BODY IMAGE ACROSS HEALTH AND DISEASE - A BIO-PSYCH-SOCIAL PERSPECTIVE

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BODY IMAGE ACROSS HEALTH AND DISEASE - A BIO-PSYCH-SOCIAL PERSPECTIVE

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Table of Contents

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Body Image as Well as Eating Disorder and Body Dysmorphic Disorder Symptoms in Heterosexual, Homosexual, and Bisexual Women

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Body image disturbance is a core symptom of eating disorders (EDs) and body dysmorphic disorder (BDD). There is first evidence that females' body image differs depending on sexual orientation, with heterosexual women (HEW) appearing to show more body image disturbance symptoms than homosexual women (HOW). Such disparities might be moderated by everyday discrimination experiences and involvement with the lesbian community. However, to date, there has been no comprehensive assessment of a broad range of body image facets such as drive for thinness, leanness, and muscularity; body avoidance; body checking and body dissatisfaction; and ED and BDD pathology as well as moderating factors. Moreover, studies have often neglected bisexual women (BIW). A total of N = 617 women (n = 180 HOW, n = 322 HEW, n = 115 BIW) completed an online survey assessing the various facets of body image, ED and BDD pathology, discrimination experiences, and involvement with the lesbian community. Significant group differences were found regarding drive for leanness and thinness, body checking, investment behavior, and body ideal (all p<.05). BIW showed significantly more body checking than HOW. Compared to HEW, HOW reported a significantly lower drive for leanness and thinness as well as compared to HEW and BIW less investment behavior. HOW preferred a body ideal with significantly more body fat than did HEW (all p<.05). In contrast, no differences emerged in body dissatisfaction, drive for muscularity, body-related avoidance, ED and BDD pathology, and body image disturbance (all p>.05). In all groups, discrimination experiences were positively related to ED and BDD pathology and to body image disturbance (all $p < .05$); however, discrimination was significantly correlated with more body image facets in HEW than in HOW or BIW. Involvement with the lesbian community was positively correlated with a larger ideal body size in HOW ($p < .05$) and negatively correlated with drive for muscularity in BIW ($p < .05$). Despite the group differences in several body image facets, we found no consistent evidence of increased vulnerability to body image disturbance or associated pathology depending on sexual orientation. However, in HEW, discrimination experience might pose a risk factor for the development of body image–related pathology and single facets of body image disturbance.

Keywords: body image, women, sexual orientation, discrimination experiences, involvement with the lesbian community, eating disorder symptoms, body dysmorphic disorder symptoms

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INTRODUCTION

Body image describes the mental representation of the size, shape, and form of one's own body as well as the feelings regarding these characteristics (1). It shows a strong positive association with self-esteem (2) and psychosocial quality of life (3). Body image disturbance is a hallmark characteristic of eating disorders (EDs) (4) and body dysmorphic disorder (BDD) (5). Moreover, it has been shown to be a risk factor for the development and maintenance of EDs (6) and BDD (5).

Body image disturbance is a multidimensional construct comprising a perceptual component, e.g., overestimation of one's own body size and body fat (7, 8) and underestimation of one's muscularity (9); a cognitive–affective component; and a behavioral component (4, 10) (11). The cognitive–affective component includes negative thoughts, attitudes, and feelings towards one's own body, which can manifest as body dissatisfaction, disgust, shame, or sadness (7, 12, 13). The behavioral component describes body-related behaviors (7) such as investment in one's own body in terms of dieting or exercise, appearance fixing (14), body-related avoidance (15, 16), and body checking (17).

In general, women have a more negative body image than men [e.g., (18, 19)], with up to 80% of females reporting dissatisfaction with their own bodies (20). Additionally, women are also more likely to show ED [e.g., (21, 22)] and BDD symptoms (23), as well as full-syndrome ED (24). Besides age, other intraindividual characteristics such as sexual orientation have an impact on body image disturbance [e.g., (4, 12)]. However, previous findings are inconsistent, or results are missing in general regarding the influence of women's sexual orientation on the different components of body image disturbance.

Research examining the cognitive–affective component of body image disturbance has revealed a significantly lower drive for a thinner body (drive for thinness) in homosexual women (HOW) than in heterosexual women (HEW) (25–29), although some studies have reported similar levels (30, 31). To date, no study has investigated the association between sexual orientation and drive for leanness, i.e., the preference for a thin and well-toned body with as little body fat as possible (32). However, a recent study reported a higher drive for muscularity (33) in HOW and bisexual women (BIW) than in HEW (31). In terms of attitudes and emotions towards one's own body, the majority of recent studies reported a lower degree of body dissatisfaction in HOW than in HEW (34–36), although some studies reported similar levels of dissatisfaction in both groups [e.g., (31, 37)]. Notably in this context, some studies did not report any associations between sexual orientation and body mass index (BMI) [e.g., (38, 39)], while others found a higher BMI in HOW compared to HEW [e.g., (34, 40, 41)], which might account for the aforementioned findings (41). Additionally, studies employing such rating scales revealed that HOW prefer a body ideal with significantly more body fat compared to HEW (34, 42–44), although again, other studies found evidence of a similar body ideal among women, independent of sexual orientation [e.g., (37)]. To date, only a small number of studies have focused on the behavioral component of body image disturbance in relation to sexual orientation in women. While Wagenbach (29) and Siever (45) reported significantly less investment in one's own body, such as dieting or exercise (14), in HOW compared to HEW, Cella et al. (30) did not find differences between these groups regarding avoidance behavior. Findings regarding the perceptual component are lacking.

As mentioned above, body image disturbance is a risk factor for the development and maintenance of EDs and is strongly associated with BDD (5, 6, 46). Given this association, the aforementioned findings concerning body image disturbance might reflect disparities in ED and BDD pathology between women with different sexual orientations. Over the course of time, research has focused, among other things, on homosexual orientation as a protective factor for developing eating and weight concerns [e.g., (45, 47, 48)]. However, according to Meneguzzo et al. (49), who investigated the relationship between EDs and sexual orientation in women in a systematic review, none of the examined studies had shown a protective factor against ED symptoms in non-heterosexual women. The authors reported no divergences regarding ED diagnoses in general. However, in terms of ED symptoms, according to the majority of papers as well as a review published by Calzo et al. (50), non-heterosexual women are more likely to show ED symptoms including fasting, dieting, or purging compared to HEW. In contrast, Yean et al. (31) did not find that women differed regarding body image disturbance and ED symptoms depending on their sexual orientation, and Feldman and Meyer (51) reported that lifetime prevalence rates of EDs did not vary in HOW, HEW, and BIW.

Regarding BDD, gender differences in general, and sexual orientation in women in particular, have received little attention in previous research. Boroughs et al. (23) reported more pronounced BDD symptoms in non-heterosexual women than in HEW, and Davids and Green (52) found a higher degree of ED symptoms among bisexual men and women compared to heterosexual and homosexual individuals.

The heterogeneous findings regarding body image disturbance, ED, and BDD symptoms in women with different sexual orientations have been attributed to several factors, including age (53); social context (54), in particular, involvement with the lesbian community (55); and discrimination experience [e.g., Ref. (50)]. Despite changes in body image over the course of an individual's life span (53, 56), most previous studies examining body image disturbance in women have focused on samples from student populations (57). Moreover, research investigating a possible influence of age on the association between body image disturbance and women's sexual orientation is mostly lacking. Brown (55) postulated that involvement with the lesbian community might act as a protective factor in the evaluation of one's own body and the development of a positive body image. Furthermore, the extent of involvement with the lesbian community is negatively correlated with weight concerns (47) and appearance-related concerns (58). By contrast, Beren et al. (59) did not find any relation between involvement with the lesbian community and body image disturbance. Moreover, a report published by the European Union Agency for Fundamental Rights (FRA) showed that individuals with a sexual orientation other than heterosexual still experience high levels of discrimination due to their sexual orientation in different European countries (60), which may endanger the mental health of non-heterosexual individuals [e.g., (61, 62)]. Again, however, studies investigating discrimination as an influencing factor in the relationship between sexual orientation and body image disturbance and associated pathologies are lacking.

In sum, previous studies have shown inconsistent findings regarding body image disturbance and associated pathology of women of different sexual orientations, and BIW have mostly been neglected or integrated into an overall minority group (62). Moreover, past research on this topic has mainly focused on body dissatisfaction, as the cognitive–affective component of body image disturbance. There has been no comprehensive assessment of the broad range of components, and potential influencing factors have largely been disregarded. A deeper understanding of the impact of sexual orientation on body image disturbance would be helpful in order to better tailor existing interventions to individuals and to include previously neglected groups in preventive measures. Therefore, the present study sought to examine the cognitive–affective and behavioral components of body image and associated psychopathology in HOW, HEW, and BIW based on a large data set collected through an online survey. It should be noted that as the survey design did not encompass objective ratings of the participants' bodies by others, it was not possible to examine the perceptual component of body image. We were also interested in associations of body image components with various potentially relevant factors such as age, experience of everyday discrimination, and involvement with the lesbian community.

Based on the aforementioned findings, we hypothesized that compared to HEW, HOW would show lower scores on drive for thinness, body checking, body avoidance, investment behavior, and body image disturbance as a whole. We further expected that drive for muscularity as well as ED symptoms would be higher in HOW, while HEW would show higher scores on BDD symptoms compared to the other groups. From an exploratory perspective, we investigated differences in drive for leanness. Furthermore, we assumed that compared to HEW, HOW would show a higher number of everyday discrimination experiences, stronger positive associations of discrimination experiences with body image disturbance facets and associated psychopathology, and stronger negative associations of age with these variables. Lastly, we hypothesized that a greater affiliation of HOW with the lesbian community would be negatively correlated with body image disturbance components and psychopathology measures. To complement all of the analyses, we compared the findings from HOW and HEW with the group of BIW from an exploratory perspective.

