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# Age modify the associations of obesity, physical activity, vision and grip strength with functional mobility in Irish aged 50 and older

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ABSTRACT

*Objective:* To estimate whether the associations of obesity, physical activity, vision and grip strength with functional mobility were modified by age.

*Methods:* Data from The Irish Longitudinal Study on Ageing (2009–2012) were analyzed and 5001 individuals were included in this study. Mobility was assessed by the timed up and go test (TUG-test). Main exposure variables were obesity, physical activity, visual acuity and grip strength at baseline. Multiple linear regression models were fitted to assess the associations of baseline main exposure variables with 2-year follow-up functional mobility and potential confounders were adjusted. Stratified analyses by age were used to assess the interaction between main exposures and age on functional mobility.

*Results:* Multiple linear regression models identified significant interactions of obesity ($P < 0.001$), vigorous physical activity ($P = 0.001$), vision ($P < 0.001$) and grip strength ($P < 0.001$) with age on functional mobility. Stratified analyses suggested that the risk effect of obesity on functional mobility was greater in middle-aged group ($\beta = 0.025$, $P < 0.001$) than in older group ($\beta = 0.016$, $P = 0.017$). The protective effects of high level of physical activity and grip strength on functional mobility were stronger in older group ($\beta = -0.023$, $P = 0.004$ for physical activity; $\beta = -0.002$, $P < 0.001$ for grip strength) than in middle-aged group ($\beta = -0.012$, $P = 0.008$ for physical activity; $\beta = -0.0015$, $P < 0.001$ for grip strength). The benefit of better vision on functional mobility was observed in middle-aged group only ($\beta = -0.032$, $P = 0.002$).

*Conclusion:* Non-obesity, higher level of physical activity, vision and grip strength at baseline were associated with better mobility performance among middle-aged and older Irish. And these associations were modified by age.

## 1. Introduction

Population ageing is one of the most significant trends worldwide. Human ageing process is associated with physiological and functional changes, leading to impaired mobility and autonomy (Soares, Marcelino, Maia, & Borges, 2017). Data from the English Longitudinal Study of Ageing suggested that 62% of adults over 60 years have at least one of a number of mobility limitations with 11% having difficulty walking 100 yards and 14% having difficulty climbing one flight of stairs (Gale, Cooper, & Sayer, 2015). Many studies indicated that mobility limitations can lead to numerous adverse health outcomes, such as falls and related-injuries, disability, loss of independence and even death (Guralnik et al., 1993; Lo, Brown, Sawyer, Kennedy, & Allman, 2014; Thorpe, Clay, Szanton, Allaire, & Whitfield, 2011; Wang & Wu, 2018; Wolinsky et al., 2007). Thus it is considered as a topic worthy of investigation in elderly.

Functional mobility is a very complicated trait involving all levels of the nervous system and many parts of the musculoskeletal apparatus. Based on observational studies, several potential mechanisms for mobility in older adults have been documented. Vincent HK et al systematically examined 13 cross-sectional and 15 longitudinal previous studies and concluded that walking, stair climbing and chair rise ability were compromised with obesity (Vincent, Vincent, & Lamb, 2010). Tsai LT et al conducted a two-year follow-up study and identified that life-space mobility declined significantly among those with physical inactivity at baseline in older adults (Tsai et al., 2016). Laitinen A et al

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used a nationally representative population data to found that visually impaired persons had activity of daily living disabilities four times more likely than those with good vision after adjusting for socio-demographic and behavioral factors and chronic diseases (Laitinen et al., 2007). Recently, McGrath R et al reported the protective role of muscle strength not only in long-term but also in shorter-term losses of physical function and disability status in older Mexican Americans (McGrath, Robinson-Lane, Peterson, Bailey, & Vincent, 2018).

Despite the above-mentioned studies, data to establish the determinants for functional mobility in old age are insufficient. There is an increasing awareness of the importance of considering underlying biology when examining specific exposure-disease relations. Indeed, several recent studies highlighted effect modification in the relation between various predictors and health outcomes (Beaulieu-Jones et al., 2015; Fan et al., 2015; Rovella et al., 2018). It is well known that the risk of mobility disorder varies with age, and it is plausible that the adverse effects of obesity, physical inactivity, poor vision and low muscle strength may differ by age. However, to our knowledge, there are no previous studies focused on the interaction of age and traditional risk factors with functional mobility.

Here we present a prospective study by using a large, population-based sample derived from "The Irish Longitudinal Study on Ageing (TILDA)" (2009–2012) to: (1) estimate the effect of baseline obesity, physical activity (PA), visual acuity (VA) and grip strength (GS) on the 2 year follow-up functional mobility in Irish aged 50 and older; (2) examine how age modify the associations of these determinants with functional mobility.

