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Defying geometric similarity: shape centralization in male UK offshore workers

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Abstract

OBJECTIVES: Applying geometric similarity predictions of body dimensions to specific occupational groups has the potential to reveal useful ergonomic and health implications. This study assessed a representative sample of the male UK offshore workforce, and examined how body dimensions from sites typifying musculoskeletal development or fat accumulation, differed from predicted values.

METHODS: A cross sectional sample was obtained across seven weight categories using quota sampling, to match the wider workforce. 588 UK offshore workers, 84 from each of seven weight categories, were measured for stature, mass and underwent 3D body scans which yielded 22 dimensional measurements. Each measurement was modelled using a body-mass power law (adjusting for age), to derive its exponent, which was compared against that predicted from geometric similarity.

RESULTS: Mass scaled to stature $^{1.73}$ (CI: 1.44-2.02). Arm and leg volume increased by mass$^{0.8}$, and torso volume increased by mass$^{1.1}$ in contrast to mass $^{1.0}$ predicted by geometric similarity. Neck girth increased by mass $^{0.33}$ as expected, while torso girth and depth dimensions increased by mass$^{0.53\text{-}0.72}$, all substantially greater than assumed by geometric similarity.

CONCLUSIONS: After controlling for age, offshore workers experience spectacular 'super-centralization' of body shape, with greatest gains in abdominal depth and girth dimensions in areas of fat accumulation, and relative dimensional loss in limbs. These findings are consistent with the antecedents of sarcopenic obesity, and should be flagged as a health concern for this workforce, and for future targeted research and lifestyle interventions.

INTRODUCTION

Oil and gas exploration and production have required offshore workers to work from installations in the UK continental shelf sector for over four decades. In the mid 1980s, when an anthropometric survey was conducted which described their body size (Light and Dingwall, 1985), a subsequent comparison suggested offshore workers were already heavier and fatter than their onshore counterparts (Light and Gibson, 1986). Although the prevalence of global obesity has trebled since then, ratings of body mass index (BMI; Mass in kg and stature in m^{-2}) available via occupational medical screening are not in the public domain. Only the clothed weight of offshore workers, monitored closely at heliports for payload calculations, forms part of demographic data tracked by the UK offshore industry, which highlighted concern over heavier individuals (Aker, 2010) revealing weight has increased by an average of 19%. This resulting increased body size has subsequently been shown to have adverse consequences for passing ability in restricted space (Stewart et al., 2015) and helicopter window egress (Stewart et al., 2016).

While overall body size is important in terms of a person's space requirements, the classification of overweight and obesity involves no assessment of body composition, relying on raw measurements to calculate BMI to estimate fatness (WHO, 2000). However, the extent to which an elevated BMI is attributable to fat is questionable because despite its convenience, it has a non-linear relationship with fat quantity, has poor sensitivity and specificity, and observed increasing fatness and declining muscle with ageing may not be reflected by BMI (Rothman, 2008). Particularly within certain occupations and sports, this may lead to miss-classification of muscular or largeframed individuals as overly fat. In such instances more detailed anthropometric measurement is required to attribute meaning to the physique, where key dimensions associate with musculoskeletal development (such as chest and shoulder girth) or are reflective of fatness (such as abdominal or waist girth).

In addition to the raw data themselves, knowing how such measurements scale to body mass will enhance the understanding of observations of relative weight, by being able to attribute excess weight to areas associated with muscularity or adiposity, or both. This approach involves calculating mass exponents of body measurements after adjustment for age, and comparing the result with that anticipated by geometric similarity (where larger individuals are simply scaled up equivalents of smaller individuals). Such exponents are 0.33 for girths, 0.67 for surface/cross-sectional areas and 1.0 for volumes, following this principle. This methodology has previously demonstrated that different sporting groups scale specific girths differently relative to those of controls in a form of physique specialization (Nevill et al., 2004). Examination of skinfold measurements also revealed disproportionate increases with body mass, yet reduction with stature (Nevill et al., 2006) suggesting that as stature increases, a greater area to distribute fat results in a reduced thickness (Nevill et al., 2010). Although evidence elsewhere suggests certain occupational groups may be anatomically larger than expected from national survey data (Hsaio et al., 2002), to the best of the knowledge of the authors, this allometric modelling approach has not previously been applied in specific occupational groups, precluding the insight it would yield relating a larger body size to muscularity or adiposity.

