The relationship between body mass index and 10-year trajectories of physical functioning in middle-aged and older Russians: Prospective results of the Russian HAPIEE study

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Conflict of interest

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Abstract

Objective: To investigate the associations of overweight and obesity with longitudinal decline in physical functioning (PF) among middle-aged and older Russians.

Design: Prospective cohort study

Setting: Four rounds of data collection in the Russian Health, Alcohol and Psychosocial factors In Eastern Europe study with up to 10 years of follow-up

Participants: 9,222 men and women aged 45-69 years randomly selected from the population of two districts of Novosibirsk, Russia

Measurements: PF score (range 0-100) was measured by the Physical Functioning Subscale (PF-10) of the 36-item Short Form Health Survey (SF-36) at baseline and three subsequent occasions. Body mass index (BMI), derived from objectively measured body height and weight at baseline, was classified into normal weight (BMI 18.5-24.9), overweight (BMI 25.0-29.9), obesity class I (BMI 30-34.9), and obesity class II+ (BMI≥35).

Results: The mean annual decline in PF score during follow-up was -1.92 (95% confidence interval -2.17; -1.68) in men and -1.91 (-2.13; -1.68) in women. At baseline, compared with normal weight, obesity classes I and II+ (but not overweight) were associated with significantly lower PF in both sexes. In prospective analyses, the decline in PF was faster in overweight men (difference from normal weight subjects -0.38 [-0.63 to -0.14]), class I obese men and women (-0.49 [-0.82; -0.17] and -0.44 [-0.73; -0.15] respectively) and class II+ obese men and women (-1.13 [-1.73;-0.53] and -0.43 [-0.77;-0.09] respectively). Adjustment for physical activity and other covariates did not materially change the results.

Conclusions: PF decreased more rapidly in obese men and women than among those with normal weight. The adverse effect of high BMI on PF trajectories appeared to be more pronounced in men than in women, making more extremely obese Russian men an important target population to prevent/slow down the process of decline in PF.

Key words: body mass index, physical functioning trajectories, growth curve modeling, middle-aged and older Russians

Introduction

Obesity is more common among older people than younger persons due to many lifestyle and biological factors, including age-dependent changes of body composition involving increased fat mass, decreased muscle mass, and redistribution of fat (increased visceral and intra-abdominal fat and reduced subcutaneous fat).[1-3] This poses a significant threat to older people's health, given the well-established link between obesity and heightened risk of a number of medical conditions, including type 2 diabetes, metabolic syndrome, hypertension, heart disease, dyslipidaemia, some cancers, osteoarthritis and disability.[2-6]

Considering the rapid population ageing phenomenon[7] and the high disease burden attributed to elevated body mass index (BMI) in Eastern Europe[8], obesity in the elderly is becoming one of the major challenges to public health in this region. Particularly in Russia, the ensuing political and economic transitions had a major impact on living standards, lifestyle and health status of the population.[9-14] One consequence accompanying these transitions is the rising prevalence of overweight and obesity.[10-12, 15] While in 1994, 28% of Russian adult women and 10% of adult men were obese (BMI≥30 kg/m^2),[10] by 2008 the prevalence increased to 33% and 19%, respectively.[16] In Novosibirsk, the 3rd populous city in Russia, the prevalence of obesity sustained high among women aged 25-64 years (40% in 1985/86 and 34% in 1994/95), but increased from 11% in 1985/86 to 15% in 1994/95 among men.[17]

Physical functioning (PF) is a key domain of health and quality of life of older people.[18, 19] Several systematic reviews have consistently confirmed obesity as a risk factor for loss of physical functioning (including physical impairments, functional limitations and physical disability) in older populations.[1, 2, 4-6, 20-24] The detrimental impacts of obesity on PF have been shown to be more pronounced in women than in men.[5, 6, 25, 26] The vast majority of previous prospective studies have focused on the relationship of overweight and obesity with the risk of impaired PF, using data from one or two measurement occasions. However, cross-sectional studies are prone to reverse causality bias, and estimation of longitudinal rate of change requires repeated measurements from at least three time points.[28] Given the limited number of studies with repeated measurements is limited, the evidence on the important question whether overweight and obesity affects the longitudinal rate of change in PF in older adults remains incomplete.[27] In addition, most such studies come from western populations; we are not aware of any such longitudinal study from the Eastern European region.

