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BRIEF REPORT

A post hoc comparison between inpatients with obesity and healthy-weight subjects in the size estimation accuracy of shoulders, waist, and hips widths and circumferences

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Abstract

Purpose This post hoc study aimed to assess the hypothesis that subjects with obesity could underestimate their body size.

Methods Data from a previous study with different aims were used to compare 22 female inpatients with obesity with 21 healthy-weight women in the size estimation accuracy of their shoulders, waist, and hips circumferences and widths. The body estimation task with an individualized metric methodology was used to collect data. Frequentist and Bayesian analyses were performed.

Results Samples differed significantly in the accuracy measures of shoulders width and hips as well as waist circumferences: inpatients with obesity underestimated them, while healthy-weight subjects estimated shoulders width accurately but overestimated their hips and waist circumferences. Multiple regression showed that the between-group difference in the accuracy measure of shoulders width was explained by the individuals' education level, while the difference in the accuracy measure of waist circumference resulted to be independent of both age and education level.

Conclusion This post hoc study supports the hypothesis that female patients with obesity might underestimate their body size. If these results will be confirmed in future studies, interventions specifically designed to equalize estimations to match the real measures of body size may play a key role in weight-reduction programs for people with obesity.

Level of evidence Level III, evidence obtained from cohort or case–control analytic studies.

Keywords Body image · Obesity · Body size perception · Body size underestimation

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Introduction

Underestimation of body size represents a key issue for individuals with obesity as it may trigger, maintain, and worsen their weight status, and negatively affect the long-term outcome of weight-loss rehabilitative interventions [1]. Indeed, individuals with obesity who underestimate their body size and weight might not perceive them as potentially problematic and, consequently, might be less prone to reduce weight.

Several theories explaining body size misperception are available (i.e., visual perception theory), among which the Allocentric Lock Hypothesis (ALH) [2] received particular interest. According to the ALH, body experience evolves by integrating the different multisensory body signals within the "body matrix". Despite a dramatic body size increase, individuals with obesity may be locked to an allocentric body memory (observer view, offline), not altered nor updated by the contrasting new sensory information and real-time perceptual representation (egocentric view, online). Egocentric sensory signals about overweight are perceived but do not update the allocentric body memory, thus resulting in body size underestimation.

However, the literature shows controversial findings, mainly due to the use of different research designs and, more importantly, to the employment of different measures and methods for the assessment of body perceptions and representations [3]. *Depictive* methods address the explicit body representation, i.e., what subjects "think" their body looks like (i.e., judge pictures of the entire body). Among them, *non-individualized* methods (i.e., figural drawing scales) found body size underestimation, while *individualized* methods (i.e., select and adapt a presented body to your size) found body size overestimation in people with obesity [4]. Interestingly, the *individualized metric* method addresses both the explicit and the implicit body representations, respectively, i.e., how individuals "perceive" their body rather than how they "think" of it (i.e., reproduce body parts sizes as spatial distances). Results of previous studies using this method showed that females with obesity underestimated their body size [5].

To confirm these results, this post hoc study aimed to investigate whether female inpatients with obesity show perceptual underestimations of some body parts when compared to healthy-weight subjects, and to explore the predicting effects of age and education level.

Methods

A part of data collected in a previous study [6] involving 22 female inpatients with obesity hospitalized for a weight-reduction program and 21 healthy-weight females from the general population were obtained and analyzed with the consent of the previous study's authors. Participants had neither neurological issues nor concurrent medical conditions, they were matched for age and height, and all provided signed informed consents. Detailed characteristics of the samples are available within the article describing the previous study [6].

Measures and procedure

Participants' demographic data (i.e., age and education), body mass index (BMI), as well as their actual and estimated sizes of three different body parts were used in the current analysis. Latter measures were obtained using the *body estimation task*, an individualized metric method, that was developed to evaluate explicit and implicit body representations [7]. First, without looking at their bodies, participants placed stickers on a wall in front of them to indicate the width between the left and right sides of their shoulders, waist, and hips. Second, participants retrieved a "memory" of their body representation and—within a third-person perspective (allocentric)—reproduced the circumference of their shoulders, waist, and hips by placing a rope on the floor. Each body part was separately estimated and counterbalanced. Third, actual body measures were taken.