METHODS

Recruitment and Participants

Data were collected through an online survey by Unipark (Questback GmbH, Cologne, Germany) including individuals of 18 years or older and with sufficient knowledge of the German language. The sample was recruited from the German-speaking population worldwide from 04/2017 to 09/2018 *via* university e-mail distribution lists, posters and flyers, press releases; lesbian, gay, bisexual, and transgender (LGBT) websites, and Facebook groups. The questionnaire battery used in the current study did not contain any instruments specifically asking for race and ethnicity. However, given the racial and ethnic structure of Germany (63) and the composite of the final sample comprising *n* = 617 female participants, of which the majority had German nationality (*n* = 578), it can be assumed that most of the respondents were Caucasian. Additionally, it is very likely that a large part of the remaining participants were from either Switzerland (64) or Austria (65), countries with similar structures regarding race and ethnicity. The program automatically assesses the IP addresses of the participants. However, this information was not used to prevent repeated participation for the sake of anonymity. Due to the length of the survey of around 40 minutes and no opportunity to skip any questions, however, we assume that no multiple participation occurred. A total of *N* = 6,059 participants of all genders and sexual orientations opened the landing page of the survey, of whom *n* = 1,709 began the survey. The dropout rate was at 30.72%, with *n* = 521 of *n* = 1,709 participants not completing the survey. Out of those who finished the survey, *n* = 424 were excluded due to reporting a sex other than female. Moreover, *n* = 147 women needed to be excluded as they named a sexual orientation other than HOW (*n* = 180), HEW (*n* = 322), or BIW (*n* = 115) (the cell count of other sexual orientations was too low for further analysis).

Procedure

The study protocol was approved by the university ethics committee. Upon arriving at the landing page of the survey, participants were informed about the aim, duration (around 40 min), privacy, and confidentiality issues of the study; the inclusion criteria; and reimbursement. After they provided informed consent by agreeing to participate, the survey began, and the questionnaires were presented (see below under *Instruments*). After completion, participants were given the opportunity to leave their e-mail address in order to receive a summary of study findings and to enter a lottery to win shopping vouchers.

Instruments

Below, all instruments reported in the manuscript are listed in alphabetical order. Internal consistencies of all scales employed in the present study were acceptable to excellent (**Table 2**). Additionally, the following instruments were part of the survey but were not included in the present report as they had not yet been validated: Body Image Matrix of Thinness and Muscularity—Female Bodies (Steinfeld et al., in preparation) and Body Parts Evaluation (66; used but not validated in the Cordes study).

Body Appreciation Scale-2 (BAS-2). The BAS-2 [Tylka and Wood, (67); revised version of the German-language version of the BAS: (68)] assesses an individual's general body satisfaction and comprises 10 items.

Body Image Coping Strategies Inventory (BICSI). The BICSI [(14); unpublished German translation] identifies how individuals deal with events and circumstances that can threaten their own body image. Only the two subscales *appearance change* (10 items) and *avoidance* (eight items) were used in the present study.

Body Image Disturbance Questionnaire (BIDQ). The BIDQ [(69); German-language version, (70)] measures the impact of a negative body image including appearance concern, perceived distress, functional impairment, and avoidance behavior. The questionnaire comprises 12 items, of which seven were included, while the additional five qualitative open-ended items were not used in the present study.

Contour Drawing Rating Scale (*CDRS*). The CDRS [(71); German version, (72)] is a silhouette procedure consisting of nine female contour drawings with precisely graduated sizes. Participants are asked to choose the silhouette that most closely resembles the dimensions of their own body. Finally, they are asked to select the silhouette that best represents their own body ideal [cf. Ref. (73)].

Dysmorphic Concern Questionnaire (DCQ). The DCQ [(74); German-language version, (75)] is a screening instrument for BDD and comprises seven items.

Drive for Leanness Scale (DLS). The DLS [(32), unpublished German translation] is a six-item self-assessment questionnaire to identify the desire for low body fat and visible muscularity (muscle definition).

Drive for Muscularity Scale (DMS). The DMS [(33); German-language version] reflects the striving for a more muscular shape. The two subscales *muscle-related cognitions* (seven items) and *muscle-related behavior* (seven items) could not be replicated in women; thus, only the total score is used in the present study.

Drive for Thinness Scale (DTS). The seven-item DTS [subscale of the Eating Disorder Inventory [EDI], (76); German-language version, (25)] aims to capture preoccupations with diet and weight and the desire to be thin.

Eating Disorder Examination-Questionnaire—short version (EDE-Q). The EDE-Q [German-language version, (77)] (78) is based on the EDE-Interview and captures the psychopathology of EDs. The questionnaire comprises 22 items belonging to the four subscales *eating concern*, *restraint*, *shape concern*, and *weight concern* as well as a global score. The additional six diagnostic items were not used in the present study.

Gender-Neutral Body Checking Questionnaire (GNBCQ). The GNBCQ [(79); German version, Waldorf et al., unpublished] assesses body-checking behavior independently of gender.

Identification and Involvement with the Gay Community Scale—Women's Version (IGCS-WV). The eight items of the IGCS-MV [(80); German version, (81), modified from the men's version] measure the strength of homosexual and bisexual women's affiliation with the lesbian community.

Everyday Discrimination Scale (EDS). The 10 items of the EDS [(82), unpublished German translation] capture the frequency of experience of everyday discrimination.

Socio-demographic characteristics. We assessed age, gender, sexual orientation, nationality, relationship status, highest educational attainment, and body height and weight (for the calculation of BMI as kg/m^2).

Data Analyses

All analyses were performed using SPSS Statistics Version 24.0 (IBM, Armonk, New York, USA). Differences in demographic, body image, and pathology variables were assessed using Chi-square tests or multivariate analyses of variance with subsequent analyses of variance (ANOVAs) and Bonferroni-corrected *post-hoc tests* with the between-subjects factor group.

To test the postulated group differences in body image components, body image disturbance, ED and BBD pathology, as well as discrimination experience, ANOVAs were conducted. In the case of heterogeneity of variance, Welch's tests were employed. For ANOVAs, *p*-values were Bonferroni-corrected. Since the three groups differed significantly with regard to age, we additionally conducted analyses of covariance (ANCOVAs) with age as a covariate in order to reduce within-group error variance. Group differences in associations of everyday discrimination experiences, age, and involvement with the lesbian community with body image components and associated ED and BDD pathology were analyzed using Pearson's correlations. In line with (83), the coefficient r can be interpreted as a small effect (r = .10), medium effect (r = .30), or large effect (r = .50). Partial eta-squared was used as a measure of effect size. This indicates the amount of variability explained by the variable that is not explained by any other variable and can be interpreted as a small effect (partial $\eta^2 \approx .01$), medium effect (partial $\eta^2 \approx .06$), or large effect (partial $\eta^2 \approx .14$; 83).

RESULTS

Socio-demographic and Anthropometric Characteristics

In total, 617 participants were included in the statistical analyses, of whom n = 180 indicated their self-identified sexual orientation as homosexual, n = 322 as heterosexual, and n = 115 as bisexual. Socio-demographic characteristics of HEW, HOW, and BIW are depicted in **Table 1**. Groups significantly differed in age, with HOW being older than BIW (p < .05). Significant group differences occurred regarding relationship status, with *post-hoc tests* illustrating that more HEW (p < .001) as well as BIW (p < .05) reported being in a relationship than HOW. Groups significantly differed in educational levels, with the group of HEW showing greater percentages of higher attainment compared to HOW in *post hoc* tests (p < .005). No group differences between the groups emerged regarding BMI.

Group Differences in Body Image Components, Eating Disorder Pathology, and Body Dysmorphic Disorder Pathology

Table 2 illustrates means, standard deviations, and inferential statistics of group differences. HOW showed significantly lower scores on drive for thinness and drive for leanness than HEW as well as less investment behavior compared to HEW and BIW.

TABLE 1 | Group comparisons of the three groups regarding demographic characteristics.

Variable		HOW (n = 180)	HEW (n = 322)	BIW (n = 115)	Group compression	p
Age: *M*(*SD*)		26.4 (9.21)	24.84 (6.14)	23.98 (6.92)	F (2, 263.09) = 3.3	<.05
BMI: *M*(*SD*)		23.95 (9.66)	22.78 (7.19)	23.39 (5.70)	F (2, 301.48) = 1.14	.32
Education: *n*					χ^2 = 15.01	<.05
	University degree/ polytechnic degree	48 (26.67%)	118 (36.56%)	39 (33.91%)		
	High school graduation/ vocational baccalaureate diploma	108 (60.00%)	187 (58.07%)	63 (54.78%)		
	Secondary school	23 (12.78%)	17 (5.28%)	13 (11.30%)		
	None	1 (0.56%)	–	–		
Relationship: *n*					χ^2 = 30.23	<.001
	In a relationship[a]	62 (34.44%)	193 (59.94%)	57 (49.57%)		
	Not in a relationship[b]	113 (62.78%)	124 (38.51%)	55 (47.83%)		
	Another unlisted relationship status	5 (2.78%)	5 (1.55%)	3 (2.61%)		

HOW, homosexual women, HEW, heterosexual women, BIW, bisexual women, BMI, body mass index. One-way ANOVAs, by default Welch's tests (F_w), with Bonferroni correction as well as Chi-square tests were conducted for the group demographic characteristics. M, mean, SD, standard deviation. [a]includes committed relationship, married/partnered, living together; [b]includes single, separated, divorced.

