NEUROCOGNITIVE FUNCTION IN INDIVIDUALS WITH SUB-CLINICAL BODY DYSMORPHIC DISORDER

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
SC-BDD	Subclinical body dysmorphic disorder
ANOVA	Analysis of Variance
OCD	Obsessive-Compulsive Disorder
GAD	Generalized Anxiety Disorder
CBT	Cognitive-Behavioral Therapy

ABSTRACT

Preoccupation with perceived flaws in physical appearance and body dysmorphic concerns are central symptoms of Body Dysmorphic Disorder (BDD), a condition associated with substantial psychopathological burden, increased suicide risk, and functional disability. Initial research reveals that BDD is associated with deficient cognitive functions. Less is known about Subclinical Body Dysmorphic Disorder (SC-BDD) -a psychometrically defined clinical status that is more prevalent than BDD – particularly in terms of neuropsychological function. Moreover, to date no analogue BDD study using a comprehensive neuropsychological battery has been conducted in college students, a population associated with higher risk for BDD and body image concerns compared to the general population. To fill this gap in the literature, the present study aimed at assessing cognitive functions in a SC-BDD sample using a validated computerized neuropsychological battery among college students. Initially, a sample of 1394 students completed the Dysmorphic Concern Questionnaire (DCQ). Using a psychometrically valid methodology, a SC-BDD (n = 40) and control (n = 39) groups were selected based on scores in the upper and lower quartiles on the DCQ. The two groups completed a comprehensive computerized neuropsychological battery and clinical questionnaires. The SC-BDD sample presented with significantly elevated symptoms of anxiety, stress, and depression. However, no significant differences were found on any neuropsychological outcome measures or domain indexes. Effect sizes were small, some of which favored the SC-BDD group. Despite substantial anxiety and depression

symptoms, entailing meaningful psychopathological burden, SC-BDD exhibited intact cognitive functioning. Given the prevalence, severity, and suicide risk associated with SC-BDD, these results are important because intact cognitive functioning may result in misidentification of students who require treatment. Given that years untreated is a negative prognostic indicator, it is important for academic institution to disseminate information to their students regarding body image concerns, and offer specific support in University counselling centers.

I. INTRODUCTION

Body Dysmorphic Disorder (BDD) is a debilitating disorder, with a prevalence rate of 2.4% in the general population in the United States (Koran, Abujaoude, Large, & Serpe, 2008), and somewhat increased prevalence among females (1.9-2.5% point prevalence) compared to males (1.5-2.2%) (American Psychiatric Association, 2013; Boroughs, Krawczyk, & Thompson, 2010). BDD is characterized by substantial distress and/or dysfunction associated with irrational obsessive preoccupation with an imagined or slight defect in appearance. Individuals with BDD spend a significant amount of time performing compulsive repetitive behaviors such as mirror checking, camouflaging, comparing features to other people, excessive grooming, skin-picking and reassurance seeking (Phillips, Menard, Quinn, Didie, & Stout, 2013). These symptoms cause significant distress and impairment in daily functioning, and are socially, academically and occupationally debilitating (Barlow, & Durand, 2014).

BDD is associated with preoccupation and extreme concerns about a variety of body parts, where multiple body parts of concern may exist. In fact, most individuals diagnosed with BDD show preoccupation with several body parts, with an average of 5 to 7 different body areas during their life (Didie, Kelly, & Phillips, 2010). The most prevalent body areas of concern are the skin (73%), hair (56%), nose (37%) stomach (22%), and teeth (20%) (Didie et al., 2010). Preoccupation with physical deformities in BDD frequently result in seeking dermatological interventions and cosmetic surgeries. In fact, it has been estimated that up to 15% of individuals seeking cosmetic surgery suffer from BDD, and up to 12% in general dermatology settings, which is 3-7 times higher than the prevalence of BDD in the general population (Phillips, Menard, Fay, &

Weisberg, 2005). Indeed, Mataix-Cols and colleagues (2015) showed that up to 47% of patients with BDD are interested in undergoing cosmetic surgery and around 33% of them are interested in receiving additional elective cosmetic surgeries. However, cosmetic interventions yield no symptomatic improvement, may promote maintenance of BDD, and in some cases lead to exacerbation of symptoms (Barlow, & Durand, 2014). For example, Phillips and colleagues (2001) reported no symptomatic change following cosmetic surgery in 81% of individuals diagnosed with BDD with severe symptoms. These individuals were found to seldom demonstrate satisfaction with the outcome of dermatologic and cosmetic interventions. Moreover, in most cases, this lack of satisfaction leads individuals with BDD to file complaints against dermatologists and plastic surgeons (Crerand, Menard, & Phillips, 2010; Phillips, Grant, Siniscalchi, & Albertini, 2001). On the other hand, in some cases BDD patients with mild-to-moderate symptoms have reported satisfaction with the outcomes of the procedures, leading these individuals to pursue additional cosmetic surgeries on other body parts (Felix et al., 2014; Veale et al., 2014).

In one of the major changes in Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013), BDD has been moved from the somatic disorders category to the new category of Obsessive-Compulsive and Related Disorders (OCRDs), along with obsessive-compulsive disorder, trichotillomania (hair pulling disorder), hoarding disorder, and excoriation (skin picking) disorder (APA, 2013). Disorders in this category share symptoms of obsessions and compulsions. In fact, the transition to the newly formed superordinate category included adding a new diagnostic criterion that requires mental acts or repetitive behaviors, such as mirror checking, reassurance

seeking, and excessive grooming (APA, 2013). Notably, BDD and the other disorders in the OCRD category are reported to share genetic, neurobiological, phenomenological, and comorbidities. However, some have argued against the merit and scientific validity of the new category (Abramowitz, McKay, & Taylor, 2007).

There are several clinical similarities between BDD and OCD – the primary disorder within the OCRD category – as well as two major distinctive features. The two disorders share obsessions and compulsions as well as familial overlap. Approximately one-third of individuals diagnosed with BDD have a comorbid lifetime diagnosis of OCD (Bienvenu et al. 2012). The association between BDD and OCD is further supported by findings, that first-degree relatives of OCD probands are at considerably elevated risk of developing BDD, as well as other OCD related disorders such as trichotillomania, skin-picking and hypochondriasis compared to first-degree relatives of controls. Indeed, some researchers argue that the evidence is suggestive of a phenomenological, genetic, and environmental association between BDD, OCD and other obsessive-compulsive and related disorders (Bienvenu et al. 2012). However, two differentiating factors are nature of obsessions, and poor insight in BDD relative to OCD. In terms of obsessions, individuals with BDD are preoccupied with flaws in physical appearance that are not observable, or ones that appear very minor to others (Abramovitch, Berman, Calkins, & Wilhelm, 2015). In terms of level of insight, studies have shown that multidimensional insight in BDD is significantly poorer than in OCD patients. Phillips and her colleagues (2012) examined insight in 68 subjects with BDD versus 211 subjects with OCD. The authors demonstrated that the majority of individuals diagnosed with OCD have intact insight, and in fact, intact insight was previously included in DSM criteria for OCD.

However, individuals with BDD were classified with poor or absent insight (frequently regarded as ‘psychotic level of insight'), which is associated with the severity of the disorder, prognosis, and suicide risk.

Indeed, a prominent symptom of BDD relates to the notion of impaired insight, suggesting an inability to recognize existence of the psychopathology as well as false perception of the slight or imagined body deformity, such that they perceive the slight flaw in their physical appearance as a major conspicuous deformity (Toh, Castle, Mountjoy, Buchanan, Farhall, & Rossell, 2017). This level of insight is commonly associated with delusional thinking. For example, Phillips and colleagues (2006) assessed 136 BDD individuals with psychotic level of insight, and found that 33% of individuals had current delusions, 46% showed current ideas or delusions of reference, and 77% of them had lifetime delusions pertaining to the BDD phenomenology. In BDD, this level of insight is associated with suicidal ideations, suicide attempts, and completed suicide, as well as drug abuse and lower likelihood of seeking treatment (Eisen, Phillips, Coles, & Rasmussen, 2004; Phillips, Albertini, Rasmussen, 2002; Toh et al., 2017).

BDD differs from other OCRDs, in that it is associated with a significantly elevated risk for suicide, that has been found to be 35 times higher than in the general population (Veale et al., 2016). For example, increased occurrence of suicidal ideation is reported to occur in 80% of individuals diagnosed with BDD, as well as elevated prevalence of suicide attempts (28%; Didie et al., 2010; Phillips, & Menard, 2006). In addition to psychotic level of insight, some comorbid conditions have been associated with further elevated risk for suicide in BDD. This risk factor is considerable, considering that the majority of individuals diagnosed with BDD are further diagnosed with at least

one other comorbid DSM disorder. Indeed, (74-76%) of individuals diagnosed with BDD is met criteria for major depressive disorder – the most common comorbid condition in BDD. This is followed by OCD (67.5%), anxiety disorders (39-41%), eating disorders (32.5%), and substance abuse disorders (28-49%; Toh, Castle, & Rossell, 2017). When examined separately, studies indicate that comorbid depression, found in ¾ of BDD patients, is associated with the highest increased risk for suicide (Phillips, Didie, & Menard, 2007; Shaw, Arditte, Rsenfield, & Timpano, 2016).

II. BDD IN COLLEGE STUDENTS

Epidemiological studies on college students with BDD, particularly since the recent change in DSM-5 criteria are scarce. However, several studies indicated that BDD is particularly prevalent in young adults, and especially among college students, with a prevalence of 3.3% in student populations worldwide (Veale, Gledhill, Christodoulou, & Hodsoll, 2016) and 4.9% in United States (Boroughs et al., 2010). These studies demonstrated that the prevalence of BDD is twice as high in college students compared to the general population. The burden of BDD and the high risk of suicidality, speaks to the importance of understanding this disorder in college students as well as the need for early identification and treatment of BDD. Two early studies demonstrated that one in three college students with BDD suffered moderate to severe academic interference (Phillips, & Menard, 2005), and one in five college students with BDD dropped out of university or college due to BDD symptoms (Phillips et al., 2006).

