 likelihood of 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 to 2001.[16] The two-stage stratified cluster sample comprised 8,028 persons aged 30 and older living in mainland Finland in the community or in institutions. Participants aged 80 and older were oversampled (2:1) in relation to their proportion in the population. The present study targeted persons aged 55 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 and mobility limitation was obtained from 2,748 persons. Persons who had a BMI less than 20.0 kg/m^2 or who had experienced an unintentional weight loss of 10 kg or more during the past year because of undernourishment 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 participants provided written informed consent. The Ethical Committee for Epidemiology and Public Health in the Hospital District of Helsinki and Uusimaa in Finland approved the study.

Measures

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 using an unbending metal scale to the nearest 0.5 cm (Person-Check, Medizintechnik, KaWe, Kirchner & Wilhelm, Asperg, Germany). BMI was calculated as weight divided by height squared (kg/m^2). Normal weight was defined as a BMI of 20.0 to 24.9 kg/m^2, overweight as a BMI of 25.0 to 29.9 kg/m^2, and obesity as a BMI of 30.0 kg/m^2 or more.[17] BMI is associated with walking limitation, as are other obesity indicators such as abdominal fatness.[18,19]

A physician ascertained prevalent chronic conditions 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 handheld 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 to 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 performed. The highest value of the stronger hand was used in the analyses. The reliability of the hand-grip test has been excellent, with an intraclass 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 m or climbing one flight of stairs.[21]

Statistical Methods

Standard statistics were used for descriptive variables means, standard deviations, and ranges. To examine whether hand-grip strength has a different effect on likelihood of mobility limitation in persons with different levels of BMI, the effect of the interaction between BMI and hand-grip strength on likelihood of mobility limitation was examined in an age-adjusted logistic regression model. In men, a significant hand-grip strength by BMI interaction was found (P for interaction = .02), whereas no such interaction was observed in women (P for interaction = .16). To improve congruence in the results, BMI-specific and overall hand-grip strength cut points were estimated for men and women.

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

The analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL). The complexity of the sampling design was taken into account in the analyses.[16] A difference was considered statistically significant when $P < .05$.

RESULTS

The mean age of the study population was 67 (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% psychiatric disease, and 10% cancer. In women, mean BMI was 28.1 ± 4.7 kg/m^2, and hand-grip strength was 23 ± 7 kg. For men, mean BMI was 27.6 ± 4.0 kg/m^2, and hand-grip strength was 41 ± 11 kg. Thirty-five percent of women and 25% of men reported difficulty walking 0.5 km or climbing stairs and were categorized as having mobility limitation.

Table 1. Sensitivity and Specificity of Hand-Grip Test to Identify Mobility Limitation in the Different Body Mass Index (BMI) Groups Using Overall and BMI-Specific Cut Points

	Overall			BMI Specific		
		%			%	
BMI, kg/m²	Cut Point, kg	Sensitivity	Specificity	Cut Point, kg	Sensitivity	Specificity
Men (n = 1,084)						
All	37	62	76			
20.0–24.9	37	79	66	33	73	79
25.0–29.9	37	62	78	39	67	71
≥30.0	37	47	80	40	57	68
Women (n = 1,562)						
All	21	67	73			
20.0–24.9	21	79	68	20	74	72
25.0–29.9	21	69	74	21	69	74
≥30.0	21	57	78	23	69	65

Mobility limitation was considered if a person reported any difficulties in walking 500 m or climbing one flight of stairs.

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

Hand-grip strength below the BMI-specific cutoff value was associated with almost three times greater odds of mobility limitation in men (odds ratio (OR) = 2.73, 95% confidence interval (CI) = 1.91–3.88) and women (OR = 2.73, 95% CI = 2.10–3.54) than in those with normal hand-grip strength.

DISCUSSION

Based on a representative population-based study, optimal hand-grip strength cut points for likelihood of mobility limitation were determined 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. In women, one threshold of 21 kg appeared to be sufficient at any level of BMI.