TABLE 2 | Group comparisons of the three groups regarding body image facets and body image–related pathology.

	Cronbach's alpha	HOW		HEW		BIW		F (df_1, df_2)	p	η^2	*post-hoc tests*
		M (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*				
Body image facets											
BAS-2	.94	3.35 (0.88)	180	3.36 (0.78)	322	3.32 (0.82)	115	0.89 (2,614)	.92	.00	Non-sig.
BICSI avoidance	.85	0.94 (0.58)	180	0.86 (0.57)	322	0.98 (0.57)	114	2.05 (2, 613)	.13	.01	Non-sig.
BICSI appearance change	.77	1.35 (0.65)	180	1.60 (0.58)	322	1.55 (0.62)	115	9.93 (2, 614)	<.001	.03	HOW < HEW, BIW
CDRS	–	4.44 (1.42)	180	3.95 (1.20)	322	4.27 (1.24)	115	9.11 (2, 614)	<.001	.03	HEW < HOW
DLS	.84	3.32 (1.02)	180	3.63 (0.98)	322	3.39 (1.03)	115	6.20 (2, 614)	<.01	.02	HOW < HEW
DMS	.84	2.13 (0.68)	180	2.14 (0.71)	322	2.20 (0.71)	115	0.32 (2, 614)	.73	.00	Non-sig.
DTS	.93	2.86 (1.38)	180	3.18 (1.27)	322	3.08 (1.35)	115	3.27 (2, 614)	<.05	.01	HOW< HEW
EDS (global score)	.95	2.05 (0.73)	180	1.88 (0.74)	322	2.08 (0.73)	115	4.12 (2, 541)	<.05	.01	Non-sig.
GNBCQ	.76	1.86 (0.55)	180	1.93 (0.03)	322	2.07 (0.58)	115	5.34 (2, 614)	<.01	.02	HEW, HOW < BIW
Body image–related pathology											
BIDQ	.90	2.06 (0.94)	173	2.19 (1.91)	312	2.12 (0.84)	104	0.38 (2, 586)	.69	.00	Non-sig.
DCQ	.81	0.93 (0.60)	164	1.01 (0.57)	300	1.07 (0.58)	100	1.86 (2, 561)	.16	.01	Non-sig.
EDE-Q	.76	1.47 (1.33)	162	1.72 (1.30)	297	1.74 (1.28)	98	2.12 (2, 554)	.12	.01	Non-sig.
IGCS-WV	.76	20.41 (4.78)	156	–	–	16.28 (4.52)	98	47.00 (1, 252)	<.001	.16	BIW < HOW

HOW, homosexual women, HEW, heterosexual women, BIW, bisexual women. BAS-2, Body Appreciation Scale-2, BICSI, Body Image Coping Strategies Inventory (two subscales, appearance change and avoidance), CDRS, Contour Drawing Rating Scale, DLS, Drive for Leanness Scale, DMS, Drive for Muscularity Scale, DTS, Drive for Thinness Scale, EDS, Everyday Discrimination Scale, GNBCQ, Gender-Neutral Body Checking Questionnaire, BIDQ, Body Image Disturbance Questionnaire, DCQ, Dysmorphic Concern Questionnaire, EDE-Q, Eating Disorder Examination-Questionnaire, IGCS-WV, Identification and Involvement with the Gay Community Scale—Women's Version. One-way ANOVAs, by default Welch's tests (F_w), with Bonferroni correction were conducted for the group of body image measures and eating disorder pathology separately. M, mean, SD, standard deviation.

Furthermore, both HOW and HEW reported a significantly lower degree of body-checking behavior than did BIW. HOW preferred a significantly larger ideal body size than did HEW. A significant main effect emerged regarding the discrepancy between the actual and ideal figure with respect to body fat, although *post-hoc tests* were not significant. There were no further significant differences in body image components between the three groups. With regard to ED and BDD symptoms, there were no significant differences between HOW, HEW, and BIW. Introducing the covariate age did not change the aforementioned effects, with the exception of the outcome variable body-checking behavior (F (2, 613) = 3.731, $p <$ 0.05): BIW still reported more body checking compared to HOW ($p < .05$) but no longer differed significantly from HEW ($p = .773$).

Group Differences in Everyday Discrimination Experience and Involvement With the Lesbian Community

While we found a significant main effect regarding everyday discrimination experience, the *post-hoc tests* did not yield any significant differences between the groups (**Table 2**). HOW reported a significantly greater involvement with the lesbian community than BIW. Again, introducing the covariate age did not significantly change any of the reported findings (all $p < .05$).

Correlations of Discrimination Experience With Body Image Disturbance, Eating Disorder Pathology, and Body Dysmorphic Pathology

Everyday discrimination experience was positively correlated only with investment behavior in all three groups. In HEW, positive correlations of everyday discrimination experience with body dissatisfaction, drive for muscularity, and body-checking behavior were found. While discrimination experience was positively associated with a higher drive for leanness in HEW and BIW, it was positively associated with avoidance behavior in HEW and HOW (**Table 3**). There was no significant correlation between everyday discrimination experience and drive for leanness or body ideal in any of the groups. Furthermore, the analyses revealed positive associations of discrimination experience with body image disturbance and symptoms of EDs and BDD in all three groups (**Table 3**).

Correlations of Age With Body Image Disturbance, Eating Disorder Pathology, and Body Dysmorphic Pathology

In BIW, age was negatively correlated with investment and avoidance behavior as well as drive for muscularity, while in HEW and HOW, age was positively correlated with a larger ideal body size. Regardless of sexual orientation, age was negatively associated with investment behavior in all three groups. A positive correlation between age and everyday discrimination experience was only found in HEW (**Table 3**). Only in BIW did a significant negative correlation of age with body image disturbance and BDD symptoms emerge. Age was not significantly associated with ED symptoms in any of the groups (**Table 3**).

Correlations of Involvement With the Lesbian Community With Body Image and Eating Disorder Pathology

With regard to involvement with the lesbian community, the correlation analyses only yielded two significant associations: a positive correlation with a larger ideal body size in HOW and a negative correlation with drive for muscularity in BIW (**Table 3**).

DISCUSSION

The aim of the current study was to provide a comprehensive assessment of the multidimensional construct of body image disturbance and the associated pathology as well as the influencing effects of age, discrimination experience, and involvement with the lesbian community in HEW, HOW, and BIW. The analyses revealed that HEW reported a greater drive for thinness and leanness and more investment behavior as compared to HOW. However, BIW did not differ significantly from the others in these facets. Furthermore, HOW reported a significantly lower degree of body checking than did BIW, and both HOW and BIW preferred a larger ideal body size compared to HEW. There were no group differences in drive for muscularity, body dissatisfaction, avoidance behavior, and BDD or ED symptoms. With regard to everyday discrimination experience, a significant main effect of sexual orientation was found, although the *post hoc*

TABLE 3 | Pearson's correlations for everyday discrimination experiences, age, and involvement with the lesbian community in HOW, HEW, and BIW.

	Discrimination experiences			**Age**			**Involvement with lesbian community**	
	HOW (*n* = 197)	**HEW (*n* = 289)**	**BIW (*n* = 98)**	**HOW (*n* = 180)**	**HEW (*n* = 322)**	**BIW (*n* = 115)**	**HOW (*n* = 156)**	**BIW (*n* = 98)**
Body image facets								
BAS-2	–.12	.29**	–.18	.05	.02	.16	.09	–.09
BICSI avoidance	.38**	.22**	.26*	–.08	.07	–.25**	–.06	.08
BICSI appearance change	.22**	.38**	.12	–.10	–.08	–.30**	–.00	.02
CDRS	.11	–.01	–.03	.25**	.12*	.11	.18*	.06
DLS	–.08	.00	.01	.06	–.07	–.13	.02	–.13
DMS	.15	.14*	.17	–.07	.03	–.22*	–.02	–.20*
DTS	.03	.31**	.22*	–.04	–.02	–.18	–.12	–.02
GNBCQ	.10	.25**	.17	–.21**	–.22**	–.29**	.10	–.01
Body image–related pathology								
BIDQ	.24**	.16**	.34**	.07	.03	–.22*	–.03	.05
DCQ	.25**	.33**	.26**	–.00	.08	–.26**	–.04	–.05
EDE-Q	.17*	.35**	.29**	–.04	.05	–.05	–.13	–.05

HOW, homosexual women, HEW, heterosexual women, BIW, bisexual women. BAS-2, Body Appreciation Scale-2, BICSI, Body Image Coping Strategies Inventory (two subscales, appearance change and avoidance), CDRS, Contour Drawing Rating Scale, DLS, Drive for Leanness Scale, DMS, Drive for Muscularity Scale, DTS, Drive for Thinness Scale, GNBCQ, Gender-Neutral Body Checking Questionnaire, BIDQ, Body Image Disturbance Questionnaire, DCQ, Dysmorphic Concern Questionnaire, EDE-Q, Eating Disorder Examination-Questionnaire. M, mean, SD, standard deviation.

**p < .05. **p < .01.*

test did not reveal any specific group differences. In all groups, the greater the experience of everyday discrimination, the more pronounced were the ED and BDD symptoms as well as body image disturbance and investment behavior. Furthermore, discrimination was linked to greater body dissatisfaction, drive for muscularity, and body checking in HEW than in HOW and BIW. For all women, younger age was associated with more body checking. Moreover, while younger age was correlated with more body-related investment and avoidance behavior and a greater drive for muscularity in BIW, older age was associated with a larger ideal body size in HOW and HEW and with more everyday discrimination experiences in HEW. Only in BIW was younger age positively related to BDD pathology as well as body image disturbance. In terms of involvement with the lesbian community, a positive correlation with the ideal body size was found in HOW, and a negative correlation with drive for muscularity emerged in BIW.

