Research Paper

Brain structural correlates of subclinical body dysmorphic symptoms: a gender-informed approach

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Background: Despite the prevalence and impact of body dysmorphic concerns on psychosocial functioning, there remains a scarcity of research examining the neurobiological and psychological correlates of these symptoms in healthy individuals. Given that previous studies on clinical body dysmorphic disorder (BDD) revealed brain structural and functional differences in limbic, frontal, and visual processing areas, as well as cognitive and emotional deficits, we sought to investigate the associations between grey matter volume (GMV), subclinical body dysmorphic symptom severity, alexithymia, and rumination. **Methods:** We assessed GMV using structural magnetic resonance imaging (MRI) in a sample of healthy participants. We employed a region-of-interest (ROI) approach, including the medial orbital superior frontal gyrus (SFG), precuneus, amygdala, hippocampus, anterior cingulate cortex (ACC), and inferior occipital gyrus (IOG). We analyzed associations between ROIs and body dysmorphic symptoms, with particular emphasis on the impact of gender on these associations. We corrected *p* values using threshold-free cluster enhancement and established a conservative family-wise error (FWE) threshold value of 0.05. **Results:** We included 219 participants. Our analysis revealed an interaction effect between body dysmorphic symptom score and gender in the right amygdala (p_{FWE} = 0.01), bilateral hippocampus (right p_{FWE} = 0.02; left p_{FWE} = 0.04), and right IOG (p_{FWE} = 0.01), reflecting a trend toward positive associations between body dysmorphic symptoms and GMV among men and negative associations among women. No significant relationships were found in the SFG, ACC, and precuneus. Women exhibited elevated levels of body dysmorphic symptoms compared with men, and body areas of concern differed between genders. Additionally, alexithymia predicted body dysmorphic symptom severity among women only. **Limitations:** The specificities of structural MRI measurements and cross-sectional study designs should be taken into account when interpreting these results. **Conclusion:** Our findings suggest an association between subclinical body dysmorphic symptoms and brain structure in limbic and visual areas moderated by gender. Insights into body dysmorphic symptomatology drawn from subclinical samples may offer valuable insights into predisposing factors in the etiology of BDD and may aid in developing targeted prevention strategies.

Introduction

In recent years, social media platforms focusing on physical appearance have become an integral part of daily life for numerous users. Opportunities to compare one's body and looks with others and to receive feedback on it have become more accessible than ever. However, there is growing evidence that passive and comparison-oriented use of social media is associated with body dissatisfaction, which, in turn, can contribute to the development of body dysmorphic disorder (BDD).[1] This psychiatric disorder is characterized by excessive concerns about perceived flaws in one's appearance that are judged to be ugly or disfiguring.[2] These concerns typically centre around specific body areas, leading to daily preoccupation with those alleged defects and corresponding checking behaviours.[2]

Subclinical body image concerns are widespread across various populations (e.g., 74.3% of an American student sample[3] and 35.3% in a general German population[4]), but BDD remains an underdiagnosed condition.[5] Both BDD and subclinical BDD are associated with high levels of suicidal ideation,[5,6] psychosocial impairment,[7] and comorbid psychiatric diseases.[7] Psychopathological processes in body dysmorphia may be gender-specific, which could be reflected in an increased prevalence among women compared with men[8] and differences by gender regarding areas of body concerns.[9,10]

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Studies involving young adults with BDD suggest that women exhibit poorer illness insight and experience greater distress related to behavioural symptoms than men.[9] In adolescents with subclinical body dysmorphic symptoms, female and nonbinary participants report engaging in more appearance-related safety behaviours.[11] Furthermore, while women tend to experience an earlier onset of subclinical body dysmorphic symptoms, men report higher levels of associated functional impairment.[12] However, in adulthood, similarities regarding body dysmorphic symptoms emerge between genders, with comparable rates of comorbid disorders like major depressive disorder or panic disorder, as well as similar frequencies of suicide attempts and use of medical treatments for perceived appearance deficits.[12] The integration of these findings alongside the classification of BDD as a dimensional construct[13] highlights that examining body dysmorphic symptoms and concerns is of importance, even in the subclinical domain. Although progress has been made in comprehending BDD as the clinically important endpoint on the continuum of body dysmorphic experiences, particularly in terms of understanding etiological factors and neurobiological correlates, there remains a dearth of research examining subclinical appearance-related symptoms among healthy individuals. Drawing on prior insights into BDD, we sought to address this gap in the current research literature, focusing specifically on the brain structural correlates of body dysmorphic symptomatology.

With abnormalities in the orbitofrontal–striatal and limbic networks, BDD shares important brain structural and functional abnormalities with obsessive–compulsive disorder[14] (OCD), which could be attributed to the fact that core symptoms of BDD exhibit compulsive and repetitive characteristics (e.g., excessive mirror-checking, grooming). That is why BDD is categorized within the domain of obsessive–compulsive and related disorders.[2] However, BDD pathophysiology appears to be further influenced by disruptions in the early visual system,[14] leading to disturbances in the perception, processing, and emotional evaluation of visual stimuli. At the neuroanatomical level, Feusner and colleagues[15] identified increased grey matter volume (GMV) in early extrastriate visual areas among patients with BDD, suggesting a potential morphological correlate of the observed perceptual distortions characterized by an overrepresentation of visual details. Several studies investigated visual processing both in appearance- and non-appearance-related elements in BDD, revealing the pre-eminence of detail-oriented versus holistic neural processing,[16–18] as well as altered brain functional activity and connectivity patterns during face-viewing tasks.[19–22] Face perception is mediated by a widespread cortical network of specialized areas, with the occipital face area playing a central role.[23] The occipital face area is located in the inferior occipital gyrus (IOG), an extrastriate brain region.[23] Thus, examining this area may be particularly relevant in body dysmorphic symptomatology.