## 2. Methods

### 2.1. Study sample

The TILDA is a biennial longitudinal survey of ageing process in individuals aged 50 or older living in the Republic of Ireland in residential accommodation, together with their spouses of any age. This survey collected information such as health, socio-economic status as well as social and family networks. Details about the sampling procedure can be found in the original article (Whelan & Savva, 2013). To date, TILDA has collected 4 panel waves. We used the data from the first two waves. This study was allowed by the Faculty of Health Sciences Research Ethics Committee at Trinity College Dublin. Written informed consent was provided for every participants and the study adhered to the Declaration of Helsinki.

The baseline (wave 1, W1) survey was conducted in 2009–2011, and data were collected on 8504 participants with the household respondent rate about 62% (Whelan & Savva, 2013). The second wave (wave 2, W2) survey successfully re-interviewed 7207 of these individuals in 2012-2013. Some participants were excluded in this study. The excluded participants are those who were younger than 50-year-old at baseline (n = 300), had cancer (n = 401), stroke (n = 107), Parkinson (n = 34), or had body mass index less than 18.5 kg/m$^2$ (n = 23) at any wave. Meanwhile, 1341 people who shared the same household with primary respondents were also excluded so that all the observations in the sample were independent. After filtering, 5001 individuals were included in this study (Fig. 1).

### 2.2. Mobility

Mobility was assessed by the timed up and go test (TUG-test) (Podsiadlo & Richardson, 1991) in W2. Participants were observed while he/she rises from an arm chair (approximate seat height of 46 cm, arm height of 65 cm), walks 3 m at normal pace to a line clearly marked on the floor, walk back to the chair, and sit down again. Walking aids were allowed and no instructions were given about the use of arms. The time spent to carry out the test was recorded, with more test time representing worse mobility performance (Podsiadlo & Richardson, 1991). TUG-test time was log-transformed before being entered into linear regression models due to its markedly skewed distribution, as shown in Fig. 2.

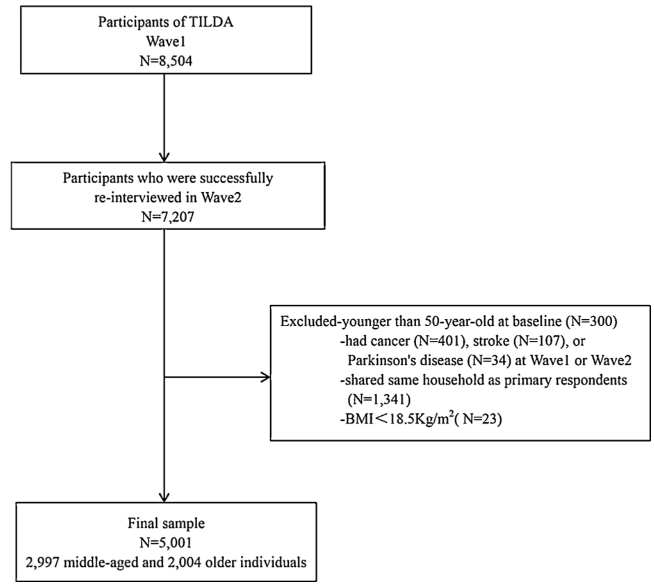


**Fig. 1.** Participants' flow in the study.

### 2.3. Obesity, PA, VA and GS

The main exposure variables in this study include obesity, PA, VA and GS. In TILDA, height (cm) was measured by wall mounted measuring rod (SECA240, Hamburg, Germany) without footwear and heavy outer clothes. Weight (kg) was measured by electronic floor scales (SECA, Hamburg, Germany). Body mass index (BMI) was calculated as the weight in kilograms divided by the height in meters squared. The baseline BMI was further categorized as non-obesity ($18.5 \leq$ BMI $< 30$ kg/m$^2$) and obesity (BMI $\geq 30$ kg/m$^2$).

Baseline PA was measured using the short International PA Questionnaire (IPAQ) (Craig et al., 2003). Participants were asked to recall PA during the past 7 days, describe the number of days for vigorous, moderate and walking activity as well as the duration of activity. According to IPAQ protocol scoring, the total PA was divided into three categories: vigorous, moderate and low intensity (Craig et al., 2003). The low intensity was set as the reference.

Baseline VA for each eye was measured according to the Early Treatment of Diabetic Retinopathy Study (ETDRS) protocol using a Logarithm of the minimum angle of resolution (LogMAR) chart (Duggan et al., 2017). Participant was allowed to wear corrective glasses for this measurement. If a respondent was unable to read any letters, they were moved closer to the chart (1 m away) and 0.6 was added to the LogMAR score for each line. We transformed LogMAR score to Chinese miao's value by using formula of miao's value = 5-lgMAR, which ranged from 3.4 to 5.3, with higher values indicative of better vision. The VA of better eye was used in this study. Baseline GS was estimated using a hydraulic hand dynamometer (Fabrication Enterprises Inc, White Plains, NY). Participants were instructed to stand or sit to keep the upper arms tight against trunk with their elbows at a 90° angle, and then squeeze the handles as hard as possible. GS for dominant hand and non-dominant hand are measured twice respectively. Two values were recorded for each hand, expressed as kilogram. The mean of two values for dominant hand was used in this study.