Following the size and shape of offshore workers (SASOW) survey (Ledingham et al., 2015) with its dimensional measurements from a representative sample of the UK male offshore workforce, an unprecedented opportunity exists to model extracted dimensions using this robust approach. Therefore, the purpose of this study is to quantify the relationships of key body dimensions with body mass, having adjusted for age, in UK offshore workers, and to test whether the observed findings align with obesity.

METHODS

A sample of 588 men aged 40.6 $\pm$ 10.7 y (mean $\pm$ SD) was selected via weight category quota sampling to represent the latest available data on UK offshore workforce weight (Aker, 2010). The weight categories (in kg) were as follows: <76.4; 76.5 - 82.4; 82.5 - 87.4; 87.5 - 91.4; 91.5 - 97.4; 97.5 - 104.4; >104.5. A total of 84 individuals were selected for each, in order to have 95% confidence that the true workforce weight was represented to within 1.1 kg, a value which could be anticipated with diurnal fluctuation in individuals. The study was an observational cross-sectional design, and was approved by the Robert Gordon University ethical review panel.

Participants were selected to match the offshore workforce. They were mostly 'core crew', (who spend a minimum of 100 nights offshore per year) but also included some more occasional offshore workers whose main roles were onshore. Participants were recruited using industry communications via various media from Oil & Gas UK member organizations and key stakeholders. Stature and mass measurements, together with a series of 3D body scans required about 20 minutes and were acquired mostly at

Aberdeen heliports where a private measurement area was set aside adjacent to the departure lounge. 3D body scans were acquired using an Artec L scanner (Artec Group, Luxembourg) with participants wearing form-fitting shorts and no top, firstly with arms and legs straight and secondly with them abducted, as part of a larger study described previously (Ledingham et al., 2015). BMI was calculated, and after processing the scans using Artec studio 9 software (Artec Group, Luxembourg), 19 dimensional measurements were extracted for each individual, an example of which is in figure 1.

*** figure 1 near here ***

The landmarks were selected because they relied on visually identifiable locations placed digitally on the scan surface, avoiding body contact and palpation as in conventional anthropometry, which may have not been tolerated by the participant group. As such, these landmarks included the axilla, nipple, naval and anterior knee, together with the most anterior, posterior or lateral aspects of convex surfaces. The measurements included linear distances, girths and segmental volumes, and reproducibility was established using blinded re-analysis of 28 individuals.

Statistical methods

A previously established model (Nevill and Holder, 1994; Nevill et al., 2004) was applied to the sample:

$$D = a_i \cdot M^{b_i} \cdot \exp(c_i \cdot age + d_i \cdot age^2) \qquad \text{(Eq 1)}$$

Where D is the measured body-size dimension, a_i and b_i are the scaling constant and scaling mass exponents for each site (i = 1,2, 18) respectively. Age was assimilated into the model by use of a quadratic polynomial (incorporating age and age^2 terms) which allowed for the variable to rise to a peak and subsequently decline. If the age ^{2} coefficient was not significant, the model was re-run without it. The model (Eq 1) can be linearized via log-transformation, and univariate ANOVA used to identify mass exponents, while controlling for age.

RESULTS

The sample selected for the study using the quota sampling approach was tested against the known mass of the offshore workforce, and was found to be an excellent match (Chi-square value = 11.7; 11 df, P=0.613). Additionally, the mean age of the sample (40.6 y) matched the mean age of the 2014 workforce (40.8 y). Physical characteristics of participants are summarized in table 1.

