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RELATIONSHIP OF INCIDENT FALLS WITH BALANCE DEFICITS AND BODY COMPOSITION IN MALE AND FEMALE COMMUNITY-DWELLING ELDERS

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Abstract: *Objective:* Sarcopenia and obesity are reported risk factors for falls, although the data are not consistent and most studies do not make sex comparisons. We investigated whether falls were associated with balance, gait, and body composition, and whether these relationships are sex-specific. *Design:* Secondary analysis of 4-year follow-up data from of the New Mexico Aging Process Study. *Setting:* Albuquerque, New Mexico. *Participants:* 307 participants (M, n=122, 75.8 yr. SD5.5; F, n=183, 74.6yr SD6.1). *Measurements:* Gait and balance were assessed annually using the Tinetti test. Lean body mass (LBM), appendicular skeletal muscle mass (ASM), fat free mass (FFM), total fat mass (FM) were assessed annually by DXA. Falls were assessed using bimonthly falls calendars. Hazard ratios (HR) for 2-point worsening in gait and balance score and falls were calculated by Cox proportional hazard for men and women. *Results:* Baseline balance deficits, and not body composition, represented the strongest predictor of falls. For the total balance score, the variables with significant sex interactions were ASM (Male-HR 1.02 95%CI 0.60-1.73; Female-HR 1.92 95%CI 1.05-3.52, p=0.03) and FFM (Male-HR 1.04 95%CI 0.64-1.70; Female-HR 1.91 95%CI 1.12-3.24, p=0.04), after adjustment for age, sarcopenia and physical activity. The body composition relationship with balance deficits was U-shaped with the strongest predictors being low LBM in males and high FM in females. *Conclusions:* Specific body composition components and balance deficits are risk factors for falls following sex-specific patterns. Sex differences need to be explored and considered in interventions for worsening balance and falls prevention.

Key words: Body composition, balance, falls, sex, older adults.

Introduction

Falls in older adults represent a major public health challenge. In the United States, about one-third of community-dwelling people aged 65 years and older fall each year (1-3). A previous fall is the strongest risk factor for future falls with a two-thirds chance of falling in the following year (4). Impairments in balance and gait, and muscle weakness are the next strongest predictive factors related to falling (5, 6). Thus, many falls prevention strategies focus on improving balance, gait, and strength along with the reduction of certain medications, removing home hazards, and correcting vision impairments (1-3).

Age-related losses in lean muscle mass are attributed to declining physical performance and mobility deficits. Both sarcopenia (7) and obesity (8) have been reported as risk factors for falls, although the data are not consistent and generally have not attempted sex-specific stratifications. A sex-specific approach in this field seems, at least, justified by the substantial differences existing between men and women for what concerns body composition, physical function, and risk of disabling conditions. For example, older women consistently perform worse on both balance and gait tasks than their male counterparts (9-11), and the prevalence of falling and the incidence of physical disability (2, 11) is greater in older women compared to men. Compounding these sex-specific risks is that older women also have higher body fat, and lower muscle mass that may impart additional risk for poor lower extremity functioning in women (12).

There is a paucity of longitudinal cohorts that have collected prospective falls incidence by calendar or diary, along with precise measures of body composition, balance and gait. This is not the case for the New Mexico Aging Process Study (NMAPS) (13), a prospective cohort study offering a unique opportunity to work in this field. The primary aim of the current study was to investigate whether incident falls was associated with balance and gait deficits and body composition, and whether these relationships were sex-specific.

Methods

Sample

This was a secondary analysis of the NMAPS, whose details are described elsewhere (13). Briefly, to qualify for entry into the study, participants were 60 years or older, free of major medical conditions, and independently living. This analysis used data from a 1993 cohort of 307 participants who had annual dual energy x-ray absorptiometry (DXA)

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body composition, balance and gait, and bi-monthly falls measurements between 1993 and 1997. Previous falls incidence was obtained from 1991-1993, prior to DXA measures of body composition being added to the NMAPS. The study was originally approved by the University of New Mexico Health Sciences Internal Review Board and has approval for secondary analysis.