Dimensionally, researchers have shown that university students have high rates of body dysmorphic symptoms (Bohne et al., 2002; Lavell, Farrell, & Zimmer-Gembeck, 2014). For example, Lavell et al. (2014) examined cognitive vulnerability factors for BDD symptoms in a sample of 246 college students. The results showed that students with higher body dysmorphic symptoms experience greater social anxiety, delusional, and obsessive beliefs (especially beliefs about the importance of thoughts and the ability to control them), uncertainty, avoidance, and perfectionism. In addition, findings showed that college students with elevated body dysmorphic concerns are more likely to be diagnosed with OCD. In fact, these students believed that their unacceptable thoughts have personal meaning and importance and should be controlled, which is similar to the

mechanism thought to underlie OCD (Lavell et al., 2014). Another US study examining 435 college students showed that appearance-based teasing was positively associated with body dysmorphic symptoms. Moreover, the authors found significant interaction between appearance-based teasing and body dysmorphic symptom severity in predicting social and occupational functional impairment and depression (Weingarden, & Renshaw, 2016).

Although a relatively small number of studies have been conducted on BDD among college students in the United States, a larger body of research is available pertaining to moderate-severe distortion in perceptions of body parts among adolescents in the US (Veale et al., 2016). Moreover, studies demonstrated that BDD in adolescence is accompanied by severe symptoms and increased comorbidity with social anxiety disorder and social isolation (Bjornsson et al., 2013; Dalrymple, Herbert, & Gaudiano, 2007). For example, it has been demonstrated that adolescents in comparison with adults have more delusional beliefs about their appearance, and they are more likely to have a current substance use disorder (31% vs. 13%) and a history of suicide attempts (44% vs. 24%). Another study reported that 94% of adolescents with BDD experienced social interference, 85% stated that their dysmorphic concerns interfered with school, occupational or social functioning, and 18% of these individuals dropped out of school (Albertini, & Phillips, 1999). In sum, research suggests an increased burden, dysfunction, and negative outcomes in adolescents and younger adult college students experiencing significant symptoms of distorted body perception/BDD. However, psychopathology and clinical research on the latter is in high demand, and nearly nonexistent in the context of neuropsychological functions.

III. BODY IMAGE DISTURBANCE AND BDD

Contemporary cognitive-behavioral models of body image suggest that the amount of psychological investment on appearance depends greatly on appearance schemas (Cash, 2002; Cash, Phillips, Santos, & Hrabosky, 2004). These body image or appearance self-schemas are triggered by internal or external cues and are thought to function as cognitive structures for one's appearance appraisals and emotions related to body image (e.g., shame, depression, hopelessness, anger, and guilt). Based on these models, a disordered body image lies at the heart of BDD. It is assumed that negative appearance evaluation about beauty and physical (or imagined) defects as well as cognitive distortions and intrusive thoughts about physical appearance result in feelings of shame, disgust, and depression, and a range of avoidant and compulsive behaviors in order to decrease negative feelings about themselves. These models further posit that disturbances in these cognitive, emotional and behavioral aspects of body image are thought to be central to the psychopathological mechanism underlying body image related disorders such as BDD (Figure 1) (Cash, 2002; Cash et al., 2004; Veale, 2004).

It is common in the research literature to equate body image disturbance with negative body image which entails body image dissatisfaction, dysphoria, and impairment (Cash, 2002). According to Cash (2002), body image has two fundamental dimensions: appearance-based evaluation, and psychological investment in physical appearance. Thus, self-evaluation of one's appearance can be viewed as a combination of levels of satisfaction with one's body image in association with one's internalization of society's beauty ideals (Jacatdar, Cash, & Engle, 2006). High psychological investment on the aesthetics of physical appearance is associated with

appearance-related cognitions which generate thoughts about the self. People who are dissatisfied with their physical appearance have dysfunctional cognitions and biased perception of body image-related information which derived from their appearance core beliefs. There is also a positive association between such cognitive distortions and body image dissatisfaction (Jacatdar et al., 2006).

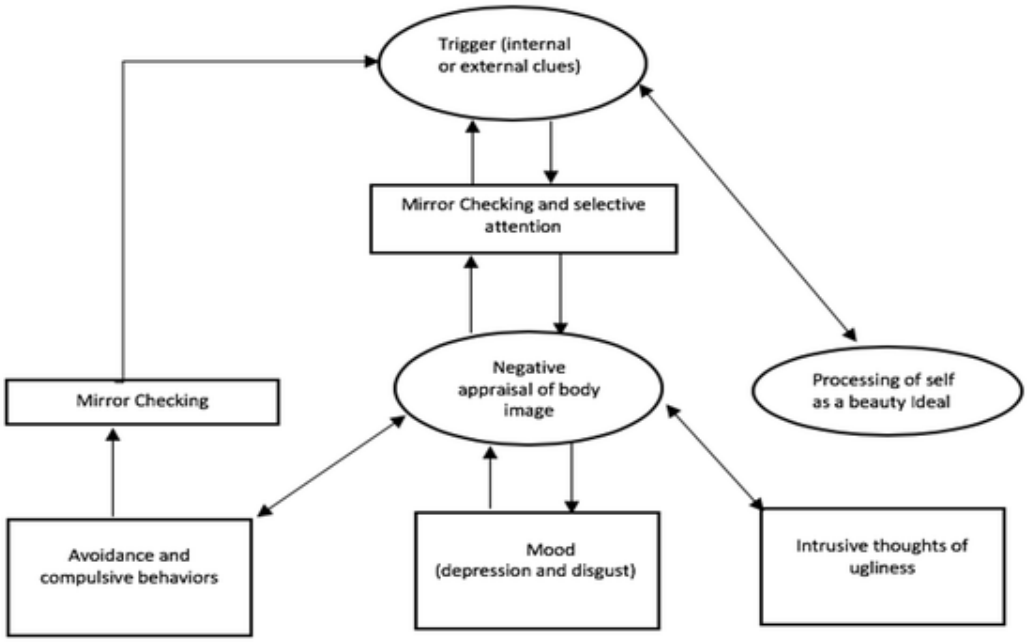

Figure 1. Cognitive-behavioral model of BDD (Veale, 2004).

IV. DISORDER-SPECIFIC VISUAL ATTENTION BIAS IN BDD

In light of the known distortions in body image in BDD, pertaining to one's own body, researchers are particularly interested in fundamental perceptual abilities in BDD, particularly using the conceptualization of cognitive attention bias towards one's own body, as well as toward others. Eye-tracking studies demonstrated that individuals with BDD tend to focus disproportionate degree of visual attention on perceived facial defects in photographs of their own face, while they tend to gaze at attractive features of others' faces, representing a negative bias. Indeed, other studies concluded that preoccupation with attractiveness, as well as perceived defects in physical appearance, represent visual attention biases (Grocholewski et al., 2012; Greenberg et al., 2014; Toh, Castle, & Rossell, 2017). Greenberg et al. (2014) demonstrated that visual attention bias toward one's unattractive features and other's attractive features (negative bias) may characterize BDD symptoms, whereas non-clinical control individuals usually pay more attention to other's unattractive and their own attractive features (positive bias; Greenberg, Reuman, Hatmann, Kasarskis, & Wilhelm, 2014). Grocholewski et al. (2012) suggested that individuals diagnosed with BDD who are preoccupied with a perceived defect in physical appearance would frequently display visual bias toward checking the same physical feature of other people for comparison.

Madsen et al. (2013) studied lower and higher order stages of visual information processing via visual processing tasks which contain images of faces, bodies, and other objects and found that the BDD sample demonstrated over-attention to details, poor processing of global features, and a tendency to focus on symptom-specific details in their own photographs and to concentrate on facial features. The findings were significant

also for images of others and for non-appearance-related stimuli (Madsen, Bohon, & Feusner, 2013). In addition, Stangier et al. (2008) reported that BDD participants were significantly more accurate than controls in identifying changes made to facial features such as size of nose or distances between different features of the face (Stangier, Adam-Schwebe, Muller, & Wolter, 2008). In contrast, another study investigated asymmetry detection in participants who were asked to identify symmetry in photographs and arrays of dots with unaltered or altered symmetry. There was no significant difference between the BDD and control groups in accuracy for detecting asymmetry with faces or arrays of dot, although the BDD participants were slower in decision making about asymmetry (Reese et al., 2010). These BDD related perceptual biases raise the question whether these are limited to perception regarding human esthetics, or are these related to some fundamental cognitive biases, transcending perceptions related to the core psychopathology.

V. NEUROPSYCHOLOGICAL FUNCTION IN BDD

Relatively little is known about neuropsychological functions in BDD, or among individuals characterized by significantly elevated body image concerns. Although information is available regarding visual attention and perception, little attention has been paid to neuropsychological functioning and little is known about core cognitive functions including executive functioning, visuospatial functions, processing speed, verbal and non-verbal memory. In the following section, these domains of neuropsychological functioning in BDD will be reviewed.

Executive Functioning

Executive functions are a set of cognitive control processes involving purposeful, self-guided behaviors and facilitation of goal attainment, that are mainly associated with frontal and prefrontal cortex, and frontal-striatal networks. Executive functioning comprises processes including inhibition, shifting, working memory, verbal fluency, and planning (Lezak, Howieson, Bigler, & Tranel, 2012).

Set shifting in BDD

Set shifting is the ability to switch attention from irrelevant stimuli to relevant stimuli or shift attention between different aspects of stimuli, and may relate to cognitive flexibility (Lezak et al., 2012; Friedman et al., 2008). Jefferies and colleagues (2017) conducted a study with BDD (n= 12) and a non-psychiatric control group (n= 16) assessing cognitive flexibility with the Intra/Extra dimensional set shift task (IED). The results demonstrated that the BDD group made significantly more errors on this task. This effect was stronger in participants with comorbid OCD (Jefferies, Chamberiain,

Fineberg, & Laws, 2017). Greenberg and colleagues (2018) found the same results utilizing IED in group of patients with BDD. Although other studies assessed the impact of comorbid BDD secondary to other disorders on set shifting (Grant, Redden, Leppink, & Odlaug, 2015), this function is under-researched in BDD.