### 2.4. Other variables

Our covariates recorded in the baseline survey included gender,

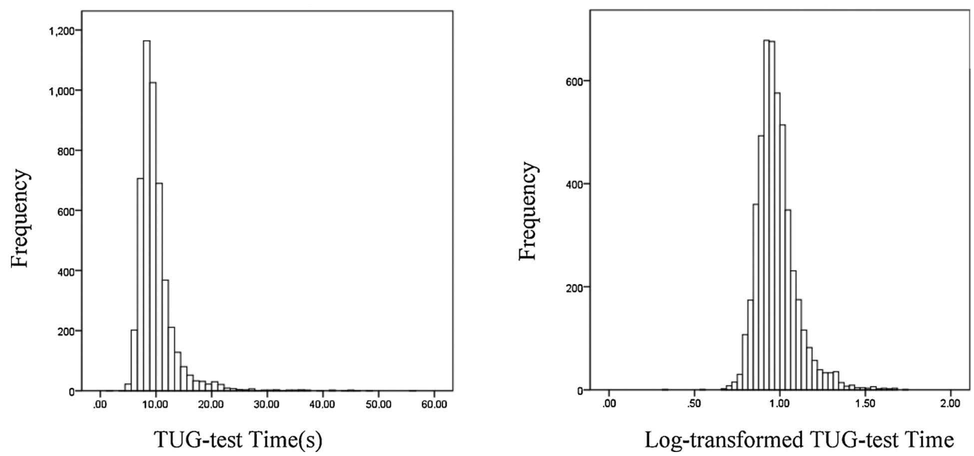


**Fig. 2.** Histogram of TUG-test time and Log-transformed TUG-test time.

education level, cigarette smoking, alcohol drinking, heart attack, arthritis, hypertension, diabetes, osteoporosis, angina and depression. Education level was categorized as 'primary level', 'secondary level' and 'high level'. Smoking was categorized as 'never', 'former' or 'current'. Alcohol drinking was grouped as 'drinking' and 'not drinking'. Heart attack, arthritis, hypertension, diabetes, osteoporosis, angina, depression were dichotomized as 'no' or 'yes' based on the answers for the questions of 'Have you been diagnosed with these problems by a doctor?'.

### 2.5. Statistical analysis

Firstly, baseline characteristics of mean ± SD and percentages were calculated stratified by age group (middle-aged individuals with 50–65 years old and older individuals with ≥65 years old) and comparison between two groups was conducted by using Student's *t*-test for quantitative variable, Kruskal-Wallis test for ordinal variable and chi-square test for qualitative variable. Secondly, multiple linear regression models were fitted to assess the associations of baseline obesity, PA, VA and GS with 2-year follow-up mobility performance. Thirdly, the age group variable was interacted with each of the main exposure variables in the models to investigate whether age significantly modify the associations between main exposures and functional mobility. When one of the main exposures was tested, variables such as gender, education level, cigarette smoking, alcohol drinking, heart attack, arthritis, hypertension, diabetes, osteoporosis, angina, depression and the other main exposures were adjusted as covariates. To ensure the stability of the results, we conducted the sensitivity analysis by excluding participants who had cardiovascular diseases such as coronary thrombosis or myocardial infarction or any other heart problem at baseline.

All the data were analyzed using STATA version 14 (Stata Corp LP, College Station, Texas, USA). R software (https://www.r-project.org/) was used to visualize the interaction in the figures.

## 3. Results

### 3.1. Participant characteristics

A total of the 5001 participants were eligible for this study after filtering, including 2997 middle-aged and 2004 older individuals. The follow-up time ranged from 1.7 to 2.3 years. Descriptive statistics for each main exposure and covariate at baseline were listed in Table 1. Paired *t*-test showed that the differences of log-transformed TUG-test time between two waves were significant in both middle-aged group (Paired-t = 22.163, $P < 0.001$) and older group (Paired-t = 15.592, $P < 0.001$), indicating that functional mobility were declined over time.