Outcome measures

Participants were seen annually for a battery of tests that is described elsewhere (13). In brief: the Tinetti Performance Oriented Assessment of Balance and Gait was used to assess balance and gait (14). The NMAPS scoring used 0 indicating normal and 1 abnormal for each test. Total scores were 13 for balance and 9 for gait. Worsening gait and balance was defined as a change of 2 or more points in total gait and total balance scores from baseline (15). Falls were defined using the standard World Health Organization definition (16). Falls were collected using bi-monthly calendars and WHO falls questionnaire. A "history of falls" (e.g. frequent fallers) was calculated using crude falls incidence between 1991 and 1993. Greater than 2 falls during this period was classified as "history of falls" and used as a covariate in the analysis (4). DXA (Lunar DPX, DXA Lunar Radiation Corp. Madison WI) assessed lean body mass (LBM) fat free mass (FFM), appendicular skeletal muscle mass (ASM), total fat mass (FM), and percentage fat (PF). Total body weight, height, and BMI (weight/height^2 in kilogram per meter^2) were also collected annually. Sarcopenic-non obese (SnO), sarcopenic-obese (SO), obese-non sarcopenic (OnS) and non-sarcopenic-non obese (normal; nSnO) were classified using ASM/height2 ratio and slow gait speed (17). Sarcopenia was defined using ASM cut scores of <5.25 kg/m2 for females, <7.4 kg/m2 for males, combined with slow gait speed (< 0.8 m/s); in accordance to the European definition (17). Obesity was defined as body fat percentage > 27% for males and 38% for females (18). Physical activity was assessed during a home interview-administered questionnaire. An open-ended question regarding hours per week of household and leisure-time physical activity was summed for a total number of hours of activity per week. Median cut-score was 17.0 hours/week. Comorbidities were assessed from the physical history questionnaire. Only 2 participants had 4 or more co-morbidities (threshold for increased falls risk (19)), thus co-morbidities were not included as a covariate in the analyses.

Statistical analysis

The analysis included participants who had annual balance, gait, and DXA data from 1993-1997. Chi-square tests for proportions, t-tests or Wilcoxon rank-sum tests for means were used to compare body composition between the sexes. Cox proportional hazard analysis for the time to a 2- point change in balance and gait scores were used to determine the association of balance and gait to each body composition variable (per 1 SD change) controlling for age. Anticipating that there could be a U-shaped relationship between balance and gait measures and body composition (7, 8), we tested this possibility by defining a simple sarcopenia-obesity scale. Due to a U-shaped relationship between body composition, balance and gait (see Figure 2 results), the relationship of our balance and gait outcomes to each of the baseline body composition measures were tested by Cox's proportional hazard ratio model using sarcopenia and physical activity as binary covariates. The sarcopenia factor adjusted for the potential U-shaped response to body composition and allowed estimation of the linear effect of each body composition measure over the sarcopenia to obese body classifications. Similarly, a Cox's proportional hazard ratio model was used for time to first fall. Falls are reported as crude falls rate in per person-years. "History of falls", to identify those participants with frequent falling, are reported as raw reported values and prevalence.

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Results

Descriptive characteristics of the participants are shown in Table 1. Mean age and BMI did not differ by sex.

Table 1
Participant's characteristics

Variable (mean SD)	Females (n=183)	Males (n=122)	p value *
Age (years)	76.4 (6.5)	76.7 (5.5)	0.63
Lean Body Mass (kg)	36.5 (3.6)	52.7 (5.8)	<.0001
ASM [a] (kg)	14.9 (1.8)	22.9 (3.1)	<.0001
Fat Free Mass (kg)	39.2 (3.8)	55.7 (6.1)	<.0001
Total Fat (kg)	23.9 (8.6)	21.2 (7.4)	0.003
BMI (kg/m2) [b]	25.0 (3.9)	25.6 (3.3)	0.15
Weight (kg)	63.2 (10.8)	76.9 (10.7)	<.0001
Normal gait speed [c] (m/s)	0.67(.18)	0.74 (.74)	<.0001

a. ASM= appendicular skeletal muscle mass; b. BMI=body mass index; c. Gait speed test was 7.5 meters (25 feet) with a turn, m/s = meters per second. *T-test comparison of females to males.