Planning in BDD

Planning is an important component of higher order cognitive functions which consists of capacities for an intentional accomplishment or goal achievement, requiring the individual to identify and organize the steps and elements toward goal attainment (Lezak et al., 2012; Miyake, & Friedman, 2012). Several studies assessed planning in BDD samples, demonstrating deficient performance on planning tasks. Dunai and colleagues (2010) investigated planning utilizing the Stockings of Cambridge task (SOC) London on 14 BDD individuals and 14 sex and age matched control participants. Results demonstrated that BDD participants solved fewer problems with minimum number of steps, made more moves to solve a problem, and made significantly more moves which were not necessary to solve the problem compared to control participants. Moreover, BDD participants indicated slower thinking times (i.e., reaction time to plan and act). These comparisons yielded large effect sizes (>1.0). In another study, Labuschagne and colleagues (2013) measured planning ability using the SOC planning task. Similar to other studies, the results showed that BDD participants had slower initiation, longer movement and thinking times, lower number of solutions using minimum number of moves, and lower number of correct solutions compared to control group (Dunai, Labuschagne, Castle, Kyrios, & Rossell, 2010; Labuschagne et al., 2013; Tasios, & Michopoulos, 2017). In sum, although only a handful of studies examined planning in the

context of BDD, the findings are rather consistent in terms of highlighting deficits in planning among individuals diagnosed with BDD.

Response inhibition in BDD

Inhibitory control is a construct associated with suppressing or resisting automatic responses in order to prevent interference with goal-driven behavior (Lezak et al., 2012; Friedman et al., 2008; Snyder et al., 2015). Repetitive compulsive rituals prevalent in BDD, such as mirror checking, comparing, and camouflaging may suggest problems with response inhibition as these may seem hard to resist, or inhibiting an urge. However, this notion has been recently criticized (Abramovitch, & McKay, 2016; Chamberlain, Leppink, Redden, & Grant, 2017). In the context of obsessive-compulsive and related disorders symptoms, Abramovitch and McKay (2016) believed that these compulsive rituals are very deliberate, predetermined, carefully planned, and carefully executed, and do not align with the notion of disinhibition. In fact, Abramovitch and Abramowitz (2014) argued that response inhibition cannot be defined as an endophenotype of OCD given that similar to impulsivity, disinhibition is associated with actions that lack forethought, and carry negative consequences. Thus, this criticism does not invalidate the notion of reduced performance on response inhibition tasks in some OCRDs, but this is not indicative of behavioral impulsivity. Indeed, it has been proposed that a cautious pattern of performance where response speed is deliberately slowed to avoid instances of commission errors, or general inattention/executive function overload may account for such underperformance in OCD (Abramovitch, & Abramowitz, 2014).

In the context of BDD, studies employing the Stop Signal Task (SST), which assesses response cancelation, may be a worthy venue of exploration given the

phenomenological difficulty in stopping a compulsion once started. To that end, Grant and colleagues (2015) demonstrated that there was no significant difference between BDD participants and a non-psychiatric control group in motor inhibition on the SST. On the other hand, one study found that a small BDD sample (*n*= 14) exhibited significant underperformance on the Stroop test (assessing an inhibitory function of interference control) compared to controls (Hanes, 1998). Finally, in a study assessing response inhibition using a Go/No-Go task incorporating emotionally negative and positive stimuli, as well as neutral stimuli, a small BDD sample was found to underperform compared to the control group on emotionally charged words, but not on neutral words, suggesting no 'cold' response inhibition deficiencies (Jefferies et al., 2017). Thus, only a few studies assessed inhibitory functions in BDD, and only one that used the Stroop test, reported meaningful underperformance in interference control. However, the limited number of investigations and the small sample sizes, characteristic of this literature, points to a need to further research inhibitory function particularly using a classic 'cold' Go/No-Go task.

Working memory in BDD

Working memory (WM) is defined as a process in which information is dynamically maintained and manipulated across a short delay. WM is associated with limited capacity in terms of units of information held (Conway, Kane, & Bunting, 2005; Lezak et al., 2012). A few studies assessed WM in BDD. Labuschagne and colleagues (2013) conducted a study to compare spatial working memory in the BDD and control groups via Cambridge Neuropsychological Test Automated Battery (CANTAB) spatial working memory task. The results showed that the BDD group made more between

search errors compared to the control group. These results are a replication of similar findings reported by Dunai and colleagues (2010) who administered the same task, and found the same results in a small group of participants with BDD (*n*= 14) (Dunai et al., 2010). Notably, to our knowledge, the only study assessing cognitive function in subclinical BDD (SC-BDD) assessed spatial WM. In this study, Blum and colleagues (2018) demonstrated that spatial working memory is intact in young adults with SC-BDD (Blum, Redden, & Grant, 2018). In sum, a handful of studies assessing WM in BDD reported underperformance compared to controls, however, these studies largely used the same task, and more studies are needed using different measures to allow for the clear inferences regarding WM in BDD.

Verbal fluency in BDD

Verbal fluency is one aspect of executive functioning, and is measured typically through semantic/category fluency, and phonemic/letter fluency tasks in which participants are requested to generate as many words as possible in one minute, either from a semantic category or beginning with a certain letter, respectively (Abwender, Swan, Bowerman, & Connolly, 2001; Snyder et al., 2015). Only a limited number of studies have examined verbal fluency in BDD. Hanes (1998) found intact performance on both letter and category fluency tasks in a BDD sample compared to controls, whereas Rossell and colleagues (2014) compared verbal fluency performance between a sample of individuals diagnosed with BDD and controls and found worse performance only for semantic fluency but not phonemic fluency.

Processing Speed in BDD

Surprisingly, no studies have directly assessed simple processing speed via classic neuropsychological tests such as Trail Making Task Part A (TMT-A), Stroop Task (congruent reaction time) or Go/No-Go Task (response reaction time for 'Go' stimuli). However, two studies administering an emotional Stroop test to BDD samples reported reaction times for neutral stimuli. These studies did not find a significant difference between BDD and control groups on processing speed on congruent neutral stimuli (word and color) (Rossell et al., 2014; Toh et al., 2017). Thus, there is an urgent demand in the field for investigations into processing speed in BDD, particularly due to the fact that slower response speed has been consistently identified in OCD (Abramovitch, Abramowitz, & Mittelman, 2013).

Visuospatial Function in BDD

Visuospatial functions are defined as capacity to process visual information as well as spatial dimensions of stimuli (Lezak et al., 2012; Meyers, & Meyers, 1995). Few studies assessed 'cold' visuospatial functions in BDD. Two common tests to assess cold visuospatial functions include the Wechsler Block Design test, and the Rey Complex Figure Test (RCFT) copy trial. Studies assessing visuospatial performance using the RCFT copy trial reported no significant differences between BDD and control samples (Deckersbach et al., 2000; Greenberg et al., 2018; Hanes, 1998). Similarly, Laniti (2005) reported no difference between a BDD and a control sample on the Block Design Test. Given that BDD is associated with marked perceptual distortions related to face perception, the limited available data suggests intact 'cold' visuospatial function. However, there is a need for more studies to substantiate these findings, that may speak

of the idea that people with BDD may have normal perception for neutral stimuli, but that perceptual biases related to physical appearance may be an epiphenomenon of BDD symptoms.

Memory Functions in BDD

Verbal memory

Verbal memory involves recall of words or language-based items (Elwood, 1995; Lezak et al., 2012). Very little is known about the nature of memory functions in BDD including verbal memory performance. Hanes (1998) reported no significant differences between a BDD and a control group on the Rey Auditory Verbal Learning Test (RAVLT). However, there are studies that found either significant or minor differences between BDD and control groups on verbal memory tasks. For example, Deckersbach and colleagues (2000) measured verbal memory functions via the California Verbal Learning Test (CVLT) in 17 individuals with BDD and 17 controls. BDD group performance was intact but they demonstrated problems in semantic clustering throughout the five learning trials in the CVLT. Toh and colleagues (2015) examined verbal memory using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) battery's word list and story tests. The results indicated significantly worse immediate memory as measured by the word list test in BDD compared to controls, although there was no significant difference in delayed memory. The BDD group also performed more poorly in the story memory recall compared to controls. In sum, this small and inconsistent body of literature precludes cogent inferences regarding verbal memory in BDD, and more research is highly needed in this domain.

Nonverbal memory

Nonverbal memory is the capacity to retain and recall non-verbal content (Lezak et al., 2012; Moye, 1997). Few studies examining nonverbal memory have been conducted among individuals with BDD. Most studies did not find any performance difference between BDD and control samples (Dunai et al., 2010; Greenberg et al., 2018; Hanes, 1998). This is somewhat surprising given that OCD is associated with underperformance on the RCFT, usually exhibiting the largest effect size found across neuropsychological tasks in OCD (Abramovitch, & Cooperman, 2015). Notably, it has been suggested that findings regarding underperformance on the RCFT in BDD may not be related to non-verbal memory problems, but to ineffective organizational strategies found in BDD and OCD where there is a preference for 'local' processing with resources directed toward finer details separately instead of organizing the information in a 'global' holistic way to allow associations between the shape items (Deckersbach et al., 2000). Overall, with the reservation of the small number of available studies, the available literature suggests intact non-verbal memory function in BDD.