Exploring the impact of emotional processing in BDD, evidence highlights abnormal morphology and dysfunction within structures of the limbic system, particularly emphasizing the roles of the amygdala[20,24] and the anterior cingulate cortex[24,25] (ACC) as regions that are crucial for the regulation and mediation of emotional responses. Atmaca and colleagues[25] and Buchanan and colleagues[24] identified decreased ACC volumes among people with BDD, while the latter study further demonstrated diminished amygdala and hippocampus volumes, alongside a negative correlation between amygdala volume and symptom severity. Moreover, alexithymia, a personality trait associated with difficulties in discerning subjective emotions and differentiating them from physical sensations, might be linked with BDD symptomatology:[26] Eye-tracking and psychometric studies involving patients with BDD showed lower accuracy in own-face emotion recognition[27] and in deciphering the emotional importance of others' facial expressions, with a tendency toward misinterpreting faces as angry or contemptuous, compared with controls.[28,29] However, a limited number of studies has explored this association.

Given the involvement of the ACC in both emotional and cognitive–executive functions,[30] as well as findings of structural aberrations in frontal cortices,[24,25,31] impairments in frontal circuits appear to be another crucial component in BDD pathology. Frontal impairments may contribute to compromised top–down control over dysfunctionally processed emotional and visual stimuli, while also facilitating compulsive and ruminative behaviours in patients with BDD.[14] Rumination is considered a core feature in the cognitive behavioural model of BDD, and could contribute to the maintenance of body dysmorphic symptoms.[32] The analysis of frontal brain regions involved in cognitive control and rumination, such as the medial orbital part of the superior frontal gyrus (SFG),[33] may be particularly relevant to the symptomatology of BDD.

In addition to findings in limbic, frontal, and visual processing areas, structural and functional alterations in the precuneus seem pertinent in the context of body dysmorphic pathology. The precuneus is conceived as a major association area, encompassing diverse functional attributes that span from perspective-taking and episodic memory to visual-spatial representation and mental imagery.[34] Moreover, its presumed involvement in self-representation and self-processing,[34] alongside observations of diminished volume[24] and altered activation patterns during visual processing[16,20] among people with BDD suggest this region's importance in subclinical body dysmorphic symptomatology.

Despite several studies indicating neurophysiological aberrations in BDD, inconsistencies remain, including reports of both volumetric and functional increases[15,20,31] and decreases,[16,24,25] as well as studies where no group differences between people with BDD and healthy controls were identified.[35] This could be owing to methodological issues or overall phenotypic variability among patients with BDD. Gender differences in body dysmorphic symptom profiles and varying psychosocial consequences that may accompany these symptoms could also contribute to these heterogeneous findings.

The objective of our study was to improve the understanding of subclinical BDD by investigating its brain structural correlates and the potential impact of gender on these

associations. Building on previous research, we sought to analyze associations between body dysmorphic symptoms and GMV in circumscribed brain regions in a theoretically sound manner. Accordingly, we employed a region-of-interest (ROI) approach to test hypotheses, defined a priori, concerning the bilateral medial orbital SFG, precuneus, amygdala, hippocampus, ACC, and IOG. These regions are of particular relevance to our study given their previous implementation in clinical BDD research (e.g., amygdala,[20,24] hippocampus,[24] ACC[24,25]) and their functional roles, which may be associated with body dysmorphic symptoms (e.g., SFG,[33] IOG,[23] precuneus[34]). Given the inconsistencies regarding the effect direction in previous studies, our hypotheses remained undirected.

To gain deeper insights into subclinical body dysmorphic symptomatology, we sought to investigate its relation with alexithymia and rumination. As BDD is associated with difficulties in emotion recognition[29] and processing,[36] we hypothesized that alexithymia and rumination might be predictors of subclinical body dysmorphic symptoms.

As we hypothesized that the associations between body dysmorphic symptom severity and GMV in the ROIs, alexithymia, and rumination, are influenced by gender, the impact of gender was explicitly included in all analyses.

Methods

Participants and procedure

We used data from the Münster Neuroimaging Cohort, an ongoing neuroimaging study conducted by the University of Münster investigating the neurobiology of affective disorders. Data were collected between 2017 and 2021. Participants were recruited via public notices and newspaper announcements. Exclusion criteria were any neurologic abnormalities, previous traumatic head injuries, organic mental disorders, dementia, chronic medical diseases, substance or alcohol abuse or dependence, any lifetime psychiatric disorders, or contraindications to magnetic resonance imaging (MRI).

All participants underwent structural MRI measurement and completed a self-report inventory assessing the severity of body dysmorphic symptoms (Body Dysmorphic Symptom Inventory [BDSI][37]), alexithymia (Toronto Alexithymia Scale, [TAS-20][38]), and rumination (Response Style Questionnaire, [RSQ][39]). To ensure the absence of any lifetime psychiatric disorder including BDD, structured clinical interviews were conducted (Structured Clinical Interview for the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* [SCID-I][40]). Only people who did not meet the diagnostic criteria for BDD or any other psychiatric disorder were included in the final sample.