Concerning the cognitive–affective body image component, the higher degree of drive for thinness in HEW compared to HOW is in line with most previous research [e.g., (26–29)]. Authors such as Moreno-Domínguez et al. (39) and Swami and Tovée (38) reported significant differences in women's BMI depending on sexual orientation, which they discussed as a potential reason for the variability in the cognitive–affective body image. As HEW, HOW, and BIW did not differ in BMI in the current study, BMI cannot account for the reported differences in drive for thinness. Both HOW and BIW reported a larger ideal body size compared to HEW. This is consistent with previous research demonstrating that HOW are less influenced by sociocultural standards of beauty, leading to a lower degree of body dissatisfaction and a larger ideal body size (34, 42, 44). According to the present findings as well as previous research, HOW are less concerned about their own weight, leading to a lower drive for thinness, and have a more flexible idea of beauty [e.g., (31, 36, 84, 85)] compared to HEW. In relation to this, drive for leanness, which is presented as the new body ideal ("Strong is the new skinny") (32), was also lower in HOW compared to HEW in the current study. However, the three groups did not differ in drive for muscularity, which contradicts the findings of Yean et al. (31), who reported a significantly higher drive for muscularity in HOW. In this context, it should be noted that even though the two studies used the same scale to collect data, in the study by Yean et al. (31), HEW were significantly overrepresented in the sample compared to HOW. Moreover, Yean et al. (31) reported that the average BMI differed depending on sexual orientation, with more HOW being overweight or obese than HEW. These differences may have led to the reported higher drive for muscularity in HOW (31).

Concerning the behavioral body image component, HOW showed less investment behavior compared to HEW, which is consistent with the results of Siever (45) as well as Wagenbach (29), who showed that one's own appearance seems to be less important for HOW than HEW. Even after controlling for age, BIW showed significantly more pronounced body checking than did HOW. In this context, Brewster et al. (86) discussed the impact of antibisexual discrimination and internalized biphobia on the amount of internalization of sociocultural standards of beauty and body surveillance. Since BIW experienced a higher degree of discrimination compared to HEW and HOW, they might have internalized the beauty standards to a greater extent (86). In the current study, BIW did not report more discrimination experiences than HOW and HEW. This discrepancy may be due to the different specificities of the instruments used in the two studies. In contrast to the differences found with respect to body checking, no differences in avoidance behavior were found in the present study. Repetitive checking occurs with the objective of checking that one's own appearance fully conforms with social and/or personal norms, probably with the aim of decreasing discrimination experiences in the future. Furthermore, we found no differences between BIW and the other two groups regarding drive for thinness, leanness, and muscularity. This is likely due to a mix of genders of the participants' romantic partners, which has been shown to affect the internalized beauty ideal in BIW (87). A previous study found that BIW with a male partner showed a more traditional feminine body ideal, while BIW with a female partner had a less strictly defined body ideal (88). Accordingly, the gender of the current partner may have led to different body image ideals among the BIW, which in turn may have resulted in the intermediate position of BIW between the two other groups.

In terms of the influence of sexual orientation in women on ED symptoms, two recently published reviews have found that non-heterosexual women have greater ED symptoms than HEW (49, 50), while others reported no significant differences [e.g., (30, 50)]. In the current study, women did not differ in pathological symptoms regarding sexual orientation. We concluded, in line with, for example, Share and Mintz (85) as well as Feldman and Meyer (51), that the general societal preference of a thin body and concomitant high body image standards, and therefore the risk for EDs, are equal in women regardless of their sexual orientation. However, since the sample of the study is mostly German, these results may only apply to patterns of ED symptoms in Western cultures. The impact of acculturation-related variables on ED pathology and sexual orientation are interesting topics for further studies since research has already underscored the significance of cultural influence on body image dissatisfaction and developing ED symptoms [e.g., (23, 89)].

In terms of everyday discrimination experience, a positive association with body image–related pathology was found regardless of women's sexual orientation. In contrast to findings from the European Union Agency for Fundamental Rights (60), in the current study, BIW did not report more discrimination experiences than the other women. We found that the greater the experience of discrimination, the more pronounced was the investment behavior in all three groups. Additionally, a greater experience of discrimination was linked to stronger effects on body image facets in HEW compared to BIW or HOW. It is possible that HOW and BIW are more used to discrimination than HEW in general, and that they attribute these experiences to internal, stable characteristics of their sexual orientation rather than to their appearance. This, combined with their lower degree of internalization of stereotypically feminine beauty ideals evoked by the media (90), may provide an explanation for this lack of association.

Regarding the association between age and body image components, we found that younger age was positively associated with more body checking irrespective of sexual orientation. In comparison to BIW, with increasing age, HOW and HEW showed a greater preference for a body ideal with significantly more body fat. This is in line with the findings of Tiggemann (53), who reported that the relevance of figure, weight, and appearance decreases over time.

In terms of involvement with the lesbian community, a positive association with a larger ideal body size was only found in HOW. This is in accordance with previous studies reporting that involvement with the lesbian community is related to fewer weight concerns (47), fewer appearance concerns (58), and more acceptance of different body shapes (91) in HOW. Such an association is lacking in BIW, possibly due to the impact of biphobia, a specific form of discrimination, stereotypes, and stigma (92) held by both HEW and HOW towards BIW (93), which may lead to BIW feeling less protected by involvement with the lesbian community. Moreover, greater involvement with the lesbian community was associated with a lower drive for muscularity in BIW. It may be that BIW try to dissociate themselves from the "masculine stereotype" held about HOW, with a lower drive for muscularity leading them to feel a greater belonging to the lesbian community (94). A lower drive for muscularity relates to a feminine body ideal, with which most BIW identify themselves [e.g., Ref. (95)]. For all of the other body image components and related pathology, no associations with involvement in the lesbian community were found in HOW and BIW.

LIMITATIONS AND CONCLUSION

The results of the present study need to be interpreted in light of some limitations pertaining to sample and design. The three groups differed in size, although this is in line with the different distributions of HEW, HOW, and BIW in the general population. Additionally, there were differences regarding age and educational level, which may explain some of the variance in the body image components. Nevertheless, statistically controlling for these differences did not significantly change the results. Since only women with a minimum age of 18 years were eligible to participate in the present study, the findings cannot be generalized to female adolescents. Future studies should therefore include female adolescents in order to capture the crucial point of coming out during a phase that is already relevant for the development of body image (96). Moreover, the study only included individuals with sufficient German language skills, which may limit the generalizability of the findings to different nationalities and cultures. Additionally, the results of the current study were compared to evidence collected across different cultures and countries, wherefore aforementioned distinctions between these study results may be attributed to the varying cultural settings each study was undertaken in. Among other reasons for why body image disturbance in general and EDs in particular could underlie a cultural impact are the suggestion that non-Western societies traditionally do not value a thin body ideal (97, 98) and that a collectivistic instead of an individualistic structure of society provides a certain degree of protection for its members (98). Furthermore, we only examined a non-clinical, mostly academic sample, thus limiting the ability to generalize the findings to a non-community-based population.

Although online surveys entail many advantages, such as time and cost efficiency or independence of location (99), they are also subject to some weaknesses, such as the inclusion only of participants who have a computer and Internet access. However, it is possible that only within this safe and anonymous context did participants feel able to answer sensitive questions regarding sexual orientation and body image openly and honestly (100). As the present study used a quasi-experimental design, it was only possible to report associations between sexual orientation and body image disturbance as well as related pathology in women. Furthermore, only explicit measurements like self-report questionnaires but not interviews or experimental paradigms, e.g., making use of eye-tracking technology, were used in the current study. This may have led to participants selectively suppressing information. Finally, we did not assess the perceptual component of body image disturbance, as due to the study design, we did not have objective ratings of the participants' bodies with which to compare individual, subjective ratings.

Despite these limitations, the present study is the first to comprehensively investigate body image disturbance, associated psychopathology, and potential influencing factors in women with different sexual orientations. In particular, due to the inclusion of a large sample of BIW, a subgroup that has often been neglected in previous research, the study contributes differentiated insights into the aforementioned issues. The main differences in HEW and HOW emerged in the cognitive–affective component of body image, with lower pathology in HOW. Regarding the behavioral component, we found a higher degree of body checking in BIW. In conclusion, although we did not find an increased vulnerability to a negative body image based on sexual orientation, differences did emerge between the three groups regarding facets of body image disturbance, suggesting that single facets or aspects of body image might hold differential relevance for the different groups, and that social context and discrimination experience may influence body image. Additionally, since body image disturbance, ED symptoms, and BDD symptoms are known to have a crucial impact on women across age, ethnicities, cultures, and socioeconomic levels (101), it seems to be important to take sexual orientation into account in order to understand the development of body image and body image disturbance in detail and to create optimally suitable prevention measures for women.

DATA AVAILABILITY

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

This study was reviewed and approved by Osnabrück University Ethics Committee (Ethikkommission der Universität Osnabrück). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ATH analyzed the data and wrote the first draft of the manuscript. CT, ASH, and SV planned the study, and critically edited the manuscript. CT conducted the recruitment and the study.