**Table 1**
Sample Description at Baseline (n = 5001).

| Characteristic | 50-65 years N = 2997 | ≥65 years N = 2004 | *P*-value |
|---|---|---|---|
| Female, n (%)[a] | 1585 (52.89) | 1085 (54.14) | 0.383 |
| Obesity, n (%)[a] | 769 (32.89) | 506 (35.09) | 0.165 |
| Physical activity, n (%)[b] | | | |
| -Low | 780 (26.32) | 727 (36.57) | < **0.001** |
| -Moderate | 1006 (33.94) | 687 (34.56) | |
| -Vigorous | 1178 (39.74) | 574 (28.87) | |
| Visual acuity [c] | 4.96 ± 0.18 | 4.88 ± 0.19 | < **0.001** |
| Grip strength, (kg)[c] | 28.09 ± 10.24 | 23.56 ± 0.19 | < **0.001** |
| Education level, n (%)[b] | | | |
| -Primary | 600 (20.05) | 860 (42.94) | < **0.001** |
| -Secondary | 1877 (62.71) | 912 (45.53) | |
| -High | 516 (17.22) | 231 (11.53) | |
| Cigarette smoking, n (%)[a] | | | |
| -Never | 1308 (43.64) | 898 (44.81) | < **0.001** |
| -Former | 1052 (35.10) | 853 (42.56) | |
| -Current | 637 (21.26) | 253 (12.63) | |
| Alcohol drinking, n (%)[a] | 2,134 (82.75) | 1099(62.51) | < **0.001** |
| Heart attack, n (%)[a] | 78 (2.60) | 148 (7.38) | < **0.001** |
| Arthritis, n (%)[a] | 607 (20.25) | 764 (38.12) | < **0.001** |
| Hypertension, n (%)[a] | 869 (29.00) | 931 (46.46) | < **0.001** |
| Diabetes, n (%)[a] | 160 (5.34) | 196 (9.78) | < **0.001** |
| Osteoporosis, n (%)[a] | 222 (7.41) | 272 (13.57) | < **0.001** |
| Angina, n (%)[a] | 65 (2.17) | 188 (9.38) | < **0.001** |
| Depression, n (%)[a] | 302 (10.07) | 136 (6.79) | < **0.001** |
| Log-transformed TUG-test time for 2011 [c] | 0.91 ± 0.08 | 0.99 ± 0.12 | < **0.001** |
| Log-transformed TUG-test time for 2013 [c] | 0.94 ± 0.09 | 1.04 ± 0.13 | < **0.001** |

Bold for $P < 0.05$.
Values are presented as mean ± SD or frequency (percentage).
TUG-test was timed up and go test.
[a] Chi-square test for qualitative variable.
[b] Kruskal-Wallis test for ordinal variable.
[c] Student's *t*-test for quantitative variable.

### 3.2. Effect modification

Table 2 displayed the results from multiple linear regression models stratified by age group and interaction analyses. Fig. 3 depicted the associations between each of the main exposures and follow-up functional mobility in two age groups, which should be focused on differences in the slopes.

Obesity and functional mobility. Obesity was independently associated with increased TUG-test time in both age groups. The statistically significant obesity × age group interaction on TUG-test time (*P*-interaction < 0.001) indicated that the risk effect of obesity on mobility was stronger in middle-aged group (β = 0.025, $P < 0.001$) than in

**Table 2**
Multiple Linear Regression Models for the Associations between Baseline Obesity, Physical Activity, Vision, Grip Strength and Follow-up Functional Mobility Stratified by Baseline Age.

| Independent | Functional mobility | | | | *P*-Interaction |
|---|---|---|---|---|---|
| | 50-65 years | | ≥65 years | | |
| | β ± SE | *P* | β ± SE | *P* | |
| Obesity | 0.025 ± 0.004 | **< 0.001** | 0.016 ± 0.007 | **0.017** | **< 0.001** |
| Physical activity | | | | | |
| Low (ref.) | – | – | – | – | – |
| Moderate | −0.010 ± 0.005 | **0.036** | – | – | 0.320 |
| Vigorous | −0.012 ± 0.005 | **0.008** | −0.023 ± 0.008 | **0.004** | **0.001** |
| Visual acuity | −0.032 ± 0.011 | **0.002** | – | – | **< 0.001** |
| Grip strength | −0.0015 ± 0.000 | **< 0.001** | −0.002 ± 0.000 | **< 0.001** | **< 0.001** |

Models were adjusted for age, gender, education level, cigarette smoking, alcohol drinking, heart attack, arthritis, hypertension, diabetes, osteoporosis, angina and depression.
Bold for $P < 0.05$.
*β* beta coefficient, *SE* standard error.