Falls

In 1993, 108 (35.2%) participants reported a fall, and 39 of these (36.1%) had 2 or more falls (i.e. history of falling). From the 214 participants in 1993 who did not have a history of falling, 138 (64.5%) had their first fall within 48 months of follow up, with a higher percentage (69.3%) of females falling during this period than males. One hundred twenty seven women had a total of 213 falls over 554 person-years with an average of 0.38 falls per person-year. The 87 men had a total of 110 falls over 383 person-years with an average of 0.29 falls

Table 2
Adjusted Hazard Ratios for Worsening Total Balance Score associated with Body Composition Variables

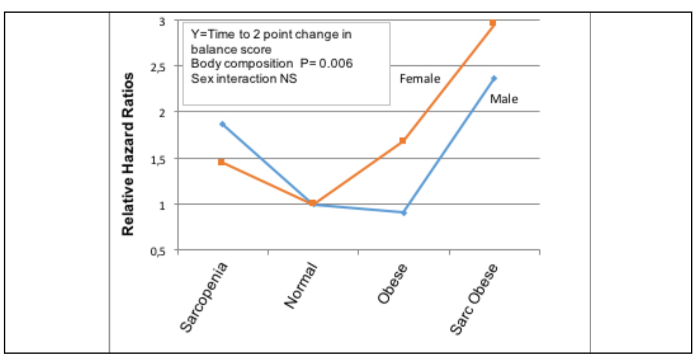
	Female		Male		
Variable	**Adjusted HR 95%CI**	**P-value**	**Adjusted HR, 95%CI**	**P value**	**Sex-Interaction P-value**
Weight	1.32, 1.02-1.69	0.03	1.05, 0.72-1.53	0.79	0.20
BMI	1.21, 0.98-1.51	0.08	1.10, 0.78-1.56	0.57	0.36
LBM	1.79, 1.04-3.11	0.03	1.07, 0.64-1.79	0.79	0.06
FFM	1.91, 1.12-3.24	0.01	1.04, 0.64-1.70	0.86	0.04
ASM	1.92, 1.05-3.52	0.03	1.02, 0.60-1.73	0.94	0.03
FM	1.19, 0.96-1.48	0.10	1.04, 0.74-1.46	0.82	0.39
FAT %	1.09, 0.83-1.43	0.52	1.03, 0.71-1.50	0.87	0.80

Legend: BMI=body mass index, LBM-lean body mass, FFM=fat free mass, ASM, appendicular skeletal muscle mass, FM=fat mass, FAT%=percentage fat. The row Model for each predictor variable is adjusted for the age (continuous). Hazard Ratios (Adjusted HR) are per one SD change in the row variable. The sex-interaction P-value is for the sex-row variable interaction. All female and male HRs together with their sex-interaction are adjusted for age, sarcopenia and physical activity in the Cox proportional hazard models.

per person-year.

Figure 1 shows participants with balance or gait deficits at baseline, the time to first fall over the 4-year follow-up occurred significantly sooner than in participants without balance or gait deficits at baseline (Kaplan-Meier survival curves, log rank test, P=.001). Those with a history of falls at baseline had significantly more balance deficits at baseline than those who did not have a history of falls (46.7% vs 30.4%, p=0.008), with no difference between males and females (28.7% vs 30.7%, respectively, p=0.71).

Figure 1
Relative Hazard Ratios (HR) of time to a 2-point decrease in balance total score

