

## SUMMARY

## **Obesity in an aging population**

Worldwide, populations get older and an increasing percentage of the population is aged over 65 years. Also, the prevalence of overweight and obesity is increasing in all age groups. The highest prevalence of overweight is reported among persons around the age of 65 years. As a consequence of the combination of the demographic changes and the obesity epidemic, the absolute number of overweight and obese older adults has increased dramatically over the last decades. However, the largest part of scientific research on overweight and obesity has been conducted in adult populations, including developing methods used for assessing overweight and the investigation of consequences of overweight.

Overweight and obesity are typically assessed using anthropometric indicators. The measures most commonly used are the body mass index (BMI) and waist circumference. Cut-off values of BMI included in the guidelines of the World Health Organization (WHO) are  $\geq 25$  kg/m<sup>2</sup> for overweight and  $\geq 30$  kg/m<sup>2</sup> for obesity. The same guideline includes sex-specific cut-off values for waist circumference; 102 cm for men and 88 cm for women. However, age-related changes in body composition and health parameters and their mutual relationships yield the consequence that (categorized) anthropometric indicators need to be carefully interpreted in older adults. Misclassification of health risks in older adults has been reported when applying the cut-off values which are established in adult populations.

The studies included in this thesis add to the knowledge on the consequences of overweight and obesity in old age. Furthermore, we describe the process of developing new criteria for overweight in old age.

## **Main findings**

A cumulative effect of overweight over the life course on functional limitations at young old age is described in Chapter 2. We found that being overweight since young adult age (25 years), as assessed by self-reported weight, increased the risk for the (development of) functional limitations at young old age (55-65 years).

While a 30% increased risk for functional limitations was found in participants who were only currently overweight, participants who were overweight since the age of 25 years or 40 years had approximately a 100% higher risk as compared to older adults who were never overweight. A longer overweight history also increased the risk for an increase of self-reported functional limitations after six years of follow-up from the age of 55-65 years. Both cross-sectionally and prospectively, these associations were strongly attenuated after adjustment for current BMI. The mean current BMI was higher with longer overweight history and the attenuation of the associations suggests that this largely explained the higher risk for functional limitations. However, a high current BMI in old age could not have been attained without either a high BMI at young adult age or a large increase of BMI over the adult life course.

In Chapter 3, we showed that pain is highly prevalent among older adults and that overweight in older adults is strongly associated with both the prevalence and the incidence of pain. The associations with BMI as well as waist circumference were assessed and found to be equally strong. Our study was one of the first to report the longitudinal association between overweight and pain. By doing so, we added to the understanding of the direction of the causal relationship between overweight and pain. While being overweight led to the development of pain, pain did not add to the development of overweight. A statistically significant two- to threefold higher odds for the development of pain in 6 years of follow-up in the highest as compared to the lowest quartiles of BMI and waist circumference was found.

In Chapter 4 through 6 we described the study of the appropriateness of the use of current standards for the assessment of overweight in older adults. Subsequently, the process of developing new standards was illustrated. First, we decided to explore the usability of known and accepted anthropometric measures. The use of these anthropometric indices and their cut-off values in older adults was shown to lead to misclassification of health risks. However, the same anthropometric indices might be capable in appropriately detecting health risks in older adults when using age-specific cut-off values. Based on the strong association of waist circumference with various health outcomes in older adults

described in literature, we decided to focus on developing new cut-off values of this anthropometric measure for older adults.

We explored several methods on their applicability to define new cut-off values in Chapter 4. We started off by studying the linear association of waist circumference with BMI in a representative population of Dutch older adults aged  $\geq 70$  years. We identified the values of waist circumference corresponding to the BMI cut-off values of  $25 \text{ kg/m}^2$  and  $30 \text{ kg/m}^2$  in men and women separately. According to the analyses results, the cut-off values of waist circumference needed to be shifted upwards in both men and women.

In a second step of analyses we tested the newly defined cut-off values by applying them to categorize waist circumference and studying the association with mobility limitations. The associations between the categories of waist circumference defined by the newly identified cut-off values and mobility limitations were stronger as compared to the association of the categories according to the WHO cut-off values and mobility limitations. Furthermore, the sensitivity-specificity trade-off and the quality of the regression models improved when applying the newly identified cut-off values.

Finally, for assessing the applicability of the new cut-off values in stratifying health risks, spline regression curves were drawn to visualize the shape of the dose-response relationship between waist circumference and mobility limitations. Clearly, the risk for mobility limitations increased at higher levels of waist circumference as compared to current cut-off values, but threshold values on which the risk for mobility limitations started to rise (more steeply) were absent in the spline regression curves. The spline regression curves confirmed the appropriateness of an upward shift of the cut-off values of waist circumference in older men and women as compared to the WHO cut-off values.

In Chapter 5, we went on assessing the dose-response relationships between waist circumference and several important health outcomes in older adults. We selected pain, mobility limitations, urinary incontinence, knee osteoarthritis, cardiovascular diseases (CVD) and diabetes as outcomes of interest because of their association with a high waist circumference and/or their known importance to the quality of life of older adults. The shapes of the associations with CVD, diabetes and knee osteoarthritis were almost linear and no thresholds could be

detected. By visually inspecting the non-linear curves of the associations between waist circumference and pain, mobility limitations and urinary incontinence, cut-off values were proposed. A cut-off value of 109 cm was selected in men and a cut-off value of 98 cm was selected in women. In women, the quality of the statistical models improved with the application of higher cut-off values in accordance to the results of the visual inspection of the shapes of the associations. A shift of one centimeter to 99 cm was shown to further improve the performance of the models. In men, cut-off values between 100 cm and 106 cm were shown to perform equally well, but applying cut-off values above 106 cm deteriorated the models. Therefore, cut-off values of 106 cm in men and 99 cm in women were considered optimal.

In Chapter 6 we aimed to assess the validity of the new cut-off values for waist circumference in association with health outcomes in data of four cohort studies of older men and women from four different countries. The associations of waist circumference with the same health outcomes as studied in chapter 5 were assessed. Shifting the cut-off value upwards from the WHO cut-off value of 88 cm to 99 cm in women consistently improved the classification of health problems with 5-10% in association with the majority of health outcomes in all cohorts. In men, no significant improvements or deteriorations of the classification of health risks were found when shifting the cut-off value upwards from the WHO cut-off value of 102 cm to 106 cm. It can be concluded that in men aged 70 years and older, there is no need for a shift upwards of the waist circumference cut-off value, as compared to the cut-off used in adult populations. A shift of the waist circumference cut-off value from 88 cm to 99 cm in women aged 70 years and older is found to improve the classification of health complications.

### **Conclusions**

The studies in this thesis further the understanding of the detrimental effects of overweight in old age. When studying possible applicable cut-off values of high-risk waist circumference in old age, advanced methods were applied. By carefully modeling the dose-response relationship between waist circumference and several parameters of health, important insides in overweight-related health

## SUMMARY

---

problems in old age were gained. Although health problems may not have been increased at the level of the current WHO cut-off values for waist circumference, the increased prevalence of health complications at higher levels of waist circumference in old age was evidently shown. Future research should address whether or not the improved cut-off value of 99 cm in women predicts future health risks and is able to select older women in need for weight management interventions and to monitor their effects.