Psychometric measures

To evaluate the severity of body dysmorphic symptoms, participants completed the German version of the BDSI (Fragebogen körperdysmorpher Symptome[37]). The BDSI consists of 18 items in 2 subscales: specific body dysmorphic symptoms and associated features. The latter includes, for instance, the occurrence of cosmetic surgery and suicidality in the context of body dysmorphic symptomatology. The following analyses refer to the sum score of the specific body dysmorphic symptoms scale, comprising 13 items. The sum score of this scale shows high internal consistency (Cronbach $\alpha = 0.88$) and good discriminant validity in distinguishing between people with BDD and healthy controls.[37] In addition, the BDSI is moderately correlated with the German version of the Yale–Brown Obsessive–Compulsive Scale Modified for Body Dysmorphic Disorder, a clinician-administered interview used to diagnose BDD.[41]

To further characterize the sample concerning its manifestations in alexithymia and rumination as emotion regulation mechanisms, we evalauted the TAS-20[38] and the rumination scale of the RSQ.[39] The TAS-20 is a reliable (Cronbach $\alpha = 0.66–0.81$) and valid self-report instrument used to assess 3 aspects commonly associated with alexithymia: difficulty identifying feelings, difficulty describing feelings, and externally oriented thinking. In addition to the 3 subscales, we calculated the total score of all 20 items.

The RSQ is a widely used instrument to assess cognitive and behavioural coping mechanisms with high reliability (Cronbach $\alpha = 0.76–0.88$). We focused on the rumination subscale, comprising 15 items.

Image acquisition and preprocessing

A 3-T MRI scanner (Gyroscan Intera 3T, Philips Medical Systems) was used to acquire T_1-weighted high-resolution anatomic images with a 3D fast-gradient echo sequence (turbo field echo, repetition time 7.4 ms, echo time 3.4 ms, flip angle 98°, from 2 signal averages, inversion prepulse every 814.5 ms, field of view 256 mm × 204 mm × 160 mm, phase encoding in anterior–posterior and right–left directions, reconstructed to cubic voxels of 0.5 mm × 0.5 mm × 0.5 mm). The cross-sectional preprocessing pipeline of the computational anatomy toolbox (cat12-toolbox v1184; http:// dbm.neuro.uni-jena.de/cat/) with default parameters was used for preprocessing to create bias-corrected, tissue-classified, and normalized images. The resulting grey matter segments were smoothed (8 mm full width at half maximum). Segmentation results were carefully checked for quality, outliers, and artifacts.

Statistical analysis

We used statistical parametric mapping to analyze structural MRI data (SPM12, Wellcome Trust Centre for Neuroimaging, London, http://www.fil.ion.ucl.ac.uk/spm/). For all second-level analyses in SPM, we included age and total intracranial volume as covariates of no interest. We applied an implicit mask using a grey matter threshold of 0.1. Significance thresholds for multiple testing were obtained at the cluster level by threshold-free cluster enhancement (TFCE), a method that provides nonparametric statistics and is based on permutation testing.[42] It is implemented in the

TFCE toolbox (http://dbm.neuro.uni-jena.de/tfce, version 232). We corrected p values using the family-wise error (FWE), establishing a conservative threshold of less than 0.05, obtained by 5000 permutations per test.

To capture both dimensional effects of severity of body dysmorphic symptoms on GMV and gender-specific interaction effects, we implemented a full factorial model in SPM12 with gender as a dichotomous factor and BDSI scores as a metric variable. We initially evaluated gender-specific interaction effects using undirected F contrasts; upon observing significant effects, we used post hoc directed analyses using T contrasts to determine the direction of the effect. Following the identification of a significant interaction effect in specific brain regions, we conducted separate regression analyses for women and men, employing the BDSI total score as the independent variable and GMV as the dependent variable. If no interaction effect was observed for a specific brain region, we performed the regression analysis on the total sample.

We performed brain structural analyses using an ROI approach including the bilateral SFG, the precuneus, the amygdala, the hippocampus, the ACC, and the IOG. We defined ROIs according to the automated anatomical atlas[43] implemented in the Wake Forest University PickAtlas.[44] The minimum cluster size was set at k of 10 or greater. To address potential issues of multiple testing, we corrected for the false discovery rate (FDR) to the obtained p_{FWE} values of significant clusters. Only results that remained significant after FDR correction are presented. Further results can be found in Appendix 1, available at www.jpn.ca/lookup/doi/10.1503/jpn.240069/tab-related-content. To identify potential additional structural correlates of body dysmorphic symptoms, we conducted an exploratory whole-brain analysis on both the total sample and the subgroups. For visualization, we extracted grey matter values of significant clusters using the eigenvariate function in SPM.

