

## EXPLORING CUT-OFF VALUES FOR LARGE WAIST CIRCUMFERENCE IN OLDER ADULTS: A NEW METHODOLOGICAL APPROACH

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**Abstract:** *Background:* There is an ongoing debate about the applicability of current criteria for large waist circumference (WC) in older adults. *Objectives:* Our aim was to explore cut-off values for large WC in adults aged 70 years and older, using previously used and new methods. *Design:* Prospective cohort study. *Participants:* Data of 1049 participants of the Longitudinal Aging Study Amsterdam (LASA) (1995-1996), aged 70-88y, were used. *Measurements:* Measured BMI and WC, and self-reported mobility limitations. Results Linear regression analyses showed that the values of WC corresponding to BMI of 25kg/m<sup>2</sup> and 30kg/m<sup>2</sup> were higher than the current cut-offs. Cut-offs found in men were 97 and 110cm, whereas 88 and 98cm represented the cut-offs in women. Areas under the Receiver Operating Characteristic (ROC) curves showed that the accuracy to predict mobility limitations improved when the higher cut-offs were applied. Spline regression curves showed that the relationship of WC with mobility limitations was U-shaped in men, while in women, the risk for mobility limitations increased gradually with increasing WC. However, at the level of current cut-off values for WC the odds for mobility limitations were not increased. *Conclusion:* Based on results of extensive analyses, this study suggests that the cut-offs for large WC should be higher when applied to older adults. The association of WC with other negative health outcomes needs to be investigated to establish the final cut-points.

**Key words:** Older adults, obesity, waist circumference, cut-off values, mobility limitations.

### Introduction

Simple anthropometric measures are widely used to identify an increased risk of adverse health outcomes associated with obesity. Waist circumference (WC) is a widely used and easy accessible measure and has been suggested to be a better predictor of cardiovascular diseases and mortality than body mass index (BMI) in both younger and older adults (1, 2). Furthermore, functional disability has been shown to be better predicted by WC as compared to BMI in older adults (3, 4). Cut-off values of WC for two different action levels have been established in a sample of adults aged 25-74 years (5). Women with a WC  $\geq 80$  cm should avoid gaining further weight (action level 1), while women with a WC of  $\geq 88$  cm should try losing weight (action level 2). In men these cut-off values are 94 cm and 102 cm, respectively. These cut-off values are well established and widely applied to young and middle-aged adults (6) and have been adopted in the guidelines by the World Health Organization (WHO) for adults under the age of 70 years (7).

It has been proposed, however, that the application of these cut-off values to older adults might lead to misclassification (8, 9) due to age-related changes in body composition. Aging is accompanied by the loss of stature, loss of fat free mass, increase of fat mass and redistribution of adipose tissue (10). With the rising prevalence of obesity in older adults, the importance of the development of appropriate cut-off values of indices to assess overweight and obesity in older adults is rising congruently (6).

In the evaluation of cut-off values of anthropometric measures in adult populations, much attention was paid to the risk of (early) mortality. However, in gerontological research and by older persons themselves, outcomes like quality of life, functional limitations and disability are considered more relevant. It was decided to study the association of WC with mobility limitations in the present study because of their importance to the quality of life in older adults (11).

The aim of the present study was to explore cut-off values for large WC in adults aged 70 years and older, using previously used and new methods. First, new cut-off values for WC based on the association of WC with BMI in older persons were identified, as has been done in previous studies (12, 13). Secondly, the current and newly identified cut-off values of WC were applied and their ability to detect a high risk for mobility limitations in older adults was compared. Finally, in order to further explore optimal cut-off levels of WC in old age the association of WC with self-reported mobility limitations was assessed using spline regression curves.

### Materials and methods

#### Study sample

Data for this study were collected within the Longitudinal Aging Study Amsterdam (LASA), a prospective study on predictors and consequences of changes in autonomy and well-being in the aging population in the Netherlands. Details on the sampling and data collection procedures have been described elsewhere (14, 15). Briefly, a representative sample of older

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men and women (aged 55-85 years), stratified by age, sex, urbanicity and expected 5-year mortality, was drawn randomly from the population registers of 11 municipalities in three culturally distinct geographical regions of the Netherlands. Examinations consisted of a main and a medical interview administered in the participants' home conducted by specially trained and intensively supervised interviewers (main interview) and nurses (medical interview). In total, 3,107 subjects were enrolled in the baseline examination (1992-1993).

