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Differences in geriatric anthropometric data between DXA-based subject-specific estimates and non-age-specific traditional regression models

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Abstract

Age, obesity, and gender can have a significant impact on the anthropometrics of adults aged 65 and older. The aim of this study was to investigate differences in body segment parameters derived using two methods: (1) a dual-energy x-ray absorptiometry (DXA) subject-specific method (Chambers et al., 2010) and (2) traditional regression models (de Leva, 1996). The impact of aging, gender, and obesity on the potential differences between these methods was examined. Eighty-three healthy older adults were recruited for participation. Participants underwent a whole-body DXA scan (Hologic QDR 1000/W). Mass, length, center of mass, and radius of gyration were determined for each segment. In addition, traditional regressions were used to estimate these parameters (de Leva, 1996). A mixed linear regression model was performed ($\alpha = 0.05$). Method type was significant in every variable of interest except forearm segment mass. The obesity and gender differences that we observed translate into differences associated with using traditional regressions to predict anthropometric variables in an aging population. Our data point to a need to consider age, obesity, and gender when utilizing anthropometric data sets and to develop regression models that accurately predict body segment parameters in the geriatric population, considering gender and obesity.

Keywords

anthropometry; elderly; obesity

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In recent years we have seen a growing population of adults aged 65 years and older in the United States. One of the major health concerns of this aging population is obesity. In the United States alone, adults aged 65 years and older have the highest rate of increasing obesity (Flegal et al., 2002; Ogden et al., 2006). Injuries, especially resulting from falls, are also a serious health burden for older adults. In 2003, injury ranked sixth in leading causes of death among adults aged 65–74 years and seventh among adults aged 75–84 years, making it comparable to diabetes and Alzheimer's disease (Dellinger & Stevens, 2006; Gillespie et al., 2003). Overweight adults aged 65 and older have a greater risk of impaired physical function and are at higher risk for injury (Lang et al., 2008; Ostbye et al., 2007). Biomechanical investigations have shown that obesity is associated with difficulties in postural control and gait variations, both of which may increase injury risk (Colné et al., 2008; Lai et al., 2008). The costs of nonfatal injuries doubled from ages 65–74 years to 75–84 years, suggesting an increased burden with increasing age (Stevens, 2005). The aging population and related obesity concerns point to a need to determine the impact of obesity on injury risk (Wearing et al., 2006). Such research requires body segment parameters that accurately represent obese older adults.

Anthropometric data are necessary to develop biomechanical models of the body used in injury prevention research (Durkin & Dowling, 2003; Hughes et al., 2004; Kuczmarski et al., 2000; Matrangola et al., 2008). Age, obesity, and gender can have a significant impact on segment mass, center of mass location, and radius of gyration for a number of body segments in older adults (Chambers et al., 2010; Matrangola et al., 2008; Muri et al., 2008). Muri et al. (2008) found significant differences for all the inertial properties of the upper arm, center of mass location of the forearm, and thigh mass in old adults compared with young adults. Chambers et al. (2010) found that males aged 65 and over had a greater trunk and upper-extremity mass whereas females aged 65 and over had a higher lower extremity mass. Body segment parameters also vary with weight and obesity (Chambers et al., 2010; Damavandi et al., 2009; Matrangola et al., 2008). Obese adults aged 75 and over were found to have a significantly greater trunk segment mass with less thigh and shank segment mass than nonobese. Females possessed a more distal trunk center of mass than males (Chambers et al., 2010).

Typically, body segment parameters are derived from regression equations or models based on cadaveric studies (Chandler et al., 1975; Dempster, 1955) or imaging (de Leva, 1996). A major limitation of these predictive equations is their lack of incorporating age, race, or body type (Durkin & Dowling, 2003; Matrangola et al., 2008). As a result, the use of these parameter estimates has been shown to be inaccurate in populations of varying ages (Bauer et al., 2007; Dumas et al., 2005; Durkin & Dowling, 2003; Ganley & Powers, 2004). In fact, certain authors suggest that predictive equations should not be used outside the population on which they are based (Dumas et al., 2005).While the impact of these inaccuracies remains unclear, the potential errors associated with traditional body segment estimations warrants a need for accurate body segment parameters that consider obesity in an aging population (Dumas et al., 2005; Ganley & Powers, 2004; Rao et al., 2006; Silva & Ambrósio, 2004).

The aim of this study was to investigate differences in body segment parameters that are derived using two methods: (1) a subject-specific method based on dualenergy x-ray absorptiometry (DXA) (Chambers et al., 2010) and (2) traditional regression models (de Leva, 1996). Such comparison is important to assess the magnitude of differences between the two models when they are used to estimate body segment parameters in a geriatric population with respect to gender and obesity. These comparisons will educate us as to whether caution should be used when applying traditional regression models to an obese aging population.