To further investigate subclinical body dysmorphic symptomatology, its potential predictors, and gender-specific correlates, we analyzed questionnaire measures using SPSS (version 28.0.1.1; IBM). To identify associations between body dysmorphic symptomatology, alexithymia, and rumination, we conducted separate linear regressions for each predictor. Rumination (RSQ), alexithymia (TAS-20), and their respective subscales (difficulty identifying feelings, difficulty describing feelings, externally oriented thinking) were individually used as independent variables, with body dysmorphic symptoms (BDSI) as the dependent variable. We performed these analyses separately for women and men. Results of the linear regressions are presented if they survived FDR correction for multiple testing. Additionally, to assess gender differences regarding the questionnaire measures, we conducted a 1-way multivariate analysis of variance (ANOVA) using gender as the independent variable. We conducted subsequent post hoc univariate ANOVAs for every dependent variable. Finally, we conducted logistic regression analysis to identify potential gender-specific variations in body regions linked to body dysmorphic concerns as reported in the BDSI.

As previous studies have noted elevated levels of depressive symptoms[45] and associations with personality traits such as neuroticism[46] in people with BDD, associations with these constructs were analyzed as well, detailed in Appendix 1.

Ethics approval

The experimental procedure was approved by the local institutional review board (2007–307-f-S). All participants provided written informed consent and received financial compensation.

Results

The sample included 219 healthy, adult participants with a mean age of 38.56 (standard deviation 14.24) years, of whom 95 were men and 124 were women. All participants were free of psychotropic medication. Further sample characteristics are provided in Table 1.

Effects of body dysmorphic symptom severity on grey matter volume

A significant interaction effect of body dysmorphic symptom score and gender was observed in the right amygdala ($x = 27$, $y = 0$, $z = –22$; $k = 292$, $TFCE_{213} = 132.50$, $t_{213} = 2.98$, $p_{FWE} = 0.01$; Figure 1), the bilateral hippocampus (right: $x = 21$, $y = –8$, $z = –21$; $k = 444$, $TFCE_{213} = 196.26$, $t_{213} = 3.10$, $p_{FWE} = 0.02$; left: $x = –36$, $y = –18$, $z = –16$; $k = 405$, $TFCE_{213} = 159.52$, $t_{213} = 2.86$, $p_{FWE} = 0.04$; Appendix 1, Figure 1), and the right IOG ($x = 42$, $y = –78$, $z = –9$; $k = 424$, $TFCE_{213} = 278.63$, $t_{213} = 3.66$, $_{pFWE} = 0.009$; Figure 2). Analyzing the men and women separately, body dysmorphic symptoms and GMV were positively associated among men ($x = 40$, $y = –78$, $z = –10$; $k = 68$, $TFCE_{213} = 205.75$, $t_{213} = 3.57$, $p_{FWE} = 0.003$) and negatively associated among women ($x = 44$, $y = –88$, $z = –3$; $k = 277$, $TFCE_{213} = 197.60$, $t_{213} = 3.15$, $p_{FWE} = 0.003$) in the right IOG. No significant associations emerged at the subgroup level concerning the amygdala ($p_{FWE} > 0.06$) and hippocampus ($p_{FWE} > 0.06$); however, associations followed the same effect direction. Scatterplots depicted in Figure 1 and Appendix 1, Figure 1 illustrate a qualitative positive correlation between body dysmorphic symptoms and extracted GMV values among men, juxtaposed with a negative association among women within these regions. With regard to the SFG ($p_{FWE} > 0.08$), ACC ($p_{FWE} > 0.05$), and precuneus ($p_{FWE} > 0.06$), there were no interaction or main effects of body dysmorphic symptoms on GMV. Exploratory whole-brain analyses yielded no additional findings at either subgroup or the whole sample.

Associations between gender, body dysmorphic symptomatology, alexithymia, and rumination

Among women, the alexithymia subscale on difficulties identifying feelings ($R^2 = 0.073$, $F_{1,122} = 9.656$, $p = 0.002$) and the alexithymia sum score ($R^2 = 0.036$, $F_{1,122} = 5.626$, $p = 0.02$)

predicted body dysmorphic symptoms. Rumination, difficulties describing feelings, and externally oriented thinking did not have a significant effect ($p > 0.06$). Among men, none of the assessed scales exhibited a significant association with body dysmorphic symptoms after correction for multiple testing ($p > 0.02$).

We observed differences by gender for the BDSI score ($F_{1, 217} = 11.944$, $p < 0.001$, partial $\eta^2 = 0.052$), with women exhibiting higher body dysmorphic symptom scores than men. Men reported significantly higher alexithymia, as indicated by the total sum score ($F_{1, 217} = 4.059$, $p = 0.04$, partial $\eta^2 = 0.018$) and by the subscale on difficulties describing feelings ($F_{1, 217} = 8.700$, $p = 0.004$, partial $\eta^2 = 0.039$). No group differences were observed regarding the alexithymia subscales on difficulties identifying feelings ($p = 0.97$) and externally oriented thinking ($p = 0.08$) or rumination ($p = 0.06$).

In terms of body-related issues addressed in the BDSI, the subgroups reported differences in their concerns regarding hair ($W_1 = 7.671$, $p = 0.006$) and size and shape of muscles ($W_1 = 12.623$, $p < 0.001$), with men indicating more frequent worries about these areas. Women reported more facial concerns, including hair, ears, nose, eyes, skin, and mouth ($W_1 = 4.894$, $p = 0.03$). There were no differences with respect to other body regions ($p > 0.06$).

Additional tables and figures providing a summary of the results of the regression analyses can be found in Appendix 1. Additionally, the results of the analyses examining the associations between body dysmorphic symptoms, depressive symptoms and personality traits are presented in the appendix.