The sample in the present study is comprised of subjects who participated in the medical examination at the 3-year follow-up measurements (1995-1996) (n=1,509) and were 70 years or older at the time (n=1,140). Furthermore, participants with missing data on self-reported mobility limitations (n=43), BMI (n=26) and/or WC (n=77) were excluded from analyses. Therefore, 1,049 participants were included in the analyses.

### **Anthropometry**

Anthropometric measures were obtained during the medical interview. Height was measured to the nearest 0.001 m using a stadiometer. Body weight was measured to the nearest 0.1 kg with light clothing only, using a calibrated scale. BMI was calculated as measured body weight (kg) divided by measured height (m) squared. WC (cm) was measured to the nearest 0.001 m in duplicate in standing position, midway between the lower rib and the iliac crest after a normal expiration. The mean of the duplicate measurements was used in the analyses.

### **Mobility limitations**

Self-reported mobility limitations were assessed as part of the main interview, using three questions; "Can you walk up and down a staircase of 15 steps without resting?", "Can you sit down and stand up from a chair?" and "Can you walk outside during five minutes without stopping?". Response categories were "Yes, without difficulty", "Yes, with some difficulty", "Yes, with much difficulty", "Only with help" and "No, I cannot". Participants were considered to be limited in their mobility when they answered "Yes, with much difficulty" or worse on one or more of the items.

### **Descriptives**

Information on the level of education, physical activity and chronic diseases was obtained during the main interview; the assessment of smoking behavior was part of the medical interview. Participants were asked for their highest education level completed, ranging from primary to university education. Responses were categorized as low (elementary school or less), moderate, and high (higher vocational, college or university education). Physical activity in the previous two weeks was assessed using the validated LASA Physical Activity Questionnaire (LAPAQ) (16). Using the LAPAQ, a face-to-face interview, information on the frequency and duration of walking outdoors, bicycling, light and heavy household activities and a maximum of two different sport activities was obtained. Total physical activity was expressed in minutes per

day. The presence of chronic diseases was assessed by self-report. Chronic diseases included were obstructive lung disease, heart disease, arthritis, peripheral atherosclerosis, diabetes mellitus, stroke and cancer (17). Smoking behavior was based on self-report (never, former, current).

### **Statistical analyses**

#### *Identifying WC cut-off values using an established method*

All analyses were performed separately for men and women. To identify new cut-off values in a similar way as has been done in previous studies (12, 13), sex-specific linear regression analyses were performed with BMI as the independent and WC as the dependent variable. Based on the regression lines, values of WC corresponding to the WHO cut-off scores of 25 and 30 kg/m<sup>2</sup> for BMI were computed.

#### *Comparison of current and newly identified WC cut-off values*

To compare the strength of the associations of both WC categorization methods, univariate logistic regression analyses were performed. WC categorized according to the currently used cut-off values and according to the newly identified cut-off values were used as the independent variable and mobility limitations as the dependent variable. Odds ratios (OR) with 95% confidence intervals (CI) were presented.

In addition, the accuracy to predict mobility limitations using the current cut-off values and the newly identified cut-off values was compared. Receiver Operating Characteristic (ROC) curves were fitted using univariate logistic regression models to assess the predictive accuracy of the categorizations based on both the currently used and the newly identified WC cut-off values. The categorization with the best predictive accuracy would have the largest area under the curve (AUC).

The Akaike's Information Criterion (AIC) of both categorical univariate logistic regression models was assessed to explore whether the description of the association between WC and mobility limitations improved. The AIC is a statistic that estimates the mean squared error of a model while adjusting for the number of determinants included in that model. The model that fits best would have the lowest AIC. Models with a (more than) 10 points lower AIC are considered to describe the data substantially better, whereas a 4-7 points lower AIC indicates a slightly better fit of a model (18).