Methods

Eighty-three healthy adults, screened for metal implants, were divided into eight groups based on gender (female; male), obesity group determined from body mass index (BMI; ≤30, nonobese, and >30, obese), and age group (65–75 years, old, and >75 years, elderly) (Table 1). Before participation, written informed consent approved by the University of Pittsburgh Institutional Review Board was obtained.

Each participant underwent a whole-body DXA scan (Hologic QDR 1000/W, Bedford, MA, USA) lying supine. For each DXA scan, segment boundaries were identified similarly to de Leva (1996), using bony landmarks or anatomically defined planes. The head segment was defined from vertex to gonion. The forearm was defined from elbow joint center to wrist joint center. The upper arm was defined from shoulder joint center (estimated as the midpoint of the right and left acromion) following the trunk/upper-arm plane to elbow joint center. The trunk/upper-arm plane ran through the acromion to the axilla and was used to divide the trunk and upper-arm segments. The trunk was defined from shoulder joint center (estimated as the midpoint of the right and left acromion) following the trunk/upper-arm plane to the midpoint of the hip joint center following the trunk/thigh plane. The trunk/thigh plane, located just lateral to the anterior superior iliac spine and the ischial tuberosity of the pelvis, was used to divide the trunk and thigh segments. The thigh was defined from hip joint center following the trunk/thigh plane to knee joint center with the mass of pelvis not included. The shank was defined from knee joint center to lateral malleolus. Only the dominant appendage was used for this analysis.

Each scan was divided into 3.9-cm sections, perpendicular to the long axis of the bone, and processed in a method similar to that described in Ganley and Powers (2004). Each scan was characterized by a pixel size of .205 cm × 1.30 cm, that is, an area of .27 cm2. Assumed densities for bone (2.5–3.0 g/cc), fat (0.9 g/cc), and lean (1.08 g/cc) tissue were used (Hologic QDR 1000/W). Scan calibration error was less than 1.5% as specified by the manufacturer.

Segment inertial parameters were then calculated for the frontal plane only. Segment mass (SM) as a percent of body mass (%BM); segment length (SL) as a percent of total height (%H); distance from the center of mass to the proximal end of the segment (COM), assumed along the longitudinal axis, as a percent of segment length (%SL); and radius of gyration (k) about an axis perpendicular to the frontal plane, through the center of mass, as a percent of segment length (%SL) were determined (Durkin & Dowling, 2003; Ganley & Powers, 2004). In addition, traditional regression-based proportions were used to estimate SM, SL, COM, and k (de Leva, 1996).

Each dependent variable of interest was entered individually in a mixed linear regression model using method (DXA/de Leva), gender, obesity, and age group (main effects and first- and second-order interactions) as fixed factors. Subject was a random factor in the model. Post hoc analyses included comparisons using a Tukey test. Statistical significance was set at 0.05. In addition to the statistical analysis, percent difference was calculated to aid in assessing the differences between DXA and the traditional regression model (Eq. 1).

$$\text{Percentage difference}=[(\text{DXA}-\text{de Leva})\div\text{de Leva}]\times 100\% \quad (1)$$

Results

As mentioned previously, since findings related to the absolute effects of obesity, gender, and age on DXA-generated parameters were previously reported (Chambers et al., 2010), the results here will focus on the differences between the two derivation methods (DXA and de Leva) and how these differences are affected by obesity, gender, and age group.

Method was significant in every variable of interest for each segment except forearm SM (Table 2). Traditional regressions significantly underestimated head, trunk, upper arm, forearm, and thigh SL while significantly overestimating shank SL. Nonobese individuals were underestimated more by traditional regressions than obese for head SL. Females were underestimated more by traditional regressions than males for trunk and thigh SL, with a total of approximately 21% and 29% difference, respectively. Upper-arm SL was underestimated more for elderly adults than old adults.

Head, upper-arm, thigh, and shank SM were significantly overestimated by the traditional regressions while trunk SM was significantly underestimated (Table 2, Figure 1). The obese group possessed a greater difference in head and trunk SM than nonobese. More specifically, obese individuals had a 13% difference compared with nonobese at 6% for trunk SM. Forearm and shank SM were significantly overestimated by traditional regressions in obese while no difference was found in nonobese individuals. Males had a greater head and thigh SM overestimation than females. However, shank SM was overestimated by traditional regressions in females but no difference was noted in males. Obese females had the greatest overestimates in shank SM with approximately –20% difference. Thigh SM was overestimated more by traditional regressions in the elderly group than in old adults. Interestingly, the obese elderly group presented the greatest differences with underestimates in trunk SM, approximately 16%, and overestimates in thigh, ~25%, and shank SM, ~20% (Figure 1).