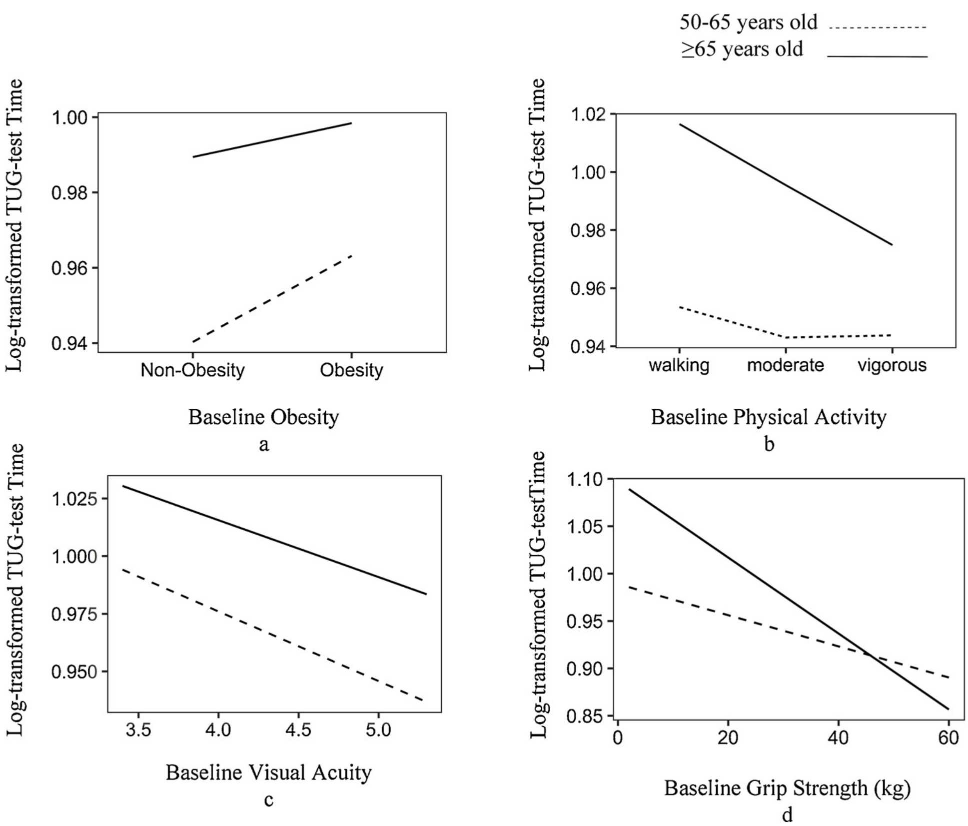


**Fig. 3.** (a) Relationship between baseline obesity and Log-transformed TUG-test time stratified by age group; (b) Relationship between baseline physical activity and Log-transformed TUG-test time stratified by age group; (c) Relationship between baseline vision and Log-transformed TUG-test time stratified by age group; (d) Relationship between baseline grip strength and Log-transformed TUG-test time stratified by age group.

older group (β = 0.016, *P* = 0.017) (Fig. 3-a).

PA and functional mobility. Compared to low intensity of PA, moderate PA was negatively associated with TUG-test time in middle-aged group only (β = −0.010, *P* = 0.036), vigorous PA was associated with TUG-test time in both age groups (β = −0.012, *P* = 0.008 in middle-age people; β = −0.023, *P* = 0.004 in older people), suggesting the protective role of PA in functional mobility. The interaction analysis showed that the vigorous PA effect on mobility was greater in older individuals than in middle-aged individuals (*P*-interaction = 0.001) (Fig. 3-b).

VA and functional mobility. VA of better eye showed an inverse association with TUG-test time in middle-aged individuals only (β = −0.032, P = 0.002). There was no significant association in older people. The protective impact of VA on mobility was modified by age (*P*-interaction < 0.001) (Fig. 3-c).

GS and functional mobility. Greater GS was associated with less TUG-test time in both age groups. While the GS effect on functional mobility were greater in older group (β = −0.002, *P* < 0.001) than in middle-aged group (β = −0.0015, *P* < 0.001). This was further qualified by a significant GS × age group interaction on the functional mobility (*P*-interaction < 0.001) (Fig. 3-d).

The results of multiple linear regression models for covariates were listed in Appendix A1. Sensitivity analysis excluding participants who reported cardiovascular diseases at baseline yielded results similar to those of the primary analyses (Appendix A2).

## 4. Discussion

This longitudinal study documented two major findings. First, non-obesity, higher level of PA, better VA and greater GS at baseline were associated with less follow-up TUG-test time among middle-aged and older Irish. Second, these associations were modified by age. The risk effect of obesity on functional mobility was greater in middle-aged group than in older group. The protective effects of high level of PA and GS on functional mobility were stronger in older group than in middle-aged group. The benefit of better VA on mobility was observed in middle-aged group only. There was no significant association between VA and functional mobility in older group.

