This article discusses the consequences of sarcopenia in older persons. The focus is on three specific consequences: (1) functional status, (2) falls, and (3) mortality. The described relationship between sarcopenia and these outcomes is based on the results of epidemiologic studies in large cohorts of older men and women.

The original definition of sarcopenia refers to the age-related loss of muscle mass. However, it is important to realize that as yet very limited data have been published on repeated measures of muscle mass in older persons to establish that the age-related change is muscle mass and to subsequently relate this change to negative health outcomes. Therefore, this overview is mainly based on both cross-sectional and longitudinal, epidemiologic studies using a single assessment of muscle mass. In these studies, the health outcomes of older persons with a lower muscle mass have been compared with those of older persons with a higher muscle mass. In other studies the term “sarcopenia” was used to define older persons with a low muscle mass. These sarcopenic persons were then contrasted with older persons with a normal muscle mass to investigate potential differences in various health outcomes.

In the scientific literature the term “sarcopenia” has also been used in a much broader sense, for example to indicate the age-related loss of muscle strength or the presence of poor muscle strength in older persons. In this article, the term “dynapenia” is used to describe this process. Sarcopenia and dynapenia are distinct processes with different pathophysiology. Although the two processes may occur simultaneously in some individuals, they do not necessarily overlap. The use of these...
two different terms allows a clear distinction between the consequences of low muscle mass and those of low muscle strength.

**SARCOPENIA AND FUNCTIONAL STATUS**

Several cross-sectional, observational studies have related sarcopenia to measures of functional status, such as mobility performance, self-reported functional limitations, and disability.\(^2\) In the New Mexico Elder Health Survey, appendicular skeletal muscle mass (ASMM) was estimated using a prediction equation that included weight, height, hip circumference, grip strength, and gender. Sarcopenia was defined as having a ratio of ASMM/height\(^2\) less than 7.26 for men and less than 5.45 for women. Sarcopenia was significantly associated with a threefold to fourfold increased risk of self-reported physical disability in both men and women.\(^2\) Sarcopenia measured as skeletal muscle mass index (SMI = the ratio of skeletal muscle mass by bioelectrical impedance divided by total body mass) in men and women enrolled in the National Health and Nutrition Examination Survey (NHANES) study was associated with an increased need of assistance with personal care or handling routine daily chores.\(^3\) These findings were confirmed in an Italian study among 167 community-dwelling women aged 67 to 78 years. After adjustment for age and several chronic diseases, women with an SMI less than or equal to two times the standard deviation (SD) of a young reference group (120 premenopausal healthy women) had a 3.8 times increased risk of having functional limitations compared with women with normal SMI values.\(^4\) In the Health, Aging, and Body Composition (Health ABC) study, older adults in the lowest skeletal muscle quintile (adjusted for height and fat mass) were 80% to 90% more likely to have mobility impairment than older persons in the highest quintile.\(^5\) In another study using data from the Health ABC study, smaller mid-thigh muscle cross-sectional area, assessed by CT scans, was significantly associated with poorer performance on a 6-m walk test and a repeated chair-stands test in older men and women.\(^6\)

In contrast to the previously mentioned studies, other epidemiologic studies failed to observe an association between sarcopenia and functional status. These studies include older\(^7\) and more recent\(^8\) cross-sectional studies and several prospective studies.\(^12,13\) In the Framingham Heart Study, total body and lower-extremity muscle mass by dual-energy x-ray absorptiometry (DXA) were not associated with disability using a nine-item questionnaire among 753 men and women aged 72 to 95 years.\(^7\) In a large, community-based cohort of 1655 men and women aged 55 years and older, lean mass as estimated from bioelectrical impedance measurements was not associated with self-reported functional limitations after adjustment for age, fat mass, height, chronic disease, physical activity, and smoking.\(^8\) After adjustment, higher lean mass was associated with faster, objectively assessed walking speed in men but not in women.