Two measures of *accuracy* were computed: (1) the difference between the actual and the estimated sizes (DF), and (2) the ratio of the estimated size to the actual size multiplied by 100. Negative values indicate *underestimation*, while positive values indicate *overestimation*. Scores higher or lower than 5% in the second measure were considered indicative of significant misestimations.

Data analysis

JASP (v.0.9.1.0) and RStudio (v.1.1.453) with the *BAS* package (v.1.5.3) were used.

The frequentist and the Bayesian independent sample t tests were used to assess if inpatients with obesity had lower accuracy measures (DFs) than healthy-weight subjects. The Bayesian t test is based on the Bayes factor (BF), which expresses the probability of the data given the alternative hypothesis (H1) relative to the null hypothesis (H0, i.e., no difference in DFs between inpatients with obesity and healthy-weight subjects): $BF < 1$ indicates that data are more likely under H0; $BF = 1$ indicates that data do not favor either of the hypotheses; $BF > 1$ indicates that data are more likely under H1. BF also suggests the strength of evidence for H1 as follow: $1 < BF < 3$ anecdotal; $3 < BF < 10$ substantial; $10 < BF < 30$ strong; $30 < BF < 100$ very strong; $BF > 100$ decisive. The prior distribution was set at $\delta \sim$ Cauchy (0, 0.707). The frequentist and Bayesian Pearson correlations explored the relationships between DFs and BMI, age and education, both in each sample and merging the two samples. Frequentist and Bayesian multiple regressions assessed the effects of the obesity condition (inpatients with obesity vs. healthy-weight subjects) on DFs controlling for age and education level (the Zellner–Siow prior on the coefficients and the uniform prior were used for the Bayesian multiple regression models [8]).

Results

An inpatient with obesity and one healthy-weight subject showed huge overestimation of waist circumference (97.35% and 84.40%, respectively), and one healthy-weight subject showed a huge overestimation of hips width (63.51%). Their data were, thus, pairwise removed from the analysis.

Inpatients with obesity showed significantly lower mean DFs than healthy-weight subjects for shoulders width and hips as well as waist circumferences with medium-to-large between-group standardized differences. The Bayes factors (BFs) showed positive and substantial evidence in favor of alternative hypotheses concerning differences in DFs for shoulders width and hips circumference, and a decisive evidence for the between-group difference in DFs for waist circumference (Table 1), even when increasing the prior distribution width. No between-group difference in the DFs was, instead, found for the other body parts. In particular, inpatients with obesity underestimated shoulders width (− 11.04 ± 19.82 cm) and waist circumference (− 3.51 ± 16.14 cm), and overestimated hips circumference mildly (+ 6.72 ± 19.92), while healthy-weight participants accurately estimated shoulders width (0.16 ± 17.18 cm) but largely overestimated both waist and hips circumferences (29.55 ± 21.02 cm and 21.53 ± 20.05, respectively) on average.

The DFs for waist circumference showed a negative anecdotal correlation with age ($r = -0.36$; BF = 2.446). Such evidence was higher and substantial among inpatients with obesity ($r = -0.56$; BF = 5.939) compared to their healthy-weight counterparts ($r = -0.48$; BF = 2.539). A significant and very strong correlation emerged between DFs for shoulders width and education level ($r = 0.51$; BF = 50.268), which also resulted to be positively and significantly correlated with the DFs for waist circumference ($r = 0.38$; BF = 3.865), waist width ($r = 0.36$; BF = 2.603) and hips width ($r = 0.31$; BF = 1.347), even if the evidences in favor of the latter correlations were only anecdotal. A significant but negative and anecdotal correlation was found between the DFs for shoulders circumference and education level ($r = -0.31$; BF = 1.346). This correlation was very high but still anecdotal ($r = -0.85$; BF = 2.472) among inpatients with obesity. Last, BMI significantly correlated with both the DFs for waist circumference ($r = -0.49$; BF = 31.090) and shoulders width ($r = -0.40$; BF = 5.480). All correlations for the two samples merged are reported in Table 2. The frequentist multiple hierarchical regression revealed

Table 1 Comparison of DFs between inpatients with obesity and healthy-weight subjects