The estimate of the COM position for every segment was significantly different between methods. DXA-based subject-specific COM for the head, upper arm, forearm, and shank were more proximal while trunk and thigh were more distal than traditional regressions (Table 2, Figure 2). Nonobese individuals had a greater difference across method in thigh COM yet obese individuals had a greater shank COM difference. In general, females showed greater differences in COM than males, specifically, ~45% difference in trunk, ~26% difference in thigh, and ~10% difference in shank COM. It should be noted that males still reported approximately 24% difference in trunk COM. Males also possessed a greater difference, ~13%, in upper arm COM than females. Nonobese females had the greatest difference in head COM(Figure 2).

In general, k, except for forearm and shank, was significantly overestimated by traditional regressions (Table 2, Figure 3). Head, trunk, and thigh k had as much as ~35%, ~25% and ~29% difference, respectively. Obese individuals were found to have greater differences in trunk and forearm k than nonobese. The nonobese group had greater overestimation by traditional regressions of head k than obese. Interestingly, males reported the greatest differences in head, upper-arm, forearm, and shank k compared with females. In fact, there were no differences reported between methods for shank and forearm k in females. Thigh k was the only segment in which females had higher overestimation associated with method than males at ~29% compared with ~22%. For upper arm k, nonobese old males had the greatest differences while nonobese old females had the least differences (Figure 3).

Discussion

Age, obesity, and gender can have a significant impact on body segment parameters (Chambers et al., 2010). The aim of this study was to report on potential differences in body segment parameters when derived with using DXA compared with traditional regressions in an obese geriatric population. In summary, an average of 13.82% difference (mean of all percent differences) was found in body segment parameters derived with de Leva compared with DXA-based subject-specific estimates. This average, which varied with gender and obesity, ranged from 0.15 to 47.01%.

Method was significant for SL in every segment of interest. Traditional regressions significantly underestimated head, trunk, upper-arm, forearm, and thigh SL while significantly overestimating shank SL. Nonobese individuals were underestimated more than obese for head SL. Females were underestimated more than males for trunk and thigh SL with a total of approximately 21% and 29% difference, respectively. It is possible that limitations concerning vertical resolution may account for the DXA SL values being in general larger than for the traditional regressions. However, the mean summed SL was within an acceptable range of error (Chambers et al., 2010). It should be noted that the larger differences associated with nonobese and females SL illustrate the need for certain adjustments in specific populations.

All segments, except forearm, reported that method was significant for SM. Head, upper-arm, thigh, and shank SM were significantly overestimated by the traditional regressions while trunk SM was significantly underestimated. Although previous research has found underestimates of thigh SM in children and young adults (Dumas et al., 2005; Ganley & Powers, 2004), overestimates of thigh SM were found in young and middle-aged adults (Durkin & Dowling, 2003). Similar to Durkin and Dowling (2003), our results show an overestimation of thigh SM with traditional regressions in old and elderly adults. In fact, thigh SM was overestimated more in the elderly group than in old adults. This redistribution of mass with age is expected (Jensen & Fletcher, 1994; Stoudt, 1981). Obese individuals possessed a higher difference in head, forearm, shank, and trunk SM than nonobese. Almost 23% difference was found in head SM and ~13% in shank and trunk SM of the obese group. Males had a greater head and thigh SM overestimation than females. The greater difference associated with thigh SM in old and elderly males is especially interesting. Previous literature has found greater misestimations of thigh SM in middle-aged females compared with males (Durkin & Dowling, 2003). While there are still differences associated with female SM in our old population, they appear to be more accentuated in males. However, shank SM was overestimated in females and no difference was noted in males. Obese females had the greatest overestimates in shank SM at around –20% difference. Previous research found that shank SM is dependent on age, with traditional regressions resulting in underestimations in young adults and overestimations in middle-aged adults (Durkin & Dowling, 2003; Mungiole & Martin, 1990). Our results suggest a similar trend is maintained in elderly females but lost in males. A combination of age and obesity presented the greatest differences, with the obese elderly group having underestimates in trunk SM, ~16%, and overestimates in thigh SM, ~25%, and shank SM, ~20%. Previous literature has found that trunk and thigh SM increases with obesity, especially in the elderly (Chambers et al., 2010; Hughes et al., 2004; Okosun et al., 2004; Price et al., 2006). It is apparent that the traditional regressions do not accurately represent these age-, obesity-, and gender-specific changes in SM.

