Research Article

Association of Breathing Reserve at Peak Exercise With Body Composition and Physical Function in Older Adults With Obesity

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Abstract

Background: Adiposity-related ventilatory constraints in older adults can potentially contribute to greater risk of exercise intolerance and mobility disability. This study investigated whether ventilatory limitation, measured by breathing reserve (BR) at peak exercise, is associated with body composition and physical function in older adults with obesity.

Methods: This study was a cross-sectional analysis of data from a community-based cohort ($N = 177$) of older men and women (65–79 years) with obesity (body mass index = 30–45 kg/m²). All participants underwent cardiopulmonary exercise testing on a treadmill, dual-energy X-ray absorptiometry for body composition, and physical function assessments. We examined relationships between BR and body composition and physical function using multiple linear regression and compared a subset with (BR ≤ 30%; BR-low; $n = 56$) and without (BR ≥ 45%; BR-high, $n = 48$) ventilatory limitation using unpaired Student's t test and analysis of covariance.

Results: BR was inversely related to total body mass, lean mass, fat mass, % body fat, and waist circumference ($p < 0.05$ for all). BR was positively related to 400 m walk time ($p = .006$) and inversely related to usual gait speed ($p = .05$) and $\text{VO}_{2\text{peak}}$ ($p < .0001$), indicative of worse physical function. BR-low had greater adiposity, but also greater lean mass, higher $\text{VO}_{2\text{peak}}$, and faster 400 m walk time, compared to BR-high ($p < .05$, for all).

Conclusions: Older adults with obesity who also have ventilatory limitation have overall higher measures of adiposity, but do not have lower peak exercise capacity or physical function. Thus, ventilatory limitation does not appear to be a contributing factor to obesity-related decrements in exercise tolerance or mobility.

Keywords: Aging, Respiratory mechanics, Lean mass, Functional performance, Maximal oxygen consumption.

Aging is associated with a progressive decline in respiratory function and gas exchange efficiency that is often overlooked as a contributing factor to declines in overall physical function in older adults (1,2). The Framingham Offspring cohort showed a mean decline in the forced expiratory volume in the first second (FEV₁) on the order of 17–20 mL/y starting at the age of 23–40 years, in healthy women and men (3). Furthermore, when challenged by an increase in ventilatory demand during peak exercise, older adults have reduced ventilatory capacity and use a greater amount of breathing reserve (BR)

compared to younger individuals (4,5). Although this progressive deterioration in lung function is a natural process of aging, little is known about the consequences of reduced ventilatory capacity for maintaining physical function and independence with aging.

Furthermore, these aging-related ventilatory constraints may be exacerbated by aging-related changes in body composition, especially by increases in adiposity. Compared to normal-weight individuals, persons with obesity have lower respiratory system compliance, functional residual capacity, and expiratory reserve volume (perhaps

due to mechanical loading of excess adipose tissue on the chest wall) (6). During exercise, individuals with obesity require more respiratory work to maintain ventilation related to excess metabolic demand, possibly reflecting movement of heavier limbs (7,8). A progressive reduction in ventilatory capacity is associated with increasing body mass index. The BR reflects how closely ventilatory demand approaches ventilatory capacity at peak exercise in individuals with obesity (9). With this, exercise intolerance due to a physiological ventilatory limitation is seen in those with little to no BR (10). In obesity, ventilatory capacity is reduced; however, the amount of ventilatory demand elicited by individuals is variable (11). Further, there is increasing evidence suggesting that lower pulmonary function and respiratory muscle strength correlate with lower total muscle mass in community-dwelling older adults who are overweight or obese (12). Thus, older individuals with greater adiposity and less muscle may have even greater limitations in ventilatory capacity during exercise.

With this, the BR is used to classify the cause of exercise limitation whereas peak oxygen uptake ($\text{VO}_{2\text{peak}}$) is used to determine the extent of exercise limitation during a cardiopulmonary stress test (13). As such, a $\text{BR} \leq 30\%$ is often used to discriminate a ventilatory limitation. To date, there have been few studies that have looked at BR in older adults or which have used small sample sizes or had highly selected participants.

The aim of this study was to investigate whether BR at peak exercise in older persons with obesity is associated with physical function and body composition. We hypothesized that the presence of a ventilatory limitation (indicated by a low BR) is associated with greater adiposity, lower lean mass, and worse physical function in healthy older individuals with obesity.