*** table 1 near here ***

Physical characteristics and prevalence of obesity by weight category are highlighted in table 2.

*** table 2 near here ***

Technical error of measurement for extracted measures averaged 1.05% of measurement values (range 0 – 3.47%) and compared favorably with that of experienced anthropometrists using manual measurements.

Univariate analysis of ln mass against stature (adjusted for age and age^2), revealed an exponent of 1.73 (95%CI 1.44-2.02). Further analyses yielded mass and age exponents for volumes which are in table 3, and linear measurements in table 4.

*** table 3 near here ***

*** table 4 near here ***

Leg, arm and total volume, together with wrist girth increased by less than predicted by geometric similarity, while torso volume, seated hip breadth, chest, chest (at deltoid) and abdominal depth, together with shoulder, hip, chest, waist and abdominal girths all increased at a greater rate than that predicted by geometric similarity. Summary outcomes of dimensional measures and their relationship to those expected from geometric similarity are depicted in figure 2.

*** figure 2 near here ***

Images typifying the abdominal depth which showed the greatest departure from geometric similarity are depicted in figure 3.

*** figure 3 near here ***

DISCUSSION

Key Findings

The non-geometric enlargement in response to increased mass for this cohort is both striking and important. Only four of the 19 measured variables enlarge according to body mass as predicted by geometric similarity. As body mass increases, the physique appears to become increasingly centralized, supporting a hypothesis of increasing fat and, in relative terms, diminishing muscle with increased body mass. Such shape centralization with increasing mass has key implications for health and functional capacity.

Observations consistent with adverse functional capacity with increasing mass

Functional capacity can be resolved, in biomechanical terms, to 'productive mass' and 'ballast' (Carter, 1985) and these have anatomical components of the fat-free mass and fat mass respectively. The density of the whole body, is a reflection of the relative proportions of these, and because constituents of fat-free mass exceed 1.0 $g.cm^3$, while fat is about 0.9 $g.cm^3$ whole body density ($mass.volume^{-1}$) is used to estimate relative fatness. Hence the observed concomitant increase in total volume with body mass in the current study suggests no change in total body density with increasing size. Thus, according to this model, any increase in fatness with body size (which would reduce density) must be compensated by a corresponding increase in the quantity or density of the fat-free mass. The two candidate tissues for this are muscle and bone.

Muscle

It has been previously observed that differential enlargement of limbs and specifically postural muscles in relation to overall body mass occurs in certain sporting groups, enabling control over disproportionately larger forces, with thigh girth exponents reaching 0.41(SEE 0.031) and 0.53 (SEE 0.018) in controls and athletes respectively (Nevill et al., 2004). Of particular note was that this enlargement was due to muscle and appeared specific to power and strength athletes but not endurance athletes. The negative age coefficients of arm and leg volumes of the present study, both of which increase relative to mass by less than that expected from geometric similarity, and appendicular muscle mass is estimated to be ~75% of the total skeletal muscle in the body (Snyder et al., 1974), this finding is consistent with reduced leg functional strength as mass increases.

Relative to total mass, body volume has a significant positive age coefficient, consistent with reduced body density with age. Thus the effect of muscle atrophy is necessarily outstripped by fat accumulation, irrespective of its anatomical distribution. Anecdotal evidence from the musculoskeletal development apparent in the physique during scanning suggests the prevalence of strength training is higher in younger offshore workers, who might be expected to have greater muscle mass and body density. This is consistent with the observed reduction in arm and thigh girths with age in a sizing survey of men 3D scanning (Wells et al., 2007), and typical rates of appendicular skeletal muscle loss of about 0.8 kg per decade in Caucasian men (Gallacher et al., 1997).