#### *Estimating the shape of the association using spline regression analyses*

Univariate spline regression analyses were used to estimate the shape of the association between WC and self-reported mobility limitations. Because of the ongoing debate on the validity of BMI cut-off values in older adults, cut-off values of WC derived by their correspondence to the BMI cut-off values should be carefully interpreted. To assess the appropriateness of the categorization according to these WC cut-off values, spline regression curves of the association with a negative health

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outcome were drawn. Splines are piecewise polynomial functions that are constrained to join smoothly at points called knots. Spline regression models provide better insight in the dose-response relationship as compared to analyses using categorized data, especially when the sample size does not allow the use of narrow categories. All data points are used to estimate the risk at each level of exposure, as opposed to step functions using categorical models which assume the risk to be constant within categories. Linear as well as restricted cubic spline models were tested with 3 to 5 knots. Linear splines estimate linear functions between the knots, while restricted cubic splines estimate cubic functions. Restricted cubic splines are restricted to be linear in the end regions in order to provide more conservative estimates of the association where data is often sparse (19).

Based on the AIC, the best fitting spline regression models were identified (20). Firstly, the number of knots that provided the best estimates of the association between WC and self-reported mobility limitations was determined. As default, knots were located symmetrically: 3 knots on the 10, 50 and 90<sup>th</sup> percentiles; 4 knots on the 5, 35, 65 and 95<sup>th</sup> percentiles and 5 knots on the 5, 25, 50, 75 and 95<sup>th</sup> percentiles. Secondly, the optimal position of the inner knot(s) was identified based on the AIC by moving the inner knot(s) five units of WC (cm) up and down. Both outer knots were kept constant because their position was at extremes of the data. In plotting the spline regression curves odds ratios were presented, the median WC was set to be the reference value. SPSS (version 15.0 for Windows) was used to study the association of WC with BMI using linear and logistic regression models. All splines regression analyses and AIC calculations were performed using R version 2.6.2.

### Results

The characteristics of the study sample are shown in Table 1. Mobility limitations were reported by 15.3% of the men in the study sample, whereas 31.9% of the women reported mobility limitations. According to current cut-off values, 40.7% of the men and 68.9% of the women had a large WC (action level 2).

Regression analyses of the association between BMI and WC showed higher values of WC corresponding to the BMI cut-off values of 25 kg/m<sup>2</sup> and 30 kg/m<sup>2</sup> in our sample of older adults compared to the currently used cut-off values. In older men, a WC of 96.8 cm corresponded to a BMI of 25 kg/m<sup>2</sup>, while 110.0 cm corresponded to a BMI of 30 kg/m<sup>2</sup> (Figure 1a). In older women, these corresponding values of WC were 88.0 cm and 98.1 cm, respectively (Figure 1b). BMI explained 73% of the variance in WC, in both men and women.

The OR (95% CI) for mobility limitations in men having a high risk WC (≥102 cm) was 1.12 (0.62, 2.04), as compared with men in the lowest risk category of WC (<94 cm), using current cut-off values. Using the newly identified cut-off values, men having a high risk WC (≥110 cm) had an odds

ratio of 2.44 (1.23, 4.81) as compared with men in the lowest risk category of WC (<97 cm). In women the odds ratios were 2.03 (1.13, 3.67) using the current cut-off value (≥88 cm) and 2.27 (1.45, 3.55) using the newly identified (≥98 cm) cut-off value.

**Table 1**

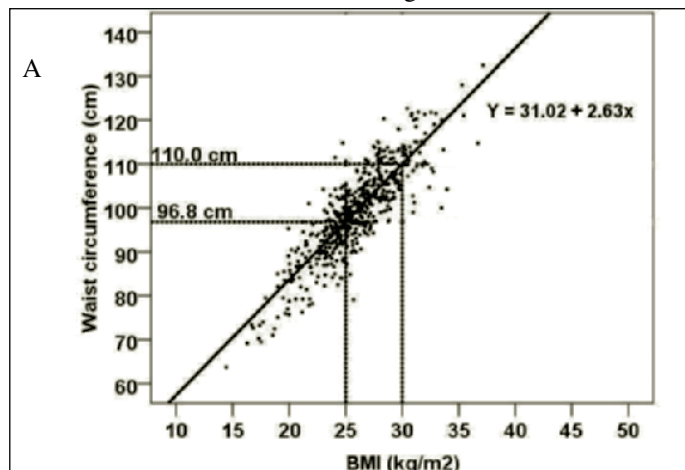
Characteristics of the study sample, Longitudinal Aging Study Amsterdam (LASA), The Netherlands, 1995/'96, by sex