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Investigating the Components of Body Image Disturbance Within Eating Disorders

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Body image disturbance has been highlighted as a common characteristic within the development and maintenance of clinical eating disorders (EDs), represented by alterations in an individual's bodily experience. However, whilst the perceptual stability of the sense of body ownership has been investigated in ED patients, the stability of the sense of body agency in those with ED is yet to be examined. Therefore, body ownership and body agency were investigated using the moving rubber hand illusion, alongside measures of explicit and implicit body satisfaction. Furthermore, with evidence demonstrating a direct link between perceptual and cognitive-affective components of body image in the healthy population, the relationship between measures of body perception and body satisfaction was investigated. Results showed that both ED and healthy individuals displayed a similar subjective experience of illusory ownership and agency towards the fake hand, following voluntary movement. However, whilst both groups initially overestimated their own hand width prior to the illusion, the ED group displayed a significant reduction in hand size estimation following the illusion, which was not matched to the same degree in healthy individuals. In addition, ED individuals displayed a significantly lower body satisfaction compared with healthy females, on both an explicit and implicit level. Such implicit outcomes were shown to be driven specifically by a weaker association between the self and attractiveness. Finally, a significant relationship was observed between specific perceptual measures and implicit body satisfaction, which highlights the important link between perceptual and cognitive-affective components of one's body image. Together, such findings provide a useful foundation for further research to study the conditions in which these two components relate with regard to body image and its disturbance, particularly in relation to the prognosis and treatment of EDs.

Keywords: eating disorders, body image, multisensory integration, moving rubber hand illusion, implicit body satisfaction

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INTRODUCTION

A common hallmark in the development and maintenance of clinical eating disorders (EDs) is a disturbance in body image (1), which refers to distortions or alterations in the way in which an individual experiences his/her body shape or weight (2). Body image disturbance is argued to be a multidimensional construct, which is commonly divided into two key components (3). The perceptual component denotes issues in estimating one's own body size and dimensions, with evidence that, at a group level, ED individuals typically overestimate the size of their own body significantly more than healthy individuals (4, 5). Additionally, the cognitive-affective component is associated with negative attitudes and emotions towards one's own body, commonly displayed by extreme feelings of body dissatisfaction amongst ED patients (3, 6). Indeed, research has suggested that ED individuals lack a self-serving body image bias that is typically observed in the healthy population, which reflects a highly biased positive perception to one's own attractiveness relative to the perception from others (7). Importantly, such a self-serving bias in healthy individuals acts as a protective factor against poor mental health (8); therefore, the lack of such a bias is likely to have a negative effect towards one's body satisfaction amongst EDs.

Historically, research has predominantly focused on the cognitive-affective component of body image disturbances within EDs (3, 9), with treatment programmes commonly targeting dysfunctional cognitions and emotions relating to the body (8, 10, 11). However, more recent research suggests that such distorted cognitions may be influenced by an inaccurate perceptual experience of the body (12, 13), which remains comparably less understood amongst EDs (14). Indeed, evidence has shown that clinical outcomes are poorer amongst those who report greater misperception of their body (14–16). Moreover, the perceptual component of body image disturbances in EDs has primarily been investigated using visual size estimation tasks (3, 4, 17). However, recent neuroscientific research has revealed higher-order perceptual disturbances amongst EDs within multiple sensory domains, including tactile perception (18, 19), proprioception (20, 21), interoception (22, 23), and the integration of multiple sensory signals (13, 24). Therefore, it is important that research investigates how ED individuals process multisensory body information and the role this might play within the perceptual component of body image disturbances.

Disturbances in the integration of sensory information have been observed amongst ED patients using multisensory body illusions (24). The most studied of these paradigms is the rubber hand illusion (RHI), in which individuals typically experience ownership over a fake rubber hand when it is stroked synchronously with their own hand, which is hidden out of view (25). Crucially, ED patients have been shown to display a greater sense of ownership towards the fake hand compared with healthy controls (HCs) during the RHI, following both synchronous (illusion) and asynchronous (control) conditions, with susceptibility to the illusion positively associated with ED psychopathology (24). Such findings suggest that ED individuals display a greater reliance towards visual body information, which dominates proprioceptive sensory input during body ownership. More recent work has provided corroborative evidence, with induction to the RHI also shown to improve initial overestimation of hand size amongst patients (13), which highlights that such malleability observed in patients' body representation can be developed to a more accurate estimation of one's own body size (13, 26). Taken together, the above evidence underlines the importance of researching perceptual disturbances of body image in EDs from a multisensory perspective (27), with improvements in the perceptual accuracy of one's own body dimensions likely to act as a protective factor against relapse if coping strategies designed to address cognitive-affective components of body image were to break down (28).

A component that is intimately linked with body ownership in contributing towards one's coherent body representation is the sense of agency, which refers to the experience of authorship over an active, volitional bodily movement (29–31). Such a sense of control over one's motor actions is essential in contributing towards one's bodily experience and interaction with the external environment (29). Indeed, disturbances in the sense of agency have been implicated as an important feature within numerous psychiatric disorders (32, 33). Importantly, whilst research has shown that ED patients display alterations in the execution of body-scaled action with regard to unconscious sensorimotor aspects of body representation (34–36), the conscious sense of agency has not been directly investigated within EDs, particularly how alterations in this component may play a role within body image disturbances. An existing experimental paradigm that measures the sense of body ownership and agency is the moving rubber hand illusion (mRHI) (37, 38), which extends upon the RHI by introducing active, volitional movement to a fake model hand. In a similar manner to the classic RHI, synchronous movements typically elicit a strong sense of ownership towards the fake hand, but also a sense of agency, i.e. feeling of controlling the movement of the fake hand. Such feelings of agency are absent when voluntary movements are asynchronous with the movements of the fake hand. Therefore, the mRHI provides the opportunity to experimentally investigate the sense of body ownership and body agency and their relationship in contributing towards a coherent body representation.

With regard to the cognitive-affective component of body image disturbance, the most commonly used assessments of ED pathology in research and treatment include self-reports (e.g. clinical interviews, standardised questionnaires) that target explicit cognitions and behaviours (39). However, research has shown that such explicit measures alone may not accurately reflect an individual's attitudes or behaviours towards certain concepts (40, 41), particularly amongst ED patients who can display denial towards the severity of their disorder (42). Therefore, it is clinically useful to supplement explicit body-related measures with implicit measures that are free from response bias. Implicit cognitive mechanisms are argued to play a key role in the pathology of EDs (44, 45) and could provide an insight into an ED individual's disordered cognitions and behaviours that cannot be obtained from self-reports (43). A commonly used measure to assess implicit attitudes is the Implicit Association Test (IAT) (46), which is a computer-based reaction time task designed to measure the strength of automatic association between certain concepts (see *Methods* section for further details). Conceptually, it is argued that individuals typically pair target words more quickly with the category that is consistent with their own beliefs or cognitions (46). Therefore, the IAT provides the opportunity to tap into an individual's implicit cognitions towards certain concepts, including the self.

Whilst many studies have used the IAT to measure implicit social attitudes (47), studies have also measured implicit attitudes and cognitions towards the self (48–51). Previous research has established a relationship between implicit body satisfaction with ED symptoms in healthy individuals (40, 52, 53). Moreover, previous studies have examined implicit attitudes towards body size (54–56) and food (57). However, to the authors' knowledge, the present study is the first to investigate implicit body satisfaction using the IAT in an ED sample. Investigating implicit cognitions towards body satisfaction amongst ED individuals is important in understanding the multifaceted constructs that underlie body image disturbances (9), particularly how explicit and implicit cognitions relate to each other, which may have important implications for long-term recovery and relapse.

Taken together, the present study examines both perceptual and cognitive-affective components of body image in EDs, extending each with agency and implicit measures, respectively. First, given the intrinsic link between body ownership and agency towards a coherent body representation, it is hypothesised that the predicted instability in the sense of body ownership would also feed into instability towards the sense of body agency in ED individuals. Moreover, the effect of the illusion was investigated towards perceptual estimations of hand size. In line with previous research (13), it is predicted that ED individuals will show initial overestimation of their own hand size but improve their accuracy following the illusion, with HCs expected to display a stable estimation throughout. Second, it is predicted that lower explicit body satisfaction, which is expected to be displayed in ED individuals, would also extend to lower body satisfaction on an implicit level, compared with healthy females. Third, whilst it has been previously argued that perceptual and cognitive-affective alterations contribute independently towards body image disturbances (3), increasing research has highlighted a direct link between the body perception and the emotional body experience within healthy and clinical samples (53, 58–60). Therefore, the possible links between body perception and body satisfaction were investigated, in relation to the influence this may have in ED psychopathology. It is predicted that individuals with greater instability on perceptual multisensory illusion measures would display reduced scores on body satisfaction measures.

METHODS

Participants

The present study received ethical approval from the NHS Health Research Authority (North East – York Research Ethics Committee; Project ID 199702); The Retreat Mental Health Care Centre, York (Research Governance Committee); *Beat* Eating Disorders Charity Research Ethics Committee; and the University of York Departmental Ethics Committee. The study was conducted in accordance with the Declaration of Helsinki, with all participants providing informed consent to take part.