Because the thigh region is not recognized as a site for excess fat deposition in men, it is broadly reflects the adequacy of the postural muscles in terms of generating power for functional movement. Mid-thigh girth was not measured in the present study (due to the need to avoid time-consuming and invasive landmarking) and as a result, comparison between the present study's leg *volume* and previous studies of thigh *girth* rest on assumptions that body proportions were comparable. Because taller individuals have relatively longer legs than shorter ones (Nevill et al., 2004), a reduced leg volume exponent with increasing body size may reflect shorter leg length and not a reduced thigh girth, which evidence shows to be inversely related in Caucasian men (Burton et al., 2012). Buttock-to-knee length, the only directly measured linear variable relating to leg length also showed a less than expected mass exponent. Creating a surrogate for thigh cross sectional area by dividing leg volume by buttock-to-knee length, revealed an exponent of 0.62 (95%CI 0.57-0.67). This upper confidence limit is the expected value from geometric similarity, and suggests a tendency for a relative reduction in muscle as mass increases. Even where relative leg-length is known to differ between ethnic groups, powers for body mass scaling to height have been found to be similar (Heymsfield et al., 2014). The present study did not select by ethnicity, and the sample was almost exclusively Caucasian. The observation for relative reduction in leg volume with increasing mass and the trend for the same in thigh girth presents a mechanical disadvantage to heavier individuals as they move, via the application of Newton's second law (Force = mass * acceleration) which will inevitably adversely affect their functional capacity.

Bone

Mechanical loading from forces generated by body weight stimulates bone formation (Cao, 2011). Conversely, fat cells manufacture bone-active hormones which can increase bone resorption. Such conflicting influences may explain why obesity protects against fractures in the spine and hip, but not the ankle or wrist (Dimitri et al., 2012). Thus heavier workers generate more mechanical loading which adds to bone, while excessive fat will reduce it, with the result that the influence of bone density on total body density with increasing mass is likely to be very small.

Observations consistent with adverse health risk with increasing mass

The 11 variables which increase greater than expected by geometric similarity are all on the torso or pelvic regions, highlighting a marked centralization of body shape. How unusual a phenomenon this is, is difficult to ascertain in the absence of normative data. Some insight into tissue distribution is available via the ratio of the body's proportional mass between different regions of the body generated using dual X-ray absorptiometry (DXA). Because DXA output yields fat, fat-free soft tissue and bone mineral regionally, it is possible to develop a volumetric estimate of body regions which removes the confounding factor of thoracic air and trapped gas in the gastro-intestinal tract (Wilson et al., 2013a). This approach has yielded a striking relationship between incident diabetes and elevated blood pressure according to the quartile of trunk-to-leg volume ratio, and an interaction with BMI category (Wilson et al., 2013b). It can be argued that because this ratio will be primarily governed by fat accumulation on the torso and muscle development or loss (primarily in the legs), there is scope to use the more convenient and portable 3D scanning in place of DXA for future studies of health risk. This will become more attractive with the rapidly advancing technology and diminished costs associated with 3D body scanning. However, direct comparison of the numerical values of the ratios of Wilson and colleagues to those of the present study is guarded for three reasons. Firstly, our torso volumes include thoracic air which would inflate our ratios by a small amount. Second, the boundaries differ between the methods, and DXA scanning can partition the spine, thorax and pelvic regions independently of the abdomen. Additionally, DXA scanning involves orthogonal 'cut lines' to divide different body regions, whereas the present study used oblique planes defined by three anatomical landmarks in 3D space, truncating the torso in the groin inferior to the pubic bone, and a point approximately mid-way between the *trochanterion* and the *iliocristale* landmarks (Stewart et al., 2011). Nevertheless, allowing for 4% total volume as residual air in the torso, the mean value for the trunk-to-leg volume ratio in the present study is 1.9, and are much higher than the mean of 1.53 and threshold of 1.66 for the 4^{th} quartile of the sample of Wilson and colleagues. Using the trunk-to-volume ratio, Wilson and colleagues used NHANES reference data and the highest quartile had a diabetes prevalence of 22.4%. This finding is suggestive that the UK male offshore workforce may also have a high prevalence of diabetes or associated metabolic co-morbidities. This is supported by other shape observation amongst the current sample, the most striking of which is that of abdominal depth (referred to variously as sagittal abdominal diameter, anterior-posterior abdominal thickness or abdominal height), and is defined as the linear distance across the abdomen in the mid-sagittal plane. This dimension corresponds closely with visceral fat (Van der Kooy et al., 1993) reflects weight loss (Stewart et al., 2009) and is a recognized marker of insulin resistance, predictor of heart disease, and incident diabetes (Risérus et al. 2004; Iribarren et al., 2006; Pajunen et al., 2013). The fact that the present study shows a high waist exponent, but a higher still abdominal depth exponent, is consistent with visceral fat accumulation amongst the heavier individuals in the current study. In some individuals this manifests as a 'super-centralized' shape, as depicted in figure 3.

