



Body-scaled action in obesity during locomotion: Insights on the nature and extent of body representation disturbances

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ABSTRACT

Objective: Conscious perception of our own body, also known as body image, can influence body-scaled actions. Certain conditions such as obesity are frequently accompanied by a negative body image, leaving open the question if body-scaled actions are distorted in these individuals.

Methods: To shed light on this issue, we asked individuals affected by obesity to process dimensions of their own body in a real action: they walked in a straight-ahead direction, while avoiding collision with obstacles represented by door-like openings that varied in width.

Results: Participants affected by obesity showed a body rotation behavior similar to that of the healthy weighted, but differences emerged in parameters such as step length and velocity.

Conclusion: When participants with obesity walk through door-like openings, their body parts rotation is scaled according to their physical body dimensions; however, they might try to minimize risk of collision. Our study is in line with the hypothesis that unconscious body-scaled actions are related to emotional, cognitive and perceptual components of a negative body image.

1. Introduction

For decades, it has been reported in the literature how difficulties in emotions, feelings and perceptions about one's own body [1–2], in other words, in *body image* [3], are implicated in body dissatisfaction and in maintaining healthy behavior [3–6] in obesity. However, this condition also has a dramatic impact on body proportions as well as on the subjective bodily experience; people affected by obesity overestimate [7–11] or underestimate [12–13] the physical dimensions of their bodies.

Critically, more recent studies suggest that an enlarged body might affect not only the subjective representation of bodily dimensions, meaning how people perceive the dimensions of their body parts, but also the perception of sensory bodily input; the perception of the intensity of peripheral pain [14–16], vibratory sensation and temperature [17], sense of satiety [18] and gastric motor functions [19] seem to be altered in

obesity. Moreover, it was recently reported that people affected by obesity show alterations in the successful integration of multiple sensory input, such as audio-tactile stimuli [20] and audio-visual stimuli [21], an essential cognitive sensory process for successful actions in the environment. Consider the common behavior of walking: it results from a complex and unaware integration of different sources of information [22], such as postural and sensory inputs related to the physical body size [23], dimensions and spatial position of possible obstacles [24], relationships between gait parameters and body proportions [25–26]. All of this information is processed and integrated together for a successful behavior. In other words, all these inputs are collapsed in the cognitive representation of *body schema* [3,27–31], which is a dynamic representation of one's own body [27–30] used to guide actions [6,31,32]. As suggested by several lines of research, the body schema arises from the integration of multi-sensory bodily inputs and, when it is impaired, incoherent sensorimotor action's representation can be observed [30–31]. Dijkerman and De Haan

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[31] specifically discussed the role of somatosensory processing, not only in the conscious perception and recognition of one's own body (i.e. the body image) [3], but also in the construction of the body schema [31]. For example, tactile input allows one “to localize and experience the various qualities of touch” on the surface of the body, as well as “to determine the position of different parts of the body with respect to each other, which provides fundamental information for action” [31].

Until now, body schema distortions in obesity have not generally been explored in literature. However we would hypothesize that enlarged body proportions, as well as aberrant sensory processing [14–21], might affect the body schema, with possible consequences for the generation of successful action.

The main aim of this work was to explore this hypothesis: it represents the first attempt to study a body action, requiring motion underpinned by entire body dimensions [33–34], in obesity. In this experimental task, participants walked towards a target, while avoiding collision with obstacles represented by door-like openings varying in width. The horizontal rotation of body parts is strictly determined by the opening dimensions [34] through which the participants have to pass: as our daily experience suggests, we rotate our body more when we have to pass through narrower openings than we do for larger openings, in order to preserve a safety margin between our body and the obstacles. This unconscious behavior is grounded on the body schema that processes the localization and the size of the body (provided by the bodily sensory input) with respect to external objects [33]. Given the features of this task, it represented a suitable way to provide a preliminary answer to the following question: is body schema affected in obesity?

Since the aforementioned results about the bodily perceptions in obesity [14–21] as well as about the estimation of body parts size [7–13], we can formulate two different predictions. If the participants affected by obesity perceive themselves as larger as their real body dimension (i.e. overestimation), they would start to rotate their body parts at relatively narrower openings. Otherwise, if they underestimate their body dimensions, they would start to rotate their body parts at relatively wider openings; in other words, they would not always rotate their body parts when they have to in order to pass safely through the aperture.

2. Materials and methods

2.1. Participants

The present study was performed in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the I.R.C.C.S Istituto Auxologico Italiano. All participants provided written informed consent before taking part in the study.

We recruited 18 female participants with obesity and 18 female normal weight participants. All participants were right-handed.

The participants with obesity were recruited during the first weeks of a rehabilitation recovery in the IRCCS Istituto Auxologico Italiano – Ospedale San Giuseppe; they had been hospitalized in order to lose weight. Exclusion criteria for the study were: (1) psychiatric disturbance diagnosed by DSM-V criteria (except for Binge Eating Disorder) [35] and (2) any concurrent medical condition not related to obesity. For the healthy weight group, exclusion criteria were a body mass index (BMI) over 24.9 and no medical condition.