More recent cross-sectional studies confirm these findings. In 109 men and women aged 60 years and older, ASMM as assessed by DXA was not associated with performance test scores or self-reported functional limitations.\(^9\) Using data from the EPIDOS study including women aged 75 years and older, the association between sarcopenia and limitations performing activities of daily living was investigated.\(^10\) Women were classified as sarcopenic if their relative ASMM corrected for height was less than or equal to two SDs below the mean of a reference population from the Rosetta Study, which included healthy Americans aged 18 to 40 years.\(^14\) Sarcopenia was not associated with having difficulty in performing daily activities, such as walking and climbing stairs.\(^10\) Data from the InChianti Study indicated that sarcopenia of the calf muscle, assessed using CT, had little influence on walking speed, a powerful predictor of incident disability and frailty in older persons.\(^11\)
Two prospective studies consistently reported a lack of association between low muscle mass and incident functional limitations or disability. In the Cardiovascular Health Study, fat-free mass as estimated from bioelectrical impedance measurements was not associated with 3-year incidence of self-reported disability based on 17 tasks among 1489 men and 1785 women aged 65 to 100 years. Another prospective study reported that lower thigh muscle cross-sectional area was not associated with the incidence of mobility limitations during a 2.5-year follow-up among well-functioning men and women aged 70 to 79 years after adjustment for muscle strength and fat infiltration.

To our knowledge, only one small study examined changes in body composition and their relationship with incidence of self-reported disability in older persons. Ninety-seven women and 62 men aged 71.4 (SD 2.2) years and 71.6 (SD 2.2) years, respectively, underwent DXA determinations and reported their disability level at baseline and after 2 and 5.5 years of follow-up. After adjustment for gender and chronic diseases, persons who lost ASMM (cut-off at median change in muscle mass) had a 2.15-fold increased risk of having a worsening disability compared with persons who remained stable. For decline in leg skeletal muscle mass the increased risk was 2.53-fold.

Regarding the relationship between sarcopenia and functional status, it can be concluded that although early, cross-sectional studies reported significant associations, most recent studies and prospective studies found weak or no associations between sarcopenia and functional status. These studies do not, however, provide information on whether loss of skeletal muscle mass in old age is detrimental to functional status. Only one study suggested that loss of muscle mass may parallel a decline in self-reported disability level and more research is warranted to confirm these findings.

**DYNAPENIA AND FUNCTIONAL STATUS**

Poor muscle strength is a well-known determinant of poor functional status based on observational studies. A recent cross-sectional study using data from NHANES showed that leg strength was associated with impaired functional status. The association remained significant after adjustment for age, sex, alcohol intake, smoking status, chronic diseases, and physical activity level. In a longitudinal study in which older men and women from the Health ABC study were followed for 2.5 years, low knee extensor strength was associated with a higher risk of mobility limitations. After adjustment for age, race, study site, body height, and total body fat mass, men and women in the lowest quartile of muscle strength were 2.64 (95% confidence interval [CI], 1.83–3.80) and 2.15 (95% CI, 1.61–2.87) times more likely to develop mobility limitations compared with those in the highest quartile of muscle strength. After additional adjustment for other potential confounders, including lifestyle and health factors, the association remained statistically significant. Although this study also observed an association between mid-thigh muscle area and increased risk of mobility limitations, this risk was not independent of poor muscle strength. Other observational studies investigating both low muscle mass and poor muscle strength in relationship to functional status in older persons consistently showed a strong association between muscle strength and function, with no or much weaker associations between muscle mass and function. Thus, at least in the wide range of study samples of community-dwelling older persons used in these studies, the function of the muscle seems more relevant in relationship to functional status in old age compared with muscle size.
The life history of muscle strength may also impact functional status in old age. A study of Rantanen and colleagues\textsuperscript{20} showed that grip strength assessed in a large sample of healthy Japanese-American men aged 45 to 68 years was highly predictive of functional limitations and disability 25 years later when all participants were at least 70 years of age. These results suggest that high muscle strength throughout life may contribute to the prevention of disability later in life.

It can be concluded that dynapenia is strongly associated with functional status. Although initial studies reported the importance of muscle mass, new data are beginning to shift the paradigm toward muscle weakness as a major risk factor for mobility limitations and disability in old age.