Given the obesity epidemic and rapid population ageing in Russia and the incomplete evidence on how obesity is associated with longitudinal rate of PF decline over time in older persons, we examined the relationship between BMI and 10-year longitudinal trajectories of PF in a cohort of middle-aged and older Russians.

Methods

Study subjects

We used data from the Russian part of the multi-centre prospective Health, Alcohol and Psychosocial factors In Eastern Europe (HAPIEE) study.[29] 9 301 men and women aged 45-69 years were randomly selected from electoral lists of two districts of Novosibirsk (Oktyabrski and Kirovski) at baseline in 2002-2005, stratified by sex and 5-year age groups. Four waves of data collection were conducted. Baseline data (2002-2005) were collected by trained nurses via a structured questionnaire and a short medical examination in a clinic. Re-examination of the cohort was conducted in 2006-2008 using face-to-face Computer Assisted

Personal Interview (CAPI). The cohort was further followed up via postal questionnaires in 2009 (PQ2009) and 2012 (PQ2012), respectively.

Physical functioning

Physical functioning was measured repeatedly using the same Physical Functioning Subscale (PF-10) of the Short-Form-36 (SF-36) questionnaire at all four occasions. The 10 items include vigorous activities (e.g., lifting heavy objects and doing strenuous sports), moderate activities (e.g., moving a table and pushing a vacuum cleaner), lifting/carrying a bag of groceries, climbing stairs, bending, kneeling or stooping, walking, and bathing and dressing. The participants reported the extent of their limitations to each activity as ‘not limited at all’, ‘limited a little’ or ‘limited a lot’. The responses to the 10 items were converted into a continuous score (0-100), with a higher score representing better PF.[30]

Body mass index

BMI (kg/m^2) at baseline was calculated by dividing body weight (kg) by the square of body height (metres). Both body weight and height were measured objectively during the examination performed in a clinic by trained nurses. Body height without shoes was measured using a mechanical stadiometer, and body weight (without shoes and outer clothes) was assessed by a balance beam scale. According to the World Health Organization (WHO)’s categorisation of BMI for adult population, participants were grouped into: normal weight (BMI 18.5-24.9), overweight (BMI 25.0-29.9), obese class I (BMI 30-34.9), and obese class II+ (BMI≥35). Only 79 participants were classified as underweight; given the small number of such individuals, we excluded them from the analysis.

Covariates

This analysis included several covariates, all measured at baseline. Marital status was coded as married/cohabiting or other. Participants' socioeconomic status was assessed by their highest educational attainment (<secondary education, secondary education, and university), economic activity, and material condition. Economic activity included four groups: employed, retired but still working, retired and no longer working, and unemployed. Material condition was based on a sum score of twelve household amenities and assets (e.g., microwave, car and cottage). At baseline, participants reported whether they had been diagnosed or hospitalised for a disease of spine or joints in the past year. Health behaviour variables contained smoking status (never, former and current smoking), drinking pattern and physical activity. Drinking pattern was obtained directly from a graduated frequency questionnaire combined drinking quantity and its corresponding frequency. Heavy vs. light-to-moderate drinking was dichotomised using ≥4 drinks during one day (≥2 drinks in women); these two categories were further split into regular vs. irregular drinking using the cut-off of ≥1/week (≥1/month in female heavy drinkers). Physical activity combined the hours per week doing physically demanding activities (e.g., gardening and maintenance of the house, averaged over summer and winter) and sports, games or hiking.

Statistical analysis

A total of 9 222 participants were included in this analysis. The missing data mainly came from the PF-10 scores at follow-up due to attrition (missingness is described in Supplementary Table 1). Multiple imputation by chained equations (MICE), a statistical method to replace missing values of variables by plausible values based on available observed data,[31-34] was applied to handle missing data. As approximately 70% of records had missing value on at least one study variable, a total of 70 imputed datasets were generated in Stata 12 (StataCorp, 2013), according to the rule of thumb that the number of imputed datasets should be equal or greater than the proportion of incomplete cases.[32] To optimise the imputation, we added a number of auxiliary variables predictive of missingness and/or values of study variables into the imputation models,[31, 32] including self-rate health, long-term health problems, history of cardiovascular disease, hypertension and cancer, history of injury, depressive symptoms, and social network. Moreover, consistent with an earlier study,[35] missing PF-10 scores due to death (1,085 deathss, 11.8% of our sample) were also imputed, considering that heavier participants may have poor PF at baseline, a faster PF decline over time, and a higher risk of death during follow-up (selective mortality bias). Once the multiply imputed datasets (with no missing data) were obtained, standard methods for complete-case analysis were used.[31-34] Random numbers were generated under normal distributions of follow-up years to replace missing follow-up years due to attrition.