Means and standard deviations of demographic features and body dimensions are reported in Table 1. The two groups were comparable in terms of Age [the data are reported in years; $t(34) = 0.38$; $p = 0.7$], while the participants with obesity reported a significantly lower Years of Education than that of the healthy weight group [$t(34) = 6.7$; $p < 0.001$; $d = 2.5$]. As expected, the two groups differed significantly in their BMI [$t(34) = 16.04$; $p < 0.001$; $d = 5.33$]; moreover, participants with obesity showed a larger horizontal dimension of both shoulders [$t(33) = 5.67$; $p < 0.001$; $d = 1.95$] and pelvis [$t(33)$

Table 1

Demographic information, body dimensions and scores relative to psychological questionnaires on the presence of eating disorders as well as body image, divided by group. Means and standard deviations (in brackets). For the body parts drawing task, a negative error indicates an underestimation; a positive error, an overestimation of the actual dimensions.

	Group with obesity	Healthy weight group
Demographical details and body measures		
Age (years)	36 (8)	35 (9)
Education (years)	11 (2)	16 (2) *
Body mass index (kg/(height in m ²))	39.67 (4.72)	20.59 (1.81) *
Shoulders – width (cm)	45.01 (2.51)	40.67 (1.89) *
Pelvis – width (cm)	48.64 (3.72)	35.5 (3) *
Eating disorder assessment		
Binge Eating Scale	14.5 (9.7)	4.1 (4.2) *
Eating Disorder Inventory 2		
- Drive for the thinness	9.5 (6.5)	1.4 (2.5)
- Bulimia	3.5 (4.4)	0.2 (0.8)
- Body dissatisfaction	17.7 (7.7)	4.8 (6.1) *
- Ineffectiveness	8.1 (6.9)	2 (3.7) *
- Perfectionism	3 (3)	1.7 (1.6)
- Interpersonal distrust	6.1 (5.5)	1.6 (2) *
- Interoceptive awareness	4.9 (6.1)	0.5 (1.5)
- Maturity fear	7.2 (6)	2.3 (2.5)
- Asceticism	5.6 (3.3)	2.3 (1.5) *
- Impulsiveness	4.2 (4.6)	1 (2.2)
- Social insecurity	6.88 (5.09)	1.8 (2.4) *
Body Uneasiness Test (BUT)		
A – Global severity index	2.1 (1.1)	0.6 (0.5) *
A – Weight phobia	2.6 (1.4)	1.2 (0.9) *
A – body image concerns	3 (1.4)	0.8 (0.7) *
A – Avoidance	1.6 (1.2)	0.2 (0.3) *
A – Compulsive self-monitoring	1.2 (0.9)	0.5 (0.6)
A – Depersonalization	1.6 (1.4)	0.1 (0.3) *
A – Total score	12.3 (6.3)	3.69 (3.27) *
B – Positive symptoms total	16.6 (7.6)	11.9 (8.8)
B – Distress index	2.9 (0.8)	1.6 (0.5) *
B – Total score	19.9 (7.6)	13.6 (9.21) *
Body part drawing task		
Shoulder	Error (cm)	3.97 (6.77)
	Relative error ^a	- 7.57 (13.57) 2 (11.95)
Pelvis	Error (cm)	4.75 (17.94)
	Relative error ^a	- 7.68 (22.41) 11.35 (19.82)

^a Formula: ((estimated size – actual size) / actual size) × 100.

* p value < 0.05.

= 10.18; $p < 0.001$; $d = 3.94$) compared to the healthy weight group.

Two self-rating questionnaires were administered, Eating Disorder Inventory 2 (EDI2) [36] and Binge Eating Scale [37]. Means and standard deviations are reported in Table 1. According to an Independent *t*-test Bonferroni-corrected ($p \leq 0.004$), the participants affected by obesity reported greater difficulties in regulation of impulsive tendencies, especially in eating (Impulsiveness) [$p < 0.001$]. Moreover, higher levels of Body Dissatisfaction [$p < 0.001$] were also present, suggesting a higher risk for disordered eating [36,38]. Reluctance to having close relationships (Interpersonal distrust) [$p = 0.002$] was consistent with the tendency to avoid sexual relationships (Asceticism) [$p < 0.001$] and they reported stronger social fears and insecurity (Social Insecurity) [$p = 0.001$], compared to the control group. According to the Binge Eating Scale [Levene Test $F = 17.68$; $p < 0.001$; $t(19.57) = 3.17$; $p = 0.005$; $d = 0.77$], our sample reported higher numbers of behavioral, emotional and cognitive responses of an eating disorder compared to the control group.

2.2. Body image

We explored the body image through two different measures. The first was the self-questionnaire Body Uneasiness Test [39] that

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