**SARCOPENIA AND FALLS**

Sarcopenia is frequently mentioned as an important risk factor for falls in older persons. However, there are not many epidemiologic studies that specifically have addressed the association between skeletal muscle mass in old age and the risk of falls. The results of two studies are presented next, although in both studies the fall data were collected retrospectively; at the time of the muscle mass assessment the falls that occurred in the previous 12 months were reported. Among 883 elderly Hispanic and non-Hispanic white men and women with mean age 74 years living in New Mexico (the New Mexico Elder Health Survey) the association between sarcopenia and reported falls in the past year was studied.\textsuperscript{2} ASMM was estimated using a prediction equation that included weight, height, hip circumference, grip strength, and gender. Sarcopenia was defined as having a ratio of ASMM/height\textsuperscript{2} less than 7.26 for men and less than 5.45 for women. Twenty-two percent of the men and 31\% of the women reported a fall in the past year. After adjustment for age, ethnicity, obesity, comorbidity, and alcohol intake, the odds ratio (OR) for falls was statistically significant in men at 2.58 (95\% CI, 1.42–4.73) but not in women at 1.28 (95\% CI, 0.60–2.67). The second study investigating the association between muscle mass and falls was conducted in 796 men aged 50 to 85 years of age who participated in the MINOS study. Relative appendicular muscle mass (RASM = ASMM by DXA divided by body height\textsuperscript{2.3}) was related to self-reported falls in the past 12 months.\textsuperscript{21} Of the men, 25.4\% reported a fall in the past year. After adjustment for age, body weight, serum free testosterone and vitamin D concentration, and chronic diseases, the OR per SD lower RASM was 1.31 (95\% CI, 1.03–1.65). Men in the highest tertile of RASM (>7.31 kg/m\textsuperscript{2.3}) were less likely to report a fall in the previous year compared with those in the lowest quartile of RASM (<6.32 kg/m\textsuperscript{2.3}; OR 0.66 [95\% CI, 0.44–0.99]).

In contrast to the extensive research focusing on the relationship between low muscle mass and functional status, only two studies have examined the relationship between low muscle mass and falls. In both studies muscle mass was assessed after the falls were experienced. It therefore cannot be excluded that muscle mass has been negatively affected by the experience of falls (eg, caused by an increased fear of falling and related decreased physical activity level) or by the potential consequences of the fall (injuries). Although both studies reported that low muscle mass was associated with more reported falls, reverse causation cannot be excluded from these studies and the results should be interpreted carefully. No prospective studies have investigated the relationship between loss of muscle mass and fall risk in older persons.

**DYNAPENIA AND FALLS**

Compared with the association between sarcopenia and fall risk, the association between dynapenia and fall risk has been studied more extensively. A meta-analysis
was conducted based on 30 cohort studies that were published between January 1985 and March 2002, met the inclusion criteria, and investigated the relationship between baseline measurements of muscle strength and prospective data on fall occurrence. At least 50% of the study sample had to be age 65 years or older. Of this selection, 13 independent studies were available for data extraction. Knee extension, ankle dorsiflexion, and chair stands were the most common measures used to assess lower-extremity weakness. The combined OR for the association between lower-extremity weakness and any fall based on six individual studies was 1.76 (95% CI, 51.31–2.37). The combined estimated OR for the association between lower-extremity weakness and recurrent falls was even higher (3.06 [95% CI, 1.86–5.04]) based on six different studies. For injurious falls, the meta-analysis showed an estimated OR of 1.52 (95% CI, 51.05–2.20) for the relationship with lower-extremity muscle weakness. However, this estimate was only based on two studies. Upper-extremity weakness was assessed by grip strength or manual muscle testing in most studies. The ORs for upper-extremity weakness were statistically significant but of a lower magnitude than the ORs for lower-extremity weakness. For example, for recurrent falls, the meta-analysis showed an estimated OR of 1.41 (1.25–1.59) for upper-extremity weakness.