	Test	Stat	*df*	*p* (one-tailed)	Cohen's *d*	BF	Error %
Shoulders width DF	Student	− 2.16	41	0.018	− 0.66	3.597	~7.48e−6
Waist width DF	Student	− 1.42	40	0.081	− 0.44	1.208	~2.27e−6
Hips width DF	Student	− 1.67	40	0.052	− 0.51	1.682	~2.64e−6
Shoulders circumference DF	Welch	0.41	34.9	0.341	0.12	0.412	~3.45e−6
Waist circumference DF	Student	− 5.68	39	< 0.001	− 1.78	18,302.486	~8.27e−7
Hips circumference DF	Student	− 2.43	41	0.010	− 0.74	5.820	~4.27e−6

DF difference between the actual and the estimated sizes

Table 2 Correlations of DFs with age, education level, and BMI

	Age			Education level			BMI		
	Pearson's *r*	*p* value	BF	Pearson's *r*	*p* value	BF	Pearson's *r*	*p* value	BF
Shoulders width DF	− 0.09	0.560	0.196	0.44	0.003	12.251	− 0.25	0.100	0.704
Waist width DF	− 0.21	0.187	1.088	0.39	0.012	4.208	− 0.27	0.089	0.780
Hips width DF	− 0.17	0.294	0.304	0.33	0.034	1.691	− 0.25	0.104	0.689
Shoulders circumference DF	− 0.23	0.129	0.406	− 0.21	0.168	0.477	− 0.03	0.853	0.193
Waist circumference DF	− 0.19	0.215	2.446	0.43	0.005	9.069	− 0.59	< 0.001	579.866
Hips circumference DF	− 0.18	0.268	0.361	0.161	0.301	0.319	− 0.28	0.073	0.903

DF difference between the actual and the estimated sizes that the significant effect of the obesity condition ($\beta = 0.42$, $t = 2.85$, $p < 0.010$, $R^2 = 0.17$) on DFs for shoulders width vanished ($\beta = 0.15$, $t = 0.83$, $p = 0.413$) after controlling for education level ($\beta = 0.41$, $t = 2.27$, $p < 0.05$, $R^2 = 0.26$). Differently, the significant effect of the obesity condition did not vanish ($\beta = 0.42$, $t = 2.84$, $p = 0.007$, $R^2 = 0.17$) after controlling for age ($\beta = -0.05$, $t = -0.36$, $p < 0.72$). The Bayesian multiple hierarchical regression confirmed these results. The model including exclusively the education level showed a posterior probability of 0.652 ($R^2 = 0.20$) and the BF of the model including the obesity factor was largely below 1 (0.22). Furthermore, the marginal inclusion probability for the obesity factor was very low (0.23), but high (0.80) for education level. When considering age, the model exclusively including the obesity factor showed a posterior probability of 0.362 ($R^2 = 0.12$), and the BF of the model including age was largely below 1 (0.18). Furthermore, the marginal inclusion probability for age was very low (0.12), but higher (0.46) for the obesity factor.

Considering the DFs for waist circumference, the significant effect of the obesity factor ($\beta = 0.61$, $t = 4.81$, $p < 0.001$, $R^2 = 0.37$) did not vanish ($\beta = 0.62$, $t = 3.68$, $p < 0.001$) when controlling for education level, which resulted not significant ($\beta = -0.01$, $t = -0.09$, $p = 0.929$). The effect of the obesity factor remained significant ($\beta = 0.64$, $t = 5.83$, $p < 0.001$) even when controlling for age ($\beta = -0.41$, $t = -3.71$, $p < 0.001$, $R^2 = 0.54$). In the Bayesian multiple regressions, the model including only the obesity factor had a posterior probability of 0.84 ($R^2 = 0.37$), and the BF of the model including education level was largely below 1 (0.19). The marginal inclusion probability for education level was very low (0.16), but very high (0.99) for the obesity factor. When considering age, the model including both the obesity factor and age showed a posterior probability of 0.983 ($R^2 = 0.54$), and the BF of the model only including the obesity factor was largely below 1 (0.041). Furthermore, the marginal inclusion probabilities were very high for both the obesity factor (1) and age (0.99).