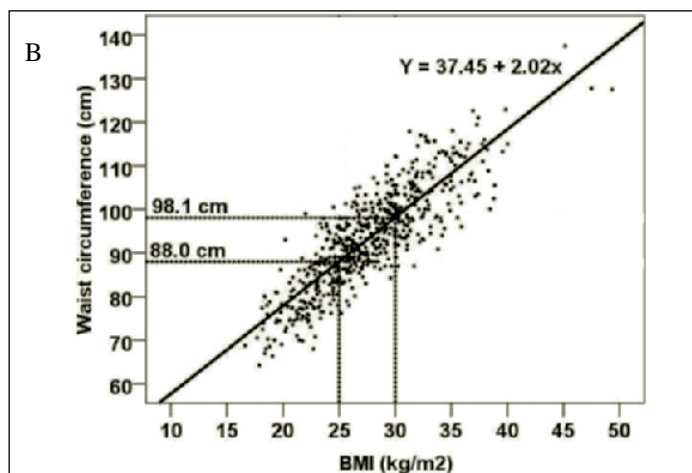
	Men (n=503)	Women (n=546)
Age (y) (SD)	78.5 (5.1)	78.3 (5.3)
BMI (kg/m <sup>2</sup> ) (SD)	25.9 (3.3)	27.6 (4.9)
Waist circumference (cm) (SD)	99.1 (10.3)	93.4 (11.5)
Mobility limitation (%)	15.3	31.9
Stair climbing (%)	11.5	27.5
Chair standing (%)	2.0	7.1
Walking outside (%)	8.5	14.6
Chronic diseases		
Obstructive lung disease (%)	17.7	13.2
Heart disease (%)	34.6	23.1
Arthritis (%)	32.6	57.1
Atherosclerosis (%)	12.1	11.5
Diabetes (%)	7.3	9.7
Stroke (%)	9.9	8.2
Cancer (%)	10.9	11.7
Physical activity (min/day) (SD)	118 (89)	160 (91)
Smoking (%)		
Current	25.0	11.0
Former	65.4	26.2
Never	9.3	62.8
Education (%)		
Low (elementary school or less)	38.6	54.4
Medium	44.9	37.1
High (higher vocational, college or university education)	16.3	8.3

Abbreviations: SD, standard deviation.

**Figure 1**

Relationship between BMI and waist circumference in men (A) and women (B) aged 70 years and older. The newly identified cut-off values were based on their correspondence with a BMI of 25 and 30 kg/m<sup>2</sup>





Based on the area under the ROC curve (AUC), the power to predict mobility limitations was higher when the newly identified cut-off values were used (Table 2). The AIC's of a categorical model were 436.43 in men and in 683.08 women using the current cut-off values. When using the newly identified cut-off values these AIC's decreased to 430.12 and 670.48, indicating that the categorizations according to the newly identified cut-off values describe the data better than the currently used cut-off values.

**Table 2**

Current and newly identified cut-off values of waist circumference in men and women aged 70 years and over and their accuracy of predicting mobility limitations in the Longitudinal Aging Study Amsterdam (LASA), The Netherlands, 1995-1996

Men	Action level		AUC	CI
	I	II		
Current cut-off values <sup>a</sup>	94 cm	102 cm	0.51	0.44, 0.58
Newly identified cut-off values <sup>b</sup>	97 cm	110 cm	0.57	0.50, 0.64
<b>Women</b>				
Current cut-off values <sup>a</sup>	80 cm	88 cm	0.55	0.50, 0.60
Newly identified cut-off values <sup>b</sup>	88 cm	98 cm	0.59	0.54, 0.64