Discussion

The objective of this study was to enhance the understanding of subclinical body dysmorphic symptomatology by investigating brain structural correlates and potential predictors in healthy individuals, with a specific emphasis on exploring the impact of gender on these associations. Our investigation revealed gender-specific interaction effects concerning the relationship between body dysmorphic symptoms and GMV in distinct brain regions, namely the right amygdala, bilateral hippocampus, and right IOG. Specifically, in the latter structure, the body dysmorphic symptom score exhibited a significant negative association with GMV among women, but a positive association among men. We also observed nonsignificant associations following the same effect direction in the amygdala and hippocampus. With regard to psychometric measures, our findings indicated that alexithymia and difficulties in identifying feelings, as a subscale of alexithymia, predicted body dysmorphic symptoms only among women. Moreover, our analysis revealed significant group differences, with women reporting higher body dysmorphic symptom severity, while men exhibited higher levels of alexithymia and difficulties in describing feelings. The overall effect sizes were moderate, indicating a relevant, although not exceptionally high, effect.

Our findings suggest an association between body dysmorphic symptoms and brain structure, even on a subclinical level, with the direction and magnitude of this effect influenced by gender. Notably, our data supported the implication of the IOG — a brain region situated in the extrastriate

Table 1: Sample characteristics

Characteristic	Mean ± SD*			*p* value†	Effect size‡
	Total sample *n* = 219	Men *n* = 95	Women *n* = 124		
Age, yr	38.56 ± 14.24	39.60 ± 13.82	37.76 ± 14.55	0.344	0.129
Total BDSI score	7.03 ± 6.41	5.36 ± 5.87	8.31 ± 6.53	< 0.001	0.052
No. of facial concerns	0.43 ± 0.65	0.43 ± 0.72	0.43 ± 0.60	0.963	0.006
RSQ, rumination subscale	1.61 ± 0.48	1.54 ± 0.42	1.67 ± 0.52	0.059	0.016
TAS-20					
Total score	40.27 ± 10.04	41.82 ± 10.69	39.08 ± 9.39	0.045	0.018
DDF	10.94 ± 4.08	11.85 ± 4.31	10.24 ± 3.76	0.004	0.039
DIF	11.48 ± 4.02	11.49 ± 4.25	11.47 ± 3.85	0.973	0.000
EOT	17.84 ± 4.60	18.47 ± 4.68	17.36 ± 4.49	0.076	0.014
Total BDI score	2.21 ± 3.05	1.97 ± 2.87	2.40 ± 3.18	0.297	–0.143
No (%) of participants with family history of psychiatric disorder§				0.008	0.209
Yes	54 (24.6)	24 (25.3)	30 (24.2)		
No	155 (70.8)	62 (65.3)	93 (75.0)		
Unknown	10 (4.6)	9 (9.5)	1 (0.8)		

ANOVA = analysis of variance; BDI = Beck Depression Inventory; BDSI = Body Dysmorphic Symptoms Inventory; DDF = difficulties describing feelings; DIF = difficulties identifying feelings; EOT = externally oriented thinking; RSQ = Response Style Questionnaire; SD = standard deviation; TAS-20 = Toronto Alexithymia Scale.
*Unless indicated otherwise.
†We obtained *p* values for age, number of facial concerns, and total BDI score using *t* tests. We obtained *p* values for the BDSI, RSQ, and TAS-20 using univariate ANOVA. We obtained *p* values for the number of participants with a family history of psychiatric disorder using the χ^2 test.
‡We calculated effect sizes for age, number of facial concerns, and total BDI score using Cohen *d*. We obtained effect sizes for the BDSI, RSQ, and TAS-20 using the partial η^2. We calculated effect sizes for the number of participants with a family history of psychiatric disorder using Cramer's V.
§Psychiatric disorders of first-degree relatives surveyed.