COM for every segment was significantly different between methods. Head, upper arm, forearm, and shank COM were more proximal, whereas trunk and thigh COM were more distal than traditional regressions. Similarly, previous research in other age groups found that the shank COM is more proximal than traditional anthropometric estimations reported (Durkin & Dowling, 2003; Ganley & Powers, 2004; Mungiole & Martin, 1990). In addition, thigh COM has been reported more distal than traditional regressions in children and young adults (Durkin & Dowling, 2003; Ganley & Powers, 2004). However, the forearm COM results here are contradictory to results found in a younger population, with the forearm COM being more distal than traditional regressions (Durkin & Dowling, 2003). Nonobese individuals had a greater difference in thigh COM, more distal, while obese individuals had a greater shank COM difference. Although no one has investigated changes in COM with obesity in the elderly, Matrangola et al. (2008) noted a more distal thigh COM after weight loss in middle-aged males. This may help to explain how our nonobese group possessed a more distal thigh COM and in turn greater differences than obese. A more proximal shank COM in obese individuals can be explained by the typical addition of mass proximally on the shank segment with weight gain. In general, females showed greater differences in COM than males, specifically, ~45% difference in trunk, ~26% difference in thigh and ~10% difference in shank COM. Okada et al. (1996) reported significantly larger mass ratio of the lower trunk and smaller mass ratio of the upper trunk in elderly females compared with males. An increased mass in the lower trunk and less in the upper trunk would translate into a more distal trunk COM in elderly females. Since traditional regressions are based on young healthy adults, typically males, it is not surprising that such large differences were found in elderly females. Differences in estimating COM may have implications in balance and stability. Previous research has found that the central nervous system adapts a more distal COM for perturbations, which may serve to increase stability, as the body's mass becomes closer to the base of support (Marigold & Patla, 2002). Applying traditional regressions that misestimate COM in an aging or obese population may result in misinterpretations in biomechanics and postural control.

In general, k, except for forearm and shank, was significantly overestimated by traditional regressions. Head, trunk, and thigh k had as much as ~35%, ~25%, and 29% difference, respectively. Previous research found that thigh k was also overestimated by traditional regressions in young and middle-aged adults (Durkin & Dowling, 2003). Interestingly, males reported the greatest differences in head, upper arm, forearm, and shank k compared with females. Thigh k was the only segment in which females had higher overestimation associated with method. Obese individuals were found to have greater differences in trunk and forearm k than nonobese. The nonobese group had greater overestimation of head k than obese. Previously, obese individuals were found to have a greater head k and less trunk and forearm k than nonobese (Chambers et al., 2010). Damavandi et al. (2009) found differences in k between obese individuals and traditional regressions. In addition, a decrease in k was noted in all segments with weight loss (Matrangola et al., 2008). These differences may account for the obesity interactions with method reported here. In general, there is little reported in the literature on the effect of obesity on body segment parameters, especially COM and k. Durkin & Dowling (2003) reported large differences within both young and middle-aged male and female body segment parameters, especially in the thigh. The authors acknowledge that these variations might be attributed to variations in body type or obesity. Damavandi et al. (2009) found that even though k derived from traditional regressions matched well for subjects with a normal BMI, they were not recommended to be applied in obese populations.

The body segment parameters presented here were consistent with values reported in the literature (Durkin & Dowling, 2003; Jensen & Fletcher, 1994; Muri et al., 2008; Pearsall et al., 1996). The mean summed SL to represent patient height was 101.49% (.61%). The mean summed SM, assuming equal dominant and nondominant limbs, was 94.03% (.93%). This shortcoming can be contributed to ignoring the hands, feet, and portions of the thigh and pelvis due to delineations (Chambers et al., 2010). Segment delineations between DXA and the traditional regression methods (de Leva, 1996) did not match exactly in all cases. The shoulder joint center was estimated as the acromion. This approximation would have affected the upper arm and the trunk segments by slightly inflating the DXA measures. This inconsistency, if corrected, would actually result in an increase in the differences seen in the upper-arm segment and a possible decrease in differences seen in the trunk segment. However, with the differences found in the trunk parameters being as large as ~45%, it is certain that significant differences would still exist.

Other limitations of this study should be considered. Whole-body DXA scans were performed while subjects were in the supine position with the foot rotated slightly inward. This prevented accurate analysis of the foot segment and may have contributed to soft tissue deformation compared with a vertical position. While this would not affected SL or SM, it may have resulted in slight misestimations of COM position and k. Standing may cause soft tissue to shift distally compared with laying supine, which could impact the results presented here, especially in the obese group. DXA scans were performed in the frontal plane only. This resulted in unknown COM and k in the sagittal and transverse planes. Race was not considered in this analysis, and it may have a significant impact on body segment parameters (Durkin & Dowling, 2003; Okada et al., 1996; Shan & Bohn, 2003). This study was mainly (94%) composed of Caucasian individuals; as such, variations in race should have minimal effects on the results.