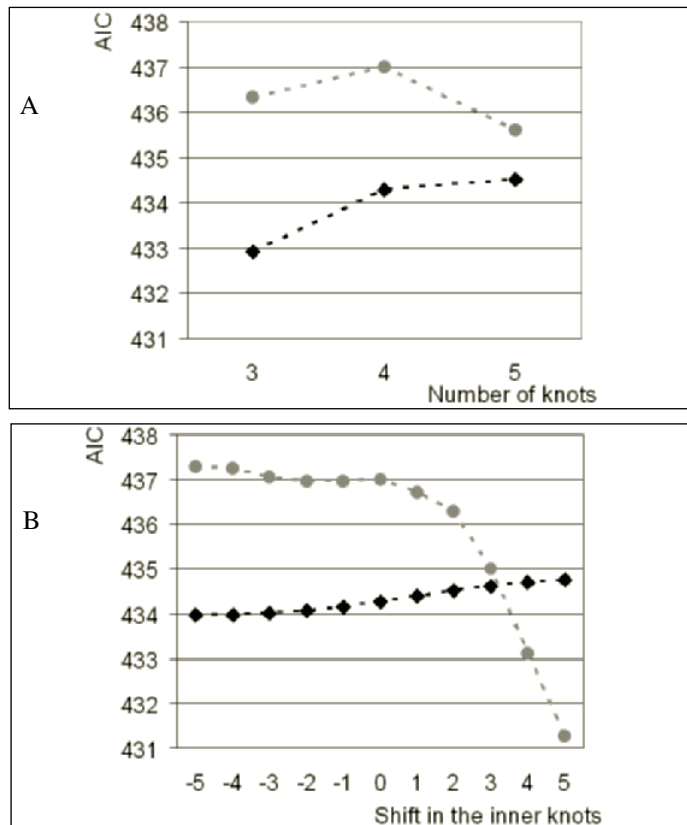
Abbreviations: AUC, area under the curve; CI, confidence interval. a. Currently used cut-off values according to the World Health Organization as developed by Lean et al. (3). b. The newly identified cut-off value based on the regression analyses between body mass index and waist circumference in older persons.

In a next step we investigated the association using univariate spline regression analyses. The model fit of linear splines and restricted cubic splines with 3, 4 or 5 knots, as assessed by AIC, did not substantially differ, neither was the best fitting model consistent over the sexes (Figure 2A and 3A). The current method classifies WC in three different categories, using two cut-off values. Therefore, to maximize comparability with this categorization, it was decided to use spline models with 4 knots in both men and women, with the two inner knots dividing the association in three parts. Restricted cubic splines were chosen over linear splines in order to show a more

cautious estimate of the association in the end regions. By moving the knots five positions up and down, the AIC did not substantially improve (Figure 2B and 3B). Therefore, it was decided to keep the standard symmetrical locations of the knots.

**Figure 2**

Akaike's information criterions (AIC) of the spline regression models tested in men



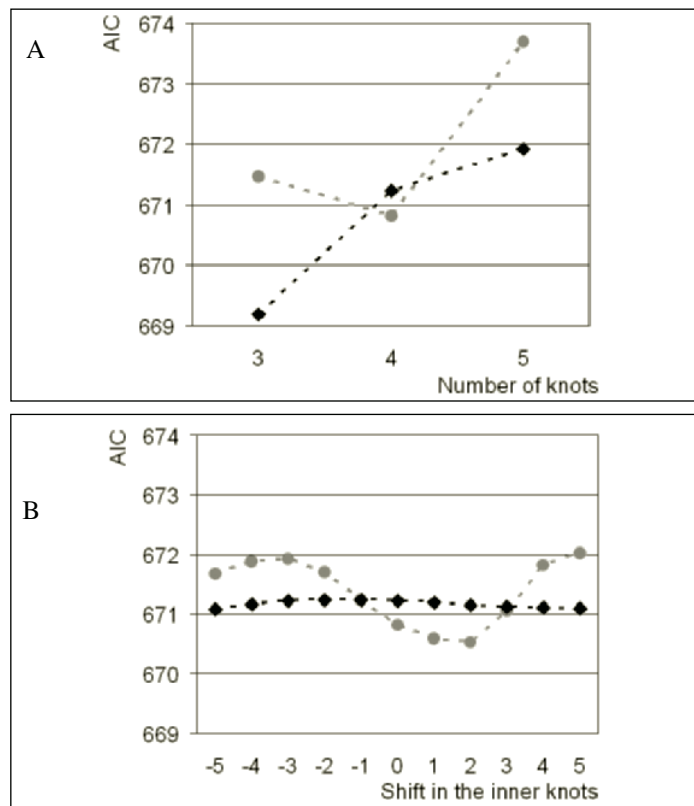
◆ AIC of the restricted cubic spline models; • AIC of the linear spline models; A AIC of linear as well as restricted cubic spline regression models between waist circumference and mobility limitations in men aged 70 years and older using 3, 4 and 5 knots. The model that fits best would have the lowest AIC. Models with a (more than) 10 points lower AIC are considered to describe the data substantially better, whereas a 4-7 points lower AIC indicates a slightly better fit of a model; B AIC of linear as well as restricted cubic spline models between waist circumference and mobility limitations in men aged 70 years and older with 4 knots during fine tuning. The optimal position of the inner knots was identified based on the AIC by shifting the inner knots five units of WC (cm) up and down from their standard position on the 5, 35, 65 and 95th percentile of WC.