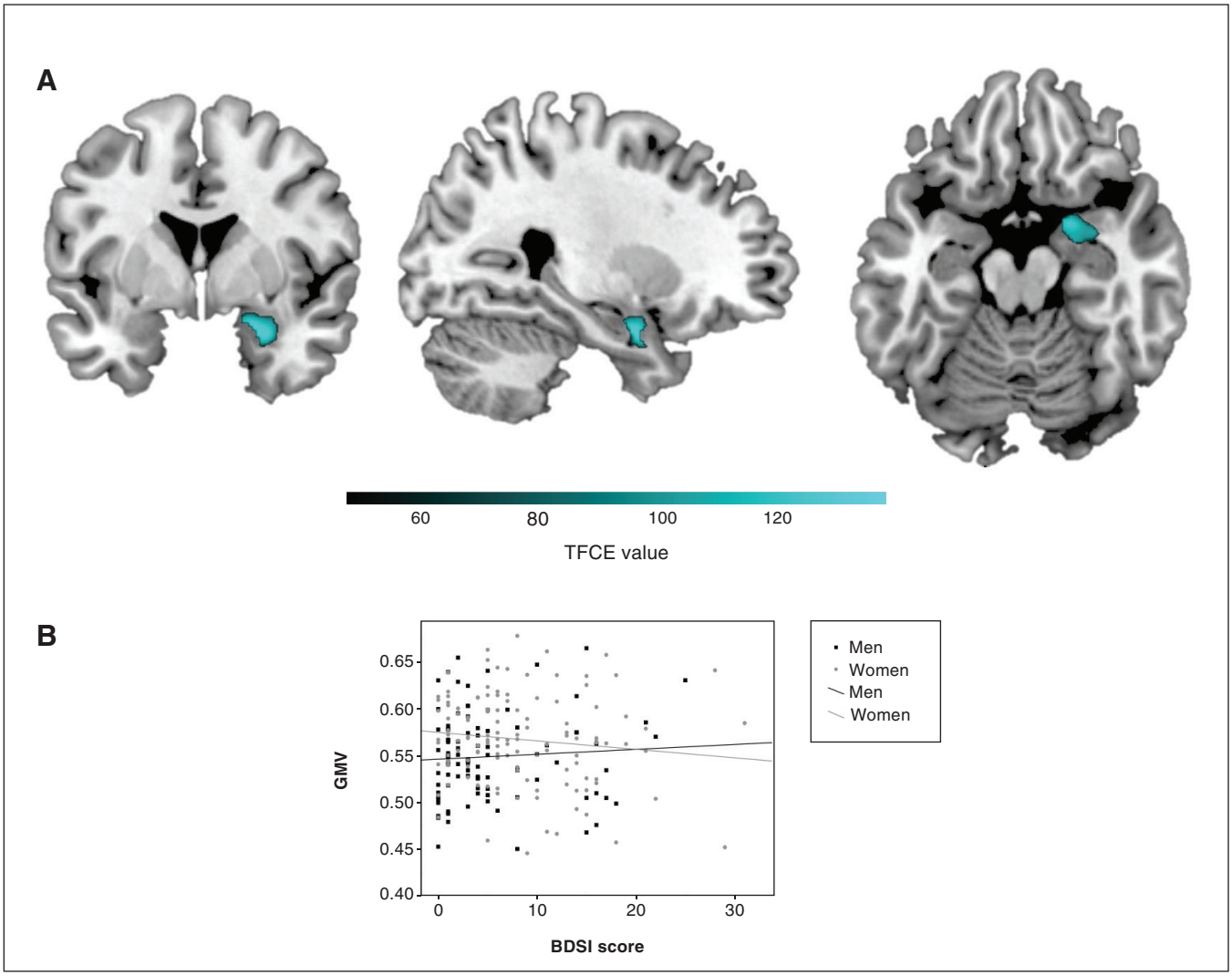

Figure 1: (A) Coronal, sagittal, and axial views, (B) and scatterplot of the interaction effect of score on the Body Dysmorphic Symptom Inventory (BDSI) and gender on grey matter volume (GMV) in the right amygdala (p = 0.01). TFCE = threshold-free cluster enhancement.

visual cortex that contains the occipital face area and is involved in the early processing stages of face perception[23] — in body dysmorphic symptomatology. During face processing, the IOG rapidly communicates with the amygdala,[47] a structure of importance in emotion processing, particularly in fear conditioning and anxiety contexts,[48] which is commonly implicated in the psychopathology of BDD.[20,24,31] Only the right amygdala showed significant associations with body dysmorphic symptomatology in our sample, which may correspond to its affinity for processing image-related stimuli.[49]

Both the IOG and amygdala exhibited associations with the severity of body dysmorphic symptoms in our sample, suggesting the relevance of face-processing areas in subclinical BDD. At a neuroanatomical level, these structures are interconnected through white matter pathways such as the inferior longitudinal fasciculus.[50] Investigating the connectivity between these regions in subclinical BDD could provide additional insight into brain communication processes that are potentially involved in the development of body dysmorphic symptomatology.

Given that the described interaction effects were observed in both the amygdala and the hippocampus, limbic structures may play a role in subclinical body dysmorphic symptomatology, which corresponds with studies involving clinical samples.[20,24,31] Compared with the amygdala, the hippocampus has received less attention in BDD. However, the results of Buchanan and colleagues[24] — who found reduced hippocampal GMV among patients with BDD — along with the findings of Borgers and colleagues[20] — who observed increased functional connectivity between the amygdala and the hippocampus and between the fusiform gyrus and the hippocampus during an emotional face processing task — suggest the potential importance of the hippocampal area in the context of body dysmorphic symptoms. There is growing acknowledgement of the hippocampus' role in social information processing and regulation of