Methods

Study Design

This is a cross-sectional analysis of baseline data collected as part of the Investigating Fitness Interventions in the Elderly study (NCT01048736), conducted January 2010–February 2014. All participants provided written informed consent. The study was approved by the Wake Forest School of Medicine Institutional Review Board.

Participants

Data regarding participant age, sex, race/ethnicity, and comorbidities were captured via self-report at the baseline screening visit in 177 study participants who were enrolled based on the following inclusion and exclusion criteria: (a) aged 65–79 years, (b) sedentary for the past 6 months (<30 minutes, <3 d/wk of structured exercise), (c) obese (body mass index = $30\text{--}45$ kg/m²), (d) weight stable ($<5\%$ weight change in the past 6 months), (e) nonsmoking for at least 1 year, and (f) without insulin-dependent or uncontrolled diabetes, uncontrolled hypertension, heart disease, chronic pulmonary disease, cancer, liver or renal disease, neurological or hematological disease, cognitive impairment, physical impairment (dependent on a cane or walker), or any contraindication to exercise.

Assessments

Body composition

Total body mass was measured on a calibrated scale after removal of shoes and outer garments. Whole-body fat mass, % body fat, and lean mass were measured using dual-energy X-ray absorptiometry (Hologic Delphi A 11.0 QDR; Hologic, Bedford, MA). Waist and hip

circumference were measured in triplicate and values were averaged for data analysis.

Physical function

Mobility was assessed using a timed 400 m walk test (14). Participants were asked to complete the distance as quickly as possible without running. Lower extremity function was assessed with the Short Physical Performance Battery (SPPB) (15). The SPPB consists of three measures: a standing balance test, usual gait speed over 4 m, and time to complete five repeated chair rises without arms. Results from each of the three tests are scored and summed from 0 (lowest function) to 12 (highest function) (16).

Cardiopulmonary exercise test

Peak aerobic capacity ($\text{VO}_{2\text{peak}}$) was determined on a motorized treadmill during a graded exercise test to exhaustion. A ramp protocol was used in which the speed was held constant according to individual ability, and the incline increased at small intervals throughout the test (17). Ventilatory and gas exchange responses were measured on a breath-by-breath basis using a computerized system (MGC Diagnostics, St. Paul, MN). This allowed measurements for minute ventilation ($\dot{V}_E$), respiratory frequency (f_R), oxygen uptake (VO_2), carbon dioxide output (VCO_2), end-tidal CO_2 ($P_{\text{ET}}\text{CO}_2$), and end-tidal O_2 ($P_{\text{ET}}\text{O}_2$); for more details, see [Supplementary Methods](#). BR was calculated as $1 - [\dot{V}_E / \text{maximum voluntary ventilation (MVV)}] \times 100\%$ using measured ventilation responses at peak exercise. Additional calculated variables included O_2 pulse [$\text{VO}_{2\text{peak}} / \text{maximum heart rate}$], $\dot{V}_E / \text{VO}_2$ ratio, and $\dot{V}_E / \text{VCO}_2$ ratio. $\text{VO}_{2\text{peak}}$ was obtained when at least two of these three criteria were met: (a) plateau in oxygen consumption with increasing workload (<200 mL/min), (b) respiratory exchange ratio (RER) ≥ 1.10 , and (c) maximal heart rate within 90% of age-predicted. All variables are presented at peak exercise.

Statistical Analysis

All analyses were performed using SAS, version 9.4 (SAS Institute, Cary, NC), and JMP Pro, version 13.0 (SAS Institute). Baseline descriptive statistics were calculated and values are reported as means and standard deviations, ranges, or as frequency in percentages. As a low BR at peak exercise less than or equal to 30% has typically been associated with ventilatory limitation (13), a subset ($n = 56$) of those participants with BR less than or equal to 30% (BR-low) were compared to a subset ($n = 48$) whose BR at peak exercise was in the upper quartile of the cohort ($\text{BR} \geq 45\%$, BR-high). We compared participants with low and high BR using the unpaired Student's t test for parametric continuous, Wilcoxon rank sum test for nonparametric continuous, and chi-square test for categorical variables.

We used multiple linear regression analyses for each measure of body composition and physical function to investigate their relationship with BR at peak exercise. BR was entered as the main predictor, both as a continuous and categorical variable. Measures of body composition and physical function were entered as dependent variables. We present the beta coefficients and their standard errors for each model adjusted for (1) sex, race, height, age, and $\text{VO}_{2\text{peak}}$ in mL/kg/min for measures of body composition and (2) sex, race, height, and age for measures of physical function.