In conclusion, age, obesity, and gender can have a significant impact on SM, COM, and k in adults aged 65 and older. These differences translate into potential errors associated with using traditional regressions to predict anthropometric variables in an aging, obese population. The data presented here points to a need (1) to consider age, obesity, and gender when utilizing anthropometric data sets, and (2) to develop accurate regression models that consider gender and obesity when predicting body segment parameters in a geriatric populations.

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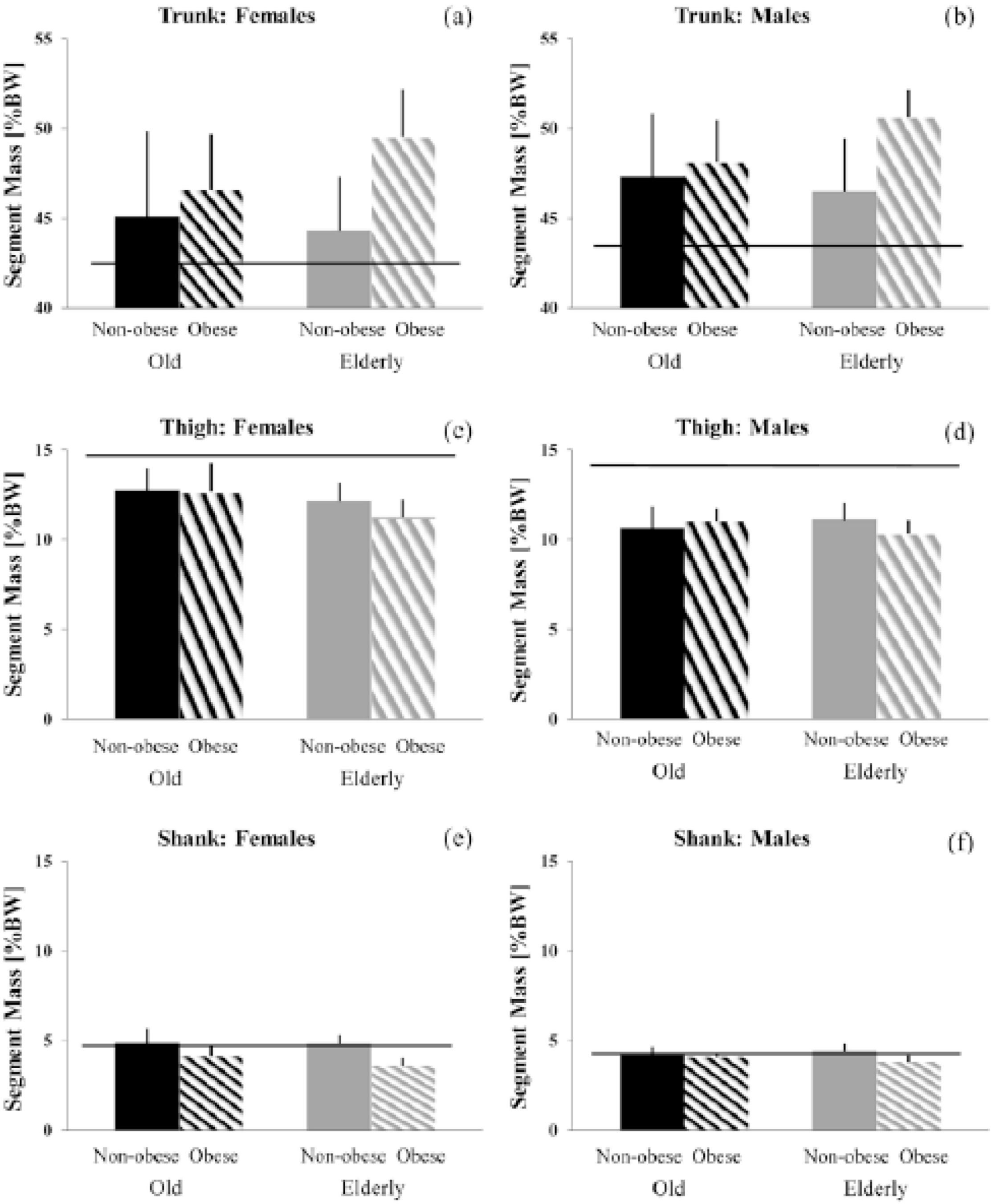

Figure 1.

Mean segment mass as a percentage of body weight (%BW) of the trunk (a,b) thigh (c,d), and shank (e,f) in females and males, left and right, respectively, determined from DXA. Nonobese shown as solid bars and obese as hashed bars, with old adults in black and elderly in gray. Black horizontal lines represent traditional regression values (de Leva, 1996). Standard errors are provided.