Motor Skills in BDD

In psychopathology, basic motor functions, and motor coordination are frequently assessed in order to rule out alternative explanation for performance deficits. Motor skills are commonly assess using the Purdue Pegboard, a well-validated task of motor speed (Hanes, 1998). As with other neuropsychological domains, there is limited literature available regarding this construct in BDD. An early study by Hanes (1998) showed that there are no significant deficits in BDD compared to a control group in motor speed and manual dexterity on the Purdue Pegboard task. Thus, research is needed to clarify this

issue, albeit very few psychological disorders have been associated with basic motor impairment.

VI. COGNITIVE FUNCTIONS IN SC-BDD

Studies on subclinical or analogue samples of DSM disorders are important given the dimensional nature of most psychological problems, and enhance our knowledge on etiology, psychopathological mechanisms, and risk factors for psychological problems (Abramowitz et al., 2014; Kalanthroff et al., 2016; Stopa, & Clark, 2001). Specifically, it has been demonstrated that there are no major differences between subclinical (analogue) BDD samples and clinical BDD samples in the frequency of comorbid diagnoses, rates of suicidal ideation/attempt, and types of symptoms (obsession and compulsions), suggesting that examination of SC-BDD may be as informative as studies using DSM-5 BDD diagnoses (Altamura et al., 2001). Research on cognitive functions in SC-BDD is scarce. As noted previously, to our knowledge, only one study assessed executive functioning in a SC-BDD sample. Blum and colleagues (2018) assessed spatial working memory and planning in a very small SC-BDD sample (n= 5) and a control sample (n= 82). The results demonstrated that SC-BDD performed significantly worse compared to the control group on the SOC planning task, but no group differences across spatial working memory were found. Importantly the SC-BDD sample size in this study was extremely small (n= 5), and more studies are needed to assess cognitive function in SC-BDD.

VII. NEUROPSYCHOLOGICAL PERFORMANCE IN OCD

Given the similarities between OCD and BDD, and the paucity of research into cognitive functioning in BDD, it is useful to briefly review the literature on cognitive function in OCD. A vast body of literature on neuropsychological performance in OCD is available (For a meta-analysis, and a systematic review (see Abramovitch, & Cooperman, 2015; Abramovitch et al., 2013). Overall, meta analyses indicate underperformance in most cognitive domains in OCD, with small to moderate effect size reported. Notably, the clinical relevancy and ecological validity of these effect sizes has been challenged (Abramovitch, Abramowitz, & Mittelman, 2013). Most studies on set shifting in OCD demonstrated no differences between OCD and non-psychiatric control samples (e.g., de Geus, Denys, Sitskoorn, & Westenberg, 2007). The majority of studies on planning reported decreased planning ability in OCD (e.g., Martoni et al., 2018). In terms of response inhibition usually intact performance is reported on the Stroop and Go/No-Go tasks in OCD (e.g., Rasmussen, Siev, Abramovitch, & Wilhelm, 2016). In contrast, most studies assessing response cancellation using the SST report significant underperformance in OCD (Eagle, Bari, & Robins, 2008). In a meta-analysis of neuropsychological performance by Abramovitch et al. (2013), the authors found an overall medium effect size for response inhibition in OCD, representing reduced performance.

Studies assessing lower load working memory utilizing tasks such as the Digit Span, usually report intact in OCD compared to non-psychiatric controls. However, in some studies, higher load working memory tasks/trials were associated with underperformance in OCD (e.g., NBack test; Hashimoto et al., 2008). Inconsistent results

are reported in studies examining spatial working memory, some of which demonstrated similar performance relative to control group on the Digit Span (e.g., Shahar, Teodorescu, Anholt, Karmon-Gideon, & Meiran, 2017); however, studies utilizing the CANTAB SWM task found reduced performance in OCD (e.g., Nedeljkovic et al., 2009). In terms of effect size small to moderate effect size were reported for verbal and spatial working memory (Abramovitch et al., 2013).

Results from studies on verbal fluency are equally inconsistent; some studies reported a significant difference between OCD and control groups (e.g., Sahoo, Grover, & Nehra, 2018), while others reported intact performance on verbal fluency (e.g., Krishna et al., 2011). Studies on processing speed demonstrated reduced processing speed on this domain (e.g., Abramovitch et al., 2011). Verbal memory in meta-analysis studies on OCD indicated small effect size (e.g., Abramovitch et al., 2013), and majority of studies on verbal memory found similar performance between control and OCD groups on verbal memory tasks (e.g., Sayin, Utku, & Candansayar, 2010). The vast majority of studies on non-verbal memory in OCD find significantly worse performance in OCD (e.g., Exner, Kohl, et al., 2009) with large effect sizes found for this domain across meta analyses (e.g., Abramovitch et al., 2013). In sum, OCD is associated with deficient performance in some EF subdomains, as well as slower processing speed, and planning difficulties with small to moderate effect sizes. However, importantly, the results are known to be notoriously inconstant (Abramovitch, & Cooperman, 2015).

VIII. PURPOSE

Nearly 2% of adults in the general population, and 3% of college students suffer from BDD, which has been associated with suicide rates up to 35 times higher than the general population (Veale et al., 2016). Body image related concerns, that are at the core of BDD, are particularly prevalent in young adults, with a prevalence of 4.9% among college students (Boroughs et al., 2010). However, in light of substantial risk for significant psychopathological burden and comorbidity, as well as suicide and functional impairments, surprisingly relatively little is known about BDD symptoms in the general population, particularly among students.

Moreover, in direct contrast to the vast OCD literature, examinations of neurocognitive function in BDD, let alone subclinical presentation, is almost non-existent. This is particularly puzzling given the known perceptual processing biases in BDD.

To our knowledge no neuropsychological study of SC-BDD, and significant body image concerns has been previously published to date. To fill this gap in the literature, the purpose of the present study was to conduct an investigation into neuropsychological function in college students with SC-BDD. The goals of the present study were to examine the 10 main neuropsychological domains, including executive functions (set shifting, response inhibition, working memory, planning, and fluency), memory (verbal/non-verbal memory), processing speed, motor skills, and visuospatial abilities. Although the scant literature on cognitive and neurobiological function in BDD does not permit clear hypotheses, in light of the available literature and the extensive literature on OCD, we hypothesized that SC-BDD will be associated primarily with reduced processing speed, and with underperformance on tasks of executive functions such as

Trial making B, and response inhibition tasks such as Go/No-Go, and they would be of small to moderate magnitude. In addition, the secondary aim of this was to examine whether severity of BDD symptoms, as well as anxiety, depression, and stress, may be associated with cognitive function. Notably, no such meaningful association has been found in OCD, both in terms of the moderating role of depression and anxiety symptoms on cognitive functions (Abramovitch et al., 2013; Abramovitch, & Cooperman, 2015), as well as in terms of the impact of symptoms severity (Abramovitch et al., 2019).

IX. METHODOLOGY

Participants

Participants were recruited from the Texas State University student population. The present study utilized a two-phase recruitment process. In the first phase, the Dysmorphic Concern Questionnaire (DCQ; Oosthuizen et al., 1998) and basic demographics was sent via email to all undergraduate, and graduate students at this university. Participants were also requested to note if they would be interested to participate in a paid study in the lab. We received responses from 1394 students who completed the DCQ and agreed to be re-contacted to be invited to a psychological research. A psychometrically valid, and common method of establishing an analogue sample is to utilize the top and bottom percentage quartiles in between-group designs (Abramowitz et al., 2014). The cutoff score for the SC-BDD group inclusion for the present sample was found to be DCQ total score ≥11, and the cutoff score for the control group was DCQ total score ≤ 4. The correct classification of 100% of BDD patients resulted from a DCQ cutoff value of 11 (Mancuso, Knoesen, & Castle, 2010). Moreover, Mancuso and colleagues (2010) showed that BDD patients (n= 57, M= 16.25, SD= 3.54) had higher DCQ scores relative to control group (n= 244, M= 4.46, SD= 3.38).

In addition to meeting the cutoffs, and agreeing to participate in an in-person study, the inclusion criteria for the second stage (in-person appointment) included minimum age of 18, no color blindness, no history of significant neurological insult or disease, intact or corrected vision and basic English proficiency. Exclusion criteria included age of 65 or higher, and any history of major neurological conditions (e.g., brain injury, epilepsy). Out of 1394 students, 493 (35%) met the criteria for inclusion in the

second stage (control group *n*= 287, and the SC-BDD group *n*= 206). We used a randomization process to invite 24 participants (12 from each group) to the lab each week to decrease cancellations and "no-shows". Among the SC-BDD sample, 117 of 157 (74%) did not respond or did not arrive to the second phase (Initial DCQ: *M*= 13.99, *SD*= 2.77) and 40 participants completed the second stage of the study (Initial DCQ: *M*= 13.25, *SD*= 2.15). No significant difference between the two groups were found on the DCQ ($F(1, 155) = 2.36$, $p = 0.13$), suggesting lack of selection bias. Of the 174 participants invited from the control group, 134 (77%) did not respond or did not show up (Initial DCQ: *M*= 2.39, *SD*= 1.18), and 40 (23%) people completed the second phase (Initial DCQ: *M*= 2.95, *SD*= 0.85). No significant difference between the two groups were found on the DCQ ($F(1, 172) = 0.98$, $p = 0.302$), suggesting lack of selection bias for the control group. Overall, of the 95 participants who responded to the invitation for the second phase, 15 (16%) participants did not show for testing. The mean age for the entire sample (*n*= 80) was 21.63 years (*SD*= 2.69) and 77.5% of the sample were female.