We used analysis of covariance to compare body composition and physical function between BR-high and BR-low and adjusted for the same set of covariates previously cited. Least squares means

with their standard errors and 95% confidence intervals are presented for each outcome based on the regression model. All possible interactions between the main predictor (BR group) and covariates that were continuous variables were examined by including specific interaction terms to evaluate for homogeneity of slopes. All tests were two-sided and a p value $< .05$ was considered to be statistically significant.

Results

Participant Demographics

Table 1 lists the demographic characteristics and chronic medical conditions of the entire cohort together, and by BR-high and BR-low. Overall, 133 (75%) of the participants were female and 130 (73%) white. The most common self-reported comorbidities were arthritis (71%), hypertension (60%), and sleep apnea (36%). BR-low were more likely to be black ($p = .001$) and had lower height ($p = .02$), similar weight ($p = .82$), but higher body mass index ($p = .03$) compared to BR-high. There was no significant difference in sex between BR-high and BR-low. Similar trends in self-reported comorbidities were seen within the BR groups as within the overall cohort and no significant differences were seen in their self-reported comorbidities (see [Supplementary Table 1](#)).

Associations Between BR at Peak Exercise Capacity and Other Cardiopulmonary Variables at Peak Exercise

A comparison of cardiopulmonary variables at peak exercise between the participants with ventilatory limitation (BR-low) and those without ventilatory limitation (BR-high) is shown in **Table 2**. The mean RER of both groups was at least 1.10. $\text{VO}_{2\text{peak}}$ mL/min was 10.4% higher in BR-low ($p = .03$) and remained significantly higher even after correcting for total body mass (mL/kg/min) compared to BR-high. Ventilatory responses at peak exercise were

significantly different between BR-high and BR-low. f_R was 24.0% higher ($p < .0001$), V_E was 24.9% higher ($p < .0001$), VCO_2 was 14.8% higher ($p = .001$), end-tidal O_2 was 5.3% higher ($p < .0001$), end-tidal CO_2 was 18.4% lower ($p < .0001$), V_E/VO_2 ratio was 16.8% higher ($p < .0001$), and V_E/VCO_2 ratio was 11.9% higher ($p < .0001$) in BR-low compared to BR-high. Work performed at peak exercise was 11% higher in BR-low compared to BR-high ($p = .002$). Self-reported rating of perceived exertion was similar in both groups.

Associations Between BR at Peak Exercise Capacity and Body Composition

The relationships between body composition measures and BR, adjusted for sex, race, height, age and, $\text{VO}_{2\text{peak}}$ are shown in **Table 3**. Overall, BR was negatively associated with total body mass, fat mass, % body fat, lean mass, and waist circumference. There was no significant relationship between BR and waist-to-hip ratio.

The association between ventilatory limitation and body composition was also examined by comparing BR-high and BR-low. There were no statistically significant BR group interactions with height (p range: .33–.88), age (p range: .34–.87), or $\text{VO}_{2\text{peak}}$ (p range: .28–.84). When comparing BR-low to BR-high, those in BR-low had higher total body mass (100.6 ± 1.4 vs 92.2 ± 1.7 kg, $p < .0001$), fat mass (42.3 ± 1.1 vs 37.2 ± 1.4 kg, $p = .002$), lean mass (55.7 ± 0.6 vs 52.6 ± 0.8 kg, $p = .001$), and waist circumference (109.0 ± 1.4 vs 101.7 ± 1.7 cm, $p = .0004$) (**Figure 1**). Waist-to-hip ratio and % body fat did not differ between BR groups.

Associations Between BR at Peak Exercise Capacity and Physical Function

The relationships between $\text{VO}_{2\text{peak}}$, 400 m walk time, usual gait speed, and SPPB and BR, adjusting for sex, race, height, and age are shown in **Table 4**. $\text{VO}_{2\text{peak}}$ was negatively related to BR (ie, higher $\text{VO}_{2\text{peak}}$ was associated with lower BR), whereas 400 m walk time was positively related to BR (ie, faster time to complete 400 m

Table 1. Baseline Characteristics of the Participants Overall and Stratified by Breathing Reserve (BR) Group