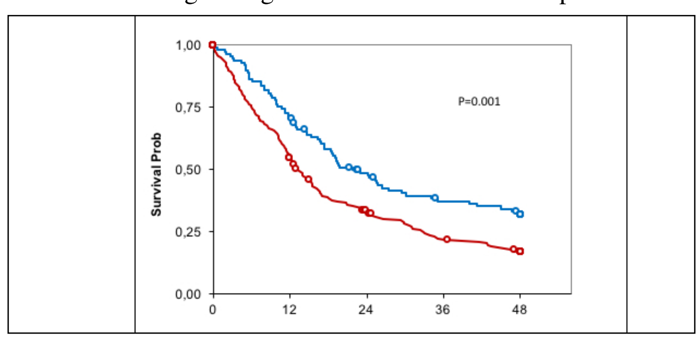


This figure shows a U-shaped relationship between worsening in balance score and body composition groups. Cox proportional hazards model P-values are reported. In post hoc testing, HRs for both sarcopenic-obesity and sarcopenic non-obese compared to normal are significant (greater than 1). This establishes the non-linear (U-shaped) effect of our body composition scale on the hazard ratios of a 2 point increase in balance total score.

Balance and Gait

Baseline body composition had a significant relationship with decreases in balance over the follow-up. For the balance score, the variables with significant sex interactions were ASM (Male-HR 1.02 95%CI 0.60-1.73; Female-HR 1.92 95%CI 1.05-3.52, p=0.03) and FFM (Male-HR 1.04 95%CI 0.64-1.70; Female-HR 1.91 95%CI 1.12-3.24, p=0.04), after adjusting for age, sarcopenia and physical activity. About 58.5% of females had 1-2 baseline balance and gait deficits compared to 42.6% of males (p=0.01). Worsening gait and balance was defined as a change of 2 or more points in total gait and total balance scores from baseline (15). Total balance score worsened in 20.8% of participants during the 4-year follow-up. Total gait score worsened in 56.2% of participants during this same period.

Figure 2
Survival analysis (Kaplan-Meier Curves) of the probability of falling during the 48 months of follow-up



Participants with balance or gait deficits at baseline, the time to first fall over the 4 year follow-up occurred significantly sooner than those without balance or gait deficits (log rank, P=.001). All participants "at-risk" in each group (112 with balance or gait deficits and 189 without these deficits at baseline) for every 12 months are shown in the plot.

The odds of balance and gait deterioration along the sarcopenia to obesity scale was U-shaped. Regardless of whether we examined a 3-point scale or added SO to either end of a 4-point scale, the relationship was U-shaped. The HR of balance deterioration along the sarcopenia-obesity scale was U-shaped and had a sex interaction (Figure 2, U-shaped versus linear, ANCOVA, P= 0.01). In males but not females, sarcopenia was associated with increased HR of future balance worsening by 2 points (M_HR 2.4, P=0.008, F_HR 1.0 P=0.92; interaction p=0.05). Table 2 shows the HR, 95%CI, and

P-values for worsening balance with sarcopenia and physical activity as a binary covariate.

For the change in total gait score, the variables FFM, FM, and weight were significantly associated for females (overall $p<0.05$, HR range=1.0-1.36), but only FFM approached statistical significance for a sex interaction (p=0.07 Male-HR=0.93, Female-HR=1.70).

Discussion

This 4-year prospective investigation of the relationships between falls, body composition, balance and gait, suggests there is no direct association between falls and body composition. However, there were relationships between body composition with worsening balance and gait, which in turn were related to falls. The presence of balance and gait deficits at baseline was the strongest predictor for future falls. These relationships were also sexually dimorphic with lean body mass, particularly the presence of sarcopenia, more strongly associated with balance deficits in men, whereas fat mass was more strongly associated with balance deficits in women.

The relationship between overweight and obesity, and functional limitations and disability in older adults has been previously reported (8, 20-25). Our findings allow to conclude that total body fat is the strongest factor associated with lower body performance in women, whereas in men, the most relevant association is found for muscle mass (12). Anthropometric predictors of physical performance have shown an increased risk of functional limitation at a BMI of 35 kg/m2 in women, whereas in men the risk was not present until BMI was over 40 kg/m2 (26). Our study may supports the existence of a relationship between body composition and lower body physical function (visa via measures of gait and balance), but the previous research did not specifically measure balance, gait or falls incidence. We used one of the more current definitions of sarcopenia that includes a functional measure (e.g. gait speed), and our data largely supports the most commonly intrinsic risk factors for falls, which has been reported as a history of falls, balance deficits, and gait deficits (3). Although we found a strong relationship with history of falls and balance deficits, the association was weak for gait deficits. This may have been influenced by a larger proportion of participants with balance deficits at baseline compared to gait deficits, which may have resulted in stronger effect for balance, thus contributing to a stronger association with falls incidence during the follow-up.