Twenty-eight female participants with an ED diagnosis participated in the present study [mean age, 26.11 (SD, ± 11.69) years]. The ED group consisted of 19 individuals with a diagnosis of anorexia nervosa (AN), 2 with a diagnosis of bulimia nervosa (BN), 2 with a diagnosis of binge eating disorder (BED), and 5 with other specified feeding or eating disorder (OSFED). Of the above sample, 5 participants were recruited as inpatients *via* The Retreat, York (Tuke Centre and Naomi Unit), and 23 were recruited as outpatients *via* the *Beat* website, which is the UK's leading charity supporting those suffering with EDs. Specifically, the study was advertised *via* the *Beat* research page and promoted *via* the charity's email distribution list. Inclusion criterion for the ED group was a clinical diagnosis of an ED, with no restrictions on previous ED diagnosis. Participants recruited *via* The Retreat had a clinical diagnosis confirmed by the patients' psychiatrist, with participants recruited *via Beat* providing a self-reported ED diagnosis, with subsequent assessment from all participants using Eating Disorder Examination Questionnaire (EDE-Q). Such recruitment of clinical individuals *via* self-reported diagnosis has been used in previous research (61). Thirty-one female HCs [mean age, 19.10 (SD, ± 1.27) years] were recruited *via* the University of York, who participated in the present study in return for course credit. Inclusion criteria for the HC group were no current or previous neurological/psychological disorders (self-report). In addition, HCs were explicitly screened for the presence of an ED using an established clinical cutoff of a global EDE-Q score greater than 2.8 (62). All participants were required to be older than 18 years, with no physical condition on their arm or hand that would prevent them from performing the experiment (e.g. severe eczema, scarring, psoriasis). Two ED participants (1 × AN diagnosis, 1 × BN diagnosis) whose age was ≥2 SDs above the group mean (64 and 60 years) were excluded from data analysis. Seven HC participants were excluded from data analysis; one self-reported a current psychological disorder, and six had a global EDE-Q score above the 2.8 global clinical cutoff. Therefore, the final sample size for analysis was 26 ED participants and 24 HC participants. Participant demographic information for both groups following exclusion can be seen in **Table 1**.

Materials

Experimental materials involved a wooden platform (35 × 30 × 13 cm; **Figure 1**) positioned on a table, on top of which was resting a life-sized wooden artist's right hand (measuring 30 cm from base of the wrist to tip of the middle finger), wearing a latex glove with the palm faced down. Participants were seated at the table and asked to wear an identical latex glove on their right hand, which they then placed underneath the wooden platform, directly below the model hand (**Figure 1**). The participant's left hand was in a resting position and kept still by their side. Participants wore a black cape around their neck, which occluded their right forearm and the open wrist of the fake hand on the wooden platform, to appear in an anatomically congruent position to the fake hand. A plastic finger cap was then placed on the tip of participant's right index finger, which was mechanically connected to a matching finger cap on the fake hand by a thin wooden dowel passing through a small hole in the wooden platform, which was attached/detached for the respective experimental condition (see *Procedure* section). Experimental trials and responses for both the mRHI and IAT were made using PsychoPy 2 (63) on an Apple iMac computer (1.6 GHz dual-core Intel Core i5 processor).

TABLE 1 | Participant Demographic Information—Means (Standard Deviations) for ED group and HC group.

	ED Group (*N* = 26)	HC Group (*N* = 24)	*t*	*p*	Cohen's *d*
Age	23.46 (5.95)	19.13 (1.42)	3.60	.001	1.00
BMI	19.80 (4.39)[a]	20.75 (2.30)	-.96	.344	.27
Illness duration (years)	6.39 (5.56)	–	–	–	–
Treatment duration (years)	2.73 (2.22)	–	–	–	–
Restraint[b]	3.70 (2.40–4.80)	1.00 (.40–1.80)	–5.12	<.001[c]	.72
Eating concern[b]	3.80 (3.00–4.60)	.60 (.60–1.15)	–5.76	<.001[c]	.81
Shape concern[b]	5.19 (4.23–5.75)	2.35 (.93–3.10)	–5.43	<.001[c]	.77
Weight concern[b]	4.60 (3.50–5.40)	1.50 (.50–2.75)	–5.49	<.001[c]	.78
EDE-Q Global[b]	4.21 (3.47–4.94)	1.55 (.69–2.23)	–5.83	<.001[c]	.82

p values corrected for multiple comparisons using false discovery rate (64).

BMI, body mass index.

[a]ED Group (N = 25). [b]Median of EDE-Q subscale and global scores with interquartile range in parentheses. [c]Mann-Whitney U statistic with r value effect size.

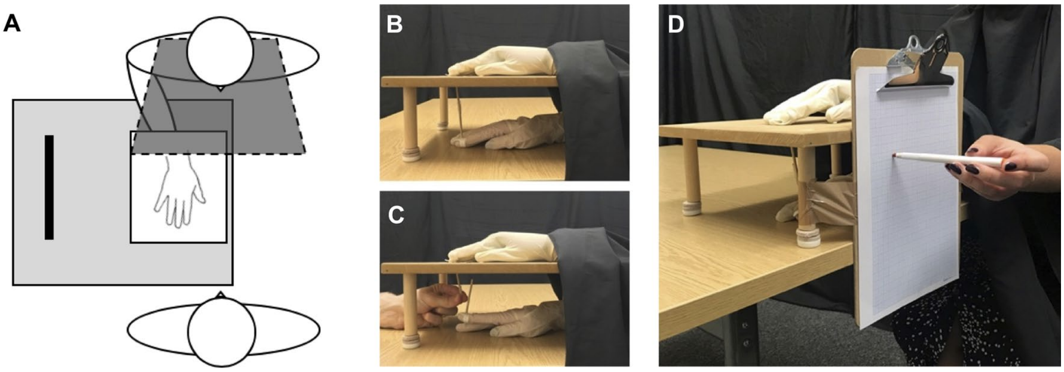

FIGURE 1 | Experimental set-up. **(A)** Participants sat opposite the experimenter and placed their right hand under the platform, directly below the fake hand, which was viewed on top, with a black cape covering their right arm. For each measure within the illusion, participants completed synchronous **(B)** conditions, in which the connection between the two hands was attached, and asynchronous **(C)** conditions, in which the connection was detached, and the experimenter moved the fake hand independently from participant's own hand. **(D)** Proprioceptive drift measure, in which participants closed their eyes and indicated the felt location of their right index finger, using a coloured marker pen on the grid paper attached to the side of the set-up.

Measures

Moving Rubber Hand Illusion

Questionnaire

Following experimental trials, the subjective experience of the illusion was recorded using a 12-statement illusion questionnaire (**Table 2**), adapted from previous studies (37). This questionnaire was composed of two subcomponents, addressing the feeling of ownership towards the fake hand (three items) and feeling of agency over the movements of the fake hand (three items). A further six control statements (three ownership control, three agency control) served to control for participant compliance and suggestibility. Participants were asked to rate the extent to which they agreed with each statement on a seven-point Likert scale (−3 strongly disagree to +3 strongly agree) specifically based on the previous trial. All statements were presented in a randomised order.

Proprioceptive Drift

With eyes closed, participants estimated the perceived height of their unseen, right index finger using an A4 sheet of (millimetre grid) graph paper attached to the side of the experimental set-up (**Figure 1D**). Participants were required to make one swift, but accurate pointing movement towards the graph paper using a coloured marker pen held in their left hand. Each pointing movement was completed three times, with the starting point randomised between participants' nose, shoulder, or hip, to account for learned motor movement. An average pointing estimation was calculated across the three responses, with pointing movements measured both pre-experimental and postexperimental trials.

Hand Size Estimation

Participants were asked to estimate the width of their own hand (at the widest point) prior to the illusion (baseline estimation) and post-experimental trial (13). Both the fake hand and the participants' own hand were hidden from view using an occluding box during all hand size estimations. For each estimation, the experimenter moved two pointers of a calliper alongside the back of the set-up, occluding their own hands to prevent any further visual cues. Estimations were made with

TABLE 2 | Questionnaire for the moving rubber hand illusion, comprising 12 statements that participants rated on a seven-point Likert scale (–3 strongly disagree to +3 strongly agree).

Questionnaire Statement	Category
1. I felt as if I was looking at my own hand.	**Ownership**
2. I felt as if the rubber hand was part of my body.	
3. I felt as if the rubber hand was my hand.	
4. I felt as if my real hand were turning rubbery.	**Ownership Control**
5. It seems as if I had more than one right hand.	
6. It felt as if I had no longer a right hand, as if my right hand had disappeared.	
7. The rubber hand moved just like I wanted it to, as if it was obeying my will.	**Agency**
8. I felt as if I was controlling the movements of the rubber hand.	
9. I felt as if I was causing the movement I saw.	
10. I felt as if the rubber hand was controlling my will.	**Agency Control**
11. I felt as if the rubber hand were controlling me.	
12. It seemed as if the rubber hand had a will of its own.	

the two pointers of the calliper, once moving towards each other (inwards) and once with pointers moving away from each other (outwards). Participants made their judgements by verbally indicating the point at which their hand would fit precisely between the two pointers. The order of calliper movement (inwards/outwards) was counterbalanced across all participants. A baseline estimation was first made before the illusion, with subsequent post-experimental estimations made following each trial. Changes in hand size estimation were calculated by subtracting the average width of post-trial estimations from the baseline estimation. Participants' actual hand size was measured at the end of the experiment.

Body Satisfaction

Explicit Body Satisfaction

A continuous visual analogue scale (VAS), ranging from 0 to 100, was used to assess participant's explicit, state body satisfaction. Participants were asked, '*Right now, how satisfied do you feel with your body?*' with the scale anchored by 'extremely dissatisfied' (0) and 'extremely satisfied' (100) (60, 65). Visual analogue scale items have been shown to have good convergent validity with other measures of body satisfaction (66).