In preparation for data analyses, we have identified one participant from the control sample with significant fluctuations between scores ranging from +1 SD above the norm and -3.3 SD below the norm, including on highly correlated tasks. Similarly, the pattern of responses for the clinical outcomes that beyond outlier results, suggested that there was a problem with the validity of this participant's performance and self-report outcomes. This participant was excluded from all analyses in the present study. Demographic information for the two groups is presented in Table 1. In addition, as presented in Table 1, of the 40 participants in the SC-BDD group, 22 (55%) reported never receiving a DSM diagnosis by a licensed psychologist or a psychiatrist. The

remaining 18 participants in SC-BDD sample self-reported the following lifetime diagnosis: Generalized Anxiety Disorder 2.5% (*n*= 1), Depression 25% (*n*= 10), Bipolar Disorder 22.5% (*n*= 9), Panic disorder 7.5% (*n*= 3), Agoraphobia 5% (*n*= 2), Social Anxiety Disorder 2.5% (*n*= 1), Post Traumatic Stress Disorder 15% (*n*= 6), Antisocial Personality Disorder 15% (*n*= 6), Anorexia 2.5% (*n*= 1), Binge Eating Disorder 2.5% (*n*= 1), Body Dysmorphic Disorder 2.5% (*n*= 1), Substance Use Disorder 2.5% (*n*= 1), Borderline Personality Disorder 2.5% (*n*= 1). Of the 39 participants in the control group, 31 reported never receiving a DSM diagnosis by a licensed psychologist or a psychiatrist. The remaining 8 participants in the control sample self-reported the following lifetime diagnosis: Generalized Anxiety Disorder 2.5% (*n*= 1), Depression 12.5% (*n*= 5), Bipolar Mood Disorder 7.5% (*n*= 3), Panic disorder 2.5% (*n*= 1), Post Traumatic Stress Disorder 5% (*n*= 2), Antisocial Personality Disorder 2.5% (*n*= 1), Substance Use Disorder 2.5% (*n*= 1), and Borderline Personality Disorder 2.5% (*n*= 1). This study was approved by the University's Institutional Review Board (IRB) in accordance with the declaration of Helsinki. All participants signed an informed consent and were compensated $ 20 for their participation.

Table 1. Prevalence of DSM disorders in SC-BDD and control groups.

	SC-BDD (n= 40)	Control (n= 39)		
Disorder	N (%)	N (%)	$X^2/F(1, 77)$	*p*
Major Depressive Disorder	10 (25%)	5 (12.5%)	2.05	.25
Bipolar Disorder	9 (22.5%)	3 (7.5%)	3.52	.11
Social Anxiety Disorder	1 (2.5%)	0 (0%)	0.31	1.00
Panic Disorder	3 (7.5%)	1 (2.5%)	1.05	.61
Agoraphobia	2 (5%)	0 (0%)	2.05	.49
Generalized Anxiety Disorder	1 (2.5%)	1 (2.5%)	0.00	1.00
Post-Traumatic Stress Disorder	6 (15%)	2 (5%)	2.22	.26
Anorexia Nervosa	1 (2.5%)	0 (0%)	1.01	1.00
Binge Eating Disorder	1 (2.5%)	0 (0%)	1.01	1.00
Substance Abuse Disorder	0 (0%)	1 (2.5%)	1.01	1.00
Body Dysmorphic Disorder	1 (2.5%)	0 (0%)	1.01	1.00
Anti-social Personality Disorder	6 (15%)	1 (2.5%)	3.91	.11
Borderline Personality Disorder	0 (0%)	1 (2.5%)	1.01	1.00
% Psychopathology	18 (45%)	8 (20%)	5.36	.02*
Average Number of Self-Reported Lifetime Diagnosis	1.02	0.38	5.02	.03*

SC-BDD, Subclinical Body Dysmorphic Disorder; % Psychopathology, the number of participants who reported being ever being diagnosed with at least one psychiatric disorder by a licensed mental healthcare provider.

Note. *<.05

Materials

Clinical measures

Dysmorphic concern questionnaire (DCQ)

The DCQ (Oosthuizen et al., 1998) is a self-report survey with seven items that measures cognitive and behavioral symptoms of preoccupation with an imagined or slight physical flaw. This measure includes items that are on a 4-point scale, rating from 0 (not

at all) to 3 (much more than most people). Respondents are asked to rate their concerns about physical appearance compared to others. Total score is calculated by summing all items, with scores ranging from 0 to 21. A DCQ cutoff score of 9 indicates clinically significant preoccupation with physical appearance. This measure was found to have good internal consistency among college students (Cronbach's α= 0.85) and clinical samples with BDD (Cronbach's α = 0.73) (Oosthuizen et al., 1998). In the present study, DCQ-Initial and DCQ-Lab were found to have good (Cronbach's α= 0.89) and excellent (Cronbach's α= 0.90) reliabilities, respectively.

Depression anxiety and stress scale-21 (DASS-21)

DASS-21 (Lovibond, & Lovibond, 1995) is a self-report survey with three subscales including Depression, Anxiety and Stress, and each subscale consists of 7 items. Responses to each item are based on a 4-point Likert scale (0= Did not apply to me at all, 1= Applied to me to some degree, or some of the time, 2= Applied to me to a considerable degree, or a good part of time, 3= Applied to me very much, or most of the time). The total score for each scale ranges from 0 to 42 since the total score is multiplied by two (Tran, Tran, & Fisher, 2013). The internal consistency of DASS-21 was excellent with Cronbach's alpha of 0.94, 0.87, and 0.91 for Depression, Anxiety and Stress, respectively in non-clinical samples (Sinclair et al., 2012). The internal consistency of the three subscales was found to be good to excellent in clinical samples with α range, 0.81-0.92 (Clara, Cox, & Enns, 2001). In the present study, DASS Depression, Anxiety, and Stress were found to have excellent (Cronbach's α= 0.91), fair (Cronbach's α= 0.76) and good (Cronbach's α= 0.87) reliabilities, respectively.

Neuropsychological measures

The NeuroTrax computerized neuropsychological battery

The NeuroTrax is a computerized neuropsychological battery assessing cognitive domains including memory, attention, executive function, information processing speed, motor skills and verbal functions (NeuroTrax Corporation, 2003). This battery is a well-validated computerized neuropsychological battery across both clinical and non-clinical samples (Dwolatzky et al., 2003; Schweiger, Abramovitch, Doniger, & Simon, 2007) with good reliability (Schweiger, Doniger, Dwolatzly, Jaffe, & Simon, 2003). The NeuroTrax battery was utilized multiple times in both clinical (e.g., Abramovitch et al., 2012, 2015), and analogue samples (e.g., Hamo, Abramovitch, & Zohar, 2018). Outcome parameters for each test include reaction time and mean accuracy. Performance scores are normalized for age and education level using normative data, on Wechsler index scales (M=100, SD=15). The battery included the following subtests:

Expanded go/No-go test: A series of large colored squares are presented at random and variable intervals. Participants are instructed to click a mouse button as quickly as possible if the color of the stimulus (Go stimuli) is any color except red (No-Go stimuli). The test has different blocks with increased "No-Go" stimuli proportion, distracting stimuli and shorter intervals between presented squares.

Verbal memory test: Ten pairs of words are presented. In the recognition test, participants are instructed to select which word (the target) from a list of four options matches a previously presented pair. Four consecutive sets of the recognition test are administered during the 'immediate learning' phase. An additional recognition test is

administered after a delay of approximately 10 minutes.

Problem solving test: Puzzles (which are similar to common Matrix tests) of gradually increasing difficulty are presented. Each puzzle contains an incomplete array consisting of three geometric forms (missing element and black-and-white line drawings), with a missing fourth geometric form. Participants must choose which of six additional geometric forms (in multiple choice format) would be best match the fourth (missing) element of the puzzle.

Stroop test: This measure is a well-developed test of response inhibition. The Stroop test contains three phases with one word and two squares in different colors. Participants are presented with a pair of large colored squares, one on the left and the other on the right side of the screen. In each phase, participants are instructed to select which of the two stimuli is a correct color by pressing either the left or right mouse button. In the first phase, participants are presented with a general word in colored letters and they are required to respond to the colored square that matches the font color of the letter. In the second phase, participants are asked to choose the square that is best fit for the meaning of the word. In the third phase (the Stroop phase), participants are asked to select the color of the letters, and not the color named by the word.

Non-verbal memory test: Eight pictures (geometric forms) are presented, and the participants are asked to memorize each form's orientation. Participants are required to remember the orientations of the originally presented stimuli during a recognition test in which four versions of each stimulus with different direction are presented. Four repetitions of the recognition test are administered during the 'Immediate recognition phase of the test. An additional recognition test is administered after approximately 10

minutes of delay.

Finger tapping test: Participants are instructed to click the mouse button as fast as they can for 12 seconds. This action is repeated twice for the right and left hands and measures motor skills.

Catch game test: Participants must catch a white object with a green paddle, while it falls down from the top of the screen. Mouse button presses control a green "paddle" horizontally, so that the participant is able to position it directly in the path of the falling white object.

*Staged information processing test***:** This test contains three phases of information processing load: single digits, two-digit (e.g., 5-1), and three-digit arithmetic problems (e.g., 1+8-2). As test continues, the digits offered at three fixed rates rise for each level. Participants are asked to tap on right mouse button as fast as possible if the result is larger than 4 and the left mouse button if it is less than or equal to 4.

Verbal function test: This task consists of two phases. In the first phase, pictures of common objects of low and high familiarity are presented. Participants are required to choose the name of the object from four options. In the second phase, participants are asked to identify the word that rhymes with the object's name out of a list of words.

Visual spatial processing test: Computer-generated red pillars are presented in different locations in a 3D scene. Participants are instructed to figure out which of four other perspectives matches the scene from the vantage point of the red pillar.

Digit Span Test

The Digit Span test is a subtest of the Wechsler Adult Intelligence Scale-IV (WAIS-IV, Wechsler, 2008) will be used for assessing working memory. This task comprises two tests; forward, and backward digit spans. In the first test (forward span), participants are asked to recall a series of numbers in the same order they were read by the examiner. Forward Span assesses working memory, and specifically repetition WM. In the second subtest (backward digit span), participants are asked to recall a series of numbers in reverse order. Performance on backward test measures higher load working memory requiring mental manipulation of data as compared to forward digit span. As part of the DS test, a new subset, Digit Span Sequencing (DSS), was introduced in the WAIS-IV as a third sub-score of the DS test. However, given that this study utilizes the letter number sequencing test, and in light of some recent criticism regarding the psychometric properties of this new subtest (e.g., Theiling, & Petermann, 2016).