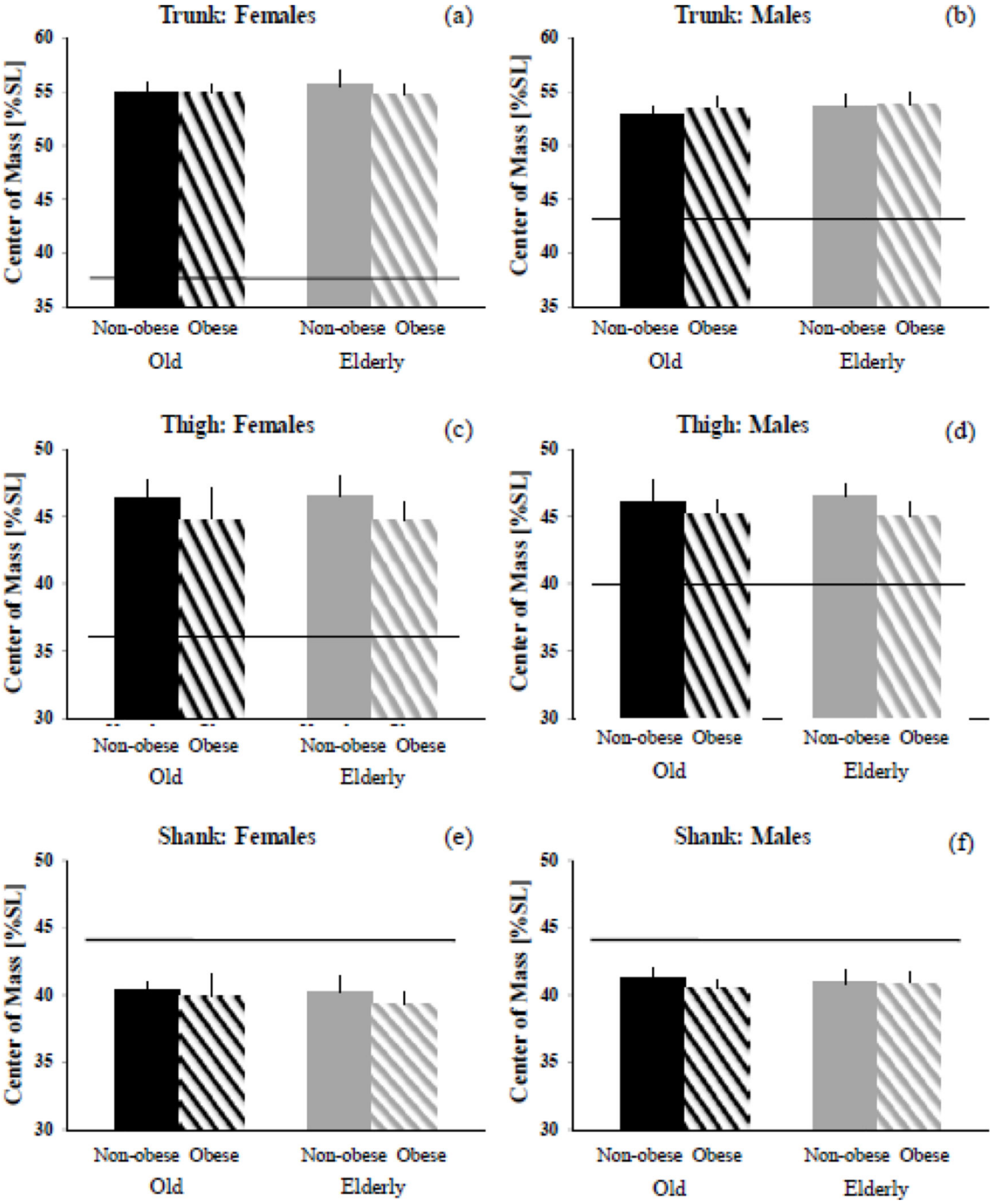

Figure 2.

Mean segment center or mass location from the proximal border as a percentage of segment length (%SL) of the trunk (a,b), thigh (c,d), and shank (e,f) in females and males, left and right, respectively, determined from DXA. Nonobese shown as solid bars and obese as hashed bars with old adults in black and elderly in gray. Black horizontal lines represent traditional regression values (de Leva, 1996). Standard errors are provided.