Implicit Body Satisfaction

Implicit body satisfaction was measured using the IAT (46), in which participants were instructed to categorise target words appearing in the centre of the screen into one of four categories, using only two response options (left/right) (**Figure 2**). Within the body satisfaction IAT [adapted from (52, 53)], target categories were *Self* and *Other*, and attribute categories were *Attractive* and *Unattractive*, with pairings from each category appearing in the top left/right corner of the screen. Target words were chosen based on pilot data from an independent sample, to ensure that words were appropriate and culturally relevant for the present study. Target words and their respective categories can be seen in **Table 3**.

In the compatible condition, *Self* and *Attractive* categories (plus *Other* and *Unattractive*) were paired on the same side of the screen. In the incompatible condition, the configuration of the categories was switched, in which *Self* and *Unattractive* categories (plus *Other* and *Attractive*) are paired on the same side of the screen (**Figures 2A**, **B**). The strength of the participants' implicit cognitions is measured by the difference in the mean reaction times between compatible and incompatible conditions. Faster reaction times indicate that the categorisation of words was more congruent with the individual's implicit cognitions towards those concepts. Thus, higher body satisfaction equates to stronger associations (i.e. faster reaction times) between compatible condition pairings, compared with incompatible condition parings.

Eating Disorder Examination Questionnaire

The EDE-Q is a 28-item questionnaire used as a self-report measure of ED psychopathology (67) amongst clinical and nonclinical populations. The questionnaire assesses disordered

TABLE 3 | Implicit Association Test categories and attributes (adapted from 52).

Stimuli Category			
Self	**Other**	**Attractive**	**Unattractive**
Mine	They	Beautiful	Ugly
My	Them	Gorgeous	Unappealing
Me	Their	Good-looking	Bad-looking
Self	Other	Attractive	Unattractive

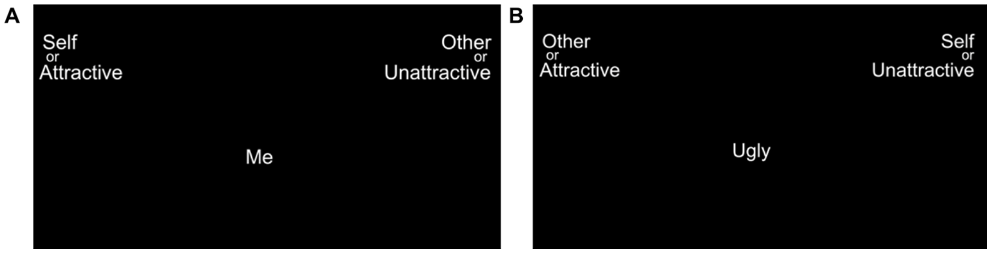

FIGURE 2 | Screenshot depicting example trials within IAT. **(A)** Example compatible condition, in which *Self* and *Attractive* categories (plus *Other* and *Unattractive*) are paired on the same side of the screen. **(B)** Example Incompatible condition in which *Self* and *Unattractive* categories (plus *Other* and *Attractive*) are paired on the same side of the screen. Target words appeared in the centre of the screen, with participants responding by categorising the target words into the left or right of the screen.

eating behaviours within the past 28 days, in which there are four subscales: *Restraint*, *Eating Concern*, *Weight Concern*, and *Shape Concern*. A global score is calculated from the average of the four subscales. Items are rated along a 7-point Likert scale, ranging from '0' to '6', in which higher scores signify higher ED psychopathology. This scoring is with the exemption of six items in which frequency of eating behaviour is recorded; however, these items do not contribute to the subscale scores and were not used in the present study, with ED psychopathology assessed based on the 22-item attitudinal scores. The EDE-Q has been shown to have good internal consistency, with Cronbach's α ranging from .70 to .83 in a clinical sample (68) and from .78 to .93 in a nonclinical sample (69). In the present study, the overall global EDE-Q measure had a Cronbach's α of.87 for ED group and .91 for HC group.

Procedure

Moving Rubber Hand Illusion

Participants were first familiarised with the experimental set-up and given instructions of the task procedure. During all conditions, participants sat at the table and placed their right hand underneath the wooden platform, with a plastic finger cap placed on their right index finger. In each trial, the participant's task was to tap his/her right index finger in a semiregular rhythm for 60 s at approximately one tap per second and was instructed to perform an additional quick 'double tap' at random intervals to avoid perfectly regular visuosomatic correlations, which is reported to weaken the illusion (37). Participants were first required to practice the tapping movement prior to experimental trials and were instructed to focus their gaze on the model hand for the duration of each trial.

During synchronous conditions, the mechanical connection (dowel connecting the real and fake index finger) lifted and lowered the right index finger of the fake hand such that movements of the fake hand were in synchrony with the movements of participants' own right index finger. During asynchronous conditions, the mechanical connection between the real and fake hand was detached, with the movements of the fake index finger controlled by the experimenter moving the dowel with a temporal delay (~ 500 ms) to participant's own movements. The experimental procedure consisted of six 60-s trials; three synchronous (illusion) and three asynchronous (control). Each of the three experimental measures (see *Measures* section) was completed once per condition (3 × synchronous, 3 × asynchronous) in separate trials. Condition order was counterbalanced across participants. Between each trial, participants were given a rest period of ~60 s, in which they removed their right hand from the set-up and flexed their hand/wrist to abolish any carry-over effects.

Body Satisfaction

In addition to an explicit measure of state body satisfaction (see *Measures* section), participants' implicit body satisfaction was measured using the IAT. Participants were first familiarised with the IAT task by completing practice blocks, in which only two categories were presented on the screen (i.e. top left and right of the screen). Participants were instructed to categorise the target words as quickly and accurately as possible using the '*Z*' (left) and the '*M*' (right) key, respectively. Data from practice blocks were not used in any subsequent analysis. In critical (experimental) conditions, each target word belonged to one of four categories, of which two were positioned on the left of the screen and two were positioned on the right (see *Measures* section). All participants completed two experimental blocks of the IAT (1 × Compatible, 1 × Incompatible), each consisting of 120 trials. All target words were presented individually in the centre of the screen, in a randomised order within each block for all participants. The order of conditions and category configurations were counterbalanced across all participants. Following the IAT, participants completed demographic information and the EDE-Q. The duration of the experiment in total was approximately 60 min.

Data Analysis

Prior to analysis, all data were tested for normality using a Shapiro-Wilk test. When the assumption of normality was not violated ($p > .05$), appropriate parametric tests were used, which are described below. When normality was violated ($p < .05$) or the data were ordinal, nonparametric Wilcoxon signed-ranks tests were used for within-subject analysis and Mann-Whitney *U* tests for between-subject analysis. Nonparametric correlations were analysed using Spearman's rank correlation. All analyses that directly tested *a priori* hypotheses are uncorrected critical α values, with all other analyses using Bonferroni-corrected α values (stated as necessary below). Effect sizes for parametric tests are indicated by partial η^2 (η_p^2) or Cohen's *d*, and nonparametric (Wilcoxon signed-ranks and Mann-Whitney *U*) tests are indicated by *r* values, which are equivalent to Cohen's *d* (70). All statistical analyses were conducted using SPSS version 23.0 (IBM, Chicago, IL, USA).

Moving Rubber Hand Illusion

For the subjective measures of ownership and agency (and respective control scores) from the questionnaire ratings, scores were calculated by averaging the individual statements within their respective categories (**Table 2**) to obtain a single score per subscale for each participant (37, 71). First, ownership and agency ratings were compared with their respective control subscale ratings to determine the reliability of the illusion scores in each group, as control scores are not expected to score highly, irrespective of illusion conditions. Control scores are particularly important when testing patient populations, to ensure that participants are not simply complying with all trials and providing high ratings to all questionnaire items (13). Second, ownership and agency scores were compared between synchronous (illusion) and asynchronous (control) conditions to determine the effect of visuomotor synchrony towards subjective illusory experience. Third, ownership and agency scores were independently compared between the ED group and HC group to directly test the hypothesis that ED individuals would show greater instability in their subjective experience body ownership and sense of agency towards the fake hand, following the illusion.

Proprioceptive drift was calculated by subtracting the average height of the pretrial estimation from the posttrial estimation within the pointing task. Positive values signify an upwards drift in the participants' perceived hand position, and thus an increased illusory experience (25, 37). For hand size estimation measures, the hand width of the fake hand was first compared with the participant's actual hand size for each group, with actual hand size subsequently compared between the ED and HC groups. Moreover, to test the hypothesis that ED individuals would display an initial overestimation of hand size prior to the illusion compared with HCs, actual hand size was compared with the participant's baseline estimation of hand width within each group. Next, to investigate whether the effects of the illusion led to a decrease in hand size estimations, difference scores were calculated by subtracting postexperimental estimations from baseline estimations for each participant, per condition. Thus, positive values would signify a decrease in hand size estimation following experimental trials.

Body Satisfaction

Explicit ratings of state body satisfaction taken from VAS scores were compared between the ED and HC groups to test our prediction that ED individuals would display a significantly lower explicit body satisfaction. Additionally, the IAT was used as a proxy for implicit body satisfaction. In line with previous research (46), the first two trials of each condition block with the IAT were removed along with all incorrect trials and reaction times outside of lower (300 ms) and upper (3000 ms) boundaries. Data were transformed using a D score algorithm, which was calculated as the difference in mean reaction times between compatible and incompatible trials, divided by the inclusive SD across both conditions (72). To directly test the hypothesis that ED individuals would display a significantly lower implicit body satisfaction, D scores were compared between the ED and HC groups. In addition, mean reaction times were analysed *via* a 2 × 2 mixed-effects analysis of variance (ANOVA) to investigate whether any group differences are driven by the compatibility of the trials, in which slower reaction times within compatible trials would signify a reduced implicit self-serving body image bias. Thus, compatibility (compatible vs. incompatible) was entered as the within-subjects factor, and group (ED group vs. HC group) entered as the between-subjects factor.