While many of the findings observed can be related to increase in adiposity and centralization of fat, other exponents may reflect skeletal changes in response to ageing. In this category is the chest depth which increases disproportionately with body mass, and is consistent with a concomitant change of thoracic compliance and increase in residual volume with age (Wahba, 1983) while chest breadth behaved as expected according to geometric similarity. The difference in exponent between hip breadth standing and sitting is less likely to be structural, as much as the plasticity of tissues resulting from compression. Evidence for this is that the difference between sitting and standing hip breadth correlated with weight ($r=0.37$, $P<0.01$) and abdominal girth variables explained 16% of the variance difference in linear regression (SEE = 1.26 cm; $P<0.0001$).

Strengths and weaknesses of the study

There are limitations to the study affecting its capability for inference. Firstly, these data are cross sectional, and, as a consequence, cannot exclude the birth cohort effect from affecting the results. Secondly, without direct body composition data, such as that from a DXA scan, ultrasound bioimpedance or skinfolds, it is necessary to relate the observed shape to a presumed composition change. The protocol adopted in the study precluded laboratory study of this kind, and instead relied on the convenience of the sampling protocol to acquire a large and representative sample of offshore workers. This involved measuring individuals during a 'convenient' waiting time at heliports, the majority of whom, in all probability, would be reluctant to make a separate visit to the university for such detailed measurements. Thirdly, it is conceivable that simultaneous increased fat and reduced muscle might result in no difference in the measured body mass or volume. Furthermore, observed fat infiltration of muscle in older individuals is independent of body mass, and causes a decrease in muscle function beyond that anticipated by its reduced size (Delmonico et al., 2009). By measuring shape in terms of volumes and linear dimensions, there is a risk that composition change is not reflected in dimensional change. Fourthly, there is the possibility that in the sample, a substantial minority might be 'fit but fat' (Duncan, 2010) and have functional health outcomes which are more favorable than static shape might suggest. In the latter study, with a mean age of 8 y less than that of the present study, the prevalence of 'fit but fat' and 'overweight and high fit' categories was 9% and 17% respectively. Recognizing this as a possibility, substantial numbers of the offshore workforce who are overweight or obese may thus ameliorate the health consequences attributable to their shape by the adoption of habitual exercise.

Accepting these limitations, the present study has contributed 3D data which are unprecedented in this occupational group, which have been modelled in a novel way to generate a more complete understanding of body shape than might be available via conventional metrics. The understanding generated by the approach adopted in the present study provides shape analysis that casts valuable light on health outcomes which go far beyond what is achievable by BMI. The fact that scans can be analyzed in retrospect means the study archive remains of value for future exploitation and data extraction for variables beyond those included here. Such future work could usefully consider the adoption of further dimensional measures to describe shape in relation to muscularity as well as adiposity.