Since the publication of this meta-analysis, new studies have been published examining the association between muscle strength and falls. Several studies developed a prediction model to predict future fall risk and identified poor muscle strength as an important predictor in the model. For example, during a follow-up period of 36 weeks, 33% of 311 community-dwelling persons aged 70 years and older reported 197 falls at 6-weekly telephone calls. Poor grip strength (≤12 kg for women and ≤22 kg for men) assessed at baseline was a predictor of recurrent falls in the final risk model (OR 3.1 [95% CI, 1.5–6.6]), which also included previous falls, abnormal postural sway, and depressive symptoms. A second example is a Dutch study in which fall data were prospectively collected during a 3-year follow-up in 1365 community-dwelling men and women aged 65 years and older participating in the Longitudinal Aging Study Amsterdam. The incidence of recurrent falls during follow-up was 24.9% in women and 24.4% in men. Men and women with a grip strength in the lowest 20th percentile (≤32 kg for women and ≤56 kg for men) were more likely to experience greater than or equal to two falls during a 6-month period compared with those with higher grip strength (OR 2.32; 95% CI, 1.71–3.13). Poor grip strength remained a statistically significant predictor of recurrent falling in a risk profile also including previous falling, dizziness, functional limitations, low body weight, high education, high alcohol consumption, fear of falling, and cats or dogs in the household. In this model, the OR of the association between poor grip strength and recurrent falls was 1.74 (95% CI, 1.19–2.54). A final example is the Women’s Health and Aging Study, in which an algorithm was developed to predict any future fall among 1002 community-dwelling women aged 65 years old or older with disability. The best performing algorithm included previous falls, and in selected subpopulations balance problems, walking speed, body mass index, and knee extensor strength. These three examples clearly show the ability of poor muscle strength to predict future fall risk in older men and women, supporting the important role of dynapenia in falls of older persons.

To our knowledge, no observational studies have investigated the association between change in muscle strength and future risk of falls. However, there is clear evidence from intervention studies that exercise decreases the risk of future falls in older men and women. However, the specific contribution of increased muscle strength caused by the exercise intervention in preventing falls independent of other
positive effects of the exercise intervention (e.g., on balance, sway, or depressive symptoms) has not yet been established.

SARCOPENIA AND MORTALITY

Several epidemiologic studies used anthropometrically assessed muscle mass, usually a measure of mid-arm muscle circumference or mid-arm muscle area as calculated from mid-arm circumference and skinfold thickness, to investigate the association between low muscle mass and mortality. A study among 1396 men and women aged 70 years and older showed that after adjustment for baseline age, gender, marital status, smoking, self-rated health, ability to conduct activities of daily living, comorbidity, cognition performance, and presence of depression, low arm muscle area (≤21.4 cm² for men and ≤21.6 cm² for women) was associated with 8-year mortality risk (hazard ratio [HR] 1.95; 95% CI, 1.25–2.00). The relationship between arm muscle area (square centimeter) and mortality was also studied in 957 community-dwelling Japanese men and women aged 65 to 102 years. During the 2-year follow-up 236 persons died. In multivariate analyses, adjusting for age, gender, functional status, comorbidity status, and triceps skinfold thickness as a measure of body fatness, low arm muscle area (<23.5 cm²) was associated with a higher mortality risk (HR 2.03; 95% CI, 1.36–3.02) compared with high arm muscle area (≥33.4 cm²). Mortality risk was highest for those persons who had a low arm muscle and a low triceps skinfold thickness (HR 3.83; 95% CI, 1.97–7.47). Among 4107 British men aged 60 to 79 years low mid-arm muscle circumference was associated with increased risk of mortality during a 6-year follow-up. Men in the highest quartile of mid-arm muscle circumference (≥27.94 cm) were less likely to die (HR 0.71; 95% CI, 0.56–0.88) compared with men in the lowest quartile of muscle circumference (<24.91 cm) after adjustment for age, social class, physical activity, alcohol intake, and smoking. This association persisted after additional adjustment for lung function, serum albumin, weight loss, height loss, self-reported poor health, preexisting cancer, diabetes, and cardiovascular disease; the HR for men in the highest muscle circumference quartile was 0.73 (95% CI, 0.58–0.92). Finally, an association between arm muscle area and 24-year mortality was also observed among 452 men aged 65 years and older. After adjustment for age, height, smoking, social class, physical activity, chronic disease, caloric intake, reported weight loss, percent body fat (from skinfolds), and grip strength, the HR per SD higher arm muscle area was 0.86 (95% CI, 0.76–0.98) in men. In the 348 women the HR was 0.94 (95% CI, 0.81–1.08) and not statistically significant. These large studies using upper arm muscle circumference (centimeter) or area (square centimeter) as a rather crude measure of muscle mass quite consistently suggest that low upper body muscle mass is associated with an increased risk of mortality in older men and women.