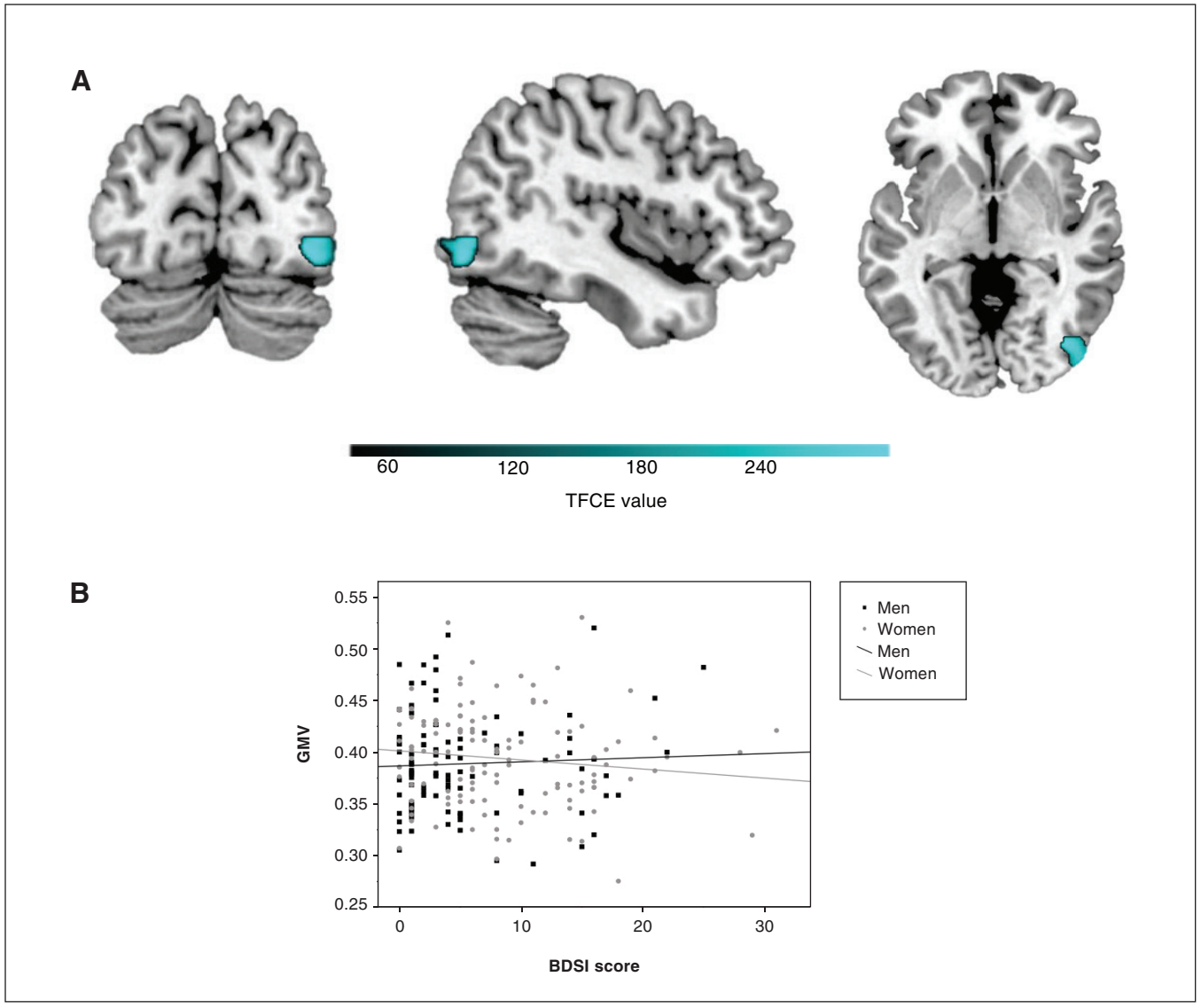

Figure 2: (A) Coronal, sagittal, and axial views, and (B) scatterplot of the interaction effect of scores on the Body Dysmorphic Symptom Inventory (BDSI) score and gender on the grey matter volume (GMV) of the right inferior occipital gyrus (p = 0.009). TFCE = threshold-free cluster enhancement.

dynamic social behaviour.[51] Given the association between BDD and increased levels of interpersonal problems,[52] our findings could underscore the importance of social impairment in the context of subclinical body dysmorphic symptoms. With regard to the different directions of association between body dysmorphic symptoms and GMV in the hippocampus among men and women, this brain region may serve as a potential indicator of gender differences. Moreover, emerging evidence suggests the existence of gender-specific variations in hippocampal plasticity and disorders related to hippocampal integrity.[53] Neurogenesis in the hippocampus can be affected by stress, and this effect is gender dependent.[54] It is therefore possible that the extent of body dysmorphic symptoms (as a form of stressor) may have a qualitatively different effect on hippocampal structure by gender, resulting in differences in the clinical picture.

Volumetric changes in the amygdala and hippocampus have also been implicated in OCD;[54,55] therefore, our results may support the previously suggested neuromorphological similarities of BDD and OCD.[14] However, in contrast to these suggested similarities, which include frontolimbic alterations, and the findings of other studies on BDD,[25,31] we did not observe associations in frontal brain regions, specifically the SFG. A tentative interpretation of these results could suggest that subclinical body dysmorphic symptoms may already be associated with changes in limbic and visual areas and their related functionalities, while frontal structures remain unaffected. This could, in turn, result in largely intact top–down control of emotion and visual processing in subclinical BDD. It is conceivable that people with higher levels of body dysmorphic symptomatology attribute high (emotional)

salience to visual stimuli; largely intact cognitive control and interpretation of these stimuli may allow for a differentiation between clinical and subclinical manifestations of body dysmorphia. However, since our study focused on the structural correlates of body dysmorphic symptoms, this hypothesis warrants further functional examination.