	Overall (N = 177)			BR-high (n = 48)			BR-low (n = 56)		
Age, y	69.2	(3.5)	65.0–79.2	69.0	(3.5)	65.0–79.0	69.4	(3.3)	65.1–78.2
Height, cm*	164.7	(9.0)	140.2–87.2	166.8	(9.6)	149.4–185.7	162.5	(8.3)	140.2–178.9
Weight, kg	93.8	(13.2)	71.1–139.7	93.9	(13.4)	73.5–124.6	93.3	(13.6)	71.1–139.7
Body mass index, kg/m ² *	34.6	(3.5)	29.9–44.6	33.7	(3.1)	29.9–43.0	35.3	(4.0)	30.3–44.6
Resting seated blood pressure									
SBP, mm Hg	135.6	(17.1)	100–183	133.7	(17.3)	100–180	138.2	(18.9)	106–183
DBP, mm Hg	74.5	(10.1)	50–101	74.3	(10.8)	51–101	74.0	(10.8)	50–98
Sex									
Female	133	(75%)		34	(71%)		44	(79%)	
Male	44	(25%)		14	(29%)		12	(21%)	
Race**									
White	130	(73%)		42	(89%)		33	(59%)	
Black	47	(27%)		6	(13%)		23	(41%)	
Comorbidities									
Arthritis	125	(71%)		35	(73%)		43	(77%)	
Hypertension	106	(60%)		26	(54%)		39	(70%)	
Sleep apnea	63	(36%)		15	(31%)		24	(43%)	
Asthma	20	(11%)		8	(17%)		7	(13%)	
Noninsulin-treated diabetes	30	(17%)		6	(13%)		9	(16%)	
Osteopenia	24	(14%)		8	(17%)		6	(11%)	

Notes: Values are mean (SD), N (%), or range. DBP = diastolic blood pressure; SBP = systolic blood pressure.

* $p < .05$, ** $p < .01$ using unpaired t test to compare BR-high and BR-low.

Table 2. Comparison of Cardiopulmonary Responses at Peak Exercise Between BR Groups

	BR high (<i>n</i> = 48)		BR low (<i>n</i> = 56)		<i>p</i> value
f_R , breaths/min	32.6	(5.5)	42.9	(7.7)	<.0001
V_E , liters/min	51.9	(11.3)	69.2	(15.3)	<.0001
BR, %	50.2	(5.2)	21.1	(6.4)	<.0001
VO_2 , mL/min	1,573.2	(359.0)	1,755.0	(460.2)	.03
VO_2 , mL/kg/min	16.5	(2.6)	18.7	(4.0)	.002
VCO_2 , L/min	1.8	(0.4)	2.1	(0.5)	.001
V_E/VO_2	33.3	(3.9)	40.0	(5.1)	<.0001
V_E/VCO_2	29.5	(3.6)	33.5	(3.7)	<.0001
$P_{ET}O_2$, mm Hg	106.6	(4.5)	112.6	(4.3)	<.0001
$P_{ET}CO_2$, mm Hg	42.3	(11.0)	35.8	(3.2)	<.0001
HR, beats/min	137.7	(11.8)	145.6	(11.1)	.0006
O_2 pulse, mL/beat	11.5	(2.7)	12.3	(2.7)	.14
RER	1.15	(0.08)	1.20	(0.10)	.005
MET	4.7	(0.7)	5.3	(1.1)	.002
RPE	17.5	(1.5)	17.7	(1.2)	.47

Note: Values are mean (SD). BR = breathing reserve; f_R = respiratory frequency; RER = respiratory exchange ratio; HR = heart rate; MET = metabolic equivalent; $P_{ET}CO_2$ = end-tidal CO_2 ; $P_{ET}O_2$ = end-tidal O_2 ; RPE = rating of perceived exertion; VCO_2 = carbon dioxide output; V_E = minute ventilation; VO_2 = oxygen uptake.

Table 3. Relationship Between Breathing Reserve and Measures of Body Composition

	β	SE	<i>p</i> value
Total body mass, kg	-0.33	0.06	<.0001
Lean mass, kg	-0.10	0.03	.0003
Fat mass, kg	-0.23	0.04	<.0001
Body fat, %	-0.08	0.03	.003
Waist circumference, cm	-0.24	0.06	<.0001
Waist-hip ratio	-0.0004	0.0005	.43

Note: Adjusted for sex, race, height, age, and VO_{2peak} in mL/kg/min. *N* = 177. β = regression coefficient; SE = standard error for the regression coefficient.

associated with lower BR). There were no significant relationships between usual gait speed and SPPB with BR.