Our findings that non-obesity, higher level of PA, greater GS were associated with better mobility performance were consistent with previous studies (Rantanen et al., 1999; Santanasto et al., 2017; Vincent et al., 2010). One prospective cohort study in people aged 70–79 years without mobility limitation showed that higher BMI as well as adipose depot area were associated with follow-up mobility limitation and poor performance (Murphy et al., 2014). Previous studies have showed that the potential mechanism of obesity as a risk factor for mobility limitation or disability was that high fatness was associated with lower muscle quality. Besides, greater fatness might lead to muscle inflammation and contribute to relations between obesity and disability or mobility impairments (Koster et al., 2011). A cross-sectional study of community-dwelling older suggested that older men with higher PA level have better physical function and functional mobility than those with lower PA level (Morie et al., 2010). Individuals with a lower PA level might be move less outdoors which accelerates functional limitation (Peel et al., 2005). Adequate physical activity level might contribute to maintain life-space mobility among community-dwelling older people (Tsai et al., 2016). Hand-grip strength can represent overall muscle strength because of the correlation with the strength of other muscle in our body, and it is an important predictor of functional mobility (Ostchega, Dillon, Lindle, Carroll, & Hurley, 2004; Rantanen et al., 1998). Koster A et al conducted a prospective cohort study and found that higher muscle strength was associated with a lower risk of IADL and ADL disability in older Mexican Americans (McGrath et al., 2018). Meanwhile, another longitudinal study indicated that obese older with low muscle strength had an increased risk of decline in gait speed and functional mobility over a 6-year follow-up (Stenholm et al., 2009). A progressive reduction in muscular strength and mass is observed with aging. This phenomenon has been called as sarcopaenia and is one factor that might explain impairment of physical function with age (Dutta & Hadley, 1995).

Our analyses extend these findings by showing that the association between obesity and mobility was more pronounced in older group, while the associations of PA and GS with mobility were stronger in middle aged group. As far as we know, there have been few studies that have explored the effect modification of age in the relations between traditional risk factors and mobility performances. A prospective study in men aged 65 and older identified that the strength of association between BMI and falls appeared stronger in younger age groups than in men aged 80 and over (Hooker et al., 2017), which supported our finding on the significant interaction between age and obesity with functional mobility. The information about effect modification helps to refine intervention programs by identifying the high-risk population.

Earlier studies on the role of VA in functional mobility have drawn conflicting conclusions. Some of them found VA as an important predictor of gait and fall (Ivers, Cumming, Mitchell, & Attebo, 1998; Jack, Smith, Neoh, Lye, & McGalliard, 1995), while others reported no independent association between VA and gait (Patel et al., 2006; Podsiadlo & Richardson, 1991). In this study, we observed the benefit of better VA on mobility in middle-aged group only. Contrast sensitivity decreased may lead to navigation difficulty, and in turn impact mobility. Previous studies have indicated that people with poorer VA shorten their stride length in order to keep mobility stable (Kuyk & Elliott, 1999; Owsley & Sloane, 1987). Modification of the association between VA and mobility by age or other characteristics possibly contributes to the inconsistency between previous findings.

In addition to the age-stratified analyses, there are several strengths to consider. First, because a nationally representative sample was studied, the findings are largely generalizable to non-institutionalized population. Second, we used a prospective design, which gave us a much greater possibility to draw conclusions of causal association. Third, obesity, VA, GS and functional mobility were all objectively assessed by validated methods, trained staff and standard operating procedures. This study is not without its limitations. About 15.3% participants dropped from the cohort, which may affect the interpretation of the results. Longitudinal data are often incomplete because of loss to follow-up. However, previous studies reported that attrition in longitudinal survey was more complex than often assumed and it may not inevitably indicate bias and limit the generalizability of longitudinal comparisons (Lacey, Jordan, & Croft, 2013; Salthouse, 2014). Moreover, measures interval for functional mobility was too short to explore the associations between these main exposures and change of mobility over time. Our finding needs to be replicated in other cohorts. Future studies should also examine the associations of obesity, PA, VA, GS with functional mobility in oldest old.

In conclusion, we found that the associations of obesity, PA, VA and GS with mobility were modified by age. The risk effect of obesity on mobility was greater in middle-aged group, while the protective effects of high level of PA and GS on mobility were more pronounced in older group. We also found the benefit of better VA on mobility was existed in middle-aged group only. These findings have important implications for general understanding on impact factors of mobility in middle-aged and elderly adults and could be helpful to design appropriate interventions to prevent impaired mobility.

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**Disclosure statement**

The authors declare no conflict of interest.

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**Appendix A. Supplementary data**

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.archger.2019.05.020.

**References**

Beaulieu-Jones, B. R., O'Brien, D. M., Hopkins, S. E., Moore, J. H., Boyer, B. B., & Gilbert-Diamond, D. (2015). Sex, adiposity, and hypertension status modify the inverse effect of marine food intake on blood pressure in Alaska native (Yup'ik) people. *The Journal of Nutrition, 145*(5), 931–938. https://doi.org/10.3945/jn.114.209619.

Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., et al. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise, 35*(8), 1381–1395. https://doi.org/10.1249/01.mss.0000078924.61453.fb.