In the present study, we found a trend toward volumetric increases in distinct brain regions as a function of body dysmorphic symptom severity among men, in contrast to volumetric decreases among women, which suggests gender-specific variations in the manifestation of body dysmorphic symptoms in neurobiological correlates. In light of inconsistent findings from previous studies on brain structural correlates of BDD, gender may contribute to this heterogeneity. The divergent effects we observed could indicate that neural mechanisms underlying body dysmorphic symptomatology may operate distinctively in men and women. Since we independently found a significant negative association between GMV in the right IOG and body dysmorphic symptoms among women and a positive association among men, the IOG may be the brain region for which these divergent effects are most pronounced. Abnormalities in visual processing in the context of BDD are well established, including a bias toward detail-oriented processing to the detriment of holistic processing.[16–18] Enlarged GMV in visual areas, such as the increased volumes observed in the IOG relative to body dysmorphic symptoms among men, may predispose individuals to specific visual distortions. Consistent with Feusner and colleagues,[15] this may represent a neural factor underlying the heightened perception of visual detail and a reduced ability to integrate them into a global context, potentially specific to men. Visual distortions associated with body dysmorphic symptoms were also likely in the subgroup of women, but the opposite direction of effect suggests that they are qualitatively different. Given the close link between the IOG and the processing of face-related stimuli, volumetric reductions may be associated with a distortion of the perception of one's face. This, in turn, may predispose individuals to perceive and overinterpret nonexistent defects. As these assumptions are based on conjecture, further verification could be conducted as part of a functional investigation. Moreover, cross-sectional analyses are not appropriate for causal interpretations. Thus, volumetric changes may also represent morphological manifestations, and may therefore be a consequence, rather than a cause, of heightened brain activity in these areas.

It is plausible that different coping mechanisms and emotion regulation strategies are employed by men and women in response to the experience of body dysmorphic symptoms, and that these are potentially associated with divergent patterns of brain morphology. This notion is supported by the findings of Phillips and colleagues,[12] who observed that women with BDD tend to employ more safety behaviours, such as concealing perceived flaws or frequently checking mirrors. With regard to attributes associated with body dysmorphic symptoms, Malcolm and colleagues[9] demonstrated lower illness insight and a higher symptom burden among women, while Phillips and colleagues[12] identified greater functional impairment among men. In our investigation, women exhibited significantly more severe body dysmorphic symptoms, predicted by alexithymia and its subscale on difficulties identifying feelings. The absence of significant associations among men, despite their higher scores and variance on the alexithymia scale, suggests that underlying, gender-specific psychological processes contribute to body dysmorphic symptomatology. Alexithymia is a trait that tends to manifest more prominently among men than women, possibly owing to traditional socialization and upbringing processes.[56] Consequently, alexithymia may be more normalized among men, leading to a more pronounced relationship between alexithymia and other psychopathologically relevant characteristics in females. Fenwick and Sullivan[26] found an association between alexithymia and body dysmorphic symptoms in an exclusively female sample, hypothesizing that the reduced ability to symbolize and regulate affective states could result in a maladaptive redirection of emotions toward body-related concerns as a coping mechanism to gain control over these emotions. The absence of similar associations between alexithymia and body dysmorphic symptoms in our sample of men suggests that this mechanism may be specific to women.

Research consistently highlights gender differences in areas of concern, with men being more worried about muscularity[9] and hair,[12] findings that align with our results. Variations in body areas that are subject to body dysmorphic cognitions and behaviours may be an expression of distinct gender-specific societal beauty norms and role expectations and may in turn be reflected in the actions taken to conform to these norms.

Contrary to our hypothesis, rumination did not predict body dysmorphic symptoms in either group. Rumination is considered a transdiagnostic factor for the onset and maintenance of psychopathology.[57] Therefore, the lack of association in our sample might suggest that rumination differentiates between clinical and subclinical BDD.

Limitations

Inferring functional relationships from structural ones was not feasible. However, it is also important to note that brain structure and function are not distinctly separable entities — brain function influences brain structure and vice versa.[58] Furthermore, observations of enlarged grey matter could be attributed to various underlying factors, including neurogenesis, gliogenesis, increased blood flow, and others.[58] Therefore, to gain a more comprehensive understanding of the underlying processes, further studies should investigate brain function in relation to subclinical body dysmorphic symptoms within the context of visual, emotion, and cognitive processing. Since we relied on self-report measures to assess body dysmorphic symptoms, it is important to recognize the limitations and potential biases inherent in such questionnaires. Future research would benefit from incorporating objective measures.

The cross-sectional design of our investigation did not allow us to draw causal conclusions; however, it provided insights into possible risk factors for the development of clinical BDD, which should be examined more closely in longitudinal studies. Since our study focused on healthy people, the generalizability of the results to clinical BDD is limited. However, emphasizing a healthy population enables the analysis of the relationship between brain structural correlates and body dysmorphic symptoms while minimizing confounding variables associated with clinical conditions. The interpretation of the effects of gender on brain structural associations observed in this study should consider the imbalance in sample size, with a greater number of women than men. Finally, although the study acknowledged gender differences, it should be noted that the sample did not represent gender diversity beyond people who identified as men or women.

Conclusion

Insights into body dysmorphic symptomatology drawn from subclinical samples may offer valuable insights into predisposing factors in the etiology of BDD and may aid in developing targeted prevention strategies. Our results, indicating the involvement of limbic brain areas and an association between alexithymia and severity of body dysmorphic symptoms among women, may indicate the necessity of improving emotion identification and regulation skills in individuals experiencing elevated levels of body dysmorphic symptoms. Volumetric differences in visual areas further suggest the potential utility of specific training interventions, which may enhance the effectiveness of visual processing.[59] Our findings shed light on the intricate relationship between brain structural correlates, subclinical body dysmorphic symptoms, and gender differences. Our findings, therefore, underscore the importance of considering gender-specific psychological processes and societal beauty norms in understanding the brain structural manifestation of body dysmorphic concerns.

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