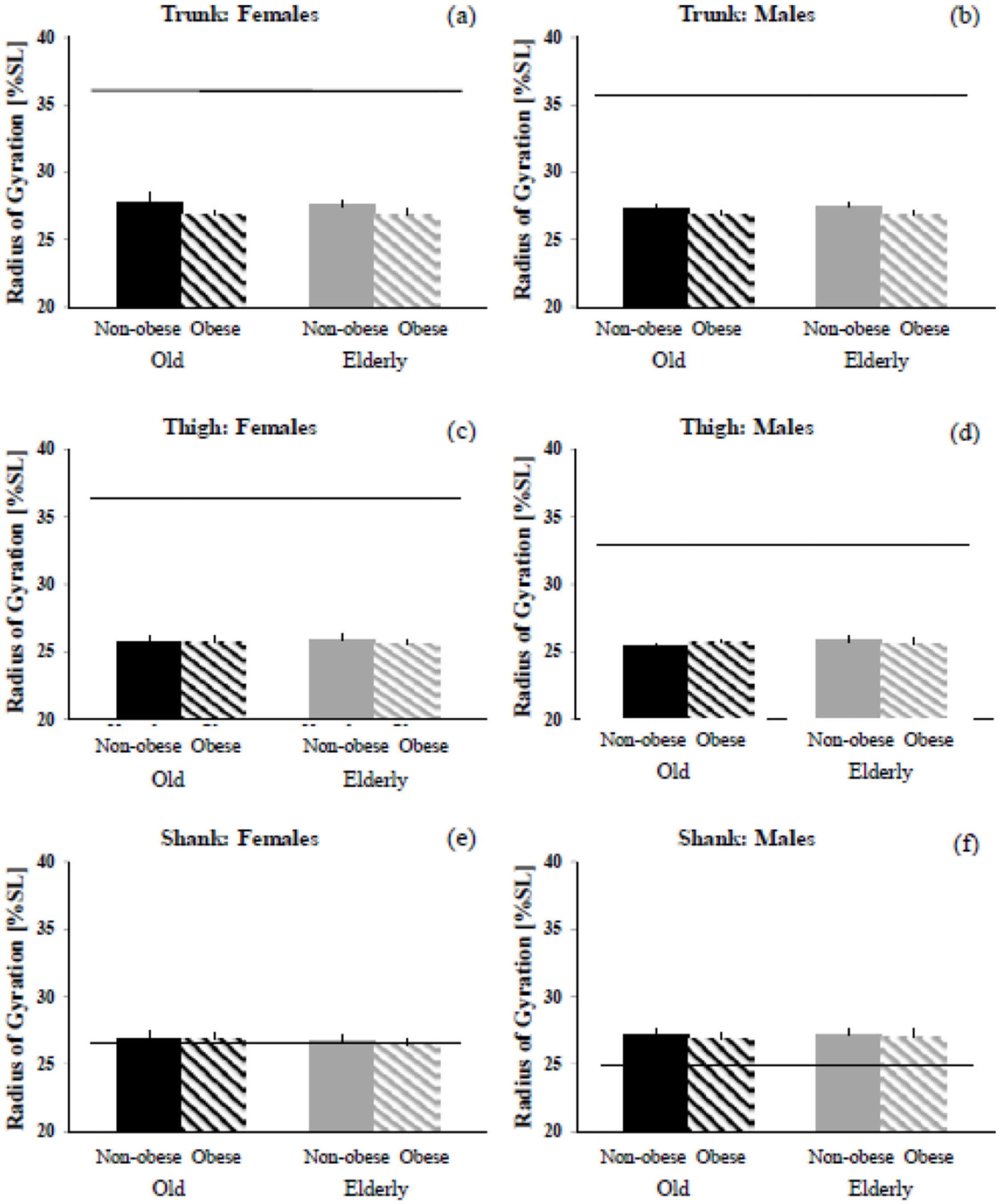

Figure 3.

Mean frontal plane radius of gyration as a percentage of segment length (%SL) of the trunk (a,b), thigh (c,d), and shank (e,f) in females and males, left and right, respectively, determined from DXA. Nonobese shown as solid bars and obese as hashed bars with old adults in black and elderly in gray. Black horizontal lines represent traditional regression values (de Leva, 1996). Standard errors are provided.