Latent growth curve modelling captures inter-individual variations in intra-individual PF trajectories,[36, 37] and it has been widely used to study the decline of functioning in ageing populations.[21, 38, 39] We used the latent growth curve modelling in this analysis Visual inspection of data indicated a linear decline in PF over the ten years of follow-up. Accordingly, linear growth curve models were used and estimated in the multiply imputed datasets by M*plus* 6.0 (Muthén & Muthén, 1998-2011). In the linear models, two growth parameters characterise the PF trajectories during follow-up: the *initial status* (model-implied PF-10 score at baseline) and the *slope* (model-implied rate of decline in the PF-10 score per year of follow-up). All models were estimated using maximum likelihood estimation with robust standard errors because of the non-normal distribution of the PF-10 scores.

Both growth parameters were regressed on BMI and covariates. All models were fitted in men and in women separately, adjusting for baseline age only (centred on 58 years, model 1) and baseline age, marital status, highest educational attainment, economic activity, material condition, history of spine/joint problems, drinking pattern and smoking status (model 2). Since smokers appeared to be slimmer than non-smokers,[2] we tested the interaction between smoking status and BMI on both growth parameters (p values for interaction>0.10). We also failed to detect statistically significant interactions between physical activity and BMI on either growth parameter (p values for interaction>0.50). An additional model was then estimated controlling for all covariates in model 2 and physical activity (model 3).

The age trends of the PF-10 score at baseline and its decline over the 10-year follow-up in the four BMI groups were demonstrated at the same time using ageing-vector graphs.[40] In the ageing-vector graphs, the starting point of the arrow represents the model-implied initial status of PF-10 score at baseline; while the arrow indicates the direction of the change in PF-10 score over time during follow-up. The ageing-vector graphs were plotted based on estimates from model 2 and produced in Stata in men and women separately.

Results

Participant characteristics based on the imputed datasets are summarised in Table 1. There were pronounced differences between men and women in the PF-10 scores and the BMI categories. Men had approximately 10 points higher PF-10 scores than women at all measurement occasions but the decline in the score at PQ2012 vs. baseline was similar between men (17.6 points) and women (18.1 points). More women than men were classified as class I obese (29.1% of women vs. 16.8% of men) and class II+ obese (18.3% of women vs. 4.2% of men), although the proportions of overweight persons were similar in men and women. Compared with men, women also appeared to have lower socioeconomic status, higher prevalence of spine/joints problems and more favourable health behaviours.

Table 2 presents the associations of BMI with the PF-10 score at baseline (*initial status*, cross-sectional relationship) and with the rate of decline in the score per year of follow-up (*slope*, longitudinal relationship). In both men and women, the lowest PF-10 score at baseline was found in those with class II+ obesity after adjustment for age, following by those with class I obesity. In the multivariable-adjusted models (model 2), the difference in the PF-10 score at baseline between normal weight and class II+ obesity categories was -7.34 points (95% confidence interval[CI]: -10.22, -4.45) in men and -11.48 points (95% CI: -13.29, -9.67) in women. The disparities of the baseline score between normal weight and obese groups appeared to be larger in women than in men, and the sex differences were marginally statistically significant (p value for interaction 0.07).

Longitudinally, overweight was not related to the PF-10 slope in either men or women but a steeper decline in the PF-10 score during follow-up was observed in class II+ obese men and in class I and II+ obese women compared to normal weight (model 1). Further adjustment (model 2) did not change the relationship of BMI with the *slope* of decline in PF in women. The *slope* of PF decline was similar between class I obese women (the *slope* compared with normal weight: -0.44, 95% CI: -0.73, -0.15) and class II+ obese women (-0.43, 95% CI: -0.77, -0.09). By contrast, in men, the association between BMI and the *slope* of decline in PF became stronger in model 2, with the gradient in slope for overweight (the *slope* compared with normal weight: -0.38, 95% CI: -0.63, -0.14) and class I obesity statistically significantly related to a faster decline (-0.49, 95% CI: -0.82, -0.17). The fastest decline *slope* was found in men with class II+ obesity (-1.13, 95% CI: -1.73, -0.53) in comparison with normal weight men. However, the sex differences in the *slopes* of PF decline were not statistically significant (p value for interaction 0.19).