Discussion

The hypothesis that female subjects with obesity underestimate body size in comparison to female healthy-weight subjects was supported only by the large between-group difference in DFs for waist circumference, which also resulted to have a significant and positive correlation with BMI (the higher the BMI, the higher the underestimation, and the lower the overestimation). Multiple regression confirmed these finding by showing that the effect of obesity on the DFs for waist circumference did not change when controlling for education and age. However, this difference was not only due to inpatients with obesity underestimating their waist circumference but also to healthy-weight subjects overestimating it. Similar results were reported by Valtolina [5], who showed some differences in the size estimation accuracy of the abdominal area and other body parts between individuals with obesity and subjects in their normal weight range: the firsts underestimated the thoracic and pelvic areas as well as the head, while healthy-weight subjects underestimated the head and the thoracic areas but overestimated the pelvic one.

A substantial between-group difference was also found in the DFs for shoulders width, but multiple regression showed that the effect of obesity vanished when controlling for the participants' education level. This means that the between-group difference was probably due to the significant difference in the education level, which was lower for inpatients with obesity on average. Education level positively correlated with the DFs for shoulders width but also for waist width, hips width, and waist circumference (the higher the education level, the lower the underestimation and the higher the overestimation), and similar results were reported in previous studies on body image in subjects with obesity [9].

Age significantly correlated with the DFs for waist circumference but in the opposite direction (the older the subjects, the higher the underestimation and the lower the overestimation), as already demonstrated in earlier research [10]. The multiple regression showed the effect of the obesity factor on the DFs for waist circumference to be independent of age, which showed to be a significant independent predictor too.

The present study has some limitations. First, the small sample size may have influenced statistical analyses; thus, anecdotal results should be carefully considered. Moreover, the generalizability of findings is limited since all participants were females and inpatients hospitalized for weight-loss treatment were considered; they might possess higher awareness of their body dimensions compared to subjects with obesity from the general population. Indeed, body size underestimation may be more prevalent in non-clinical subjects with obesity. Still, since findings from this post hoc study are supported by decisive evidence, they can be generalized to individuals similar to the study participants. Last, this post hoc study did not include key variables (i.e., binge eating, body checking and avoidance, etc.) that could have influenced the results. In particular, weight history is a key control variable that has been missed in this study. Future research conducted in the framework of the ALH theory should consider this parameter for more reliable conclusions.

Conclusion

The accuracy of waist circumference size estimation clearly distinguished between female inpatients with obesity and healthy-weight individuals, but this result provides modest support to the study hypothesis that subjects with obesity underestimate their body size. Future studies should recruit non-clinical samples with obesity and employ multi-trait multi-method models including different body size estimation methods and different traits, such as body satisfaction, body avoidance, body appearance, and body appreciation.

A further examination of the hypothesis that subjects with obesity underestimate their body size should also involve considering its consequences, as failure to recognize this condition may hamper the adoption of weight-loss behaviors (i.e., diet, exercise) and the seek of professional help until developing critical obesity-related comorbidities. Since underestimating body size may be associated with reduced motivation to lose weight and increased risk for health in subjects with obesity, prompt screening and ad hoc interventions become necessary for cost-effective rehabilitation programs.

What is already known on this subject?

Research on body size estimation in subjects with obesity leads to heterogeneous results and inconsistent evidence. This might be due to several reasons, among which the enrolment of different populations (clinical vs. non-clinical), the use of diverse research designs and statistics, and the employment of different methods for the evaluation of body size perception are the main.

What does this study add?

This post hoc study supports the hypothesis that female subjects with obesity enrolled in a rehabilitation program for weight loss underestimate their body size. These findings suggest that promptly assessing the body size perception of subjects with obesity and providing prevention-focused interventions that seek to address the perception of body size could help people better manage their weight and enhance the cost effectiveness of rehabilitation programs.

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Declarations

Conflict of interest The authors report no conflicts of interest and this post hoc study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Data were collected in a previous published research investigating the effect of ownership over a virtual body on body size estimation [6]. The dataset analyzed in the current study is available from the corresponding author on reasonable request.

Ethical approval The original study, from which data for the present post-hoc study were extracted, was conducted in compliance with the Helsinki's Declaration (of 1975, as revised in 2008) and was approved by the Ethics Review Board of the Università Cattolica del Sacro Cuore, Milan, Italy.

Informed consent Each participant voluntarily agreed to participate in the original study and signed a written informed consent including a statement about the possible re-analysis of anonymized data by authorized persons.

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