The association between ventilatory limitation and physical function was also examined by comparing BR-high and BR-low. There were no statistically significant BR group interactions with height (*p* range: .16–.55) and age (*p* range: .13–.99). The BR-low group had higher VO_{2peak} corrected for total body mass (19.5 ± 0.4 vs 16.1 ± 0.6 mL/kg/min, *p* < .0001; Figure 2). Furthermore, after correcting VO_{2peak} mL/min for lean mass, BR-low had higher VO_{2peak} mL/kg lean mass/min compared to BR-high [mean (SD): 35.0 (4.7) vs 30.9 (5.8), *p* = .0002], which remained significantly higher in BR-low even after adjusting for sex, race, height, and age (35.0 ± 0.8 vs 29.4 ± 1.0 mL/kg lean mass/min, *p* < .0001). BR-low had faster 400 m walk time (324.1 ± 9.0 vs 354.9 ± 11.6 s, *p* = .01) (Figure 2). Usual gait speed and SPPB did not differ between groups.

Discussion

To the best of our knowledge, this is the first study that investigates the relationship between BR, body composition, and physical function in sedentary older adults with obesity. Our study has several important findings. BR has an inverse relationship with total body mass, lean mass, fat mass, percent body fat, waist circumference, VO_{2peak} , and positive relationship with 400 m walk time. On average, a 1% higher BR was associated with a 0.33 kg lower total body mass,

0.10 kg lower lean mass, 0.23 kg lower fat mass, 0.08% lower percent body fat, and 0.24 cm lower waist circumference. Further, a 1% higher BR was associated with a 0.11 mL/kg/min lower VO_{2peak} and 1.03 seconds slower 400 m walk time. Our comparison of BR groups showed that BR-low had greater total body mass, fat mass, and waist circumference, but more lean mass and better physical function compared to BR-high. With this, our study describes two types of obese individuals: (a) BR-low, those with ventilatory limitation but also high cardiorespiratory fitness; and (b) BR-high, those with no ventilatory limitation but lower cardiorespiratory fitness.

An important observation from this study is the association of BR with cardiopulmonary variables at peak exercise and the influences of body composition on respiratory work at peak exercise in BR-low. Our findings are consistent with cross-sectional studies that suggest that the high ventilatory demand reflected by higher V_E at peak exercise in BR-low is a response to the high metabolic costs of performing work that is related to increased adiposity (7,8). Our study shows that BR-low had higher metabolic equivalent and RER and suggests higher energy expenditure and exercise intensity compared to BR-high at peak exercise. Peak RER effort is used as an objective criterion of effort and has been shown to be an indirect marker of muscle oxidative capacity, suggesting a higher CO_2 production and O_2 consumption in metabolism in BR-low (18). Further, at peak exercise the lower end-tidal CO_2 , higher O_2 , V_E/VCO_2 , and V_E/VO_2 in BR-low reflect the ventilatory response to metabolic acidosis and degree of ventilation–perfusion mismatch or dead space ventilation from ventilatory constraints and higher workload due to excess adiposity (19). Perhaps these individuals are physiologically adapting to exercise by increasing their V_E by increasing f_R at or near peak exercise, but ultimately have ventilatory compromise from ventilatory limitation at peak effort, as similarly described in other studies conducted in middle-aged adults with obesity (11,20).

Our data show that low ventilatory capacity is related to high adiposity and can ultimately result in physiological low BR but may not be a limiting factor for physical function or exercise capacity in the older adult population. We suspect this may be related to the independent linear relationship seen between BR and lean mass. We further hypothesize the inverse relationship between BR and lean mass to be associated with the linear relationship between lean body mass and body mass index seen in prior studies (21). Also, it is well

Figure 1. Association between measures of body composition and BR group. BR-high = breathing reserve at least 45% ($n = 48$); BR-low = breathing reserve less than or equal to 30% ($n = 56$). Data are least squares (LS) means with 95% CI for measures of body composition, adjusting for sex, race, height, age, and $\text{VO}_{2\text{peak}}$ mL/kg/min.

Table 4. Relationship Between Breathing Reserve and Measures of Physical Function

	β	SE	p value
$\text{VO}_{2\text{peak}}$, mL/kg/min	-0.11	0.02	<.0001
400 m walk time, s	1.03	0.37	.006
Usual gait speed, m/s	-0.002	0.001	.05
SPPB	-0.004	0.009	.67

Note: Adjusted for sex, race, height, and age. $N = 177$. β = regression coefficient; SE = standard error for the regression coefficient; SPPB = Short Physical Performance Battery.

established that peak VO_2 is a function of lean mass and is higher in those with a greater amount of muscle tissue (22). Studies in older adults show a positive relationship between lean mass and cardiorespiratory fitness, suggesting declines in $\text{VO}_{2\text{peak}}$ are associated with progressive declines in lean mass (23). In our study, $\text{VO}_{2\text{peak}}$ mL/kg body mass/min was 18.2% higher and 400 m walk time was 11.1% faster in BR-low compared to BR-high. Further, BR-low still had higher $\text{VO}_{2\text{peak}}$ compared to BR-high even when normalized for lean mass.