Conclusions and future research

Long before the global obesity epidemic was first recognized the 1980s, it was observed in men, that the ageing process is associated with a thicker torso but thinner extremities, and evidence suggests this relates to fat redistribution to the abdomen, and a loss of muscle in the extremities (Borkan and Norris, 1977). The present study has yielded evidence that abdominal dimensions enlarge relative to mass at approximately double the rate of that expected by geometric similarity, while limb volumes appear to diminish. Such super-centralization has not been reported in this occupational group before, but has important consequences in terms of health and ergonomics. The underlying causes of these observations require further research, in particular the environmental influence of the culture of the working environment, and factors which may create a persistent adverse energy imbalance for the workforce. In addition, the industry urgently seeks to understand why messages encouraging healthy lifestyles appear to lack impact in this group. Tracking individuals over time in a longitudinal study will also help understand whether the observations from the present study represent the antecedents for sarcopenic obesity in later life.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

GF and AS obtained the grant funding for the study, RL carried out the scanning of the workforce, and AN led mathematical modelling and interpretation, assisted by HW. All contributed to the write up of the manuscript, led by AS.

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Table and Figure Captions (in order of appearance in the text)

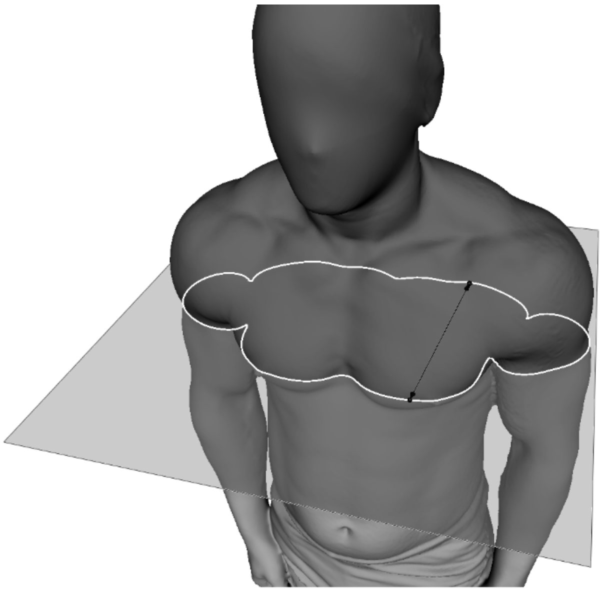

Figure 1. Example of an extracted measure (maximum chest depth) from processed 3D scan using digitally-placed landmarks

Table 1. Physical characteristics of participants

	Mean	SD	min	max
Age (y)	40.6	10.7	22.0	66.0
Stature (cm)	178.0	6.8	161.7	201.1
Mass (kg)	90.5	13.7	50.9	149.0
Body Mass Index (kg.m^{-2})	28.3	4.0	18.6	45.3
Years offshore	10.9	4.3	0.1	40.0

n = 588

Table 2. Physical characteristics of participants by weight category

	1	2	3	4	5	6	7
Age (y)	37.0 (11.2)	40.5 (11.1)	39.4 (10.3)	39.7 (10.3)	42.8 (11.0)	43.8 (9.6)	41.1 (10.2)
Stature (cm)	174.1 (6.0)	175.4 (5.9)	178.0 (6.1)	180.4 (5.8)	179.4 (5.7)	180.5 (6.2)	183.0 (7.4)
Mass (kg)	70.9 (4.3)	79.6 (1.7)	84.6 (1.7)	89.6 (1.1)	94.1 (1.7)	100.5 (2.2)	114.1 (8.0)
Body Mass Index ($kg.m^{-2}$)	23.4 (1.9)	26.0 (1.7)	26.8 (1.9)	27.6 (1.9)	29.3 (1.9)	31.0 (2.3)	34.2 (3.6)
Years in industry	9.4 (9.9)	11.0 (9.5)	11.4 (9.5)	11.3 (10.0)	12.0 (11.0)	12.5 (10.3)	10.6 (9.5)
*Obesity prevalence (%)	0.0	0.0	6.0	10.7	39.3	69.0	86.9
†Torso-to-leg volume ratio	1.88 (0.26)	1.99 (0.26)	1.95 (0.32)	1.95 (0.27)	2.03 (0.26)	2.17 (0.31)	2.28 (0.40)

Values are mean (SD); Weight categories: 1: ≤ 76.4 kg; 2: 76.5 - 82.4 kg; 3: 82.5 - 87.4 kg; 4: 87.5 - 91.4 kg; 5: 91.5 - 97.4 kg; 6: 97.5 - 104.4 kg; 7: ≥ 104.5 kg; n =84 in each weight category *BMI≥ 30 $kg.m^{-2}$

†L and R leg summed

Table 3. Estimated mass exponents (b_i) for extracted volume measurements, after adjustment for age.