Table 1

Subject population characteristics: means (*SD*), with the range in brackets

	Female				**Male**			
	Old		**Elderly**		**Old**		**Elderly**	
	Nonobese	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**
	(*n* = 8)	**(*n* = 10)**	**(*n* = 13)**	**(*n* = 11)**	**(*n* = 7)**	**(*n* = 10)**	**(*n* = 14)**	**(*n* = 10)**
Age (years)	70.36 (2.42)	70.88 (2.35)	79.23 (2.94)	79.47 (2.76)	69.84 (3.28)	70.59 (2.64)	79.08 (3.15)	78.49 (2.02)
	[66.95–73.48]	[66.69–73.66]	[75.10–85.66]	[75.65–83.68]	[65.68–74.97]	[66.46–74.99]	[75.58–85.02]	[76.41–82.24]
BMI	24.82 (3.68)	34.72 (4.57)	25.00 (2.79)	34.11 (3.09)	26.99 (1.98)	33.75 (2.09)	25.94 (2.90)	33.97 (4.20)
	[19.86–28.97]	[31.18–47.03]	[20.41–29.76]	[30.18–39.41]	[25.28–29.61]	[30.85–38.15]	[19.75–29.71]	[30.14–41.26]
Mass (kg)	65.80 (7.94)	87.78 (14.78)	61.17 (6.52)	83.60 (10.92)	80.29 (12.60)	102.00 (11.50)	78.39 (10.00)	102.10 (18.14)
	[54.40–76.50]	[70.40–124.20]	[52.20–72.80]	[65.30–105.60]	[67.00–97.00]	[88.70–122.50]	[56.00–97.10]	[83.30–133.81]
Height (m)	1.63 (0.03)	1.59 (0.06)	1.57 (0.07)	1.56 (0.08)	1.72 (0.08)	1.74 (0.06)	1.74 (0.05)	1.73 (0.06)
	[1.58–1.69]	[1.47–1.71]	[1.46–1.66]	[1.46–1.67]	[1.62–1.82]	[1.64–1.85]	[1.64–1.81]	[1.62–1.82]

Table 2

Percent differences of segment length (SL), segment mass (SM), center of mass location (COM), and radius of gyration (*k*) between DXA and de Leva for each segment of interest

	Female				Male			
	Old		Elderly		Old		Elderly	
	Nonobese	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**
SL								
Head$^{m\,o}$	21.69	17.97	16.29	12.82	5.60	7.72	7.55	3.69
Trunk$^{m\,g}$	19.09	19.85	20.91	24.83	17.12	15.32	14.25	17.57
Upper arm$^{m\,a}$	24.96	28.09	30.88	28.78	27.46	24.47	28.46	26.86
Forearm^{m}	3.33	4.84	7.06	6.71	4.21	6.73	5.52	5.67
Thigh$^{m\,g}$	27.99	28.43	23.02	25.63	10.90	10.86	11.73	12.19
Shank^{m}	−3.69	−3.38	−1.89	−5.09	−2.97	−3.58	−3.13	−3.77
SM								
Head$^{m\,o}$	3.11	−20.72	−0.22	−21.06	−7.97	−24.70	−9.95	−25.23
Trunk$^{m\,g}$	5.96	9.38	4.12	16.46	8.92	10.79	6.94	16.55
Upper arm$^{m\,a}$	−9.00	−2.81	−5.44	−2.15	−5.15	−5.57	−7.11	−4.26
Forearm^{m}	5.88	−7.35	6.36	−8.99	4.90	−3.55	−1.45	−9.47
Thigh$^{m\,g}$	−13.78	−14.18	−17.76	−24.07	−25.00	−21.89	−21.65	−26.81
Shank^{m}	1.07	−13.95	0.61	−24.90	−3.11	−5.50	2.50	−11.77
COM								
Head$^{m\,o}$	−12.95	−9.67	−10.61	−7.41	−7.65	−9.81	−9.81	−7.88
Trunk$^{m\,g}$	45.41	45.50	47.01	44.70	22.61	24.39	24.64	25.15
Upper arm$^{m\,a}$	−10.57	−10.45	−10.93	−11.28	−13.99	−12.89	−13.07	−13.33
Forearm^{m}	−2.91	−2.32	−3.62	−1.21	−3.06	−2.34	−3.53	−2.49
Thigh$^{m\,g}$	28.30	24.15	28.67	23.92	12.59	10.73	13.55	10.05
Shank^{m}	−8.65	−9.61	−8.95	−10.83	−7.48	−8.99	−8.24	−8.16
k								
Head$^{m\,o}$	−31.94	−31.38	−32.92	−30.91	−34.96	−33.61	−35.01	−33.58

	Female				Male			
	Old		Elderly		Old		Elderly	
	Nonobese	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**	**Nonobese**	**Obese**
Trunk$^{m\ g}$	−22.90	−25.46	−23.78	−25.68	−23.85	−24.88	−23.40	−25.03
Upper arm$^{m\ a}$	−2.40	−5.30	−3.11	−4.41	−7.56	−5.88	−5.81	−6.48
Forearm^{m}	0.57	−0.75	1.42	−1.68	−2.77	−3.66	−2.38	−2.95
Thigh$^{m\ g}$	−29.21	−29.42	−28.95	−29.75	−22.75	−21.89	−21.53	−22.15
Shank^{m}	0.43	0.57	−0.15	−0.93	8.82	8.06	9.24	8.44

Note. Positive values represent that a parameter underestimated, and negative values represent overestimates by traditional regressions. Only significant different related to method (main efforts and first-order interactions) are noted for clarity purpose.

Superscripts m = method effect; o = obesity × methods effect; g = gender × methods effect; and a = age × methods effect.

Percentage difference = [(DXA − de Leva) ÷ de Leva] × 100%.