Other studies investigating the relationship between muscle mass and mortality have been using total body fat-free mass as an indicator of skeletal muscle mass. Similar to the studies using anthropometrically assessed muscle mass, these studies should be carefully interpreted because they did not directly measure muscle mass. Fat-free mass also includes other lean tissues including visceral lean mass. The results of these studies are less consistent compared with the studies using anthropometric muscle measurements. Lower levels of fat-free mass as estimated from potassium 40 counting were associated with an increased mortality risk among 787 men aged 60 years and older who were followed for 22 years. In a large study among 57,053 Danish men and women 50 to 64 years old, low fat-free mass (estimated from bioelectrical impedance) divided by body height squared was associated with increased
6-year mortality risk independent of fat mass.\textsuperscript{32} In contrast, in the Study of Osteoporotic Fractures quintiles of fat-free mass estimated from bioelectrical impedance measurements were not associated with mortality during an 8-year follow-up in 8029 women aged 65 years and older.\textsuperscript{33} The HR of mortality was 1.16 (95\% CI, 0.92–1.45) for women in the highest quintile of fat-free mass versus those in the lowest quintile of fat-free mass, after adjustment for age, smoking, self-reported health, grip strength, nonthiazide diuretic use, and femoral neck bone mineral density. When restricting the analyses to never-smokers only, the HR for low fat-free mass increased to 1.32 but was still not statistically significant. Similarly, quintiles of fat-free mass as assessed by underwater weighing or the sum of seven skinfolds were not associated with 12-year mortality (\(P\) for trend 0.91) among 2603 men and women aged 60 to 100 years after adjustment for age, gender, examination year, smoking status, abnormal exercise electrocardiogram responses, baseline health conditions, and cardiorespiratory fitness.\textsuperscript{34} These findings are in line with those of Wannamethee and colleagues\textsuperscript{29} who showed that quartiles of the fat-free mass index, as estimated from bioelectrical impedance measurements, were not associated with 6-year mortality in 4107 British men aged 60 to 79 years (\(P\) for trend 0.42).

More recently, large epidemiologic studies have used accurate body composition methodology to assess skeletal muscle mass in older men and women. CT has been used to assess regional muscle cross-sectional area, usually at the mid-thigh level. DXA has also been used to measure ASMM or skeletal muscle mass only of the legs. The studies investigating the association between accurately assessed muscle mass and mortality are reviewed in detail because they provide the strongest evidence on the relationship between muscle mass and mortality. Data from the Health, Aging and Body composition study among 2292 well-functioning older men and women aged 70 to 79 years living in the Memphis and Pittsburgh regions of the United States were used to study the association between muscle mass and mortality.\textsuperscript{35} The mean follow-up was 4.9 years during which 286 persons (12.5\%) died. Both leg skeletal muscle mass from DXA and mid-thigh muscle cross-sectional area from CT were used. Moreover, many potential confounders were considered including age; race; chronic diseases; smoking status; level of physical activity; mid-thigh fat area by CT or total body fat mass by DXA; height; and markers of inflammation, including interleukin-6, C-reactive protein, and tumor necrosis factor-\(\alpha\). In men and women, leg skeletal muscle mass expressed per SD (1.8 kg) was not associated with mortality. Mid-thigh muscle area was associated with mortality risk in men. Per SD (28.1 cm\(^2\)) lower muscle area the HR was 1.26 (95\% CI, 1.02–1.55). However, in women no association was observed (HR 0.94; 95\% CI, 0.66–1.35). In a publication some years later, data from 934 Italian men and women aged 65 years or older, participants of the InChianti study who were followed for 6 years, were used to study the association between muscle mass and mortality.\textsuperscript{11} Muscle cross-sectional area (square centimeter) of the calf was measured using peripheral quantitative CT. Although unadjusted analyses showed a lower mortality risk per SD higher muscle area (HR 0.75; 95\% CI, 0.66–0.86), this association disappeared after considering potential confounders. After adjusting for height, weight, age, gender, study site, education, cognitive status, depressive symptoms, physical activity, and chronic disease, the HR increased to 0.86 (95\% CI, 0.68–1.08) and was no longer statistically significant. Muscle density (milligram per cubic centimeter) of the calf muscle was also not related to mortality risk. These findings have been recently confirmed by a French study among 715 men aged 50 to 85 years.\textsuperscript{36} During the 10 years of follow-up 137 men (19.2\%) died. Baseline ASMM was not associated with mortality after adjustment for potential confounding. Men in the lowest quartile of muscle mass were not more likely to die...
during the follow-up period (OR 1.08; 99% CI, 0.54–2.15) compared with those in the highest quartile. These three studies consistently show that having a low skeletal muscle mass, based on a single assessment of muscle mass, is not a determinant of mortality in older men and women.