Letter-number sequencing

The Letter-Number Sequencing (LNS) test is a subtest of the WAIS-IV (Wechsler, 2008) that will be used to assess high load (manipulation) working memory. In the letter-number-sequencing test, participants are asked to recall a series of letters and numbers. They must produce the numbers in order, starting with the lowest number, then the letters in alphabetical order.

Procedure

In the first stage of the study, an initial screening took place via a recruitment email sent to a random 10,000 students at Texas State University inviting participants to

complete the DCQ (Oosthuizen et al., 1998) voluntarily. Participants agreeing to participate received the secure link provided in the email and were redirected to the Qualtrics secured online platform (Qualtrics, Provo, UT). Participants completed a short demographic questionnaire, the DCQ, and were asked if they are interested in participating in a study in our lab, and if so were asked to provide their email address. No other identifiable information was provided by participant at this stage. Participants who completed the survey and agreed to participate were included in the initial dataset, which was used to create the upper and lower DCQ quartile groups. Subsequently, participant from the two pools (SC-BDD and control) were randomized each week and invited to the second, in-person phase of the study.

To increase the validity of neuropsychological data in the current study, participants were asked to avoid taking stimulant medication, benzodiazepines, or drinking more than two measures of alcohol 24 hours prior to the experiment. In the second part of the study, upon arrival to the lab, participants signed a consent including a technical description of the study session (without disclosing the aims of the study). Participants were then asked several demographic questions (e.g., gender, age, educational classification, email address). Cognitive tasks and questionnaire were administered by the authors of this thesis, in addition to two research assistants that together with the author, underwent 1-month training on administration of all neuropsychological tests, and all lab procedures.

Participants first completed a computerized demographic questionnaire, followed by a detailed self-report questionnaire regarding of any past diagnoses of a psychological/psychiatric disorder by a licensed psychiatrist or psychologist), as well as

the DASS-21, and the DCQ (for a second time). Participants were then administered the DS and LNS working memory tasks, followed by the computerized NeuroTrax battery (NeuroTrax Corporation, 2003). The entire experiment was lasted about 90 minutes. Finally, the participants were thanked, debriefed and were compensated. We measured test re-test reliability for DCQ-Initial and DCQ-Lab (r= 0.8) with time spent between 2 weeks (earliest) to 2 months (latest). Due to the technical problem (administration error) we were able to use only data from computerized tests that did not involve time and required fast or consecutive mouse clicks. The Neurotrax battery was administered using on-keyboard mouse instead of external mouse which does not allow rapid responses to be registered, and this invalidated the results of timed tests including the Stroop, Go/No-Go, staged processing speed, catch game and motor tasks.

Analytic plan

All analyses were conducted using IBM SPSS version 24 (IBM, 2017). Analyses of variance (ANOVA) was used to compare the SC-BDD and control groups on continuous clinical (DASS-21) and demographic variables. Categorical variables (e.g., gender, lifetime psychopathology) were analyzed using Pearson's Chi Squared Tests, with Fisher's Exact Test correction when needed. To assess measures' internal consistency, reliability analyses for self-report measures were conducted by calculating Cronbach's alpha. To assess overall associations between symptom severity (DCQ) and cognitive function among SC-BDD and control groups, Zero-order Pearson's correlations were computed. Group differences on neuropsychological measures were analyzed using multivariate analysis of variance (MANOVA) or MANCOVA. In order to increase the accuracy of results, analyses were conducted on raw scores, but scaled scores are

presented to facilitate interpretation. We analyzed major domain scaled index scores that are produced by the Neurotrax battery (see Table 3) and then, the specific subtests were separately analyzed (see Table 4). Effect sizes were calculated using Cohen's *d* (Cohen, 1988). Given the large number of comparisons and the risk of familywise inflation of type I error, a correction for multiple comparisons was employed across comparisons, utilizing the Holm-Bonferroni correction method (Holm, 1979). A forward stepwise binary logistic regression analysis was used to determine the key demographic, and clinical factors that are most associated with SC-BDD in college students. Finally, we used Fisher's *z* transformation to compare correlation coefficients between the groups.

X. RESULTS

Demographic and Clinical Characteristics of SC-BDD and Control Groups

Demographic and clinical information for the two samples are presented in Table 2. The SC-BDD and control groups included mostly females (SC-BDD females = 77.5%, control females = 71.8%) with no significant difference found between the groups (p= 0.56). In addition, no significant differences were found on age, education, GPA, ethnicity, and race. Moreover, univariate analyses revealed that the SC-BDD group exhibited significantly higher scores on all DASS-21 scales, including Depression (p<0.0001), Anxiety (p<0.0001) and Stress (p<0.0001; See Figure 2). Mean DCQ scores in the present study (SC-BDD: M= 12.43, SD= 3.97; control: M= 3.90, SD= 2.27) were consistent with reported scores of found in other studies examining clinical BDD participants and non-psychiatric control groups (Bartsch, 2007; Enander et al., 2018).

In terms of psychopathology, Pearson's Chi-Square revealed that participant in the SC-BDD group reported significantly higher rates of past DSM disorders (p= 0.02). Additionally, the total number of DSM disorders was significantly higher in the SC-BDD group compared to the control group (p= 0.03). Thus, in order to control for factors that may influence neuropsychological test performance, age, DASS-21 Depression, DASS-21 Stress, DASS-21 Anxiety, and the total number of DSM disorders were controlled for all following analyses. Notably, although no significant difference was observed in age (p= 0.08), the effect size was 0.39. An effect size greater that 0.2 is not trivial, therefore age scores were controlled for all subsequent analyses (Sullivan, & Feinn, 2012).

Table 2. Demographic and clinical characteristics.

	SC-BDD (n= 40)			Control (n= 39)				
							F (1,77)/X^2	p
	Mean/N (%)	SD	Range	Mean/N (%)	SD	Range		
Demographics								
Age (Years)	21.11	2.71	18.49-28.81	22.15	3.16	18.54-30.27	2.97	.09
% Females	31 (77.5%)	-	-	28 (71.8%)	-	-	0.34	.56
Education (Years)	14.85	1.21	13-17	15.15	1.70	13-21	0.83	.36
Academic Classification							7.88	.09
Freshman	12 (30.0%)			8 (20.5%)				
Sophomore	1 (2.5%)			6 (15.4%)				
Junior	14 (35.0%)			11 (28.2%)				
Senior	13 (32.5%)			11 (28.2%)				
Graduate student	0 (0.0%)			3 (7.7%)				
Ethnicity/Race							4.77	.31
Caucasian	22 (55.0%)	-	-	17 (43.6%)	-	-		
African- American	2 (5.0%)	-	-	7 (17.9%)	-	-		
Hispanic/Latino	13 (32.5%)	-	-	14 (35.9%)	-	-		
Asian	0 (0.0%)	-	-	0 (0.0%)	-	-		
Native Hawaiian/Other Pacific Islander	2 (5.0%)	-	-	1 (2.6%)	-	-		
Other	1(2.5%)	-	-	0 (0.0%)	-	-		

Table 2. Demographic and clinical characteristics (continued).

	SC-BDD (n= 40)			Control (n= 39)				
							$F(1,77)/X^2$	*p*
	Mean/N (%)	SD	Range	Mean/N (%)	SD	Range		
GPA	3.20	0.61	1.61-4	3.27	0.59	1.69-4	0.27	.60
Handedness (Right)	38 (95%)	-	-	35 (89.7%)	-	-	0.77	.38
Clinical								
DCQ	12.43	3.97	11-21	3.90	2.27	0-4	135.27	**<.0001**
DASS-21 Depression	9.0	5.17	0-21	2.82	3.19	0-12	40.55	**<.0001**
DASS-21 Anxiety	7.37	3.64	1-16	2.94	2.75	0-11	36.90	**<.0001**
DASS-21 Stress	10.10	4.66	1-21	4.43	3.85	0-14	34.51	**<.0001**

SC-BDD, Subclinical Body Dysmorphic Disorder; GPA, Grade Point Average; DCQ, Dysmorphic Concern Questionnaire, DASS-21, Depression Anxiety Stress Scale 21.

Note. $p<.05$

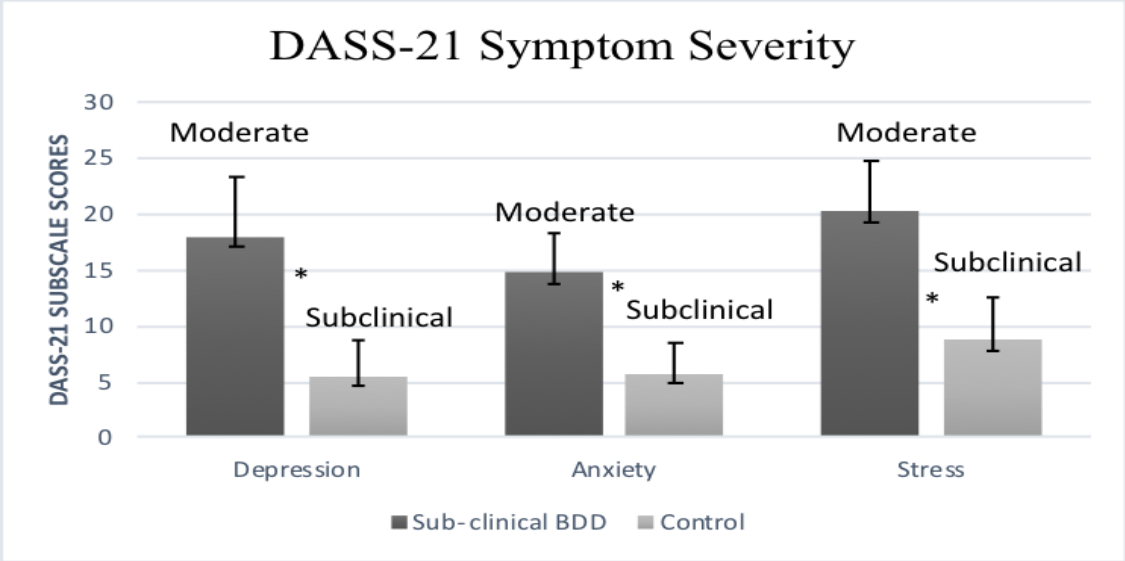

Figure 2. Comparison of DASS-21 symptom severity for the SC-BDD and control groups. Note. Degree of symptom severity categories as defined by the DASS. Error bars represent standard error. * significant different between groups.