Duggan, E., Donoghue, O., Kenny, R. A., Cronin, H., Loughman, J., & Finucane, C. (2017). Time to refocus assessment of vision in older adults? Contrast sensitivity but not visual acuity is associated with gait in older adults. *The Journals of Gerontology Series A-Biological Sciences and Medical Sciences, 72*(12), 1663–1668. https://doi.org/10.1093/gerona/glx021.

Dutta, C., & Hadley, E. C. (1995). The significance of sarcopenia in old age. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 50*(Spec No: 1-4), https://doi.org/10.1093/gerona/50a.special_issue.1.

Fan, M. Y., Su, M., Tan, Y. Y., Liu, Q. M., Ren, Y. J., Li, L. M., et al. (2015). Gender, age, and education level modify the association between body mass index and physical activity: A cross-sectional study in Hangzhou, China. *PloS One, 10*(5)), e0125534. https://doi.org/10.1371/journal.pone.0125534.

Gale, C. R., Cooper, C., & Sayer, A. A. (2015). Prevalence of frailty and disability: Findings from the English Longitudinal Study of Ageing. *Age and Ageing, 44*(1), 162–165.

https://doi.org/10.1093/ageing/afu148.

Guralnik, J. M., LaCroix, A. Z., Abbott, R. D., Berkman, L. F., Satterfield, S., Evans, D. A., et al. (1993). Maintaining mobility in late life. I. Demographic characteristics and chronic conditions. *American Journal of Epidemiology, 137*(8), 845–857.

Hooker, E. R., Shrestha, S., Lee, C. G., Cawthon, P. M., Abrahamson, M., Ensrud, K., et al. (2017). Obesity and falls in a prospective study of older men: The osteoporotic fractures in men study. *Journal of Aging and Health, 29*(7), 1235–1250. https://doi.org/10.1177/0898264316660412.

Ivers, R. Q., Cumming, R. G., Mitchell, P., & Attebo, K. (1998). Visual impairment and falls in older adults: The Blue Mountains Eye Study. *Journal of the American Geriatrics Society, 46*(1), 58–64.

Jack, C. I., Smith, T., Neoh, C., Lye, M., & McGalliard, J. N. (1995). Prevalence of low vision in elderly patients admitted to an acute geriatric unit in Liverpool: Elderly people who fall are more likely to have low vision. *Gerontology, 41*(5), 280–285. https://doi.org/10.1159/000213695.

Koster, A., Ding, J., Stenholm, S., Caserotti, P., Houston, D. K., Nicklas, B. J., et al. (2011). Does the amount of fat mass predict age-related loss of lean mass, muscle strength, and muscle quality in older adults? *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 66*(8), 888–895. https://doi.org/10.1093/gerona/glr070.

Kuyk, T., & Elliott, J. L. (1999). Visual factors and mobility in persons with age-related macular degeneration. *Journal of Rehabilitation Research and Development, 36*(4), 303–312.

Lacey, R. J., Jordan, K. P., & Croft, P. R. (2013). Does attrition during follow-up of a population cohort study inevitably lead to biased estimates of health status? *PloS One, 8*(12), e83948. https://doi.org/10.1371/journal.pone.0083948.

Laitinen, A., Sainio, P., Koskinen, S., Rudanko, S. L., Laatikainen, L., & Aromaa, A. (2007). The association between visual acuity and functional limitations: Findings from a nationally representative population survey. *Ophthalmic Epidemiology, 14*(6), 333–342. https://doi.org/10.1080/01658100701473713.

Lo, A. X., Brown, C. J., Sawyer, P., Kennedy, R. E., & Allman, R. M. (2014). Life-space mobility declines associated with incident falls and fractures. *Journal of the American Geriatrics Society, 62*(5), 919–923. https://doi.org/10.1111/jgs.12787.

McGrath, R., Robinson-Lane, S. G., Peterson, M. D., Bailey, R. R., & Vincent, B. M. (2018). Muscle strength and functional limitations: Preserving function in older Mexican Americans. *Journal of the American Medical Directors Association, 19*(5), 391–398. https://doi.org/10.1016/j.jamda.2017.12.011.

Morie, M., Reid, K. F., Miciek, R., Lajevardi, N., Choong, K., Krasnoff, J. B., et al. (2010). Habitual physical activity levels are associated with performance in measures of physical function and mobility in older men. *Journal of the American Geriatrics Society, 58*(9), 1727–1733. https://doi.org/10.1111/j.1532-5415.2010.03012.x.

Murphy, R. A., Reinders, I., Register, T. C., Ayonayon, H. N., Newman, A. B., Satterfield, S., et al. (2014). Associations of BMI and adipose tissue area and density with incident mobility limitation and poor performance in older adults. *The American Journal of Clinical Nutrition, 99*(5), 1059–1065. https://doi.org/10.3945/ajcn.113.080796.