Figure 4 shows the shape of the univariate association between WC and mobility limitations in men A and women B. In men, the plot showed increasing odds for mobility limitations in the lowest as well as in the highest range of WC. The OR was lowest at a WC of 93.7 cm, which is (near) the current cut-off value for action level 1. At the level of current action level 2 the odds for mobility limitations were still barely increased. The plot of the association in women shows increasing odds for mobility limitation with increasing WC. At the current WC cut-off levels the odds for mobility limitations were only moderately increased.

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**Figure 3**

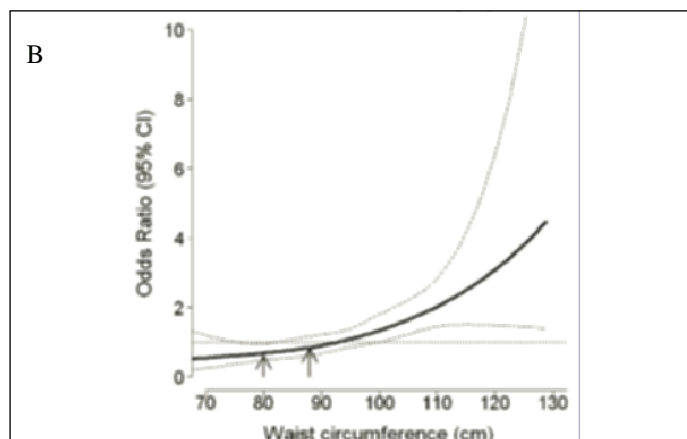
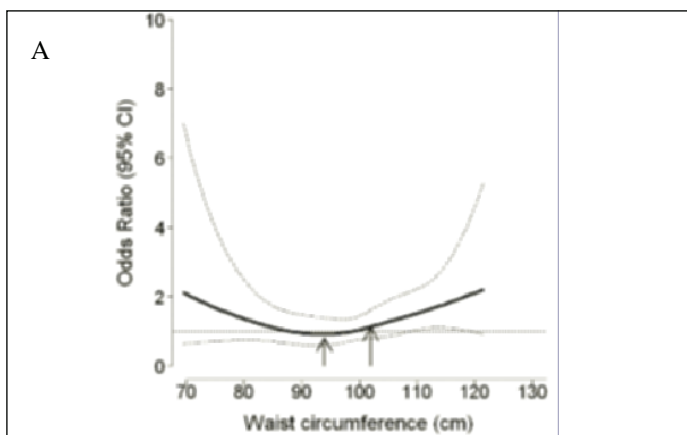
Akaike's information criterions (AIC) of the spline regression models tested in women



◆ AIC of the restricted cubic spline models; • AIC of the linear spline models. A AIC of linear as well as restricted cubic spline regression models between waist circumference and mobility limitations in women aged 70 years and older using 3, 4 and 5 knots. The model that fits best would have the lowest AIC. Models with a (more than) 10 points lower AIC are considered to describe the data substantially better, whereas a 4-7 points lower AIC indicates a slightly better fit of a model. B AIC of linear as well as restricted cubic spline models between waist circumference and mobility limitations in women aged 70 years and older with 4 knots during fine tuning. The optimal position of the inner knots was identified based on the AIC by shifting the inner knots five units of WC (cm) up and down from their standard position on the 5, 35, 65 and 95th percentile of WC.