Figure 1 illustrates the PF trajectories by BMI categories in men and women separately for six birth cohorts aged 45, 50, 55, 60, 65 and 69 years at baseline, using ageing-vector graphs based on the results of model 2. In men, differences in the PF-10 score between the four BMI categories widened during follow-up at all ages. In women, the PF trajectories in normal weight and overweight women were parallel, as were the trajectories in class I and class II+ obesity, but the gap in the PF-10 score between normal weight and obese women also widened over time at all ages.

Additional adjustment of physical activity did not alter the cross-sectional or longitudinal relationship between BMI and PF in either gender (Supplementary table 2). Physical activity was associated with baseline PF-10 scores but it was unrelated to the decline rate over time. Given that diet has been shown to be associated with PF,[5, 41-43] we also added the Healthy Diet Indicator[11, 44] in the model 2 but the association of BMI with either PF at baseline or the slope of PF decline remained essentially unchanged (results no shown). Similarly, the pattern of longitudinal results did not change after controlling for baseline health characteristics (self-rated health, long-standing illness, cancer, hypertension and cardiovascular disease), after restricting the sample to complete cases (i.e. subjects who had no missing data and survived until PQ2012), or when we restricted the sample to those with good PF at baseline (baseline PF-10 score>=75). Additionally, no statistically significant interactions between age and BMI (p values >0.10) were found on either growth parameter. The PF trajectories by BMI categories before vs. after statutory retirement age in men and women are shown in Supplementary figure 1.

Discussion

This study investigated whether BMI is associated with 10-year trajectories of PF in middle-aged and older Russian men and women. Compared with normal weight, no effect of overweight was observed on PF at baseline or longitudinally in either gender, with an exception of a faster decline among overweight men. Obesity was associated with less favourable PF at baseline and a faster decline over time in both genders. The adverse impact of obesity on baseline PF appeared stronger in women than in men but the faster decline over time in obese persons seemed more pronounced in men than women.

In general, our findings confirmed the conclusion of previous reviews that obesity is associated with impaired PF in the elderly.[1, 2, 4-6, 20-24] However, recently published analysis of the WHO's Study on global AGEing and Adult Health (SAGE) found no cross-sectional associations between BMI and limitations in activities of daily living (used to reflect severe physical disability) among middle-aged and older Russian men and women.[45] The discrepancy is most likely explained by the fact that severe physical disability, an extreme loss of PF, is relatively rare; while our study, using a continuous measure of PF was better powered to detect such an association.

The distribution of the BMI categories in our sample was similar to the SAGE Russian cohort.[45] The rising prevalence of overweight and obesity in this Russian population is fuelled by the traditional Russian diet with features of high in sugar, meat and dairy products and low in vegetables and fruits, coupled with households' shift to cheaper food such as potatoes during the transitions to cope with income and price shocks.[10, 12, 46] The expansion of fast food and westernisation of diet in Russia also contribute to the increase of obesity.

Household surveys from Russian Statistical Agency showed that cheap bread, pastries, potato and sugar provided over 50% of the calories of household meals in 2009.[15] Other contributors to the obesity epidemic may include fewer physically demanding jobs, growing cost of leisure physical activity, and urbanisation and development of public transport.[10, 11, 15]

Existing evidence on the longitudinal relationship between BMI and the decline in PF over time is sparse,[27] and to our knowledge, no previous study has explored the possible modifying role of gender in this longitudinal relationship. Our findings were in agreement with Artaud *et al.*[27] who reported a faster decrease of walking speed in obese older persons than those with normal weight. Conflicting findings were shown in three earlier studies which found no association of BMI with the rate of change in mobility or physical disability.[47-49] These inconsistencies may be partly explained by a shorter follow-up time in two studies (4-6 years),[47, 48] and a comprehensive inclusion of possible predictors (multiple testing) in the other study.[49]

The link between obesity and impaired PF is proposed to be mediated through obesity-associated medical conditions such as diabetes mellitus, metabolic syndrome, cardiovascular disease, dyslipidemia, and osteoarthritis in particular.[6, 50-52] Other biological mechanisms linking obesity and poor PF may involve degeneration of muscle quality and function caused by the accretion of fat in muscle,[53] increased expression of inflammatory cytokines released by adipose tissue,[6, 52-54] and development of insulin resistance.[6, 52-54] The excessive weight also overburdens the lower extremities when doing physical activities and causes damages to musculoskeletal systems and connective tissues.[52]

One earlier study reported a joint effect of physical activity and BMI on PF, although this effect seemed mainly driven by BMI.[55] Vasquez *et al.*[26], on the contrary, found an increased risk of functional limitations with elevated BMI regardless of physical activity status. We did not find the associations of BMI with the PF trajectories (neither *initial status* nor *slope*) to be modified by physical activity. Physical activity explained some of the disparities in baseline PF across the BMI categories but none of the differential decline rates over time. In fact, the adverse effects of high BMI on both the baseline PF and its longitudinal decline were robust, even after taking in account a number of covariates.