Ostchega, Y., Dillon, C. F., Lindle, R., Carroll, M., & Hurley, B. F. (2004). Isokinetic leg muscle strength in older americans and its relationship to a standardized walk test: Data from the national health and nutrition examination survey 1999-2000. *Journal of the American Geriatrics Society, 52*(6), 977–982. https://doi.org/10.1111/j.1532-5415.2004.52268.x.

Owsley, C., & Sloane, M. E. (1987). Contrast sensitivity, acuity, and the perception of' real-world' targets. *The British Journal of Ophthalmology, 71*(10), 791–796. https://doi.org/10.1136/bjo.71.10.791.

Patel, I., Turano, K. A., Broman, A. T., Bandeen-Roche, K., Munoz, B., & West, S. K. (2006). Measures of visual function and percentage of preferred walking speed in older adults: The Salisbury Eye Evaluation Project. *Investigative Ophthalmology & Visual Science, 47*(1), 65–71. https://doi.org/10.1167/iovs.05-0582.

Peel, C., Sawyer Baker, P., Roth, D. L., Brown, C. J., Brodner, E. V., & Allman, R. M. (2005). Assessing mobility in older adults: The UAB study of aging life-space assessment. *Physical Therapy, 85*(10), 1008–1119.

Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society, 39*(2), 142–148.

Rantanen, T., Guralnik, J. M., Foley, D., Masaki, K., Leveille, S., Curb, J. D., et al. (1999). Midlife hand grip strength as a predictor of old age disability. *JAMA, 281*(6), 558–560.

Rantanen, T., Guralnik, J. M., Izmirlian, G., Williamson, J. D., Simonsick, E. M., Ferrucci, L., et al. (1998). Association of muscle strength with maximum walking speed in disabled older women. *American Journal of Physical Medicine & Rehabilitation, 77*(4), 299–305.

Rovella, V., Anemona, L., Cardellini, M., Scimeca, M., Saggini, A., Santeusanio, G., et al. (2018). The role of obesity in carotid plaque instability: Interaction with age, gender, and cardiovascular risk factors. *Cardiovascular Diabetology, 17*(1), 46. https://doi.org/10.1186/s12933-018-0685-0.

Salthouse, T. A. (2014). Selectivity of attrition in longitudinal studies of cognitive functioning. *The Journals of Gerontology Series B, Psychological Sciences and Social Sciences, 69*(4), 567–574. https://doi.org/10.1093/geronb/gbt046.

Santanasto, A. J., Glynn, N. W., Lovato, L. C., Blair, S. N., Fielding, R. A., & Gill, T. M. (2017). Effect of physical activity versus health education on physical function, grip strength and mobility. *Journal of the American Geriatrics Society, 65*(7), 1427–1433. https://doi.org/10.1111/jgs.14804.

Soares, A. V., Marcelino, E., Maia, K. C., & Borges, N. G. (2017). Relation between functional mobility and dynapenia in institutionalized frail elderly. *Einstein-Sao Paulo, 15*(3), 278–282. https://doi.org/10.1590/S1679-45082017ao3932.

Stenholm, S., Alley, D., Bandinelli, S., Griswold, M. E., Koskinen, S., Rantanen, T., et al. (2009). The effect of obesity combined with low muscle strength on decline in mobility in older persons: Results from the InCHIANTI study. *International Journal of Obesity (London), 33*(6), 635–644. https://doi.org/10.1038/ijo.2009.62.

Thorpe, R. J., Jr., Clay, O. J., Szanton, S. L., Allaire, J. C., & Whitfield, K. E. (2011). Correlates of mobility limitation in African Americans. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 66*(11), 1258–1263. https://doi.org/10.1093/gerona/glr122.

Tsai, L. T., Rantakokko, M., Rantanen, T., Viljanen, A., Kauppinen, M., & Portegijs, E. (2016). Objectively measured physical activity and changes in life-space mobility among older people. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 71*(11), 1466–1471. https://doi.org/10.1093/gerona/glw042.

Vincent, H. K., Vincent, K. R., & Lamb, K. M. (2010). Obesity and mobility disability in the older adult. *Obesity Reviews, 11*(8), 568–579. https://doi.org/10.1111/j.1467-789X.2009.00703.x.

Wang, T., & Wu, Y. (2018). Weak grip strength and cognition predict functional limitation in older Europeans. *Journal of the American Geriatrics Society, 67*(1), 93–97. https://doi.org/10.1111/jgs.15611.

Whelan, B. J., & Savva, G. M. (2013). Design and methodology of the Irish longitudinal study on ageing. *Journal of the American Geriatrics Society, 61*(Suppl. 2), S265–268. https://doi.org/10.1111/jgs.12199.

Wolinsky, F. D., Miller, D. K., Andresen, E. M., Malmstrom, T. K., Miller, J. P., & Miller, T. R. (2007). Effect of subclinical status in functional limitation and disability on adverse health outcomes 3 years later. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 62*(1), 101–106. https://doi.org/10.1093/gerona/62.1.101.