Figure 2. Association between measures of physical function and BR group. BR-high = breathing reserve at least 45% ($n = 48$); BR-low = breathing reserve less than or equal to 30% ($n = 56$). Data are least squares (LS) means with 95% CI for measures of physical function, adjusting for sex, race, height, and age.

Our study has important implications in research and clinical settings in older adults with obesity: (a) although obesity is risk factor for reduced physical activity and physical function (24), low BR may not be a detriment to functional status and exercise capacity. We highlight the levels of complexity between the association of BR and functional status in older adults that may be related to lung function, psychosocial status, level of dyspnea at peak exercise, nutritional status, thoracolumbar curvature, and daily physical activity level, in which more studies are needed (24–26). (b) It is important to understand the mechanisms that contribute to ventilatory limitation and the physiological adaptations associated with the ability to adapt to higher intensity exercise that require high ventilatory demand as well as the ability to increase cardiorespiratory fitness in order to minimize the adverse effects of ventilatory constraints from increased adiposity in this population. This may subsequently help in prescribing exercise training in this population. (c) Randomized controlled trials have demonstrated that successful weight loss is both achievable and has beneficial effects in older adults, at least 65 years, with obesity (27). However, the effects of weight loss on BR in the older adult population are not known. Future research should investigate the effects of lifestyle changes that include both exercise and weight loss on BR. Measures of body composition including total and regional fat and lean mass distribution with specific information on upper body or thoracic and abdominal areas by regional dual-energy X-ray absorptiometry measures, pulmonary function, oxygen costs of breathing, end-expiratory lung volumes, and/or cardiopulmonary responses during exercise should be considered to investigate the influence of weight loss and exercise interventions on BR in this population.

Our study has limitations. Pulmonary function testing was not obtained; therefore, objective evaluation for restrictive or obstructive lung defects could not be done. Further, we relied on directly

measured MVV in determining ventilatory capacity and subsequent BR at peak exercise, which is dependent on patient effort and their ability to sustain rapid and deep breaths (28). As such, BR may be underestimated in individuals who exhibit poor effort. However, participants in this study achieved appropriate levels of effort at peak exercise based on RER (29). The mean of the group RER was 1.2 (0.08), 174 (98%) of participants achieved a sufficient level of effort ($\text{RER} \geq 1.0$), and 141 (80%) of participants achieved an excellent level of effort ($\text{RER} \geq 1.1$) at peak exercise. Alternative approaches have included a calculated MVV that is predicted through a resting pre-exercise FEV_1 through spirometry. Although use of FEV_1 is widely applied clinically, its accuracy is limited by the variance of the prediction equation used ($\text{FEV}_1 \times 35\text{--}40$) (28). Currently, there is no gold standard that establishes normal spirometry thresholds or that can be used to diagnose obstructive or restrictive lung disease in older adults, and standard norms for ventilatory capacity are not yet established for older adults (30). The complex interactions between aging and obesity on the effects on respiratory muscle strength, respiratory compliance, and airway resistance may further lead to variations in FEV_1 and therefore over- or underestimate MVV. Finally, calculated and measured MVV have been shown to be similar in prior studies (31). As such, we consider a directly measured MVV for calculation of BR to be the better alternative in this older population. In addition, examining end-expiratory lung volumes and operational lung volumes is an emerging tool that may further provide insight into ventilatory limitation to exercise in the older adult population with obesity (32). Second, on the basis of the study's inclusion and exclusion criteria, all participants were without physical impairment and were able to complete all study testing. Therefore, this study may not fully represent the general older adult obese population.

In conclusion, we found that BR is significantly associated with body composition and physical function. Compared to BR-high, BR-low had greater total body and fat mass, and lean mass. The ventilatory responses observed at peak exercise among BR-low are consistent with existing literature on the effects of higher adiposity on the respiratory system (7–9,19). However, this group also had better physical function and cardiorespiratory fitness, suggesting that the presence of ventilatory limitation at peak exercise is not associated with exercise intolerance and low physical function.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of interest statement

None declared.

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