To the best of the authors' knowledge, only one previous study has attempted to determine diagnostically relevant hand-grip strength cut points for poor mobility.[11] In the InCHIANTI Study, 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 the current representative sample of adults aged 55 and older, a comparable hand-grip cut point was determined for older women, whereas the analysis suggested substantially higher cut points than InCHIANTI for older men with various BMIs. In the InCHIANTI study, the inclusion of young adults (age range 20–102), the small proportion of obese people (average BMI ranged 23–28 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, performed to increase participation in the health examination, and 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, but in women, BMI-specific cut points provided only slightly greater accuracy over the overall hand grip strength cut points. There may be several explanations for this. First, earlier studies have shown that, in obese women, the correlation between hand-grip strength and leg strength, an important determinant of mobility, is lower than in normal-weight women, suggesting that, in obese women, grip strength may not be a good indicator of total body strength.[23] Second, there is some longitudinal evidence suggesting that women lose upper extremity strength at a lower rate than lower extremity strength, whereas 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. Third, 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 in women.

Although 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 in weaker and frailer adults, whereas a plateau is reached at a certain higher level of

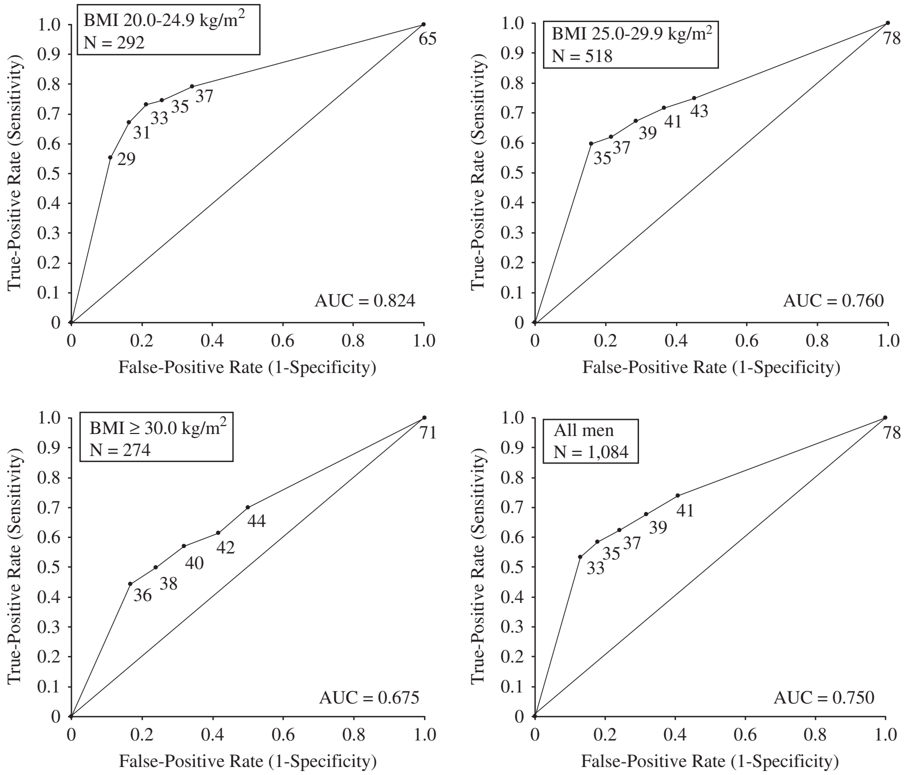

Figure 1. Receiver operating characteristic (ROC) curves for identifying mobility limitation according to different cut points for hand-grip strength (kg) in men. Area under the ROC curve (AUC) is indicated in the figure. The AUC is significantly different from 0.5; $P<.001$ for all. Mobility limitation was considered if a person reported any difficulties in walking 500 m or climbing one flight of stairs.