Variable	Mass exponent	Age exponent	Age^2
Total volume †	0.976 (0.962-0.989)	0.0003 (0.0002-0.0005)	ns
Leg volume †	0.807 (0.755–0.860)	-0.0027 (-0.0034--0.0019)	ns
Arm volume †	0.818 (0.772–0.864)	-0.0025 (0.0031-0.0018)	ns
Torso volume *	1.144 (1.112-1.175)	0.0020 (0.0015-0.0024)	ns

Figures in brackets refer to 95% CI; † less than predicted from geometric similarity; * greater than predicted from geometric similarity
Exponents only tabulated where significant (P<0.05).

Table 4. Estimated mass exponents (b_i) for extracted linear measurements, after adjustment for age.

Variable	Mass exponent	Age exponent	Age^2
Buttock-to-knee†	0.185 (0.166-0.205)	-0.0006 (-0.0008- -0.0003)	
Wrist girth†	0.286 (0.253-0.319)	0.0010 (0.0005-0.0014)	
Chest breadth	0.319 (0.293-0.345)	0.0032 (0.0003-0.0062)	
Hip breadth (standing)	0.322 (0.304-0.339)	-	
Bideltoid breadth	0.339 (0.323-0.355)	0.0022 (0.0004-0.0041)	-0.000037 (-0.000060- -0.000015)
Neck girth	0.341 (0.317–0.366)	0.0015 (0.0012-0.0019)	0.000034 (0.000001-0.000068)
Shoulder girth *	0.369 (0.349–0.389)	-0.009 (-0.0012 – 0.0006)	
Hip girth *	0.394 (0.380-0.409)	-	
Hip breadth (sitting)*	0.395 (0.373-0.416)	-0.0031 (-0.0055- -0.0007)	
Chest depth (deltoid) *	0.479 (0.445-0.514)	0.0007 (0.0003-0.0012)	
Chest girth *	0.495 (0.475–0.515)	0.0011 (0.0009 – 0.0014)	
Chest depth (maximal) *	0.532 (0.503-0.560)	0.0022 (0.0018-0.0026)	
Waist girth (minimum) *	0.579 0.554–0.605)	0.0032 (0.0028-0.0035)	
Abdominal girth (umbilicus) *	0.596 (0.569–0.622)	0.0025 (0.0022-0.0029)	
Abdominal depth *	0.717 (0.677–0.757)	0.0043 (0.0037-0.0049)	

Figures in brackets refer to 95% CI; † less than predicted from geometric similarity; * greater than predicted from geometric similarity
Exponents only tabulated where significant (P<0.05).