Although we found a clear association between body composition and balance, the relationship with falls was less clear. A study using the data from the Five Waves of the Health and Retirement Study (HRS), 1998-2006 (8) collected self-reported falls every 2 years, and reported increasing odds ratios (OR) for the risk of falling according to the severity of obesity. We did not have enough participants in the higher classifications of obesity to conduct similar analyses, but found a consistent relationship in females, but not in males. Furthermore, although the HRS was a large prospective study, asking older participants to accurately recall falls every 2 years, rather than using a monthly calendar, most likely increased the risk of recall bias and under-reporting of falls.

Rosenblatt and colleagues followed a small cohort of middle-aged women (n=86, 42 obese) prospectively for one year and reported that obesity did not appear to increase the falls incidence compared to non-obese women (27). Tseng et al. also did not find an independent association between body composition and falls (25). Conversely, using a newly proposed definition of dynapenia, Scott et al. reported a relationship between dynapenic-obesity (low LBM and function with obesity) and falls risk, but not with sarcopenic-obesity (low LBM alone with obesity) and falls risk (6). However, they measured falls risk and did not directly estimate falls incidence. This large study (~1000 participants with 30% drop out over the 5 years) reported that only 37 participants had both sarcopenic-obesity and dynapenic-obesity, and that these participants had an increase in falls risk score over the 5 years compared to non-sarcopenic/obese non-dynapenic and non-obese participants. However, this difference did not achieve statistical significance (p=0.052). Although, this study is a bit difficult to compare with the current analysis, our classification of sarcopenic-obesity included a measure of function, thus would have similarities with dynapenic-obesity and agrees with our data that sarcopenia (alone or in combination with obesity) was a risk factor (i.e. through balance deficits) for falls. Again, the lack of bi-monthly or monthly prospective falls reporting, and measuring falls risk rather than falls incidence, makes comparisons between these studies problematic. The Concord Health and Ageing in Men Project (CHAMP) (28) used both the European Working Group Sarcopenic Older People (EWGSOP) and the Foundation for the National Institutes of Health (FNIH) definitions to identify sarcopenic-obese men. They reported the EWGSOP-defined sarcopenic obesity was associated with increased fall rates over 2 years, whereas the FNIH-defined sarcopenic obese men had increased fracture risk over 6 years compared with non-sarcopenic obese men. Unfortunately, as mentioned above, our analyses were limited by the small number of sarcopenic-obese participants to conduct comparisons with this previous study.

To our knowledge, this is the first study to show a temporal relationship between body composition and balance deficits, which appeared to increase falls risk, an earlier first fall and possibly falls incidence. Furthermore, we found these associations were different between men and women; balance deficits in women are most strongly associated with fat-mass, whereas balance deficits in men are more strongly associated with sarcopenia. This may suggest that preventing changes in balance and gait (that in turn increases falls risk) should target body composition with a different emphasis for men and women. The prevention of fat gain in women, maintaining lean body mass in men as well as preserving or improving balance may be important in preserving physical function and decreasing falls. Both men and women experience declines in mobility across the life span, showed in the worsened gait over the follow-up time of 4 years in over 50% of the participants and a worsened balance in more than one fifth of the participants. It would be interesting to assess whether those with a history of falling (e.g. falling more frequently) sustain more or less severe injuries than people who have fallen once. However, injurious falls research requires very large sample sizes. A large multi-centered clinical trial, currently underway in the United States (Clinical Trial of a Multifactorial Fall Injury Prevention Strategy in Older Persons (U01) RFA-AG-14-009), might be able to answer this question. Finally, there may be other, as of yet, unexplored explanations for these findings such as sexually dimorphic differences in fat and muscle distribution, muscle quality, different gait characteristics, or even different gait and balance strategies that result in falling that require further investigations.

Ethical Standards: This study was originally approved by the University of New Mexico Health Sciences ethics committee and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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