**Figure 4**

Association between waist circumference and mobility limitations in men A and women B aged 70 years and older



**Discussion**

Our data from a sample of adults aged 70 years and older showed that higher values of WC correspond to a BMI of 25 and 30 kg/m<sup>2</sup> compared to the currently used WC cut-off values. Furthermore, the strength of the association with mobility limitations, the predictive accuracy, as well as the model fit were shown to improve when applying the higher newly identified cut-off values in both men and women. Spline regression curves also confirmed that the WC values at which the odds for mobility limitations are increased are higher as compared to currently used WC cut-off values.

Only few studies have addressed potential cut-off values of WC in older persons. To our knowledge, lower cut-off values of WC in older adults as compared to younger adults were proposed by two studies. Lemieux et al. (21) argued that older adults have a smaller WC at the same amount of visceral adipose tissue. In another study (9), it was concluded that the sensitivity specificity trade-off in identifying a high BMI using WC would be more optimal when lower cut-off values were applied in older adults. A major limitation of these previous studies was that WC was related to other anthropometric measures but not to any (negative) health outcome.

Higher cut-off values in older adults as compared to younger adults have been suggested by previous studies using the relationship between BMI and WC similarly to the use in the present study. Okosun et al. (12) showed that the WC corresponding to BMI of 25 kg/m<sup>2</sup> and 30 kg/m<sup>2</sup> were highest in the oldest men and women (aged 60 years and over) in three different race groups. The effect of age on the relationship between BMI and WC was also studied in a Chinese population (13). It was concluded that the WC corresponding to BMI cut-off values was higher in older men and women (mean age 80 years) compared to younger men and women (mean age 45 years). Using a similar approach, our study confirms the results of these previous studies, suggesting that higher WC cut-off values should be used in older persons.

However, the justification of cut-off values of WC identified based on the association of WC with (an)other anthropometric

measure(s), is highly dependent on the validity of cut-off values of the anthropometric measure used. In adult populations, the BMI cut-off values have been well validated, but in older adults, the validity of the BMI cut-off values is still subject of discussion (6, 22). Therefore, explorations of proper WC cut-off values in older populations should be based on the associated risk for relevant negative health outcomes, rather than on the association with BMI.

The use of spline regression curves is a good method to study the continuous association between WC and mobility limitations using all available data. Therefore, the spline regression curves add important insight into a potential dose-response relationship, especially when the data do not allow the use of narrow categories. Potential thresholds can be identified in the spline regression curve which serves as guidance to the appropriateness of categorization of WC. The spline regression curves in the present study did not show a clear, single threshold of WC for the risk for mobility limitations. However, they clearly indicated that a categorization by WC according to current cut-off values would be of limited value to assess the risk of mobility limitations.

In addition to the extensive analysis techniques that were used in the present study, another novel aspect of the present study is that mobility limitations were investigated in relation to WC cut-off values. Mobility limitations were chosen as the main health outcome in the present study because of their high relevance for quality of life in old age (11). In order to assess the power to predict mobility limitations solely by someone's WC, univariate analyses were performed in the current study. The strong independent association between obesity and mobility limitations has been reported in several previous studies (23-25). Furthermore, previous studies have shown that mobility limitations increase the risk of subsequent hospitalization and mortality (26, 27). A limitation of the current study is the fact that cross-sectional data were used. Using longitudinal data, stronger evidence may be provided for the predictive power of WC for negative health outcomes.

In conclusion, our results based on extensive analysis techniques suggest that WC cut-off values should be shifted upwards in older adults. In order to develop cut-off values that can be applied in clinical practice, a complete picture of the health risks associated with a large WC is needed. Therefore, the associations of WC with additional health outcomes significant to older adults need to be explored in future studies by using similar analysis techniques.

*Funding information:* This work was supported by the Ministry of Health, Welfare, and Sport of the Netherlands. They largely funded data collection in the context of the Longitudinal Aging Study Amsterdam (LASA), on which the current study is based.

*Financial disclosure:* None of the authors had any financial interest or support for this paper.

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