Consistent with previous studies,[5, 6, 25, 26] we found an apparently stronger effect of obesity on PF at baseline among women than men. The mechanisms of this gender difference are unclear. It may be connected with the overrepresentation of women with high BMI,[25] the biological differences in body composition between genders,[25, 26, 56] the better ability to recover from disability in men,[26, 57] and the tendency in men to under-report their physical limitations.[25] Alternatively, the differential PF at baseline across the BMI categories between men and women may merely mirror a longer survival time with disabling conditions (until the time of baseline data collection) in women than in men.[2, 25, 58, 59]

Longitudinally, the adverse impact of overweight and obesity on the decline rate of PF, and class II+ obesity in particular, appeared to be greater in men than in women. Besides the under-representation of class II+ obese men in our sample, a possible explanation could be the removal of differential survival effect between genders in our longitudinal analysis. In contrast to earlier studies, we did not exclude deceased cases from our analytical sample; instead, the missing data due to death during follow-up were imputed based on observed data. The expanding gaps of PF across the BMI categories in men was more pronounced than in women, and it may reflect the higher odds for men to develop disabling conditions than women.

One of the main strengths of this study is the large sample size in a rarely studied ageing population of Russia. BMI was derived from objectively measured height and weight, which minimises measurement error. An important strength that sets this study apart from the most previous studies is the use of repeated measures of PF, assessed by a widely-used and validated instrument. Such data enabled us to examine how BMI was associated with the rate of change in PF in an ageing population over time, not merely the risk of impaired PF. Furthermore, sufficient statistical power enabled us to investigate gender differences in the PF trajectories by BMI categories.

Several limitations of our study also need to be considered. First, BMI may not be an ideal indicator of adiposity in older populations, because both body height and weight change with advancing age.[2, 4] The elderly's body height shrinks as a result of vertebral compression and reduced thickness of inter-vertebral discs, leading to a false increase in BMI and an overestimation of adiposity in older people.[2, 4] On the other hand, body weight underestimates older persons' adiposity because of the age-dependent increase of fat mass and decrease of lean body mass.[2, 4]

Second, PF was self-reported and is subject to reporting bias. The reporting bias may vary by health status and PF as participants in poor health/PF may be less willing to report their physical limitations. If this misclassification was differential across the BMI categories, the PF trajectories across the BMI categories may be estimated incorrectly. However, the PF-10 score was correlated with objective physical performance measures in the expected direction, supporting the validity of the PF-10 score (Supplementary table3). Physical activity was also self-reported (based on 3 questions) and it did not take into account working-related activities. Other covariates, such as dietary factors, may also influence PF and its association with obesity. Although adjustment for physical activity and the Healthy Diet Index did not affect the estimated association between BMI and PF, misclassification of covariates may have potentially resulted in some residual confounding. Overall, however, adjustment for covariates had little effect on the results.

Third, we could not examine the association in underweight subjects because of the small number of underweight subjects (0.8% of our sample). Moreover, the accelerated decline in PF found among extremely obese men was also based on a small group of participants. Future studies with oversampling of underweight older people and extremely obese older men therefore are needed.

Finally, there were some missing data in our dataset, mainly on the PF-10 scores at follow-up. The MICE technique assumes that the missingness does not depend on unobserved data,[31, 32] however, this may not entirely hold in our study. Being obese, less healthy, and physically limited may prevent participants from staying in the cohort during follow-up. In this case, the imputed PF-10 scores at follow-up may be higher than the 'true' scores, resulting in underestimated decline in PF and underestimated gaps in the PF trajectories between BMI categories.

Conclusion

We found lower PF at baseline and an accelerated decline in PF in obese middle-aged and older Russian men and women. Overweight was associated with a slightly faster decline in PF in men but the steepest decline in PF was observed in obese men and women. This suggests that obese middle-aged and older adults are at increased risk of impaired PF and an attention should be paid to this high-risk group.

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