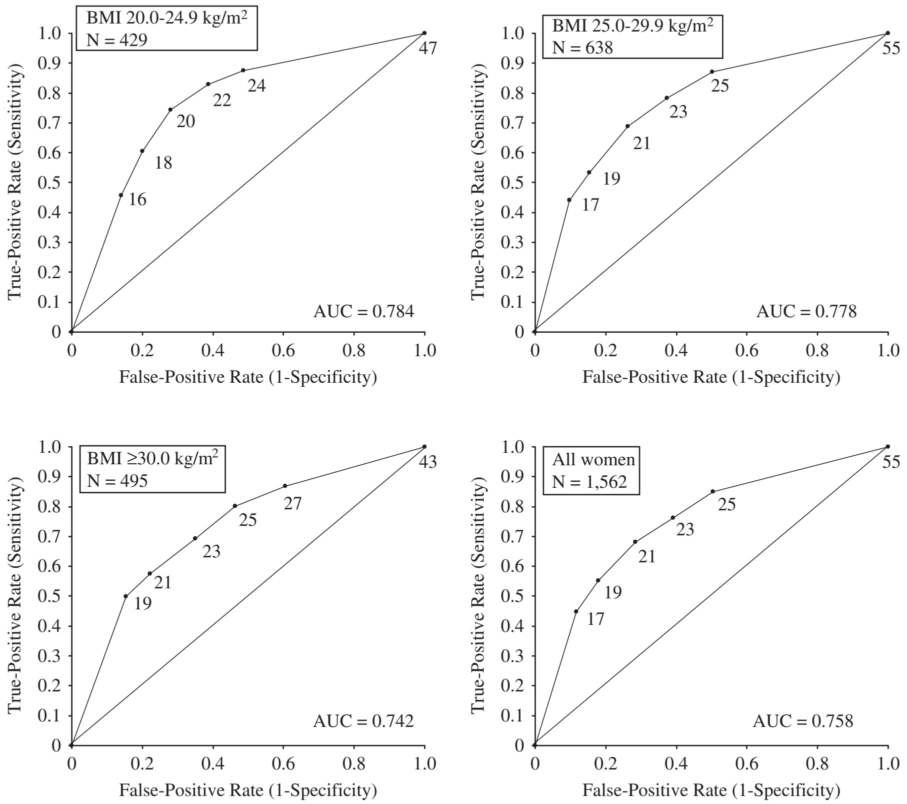

Figure 2. Receiver operating characteristic (ROC) curves for identifying mobility limitation according to different cut-points for hand-grip strength (kg) in women. Area under the ROC curve (AUC) is indicated in the figure. The AUC is significantly different from 0.5; $P<.001$ for all. Mobility limitation was considered if a person reported any difficulties in walking 500 m or climbing one flight of stairs.

strength.[3,5,6] For example, better muscle strength is associated with better function in frail institutionalized old adults,[25] whereas no functional benefit has been observed in stronger community-living older persons.[26] Thus, hand-grip strength as a determinant of functional performance may need to be interpreted with caution in young-old community-living adults. In addition, this study showed that the discrimination value of the hand-grip test decreased in 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 supports the inclusion of hand-grip strength as a component of such a scale.

In the current study, it was decided to assess mobility difficulties based on self-reports of difficulties walking 500 m and climbing stairs rather than performance-based measures of mobility. Self-reports may better reflect the immediate experience of the day-to-day reality in mobility of the participants, whereas performance-based measures of function reflect motor performance distinct from the effect 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 as to which cutoff 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, because performance-based measures such as gait speed and hand-grip strength may not reflect the effect 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 older and frail persons (ensured by over-sampling and a supplementary examination performed 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. 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 to be made, although 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 approximation of body fatness may be compromised because standard anthropometry does not capture changes in body composition and fat distribution with aging well.[19] Nevertheless, BMI is easy and quick to measure and it has been associated with walking limitation, similar to other obesity indicators such as abdominal fatness.[18,19]

In conclusion, this study determined BMI-specific hand-grip strength cut points for likelihood of mobility limitation. Moreover, this population-based study showed that the need for muscle strength for mobility-related activities increases along with BMI, 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 of mobility limitation. The grip strength cut points determined in this study should be verified in a prospective study design.

ACKNOWLEDGMENTS

Conflict of Interest: Janne Sallinen was supported by a research grant from the Ministry of Education, Finland. This research was also supported in part by the Intramural Research Program of the National Institutes of Health, National Institute on Aging, and by a grant from the Finnish Academy (125494, Sari Stenholm).

Author Contributions: Janne Sallinen: conceptualizing the ideas and took the lead in analyzing and writing the manuscript. Taina Rantanen and Sari Stenholm: conceptualizing the ideas, interpreting the findings, and reviewing drafts of the manuscript. Markku Heliövaara, Päivi Sainio, and Seppo Koskinen: planning and implementation of the Health 2000 Survey, conceptualizing the ideas, interpreting the findings, and reviewing drafts of the manuscript.

Sponsor's Role: The sponsors of this research had no role in the design, methodology, analysis of data, or preparation of the manuscript.

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