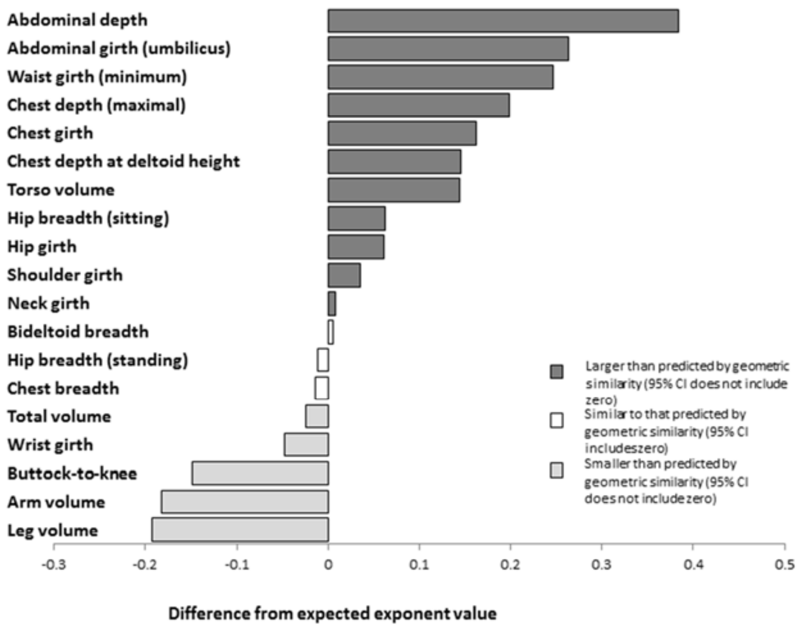

Figure 2. Dimensional departure in exponent values form that predicted by geometric similarity, calculated by predicted minus measured mass exponents, after adjusting for age

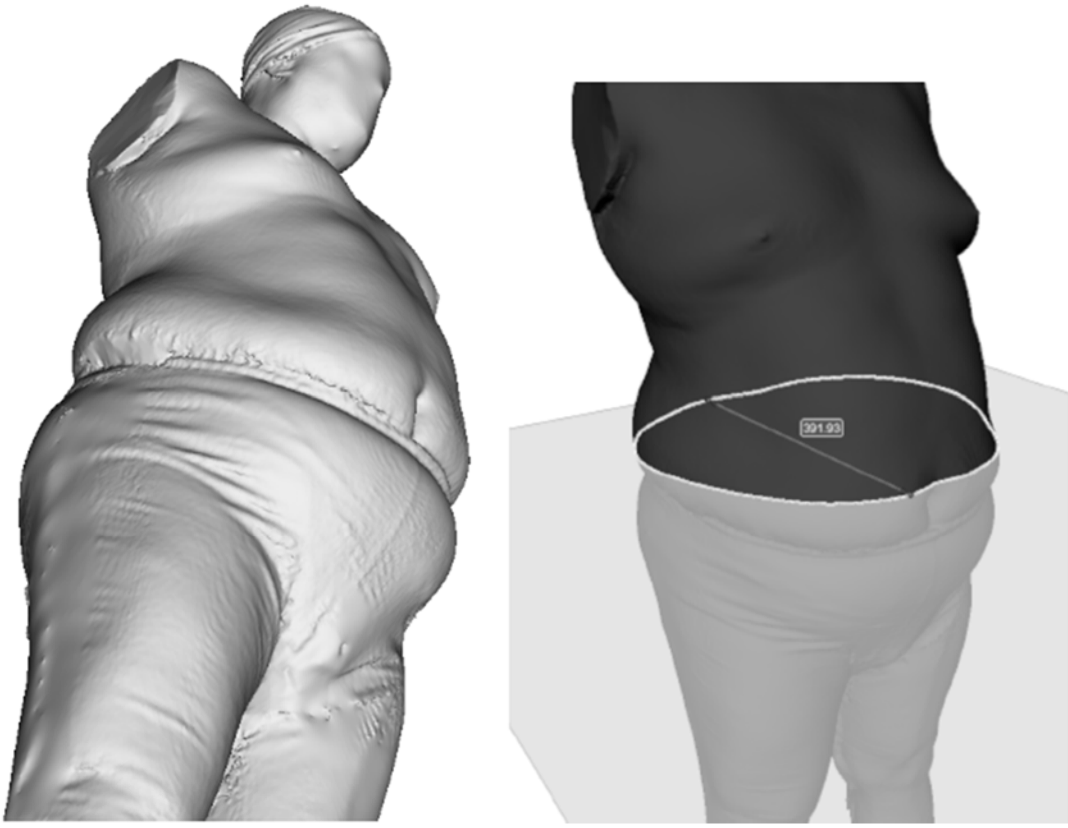

Figure 3. 3D scan depicting an individual with a ‘super-centralized’ shape (L) and digital measurement of abdominal depth (R)