Neuropsychological Major Domains

A MANCOVA was conducted to compare the SC-BDD and control groups on neuropsychological outcome measures while controlling for depression, stress, anxiety, total number of DSM disorders, and age (see Table 3). MANCOVA results revealed no significant differences between the SC-BDD and control groups (Wilks' Λ= 0.975, F(3, 70)= 0.588, p= 0.625, multivariate η^2= 0.025). Subsequent univariate analyses revealed that no significant differences were found in any of the major domains (p's range 0.41-0.76). All major domains including memory, visuospatial function, and verbal function exhibited a small effect size (d's range 0.24- 0.32). SC-BDD showed higher scores in verbal function and visuospatial function compared to the control group (negative effect size), while the control group showed higher score in memory (positive effect size). In

addition, the effect size for visuospatial function is close to zero (See Table 3). Due to the technical issue that was mentioned in the method section, we were unable to analyze the composite score for overall neuropsychological functioning. As depicted in table 3, index scaled scores were found to be within 0.75 SD from the population mean (100), with effect sizes approaching zero.

Table 3. Comparisons between the SC-BDD and Control groups on major neuropsychological domains while controlling for anxiety, stress, depression, total number of DSM disorders, and age.

	SC-BDD (n= 40)		Control (n= 39)		F (1, 77)	*p*	Cohen's *d**
	Mean	SD	Mean	SD			
Memory	97.89	12.74	101.51	9.31	0.691	.41	.32
Visual Spatial Function	100.50	15.66	99.42	17.74	0.095	.76	-.06
Verbal Function	94.51	12.83	90.51	19.75	0.355	.55	-.24

Domain index scores are normalized on a Weschler IQ (Mean= 100, SD= 15). SC-BDD, Subclinical Body Dysmorphic Disorder Group. *Positive effect sizes indicate higher scores in the control group, and negative effect size indicate higher scores in the SC-BDD group.

MANCOVA results revealed not significant differences between the SC-BDD and control groups, Wilks' Λ= 0.792, $F(13, 60)$= 1.214, p= 0.292, multivariate η^2= 0.208. Univariate analyses (ANOVA) of the 13 domain subsets showed that there is no significant difference between our two groups (see Table 4) on any outcome measure. Effect sizes across tests were small to medium (d= 0.01-0.68) and 54% of the neuropsychological effect sizes revealed better performance by the control group. However, scaled scores revealed that both groups performed in the normative range (see Table 3 and 4).

Table 4. Comparisons between the SC-BDD and Control groups on neuropsychological subdomains while controlling for anxiety, stress, depression, total number of DSM disorders, and age.

	SC-BDD (n= 40)		Control (n= 39)		F (1, 77)	*p*	Cohen's *d**
	Mean	SD	Mean	SD			
Memory							
Verbal Memory: Total Accuracy	98.35	16.41	97.07	16.59	0.140	.71	-.12
Delayed verbal memory: Accuracy	100.63	15.99	100.67	17.35	0.010	.92	.01
Non-verbal memory: Total accuracy	97.84	17.98	104.56	10.32	1.182	.28	.46
Delayed non-verbal memory	94.74	16.69	103.71	7.17	3.317	.07	.68
Working memory							
Digit Span Forward Total	9.48	3.14	9.54	2.59	1.580	.21	.03
Digit Span Backward Total	9.63	2.48	10.13	2.85	0.010	.92	.13
Digit Span Sequencing Total	10.28	2.68	10.97	3.22	0.051	.82	.23
Digit Span Total	9.68	2.55	10.33	2.71	0.138	.71	.23
Letter Number Sequencing	9.43	2.07	10.26	2.69	0.013	.91	.40
Visuospatial							
Visuospatial: Accuracy	100.50	15.66	99.42	17.74	0.059	.81	-.08
Verbal Function							
Verbal Function: Rhyming, Accuracy	94.51	12.83	90.51	19.75	0.720	.40	-.26
Verbal Function: Matching Accuracy	98.75	8.93	90.82	18.51	3.709	.06	-.42
Problem Solving							
Problem solving: Accuracy	97.47	16.43	98.52	17.13	0.106	.74	.06

Domain index scores are normalized on a scale equivalent with Weschler IQ scores (Mean= 100, SD= 15). SC-BDD, Subclinical Body Dysmorphic Disorder Group. *Positive effect sizes indicate higher scores in the control group, and negative effect size indicate higher scores in the SC-BDD group.

Correlation Between Cognitive Functions and DCQ Total Score

To assess the relationship between cognitive domains and body dysmorphic concerns, 13 zero order correlations were separately computed for the SC-BDD and control groups (see Table 5). DCQ scores were positively associated with scores in LNS within the SC-BDD group, [$r(77)= 0.38$, $p= 0.02$]. Moreover, lower scores in DCQ were found to be significantly correlated with total accuracy on the verbal memory task within the control group, [$r(77)= -0.32$, $p= 0.04$]. Scores in DCQ were positively correlated with problem solving in SC-BDD group, [$r(77)= 0.34$, $p= 0.03$], however, these correlations did not survive the Holm-Bonferroni correction for multiple comparisons, and were deemed not significant.

In order to examine interactions between DCQ and cognitive functions, we used Fisher's *z* transformation. Results revealed that the association between LNS and the DCQ total scores ($p= 0.02$) as well as the association between verbal function (matching accuracy) and the DCQ total scores ($p= 0.01$) significantly differed between the SC-BDD and control groups. These results imply that there is an interaction between correlation coefficients in that there is a significant difference between the groups pertaining to the correlations between verbal function and DCQ scores and the correlation between LNS and DCQ scores between the SC-BDD and control groups. However, these significant differences did not consider to be significant after utilizing correction for multiple comparisons (Table 5).

Table 5. Pearson correlations between cognitive functions and dysmorphic concern questionnaire indices.

Variable	SC-BDD	Control	Fisher's z	*p*
Memory				
Verbal Memory: Total Accuracy	-.15	-.32*	.77	.22
Delayed verbal memory: Accuracy	-.09	-.21	.52	.30
Non-verbal memory: Total accuracy	-.26	-.10	-.71	.23
Delayed non-verbal memory	-.10	-.21	.48	.31
Working memory				
Digit Span Forward Total	.09	-.20	1.25	.11
Digit Span Backward Total	.15	.06	.39	.35
Digit Span Sequencing Total	.23	.07	.70	.24
Digit Span Total	.21	.02	.82	.20
Letter Number Sequencing	**.**38*	-.07	2.01	.02
Visuospatial				
Visuospatial: Accuracy	-.03	-.24	.92	.18
Verbal Function				
Verbal Function: Rhyming, Accuracy	.01	-.14	.64	.26
Verbal Function: Matching Accuracy	.29	-.21	2.18	.01
Problem Solving	.34*	.01	1.47	.07

*P-value did not survive correction for multiplicity.

Note. p<.05

Logistic Regression Model Between Cognitive Functions and Stress, Anxiety, and Depression Symptoms

A binary logistic regression model was employed to determine the extent in which demographic and clinical factors were predictor of SC-BDD. DASS-21 depression, stress, and anxiety indices, and the total number of DSM disorders were included as predictors. The overall model was significant [$\chi^2(1) = 40.39$, $p< 0.0001$] with the Nagelkerke $R^2 = 0.53$, and the overall accuracy of classification model was 82.3%,

however none of the variables in the equation were individually significant, therefore, a forward Wald logistic regression was employed (see Table 6), with the same variables were including in the initial model. The omnibus model was significant [step 1: $\chi^2(1) = 33.55$, $p < 0.0001$); step 2: $\chi^2(2) = 38.92$, $p < 0.0001$]. The first model only included depression which alone predicted 76% of the model with the Nagelkerke $R^2 = 0.461$, while step 2 included depression and anxiety but not stress in the model which had predictive accuracy of 84.8 %, with a Nagelkerke $R^2 = 0.519$. The results of this analysis indicate the important role of depression as well as anxiety in being categorized as SC-BDD group.

Table 6. Forward stepwise (Wald) logistic regression model with continuous variables.

Steps		*β*	SE	Wald	*df*	*p*	OR	OR 95% CCI
Step 1	DASS-Depression	.35	.08	18.98	1	<.0001	1.41	1.21-1.65
	Constant	-1.82	.46	15.22	1	<.0001	.16	-
Step 2	DASS-Anxiety	.25	.11	4.81	1	.03	1.28	1.02-1.60
	DASS-Depression	.23	.09	6.60	1	.01	1.26	1.05-1.49
	Constant	-2.45	.59	17.00	1	<.0001	.08	-

β estimated value of the regression coefficient, SE Standard error, *Wald* Wald statistic, *df* degrees of freedom, sig level of significance, OR Odds Ratio, OR 95% CI Odds ratio with a 95% confidence interval, DASS Depression Anxiety Stress Symptoms.

XI. DISCUSSION

This is the first study to examine neuropsychological corelates of SC-BDD while addressing related clinical factors and severity of psychopathological symptoms. As mentioned earlier, due to a technical issue, we did not report the data related to executive function, attention, information processing speed and motor skills. In contrast with the proposed hypotheses, results of the comparisons between SC-BDD and control groups demonstrated intact cognitive functions in both groups, with no group difference on any neuropsychological outcome measure.