To our knowledge only two prospective studies have examined the change in muscle mass over time in older persons and its relationship with mortality risk. In the Framingham Heart Study, 2-year change in total body fat-free mass was estimated using repeated bioelectrical impedance measurements in 398 men and women aged 72 to 92 years at baseline.37 The fat-free mass index was calculated by dividing fat-free mass (kilogram) by body height (meter) squared and served as a proxy of muscle mass. Greater loss of fat-free mass was associated with increased mortality in the subsequent 2 years, during which 55 persons (13.8%) died. After adjustment for gender, body mass index, smoking, being bedridden, C-reactive protein level, arthritis, cardiovascular disease, diabetes, and levels of different cytokines, the HR per unit decline in fat-free mass index was 1.9 (95% CI, 1.3–2.6). Researchers from the MINOS study recently investigated the change in accurately assessed skeletal muscle mass by DXA in relationship to mortality.36 These unique analyses were conducted among 715 older men who were followed for 7.5 years with DXA measurements conducted every 18 months. The rate of loss in total body lean soft tissue per year was not different between those who died during the 10-year mortality follow-up and those who survived (P = .24). However, the rate of loss of ASMM per year was faster in those who died (~315.5 [SD 364.3] g/y) compared with those who survived (~182.5 [SD 190.9] g/y; P<.0001). When expressed as the relative rate of loss per year the difference was statistically significant (~1.43% vs ~0.78%; P<.0001). After adjustment for potential confounders, including age, body mass index, height, smoking, educational level, occupational physical activity, frailty index, prevalent ischemic heart disease, diabetes, aortic calcification score, 17β-estradiol, and serum 25-hydroxycholecalciferol, one SD decrease in ASMM was associated with a higher mortality risk (HR 1.61; 99% CI, 1.28–2.01). Even after additional adjustment for weight loss in the multivariate models, men in the lowest tertile of ASMM loss (losing more than 264 g/y) had a higher mortality risk (HR 2.27; 99% CI, 1.19–4.33) compared with men in the highest tertile of loss (losing <114 g/y). This final analysis suggests that accelerated muscle mass loss, independent of weight loss, might be a strong determinant of mortality in older persons.

Although observational studies that have used rather crude assessments of skeletal muscle mass based on anthropometry suggest that low muscle mass might be associated with increased mortality risk, studies using a single measurement of accurately assessed muscle mass consistently show that low muscle mass is not a determinant of mortality in older men and women. However, there is some recent evidence that accelerated loss of skeletal muscle mass, irrespective of weight loss, might be a risk factor for early mortality in older persons.

DYNAPENIA AND MORTALITY

With regard to the association between measures of muscle strength and mortality risk in older persons, the research findings have been far more consistent compared with the association between measures of muscle mass and mortality. Many studies have been published showing an inverse association between grip strength, frequently used as a proxy of overall body strength in old age, and mortality. For example, in men aged 65 years and older, poor grip strength was a strong determinant of 25-year mortality risk independent of physical activity and muscle mass as assessed
by 24-hour creatinine excretion. Among 919 moderately to severely disabled women aged 65 to 101 years, those in the lowest tertile of grip strength were twice more likely to die from cardiovascular disease (RR 2.17; 95% CI, 1.26–3.73) compared with those in the highest tertile after adjusting for age, race, body height, and weight. Similar results were observed for all-cause mortality and further adjustments for multiple diseases, physical inactivity, smoking, interleukin-6, C-reactive protein, serum albumin, unintentional weight loss, and depressive symptoms did not materially attenuate the risk estimates, suggesting that grip strength may influence mortality through mechanisms other than those leading from disease to muscle impairment. More recent data from 2292 well-functioning older men and women aged 70 to 79 years who were followed for a mean of 4.9 years showed an increased mortality risk per SD (10.7 kg) lower grip strength in men (HR 1.36; 95% CI, 1.13–1.64) and in women (HR 1.84; 95% CI, 1.28–2.65). After adjustment for age, race, comorbidities, smoking status, level of physical activity, body composition as assessed by DXA, height, and several markers of inflammation these estimates were only slightly attenuated: HR 1.36 (95% CI, 1.10–1.60) for men and 1.67 (95% CI, 1.08–2.58) for women. An association between lower grip strength and 24-year mortality was observed among 452 men aged 65 years and older. After adjustment for age, height, smoking, social class, physical activity, chronic disease, caloric intake, reported weight loss, arm muscle area, and percent body fat from skinfolds, the mortality HR per SD in grip strength was 0.81 (95% CI, 0.70–0.94). In women, however, the association was not statistically significant (HR 1.10; 95% CI, 0.86–1.40). Lower grip strength in men was also associated with cancer mortality, cardiovascular mortality, and respiratory mortality.

Other studies have extended these findings with other measures of muscle strength. In 960 older persons with a mean age of 87 years a higher extremity muscle strength, a composite strength measure of nine muscle groups ranging from pinch strength to ankle dorsiflexion, was associated with a lower risk of mortality during a follow-up of 2.2 years (HR 0.56; 95% CI, 0.38–0.83) after adjustment for age, gender, education, and body mass index. In the Health ABC study, a 48-Nm lower isokinetic quadriceps strength was associated with an increased risk of mortality in men and women (HR 1.51 [95% CI, 1.28–1.79] and HR 1.65 [95% CI, 1.19–2.30], respectively). After full adjustment these HRs changed to 1.45 (95% CI, 1.21–1.74) in men and 1.47 (95% CI, 1.02–2.14) in women and remained statistically significant. Additional adjustment for mid-thigh muscle cross-sectional area by CT or leg lean mass by CT only slightly attenuated these estimates. Finally, an association between muscle power and mortality has been reported. Arm-cranking power was stronger associated with 40-year mortality than isometric arm strength (a composite measure of eight arm strength measures and grip strength) among 993 middle-aged men. The relative risk for mortality per 100 kg/m/min of arm-cranking power was 0.987 (95% CI, 0.978–0.996) after adjustment for age, body mass index, height, physical activity, and creatinine excretion and remained statistically significant even after additional adjustment for isometric arm strength.

Similar to the studies on the relationship between loss of muscle mass and mortality, only a few studies have investigated the association of age-related change in muscle strength over time with mortality risk. In men aged 60 years and older, higher grip strength was more strongly associated with 40-year mortality risk than the rate of grip strength loss over a period of 25 years. This association persisted when muscle mass, as estimated by 24-hour creatinine excretion, and physical activity were considered. In a single proportional hazards model, the rate of change in muscle strength (kilogram per year) per year was a stronger determinant of 40-year mortality.
(HR 0.854; 95% CI, 0.809–0.901) compared with the actual muscle strength (HR 0.955; 95% CI, 0.935–0.976), although the relationship of both muscle parameters with mortality was statistically significant. In a study among 837 persons with a mean age of 81 years at baseline, 36% experienced a decline in muscle strength over 2.2 years as estimated by ordinary least squares regression with a term for time from baseline in years. During follow-up, 9.7% of the study sample died. For each unit increase in muscle strength over time a lower mortality risk was observed, even after adjustment for baseline muscle strength, age, gender, education, and body mass index (HR 0.898; 95% CI, 0.809–0.996).

With regard to the association between dynapenia and mortality risk in old age, it can be concluded that the literature provides clear evidence that poor isometric muscle strength, poor isokinetic muscle strength, and poor muscle power are determinants of mortality in older men and women. The literature also showed that indicators of low muscle mass did not explain this association and only attenuated the risk estimates to a small extent. The few prospective studies conducted in older persons seem to suggest that both the actual level of muscle strength and the age-related loss of muscle strength play a role in mortality risk in old age.

SUMMARY

Based on the results of these epidemiologic studies conducted in large samples of older men and women it can be concluded that poor muscle functioning, as indicated by poor muscle strength or poor muscle power, increases the risk of functional decline, falls, and mortality. The impact of poor muscle functioning was stronger and more consistent throughout the different studies compared with the impact of low muscle mass. Furthermore, there is evidence that the relationship between poor muscle strength and these three different outcomes is not, or very limited, influenced by the size of the muscle. Based on the limited number of studies focusing on the age-related loss of muscle mass in relationship with the three different outcomes, there is some evidence suggesting that loss of muscle mass might increase the risk of functional decline and mortality. Further prospective studies are needed to investigate the relationship between accurately assessed loss of muscle mass and loss of muscle strength using repeated measurements with functional status, falls, and mortality in older persons.

REFERENCES