In terms of major domains effect size directions, surprisingly the SC-BDD group outperformed controls on verbal function and visuospatial function, with small effect sizes. On the other hand, the control group outperformed the SC-BDD group on verbal, non-verbal, and working memory domains with small effect sizes. These results are in line with the limited available research on SC-BDD. Although research on the association between SC-BDD and neuropsychological performance in the general population is almost non-existent, our result is generally in accordance with the only study on SC-BDD assessing working memory (Blum et al., 2018). This study found the SC-BDD performance on working memory task was intact. Notably, the authors highlighted a major limitation on their study, where very small size of SC-BDD participants (n= 5) hinders generalizability from their results (Blum et al., 2018).

Our results are generally in line with neuropsychological studies in BDD, where a few studies assessed neuropsychological performance in BDD. Dunai et al (2010) measured working memory in BDD patients and control group. They did not find significant difference between two groups on working memory. Studies found intact

performance in individuals with BDD on cognitive functions such as non-verbal memory (Dunai et al., 2010; Greenberg et al., 2018; Hanes, 1998), and visuospatial function (Deckersbach et al., 2000; Laniti, 2005). There are inconsistent findings in studies measured verbal memory, and verbal function in BDD patients. Hanes (1988) demonstrated that BDD patients had intact performance on phonemic and semantic verbal fluency, however, Rossell et al. (2014) showed that BDD patients had intact phonemic fluency but impaired semantic fluency. Toh et al. (2015) showed that BDD patients had impaired verbal memory, however, Hanes (1988) indicated that BDD patients had intact verbal memory. Thus, due to a limited literature on BDD, there is a need for more research in BDD, particularly a comprehensive assessment of the cognitive functions.

However, the SC-BDD group in the present study was found to have clinically significant moderate levels of anxiety, depression, and stress symptoms as well as higher rates of DSM disorders. The result from the logistic regression showed that depression is a strong predictor of SC-BDD, followed by anxiety, such that half of the variance for SC-BDD is explained by depression and anxiety. This is in accordance with other studies in clinical and SC-BDD demonstrating that dysmorphic concern was predicted by depression and low self-esteem (Bartsch, 2007) and importantly, depression mediated the relationship between BDD and suicide ideation and attempt (Shaw, Hall, Rosenfield, & Timpano, 2016; Weingarden, & Renshaw, 2016; Weingarden, Renshaw, Davidson, & Wilhelm, 2017). Similarly, other studies demonstrated the role of stress/anxiety along with depression symptoms in experiencing low quality of life as well as functional disability in individuals with body dysmorphic symptoms (Marques et al., 2011;

Weingarden et al., 2016). In contrast, the present study found that the control group exhibited non-clinical levels of anxiety, stress and depression.

Whereas the present study found no association between elevated level of body image concerns and cognitive function, we found a clear association between body image concerns and psychopathological burden (depression, anxiety, and stress). One way to explain this association is a cognitive-behavioral model. Studies demonstrated that individuals who experience body dysmorphic symptoms would report depression and anxiety as secondary symptoms (Neziroglu et al., 2008; Veale, 2004; Wilhelm, & Neziroglu, 2002). According to the cognitive-behavioral model for BDD, individuals with body dysmorphic symptoms experience an interpretive bias for visual stimuli of normal appearance features or minor defects, which results in negative thoughts and beliefs about their physical appearance in a biased way. Maladaptive interpretation of perceived defects in their physical appearance triggers negative emotions— particularly depression— which then leads to maladaptive behaviors (e.g., checking, fixing, hiding the perceived defects, avoiding from social situations). These compulsions have been suggested to reduce these negative emotions (Fang, & Wilhelm, 2015).

Similar to BDD, our results carry important role especially in the context of SC-BDD in college students given that a significant psychopathological burden does not seem to affect cognitive functions, or academic performance. Notably, it seems that these college students may be at risk of being overlooked given that they present intact overall cognitive and academic functioning, however, studies on clinical and SC-BDD demonstrated college students with dysmorphic symptoms are at risk for suicide ideation and attempts (Shaw, Hall, Rosenfield, & Timpano, 2016; Weingarden, & Renshaw, 2016;

Weingarden, Renshaw, Davidson, & Wilhelm, 2017), and they suffer from low quality of life (Bartsch, 2007). Thus, there is a need for health centers serving college campuses to pay attention to body dysmorphic symptoms and the associated correlates including depression and anxiety symptoms as part of their psychological screening.

It appears that most of the psychiatric disorders diagnosed by DSM criteria are associated with underperformance on a wide range of cognitive tests measuring primary neuropsychological domains such as executive function, and memory (Abramovitch, & Schweiger, 2015). However, recently, studies in college students demonstrated that individuals who meet criteria for DSM disorders and that carry substantial psychopathological burden are capable of having intact cognitive and academic performance. For example, Leonard and Abramovitch (2019) demonstrated that elevated anxiety and worry in disorders such as GAD may be associated with intact performance on cognitive tasks, when the task does not need high cognitive ability and it does not involve certain threatening stimuli. Moreover, another study by Robinson and Abramovitch (2019) showed that individuals with elevated levels of perfectionism as who were found to have mild to moderate depression, anxiety, and stress, exhibited intact neuropsychological functions and academic function. The authors, who utilized a gold standard comprehensive neuropsychological battery and clinical screening, speculated that perfectionism is inherently associated with motivation to perform better in order to achieve optimal outcome. Thus, due to this motivation to perform better, intact performance in the context of perfectionism may obscure the presence of psychopathological burden. Another explanation for intact cognitive function while experiencing psychopathological burden is that a controlled lab environment may

innately decrease the amount of endogenous and exogenous triggers for worrying thoughts, smoothing normative and intact cognitive function (Leonard, & Abramovitch, 2019).

However, in the present study, our results indicate that the SC-BDD sample suffer from similar BDD symptom severity compared to clinical samples, but intact cognitive functions on the domains assessed here. It is possible that assessments of higher order executive function and processing speed would have revealed deficits in these domains, and thus, it is possible that some domains within this population are intact. However much more research on neuropsychological test performance in BDD, as well as on body image concerns in college students is highly needed.

Implications

The results from this study are important in the context of the need to identify and treat students experiencing elevated level of body dysmorphic concerns and related psychopathological burden. Indeed, the notion of intact academic performance may obscure the students' psychopathology, as universities usually provide screening for learning disabilities and less so for psychopathology. In addition, BDD is associated with significant hiding, and shame, that may further challenge identification of and treatment for these students (Sündermann, Wheatley, & Veale, 2016; Weingarden, Shaw, Phillips, & Wilhelm, 2018). It is thus important to utilize analogue sample to draw inferences about students with DSM disorders, particularly BDD which will assist in identifying mediators and moderators that may be used to facilitate early identification and treatment specifically among college students, a very high-risk population for this disorder. Indeed, transcending the restrictive DSM definition of BDD allows for a dimensional view of the

symptoms that may be more relevant in a functioning student sample. Thus, there is a need for health centers in universities to pay attention to body image concerns as part of their psychological screening, given that there are students who are suffering from body dysmorphic symptoms along with depression and anxiety symptoms, but with intact cognitive and non-affected academic performance. Moreover, it is essential for universities to disseminate information about BDD to college students via educational workshops in order to enhance students' knowledge about risk factors of body dysmorphic symptoms and body image concerns (e.g., depression, suicide ideation) (Matusek, Wendt, & Wiseman, 2004).

Pascual-Vera and Belloch (2017) demonstrated that CBT for treatment of dysfunctional thoughts about physical appearance as well as negative emotions have been effective for students. Moreover, it is necessary to disseminate the knowledge and identify individuals with body dysmorphic symptoms especially due to the high risk of suicide. Importantly, studies demonstrate that CBT is an effective evidence-based treatment for BDD (Fang, & Wilhelm, 2015; Wilhelm, & Neziroglu, 2002). Thus, beyond dissemination of knowledge regarding the symptom of BDD, university counselling centers should consider training their therapist to identify and treat BDD and body image concerns.

Limitations

This study has a number of limitations. First, a major limitation of this study is the technical problem (administration error). The Neurotrax battery was administered using on-keyboard mouse instead of external mouse which does not allow rapid responses to be registered, and this invalidated the results of timed tests including the Stroop, Go/No-Go,

staged processing speed, catch game and motor tasks. Thus, we were able to use only data from computerized tests that did not involve time and required fast or consecutive mouse clicks. Second, this study had small sample size, and studies examining larger samples are needed. Third, all participants were college students, which may theoretically limit generalizability to other populations. Nevertheless, there is significant merit in studying BDD among college students given the elevated rates of BDD in this age group (Veale et al., 2016; Boroughs et al., 2010).

Conclusion

BDD is a unique disorder in that although phenomenologically similar to OCD and related disorders, it is associated with marked perceptual distortions and a potentially poor level of insight, which in turn is associated with increased suicide rate. BDD is also not a commonly recognized disorder in the general population and is known to be under-researched. Although the present study demonstrated that college students with SC-BDD suffer from significant psychopathological burden, they revealed intact cognitive functions and overall GPA. In other words, elevated levels of concerns about physical appearance in individuals with SC-BDD, although is associated with substantial depression, anxiety and stress symptoms, is not associated with underperformance across cognitive functions. These findings contrast with findings concerning deficient neuropsychological task performance across most DSM disorders. Given that there is no significant association between elevated level of concerns about physical appearance and verbal function, memory, visuospatial function, and working memory, but significant symptoms of anxiety, depression, and stress accompany high level of dysmorphic concern, in these functionally intact individuals may be disregarded, particularly in

academic settings. Thus, there are functionally intact college students suffering from the psychological burden in universities that may be overlooked given that they do not have clear cognitive dysfunction. Future research is needed to potentially examine all domains of executive function in SC-BDD, and investigates ways to disseminate information about body image concerns, and body dysmorphic symptoms as well as interventions that target this burdensome symptoms and concerns.

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