Correlational Analyses

To directly investigate the hypothesis that perceptual and cognitive-affective components of body image would relate with each other, the association between the above measures within the mRHI and body satisfaction tasks was explored using a nonparametric Spearman's rank correlation. Moreover, correlations were also explored between perceptual and cognitive-affective measures with ED psychopathology, using the EDE-Q.

RESULTS

Moving Rubber Hand Illusion

Questionnaire

Data from subscales within the mRHI questionnaire were ordinal and found to be non-normal in the majority of cases (Shapiro-Wilk $p < .05$); therefore, appropriate nonparametric tests were used. First, a Wilcoxon signed-rank test revealed that illusory ownership was induced for both the ED group ($Z = -4.03$, $p < .001$, $r = 0.79$) and HC group ($Z = -3.88$, $p < .001$, $r = 0.79$), with significantly higher scores in response to ownership questions compared with ownership control questions, following synchronous conditions. Next, a further Wilcoxon signed-ranks test revealed a significant effect of synchrony for both the ED group ($Z = -4.29$, $p < .001$, $r = 0.84$) and HC group ($Z = -4.29$, $p < .001$, $r = 0.88$), with higher ownership scores following synchronous compared with asynchronous conditions (**Figure 3**). Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions ($U = 300.00$, $Z = -0.24$, $p = .815$, $r = 0.03$) or asynchronous conditions ($U = 283.00$, $Z = -0.57$, $p = .572$, $r = 0.08$).

The same analyses were conducted for agency scores, in which a Wilcoxon signed-ranks test revealed that illusory agency was induced for both the ED group ($Z = -4.46$, $p < .001$ $r = 0.87$) and HC group ($Z = -4.22$, $p < .001$, $r = 0.86$), with significantly higher scores in response to agency questions compared with agency control questions, following synchronous conditions. Next, a further Wilcoxon signed-ranks test revealed a significant effect of synchrony for both ED group ($Z = -4.29$, $p < .001$, $r = 0.84$) and HC group ($Z = -4.20$, $p < .001$, $r = 0.86$), with higher agency scores following synchronous compared with asynchronous conditions (**Figure 3**). Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions ($U = 290.50$, $Z = -0.43$, $p = .668$, $r = 0.06$) or asynchronous conditions ($U = 259.00$, $Z = -1.03$, $p = .301$, $r = 0.15$). Taken together, these results suggest that ED and HC groups show a significantly stronger illusory experience following synchronous conditions compared with asynchronous conditions, but had an equally strong subjective experience of ownership and agency towards the fake hand.

Proprioceptive Drift

Following synchronous conditions, mean proprioceptive drift was 7.68 (SD, ± 24.80) mm for the ED group and 9.67 (SD, ± 17.05) mm for the HC group. Following asynchronous conditions, mean proprioceptive drift was 5.62 (SD, ± 17.05) mm for the ED group and−0.85 mm (SD, ± 22.90) mm for the HC group. As proprioceptive drift data were normally distributed for both groups (Shapiro-Wilk $p > .05$), a parametric 2 × 2 mixed-effects ANOVA was run, with visuomotor synchrony (synchronous vs. asynchronous) as the within-subjects factor and group (ED group vs. HC group) as the between-subjects factor. In contrast with previous research, no main effect of visuomotor synchrony was observed between synchronous and asynchronous conditions (F (1,48) = 2.66, $p = .109$, $\eta_p{}^2 = 0.05$). Moreover, no significant main effect of group was observed

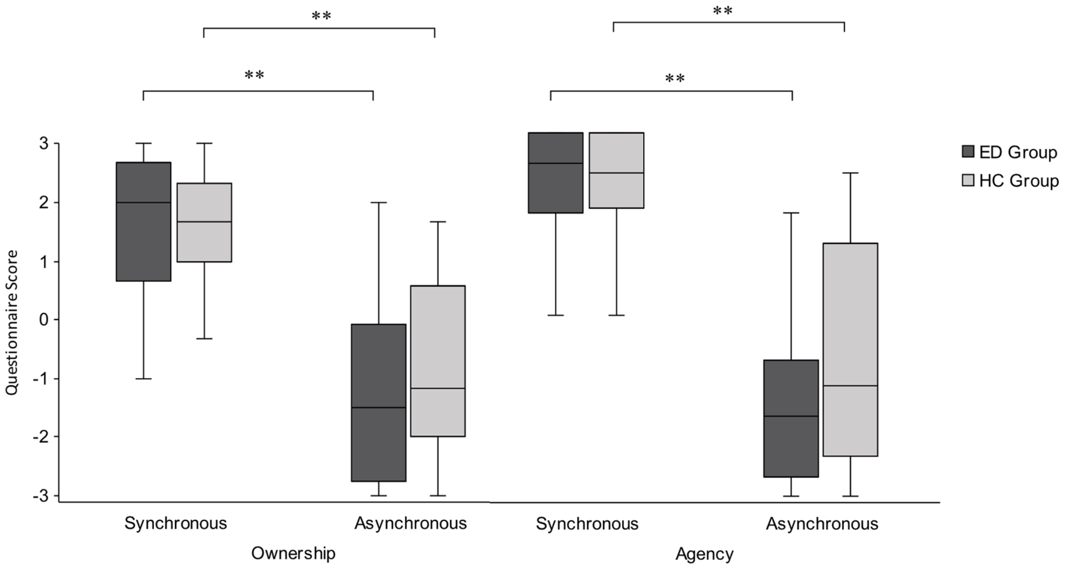

FIGURE 3 | Boxplot displaying ownership and agency scores from the mRHI questionnaire, presented by condition and group. Significantly greater subjective ownership and agency were observed following synchronous compared with asynchronous conditions, with no significant difference in subjective ownership or agency between the ED and HC groups. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values. **$p < .001$.

($F_{1,48}$ = 0.27, p = .604, $\eta_p^2 = ·01$), and no interaction between visuomotor synchrony and group was observed ($F_{1,48}$ = 1.21, p = .277, η_p^2 = 0.03).

Hand Size Estimation

Hand size estimation data were normally distributed across the whole sample (Shapiro-Wilk p > .05); therefore, appropriate parametric tests were used. First, an independent-samples t test revealed that there was no significant difference in actual hand width (in millimetres) between the ED group and the HC group (**Table 4**) (t_{48} = −0.295, p = .77, d = 0.08). Second, paired-samples t tests revealed that the width of the fake hand (74 mm) was significantly narrower compared with the actual hand width of the ED group (t_{25} = −2.89, p = .008, d = 0.57) and the HC group (t_{23} = −3.26, p = .003, d = 0.67). Finally, to directly test the hypothesis that ED individuals would overestimate their hand size prior to the illusion, actual hand size was compared with participants' baseline estimation of hand width for each group (**Table 4**) using paired-samples t tests. Participants in the ED group significantly overestimated their own hand width, prior to the illusion (t_{25} = −3.33, p = .003, d = 0.65). Additionally, participants in the HC group also significantly overestimated their own hand width, prior to the illusion (t_{23} = −2.15, p = .043, d = 0.44). Hand size overestimations did not significantly differ between the ED and HC groups (t_{48} = 0.76, p = −.453, d = 0.21).

Next, to directly test the hypothesis that ED individuals would report a significant decrease in hand size estimation after the illusion was induced, difference scores were calculated for each group by subtracting post-experimental estimations from the baseline estimation. Difference scores were compared to zero *via* a one-sample t test, in which positive values would indicate a decrease in hand size estimation following the illusion. For the ED group, participants reported significantly lower hand size estimations following induction of the illusion, for both synchronous conditions (t_{25} = 2.84, p = .009, d = 0.56) and asynchronous conditions (t_{25} = 2.74, p = .011, d = 0.54). Interestingly, for the HC group, participants also reported a significantly lower hand size estimation following induction of the illusion for synchronous conditions (t_{23} = 2.09, p = .048, d = 0.43), but not for asynchronous conditions (t_{23} = 1.10, p = .281, d = 0.22) (**Table 4**).

Finally, postexperimental hand size estimations were compared with participant's actual hand size, to determine whether such estimations reflected a more veridical measurement of hand width. For the ED group, paired-samples t tests revealed no significant

TABLE 4 | Hand size dimensions and estimations. Actual hand size dimensions (mean and SD) of participants with baseline estimations and post-experimental estimations. Units measured in millimeters (mm).

	ED Group (N = 26)	HC Group (N = 24)	t	p	Cohen's d
Actual Hand Width	76.00 (3.53)	76.29 (3.44)	−.295	.769	.08
Baseline Estimation	83.90 (12.97)	81.60 (11.10)	.675	.506	.19
Synchronous – Post-experimental Estimation	78.79 (12.20)	78.33 (6.87)	.164	.870	.05
Asynchronous – Post-experimental Estimation	79.71 (11.44)	80.00 (9.48)	−.097	.923	.03

differences between actual hand size and postexperimental estimations following synchronous ($t_{25} = -1.15$, $p = .259$, $d = 0.23$) or asynchronous conditions ($t_{25} = -1.68$, $p = .106$, $d = 0.33$). Crucially, baseline estimations made prior to the illusion were significantly different from actual hand size; therefore, this nonsignificant result reflects a reduction in hand size estimation, which is closer to the ED participant's actual hand size. Similarly, for the HC group, paired-samples *t* tests revealed no significant differences between actual hand size and postexperimental estimations following synchronous ($t_{23} = -1.29$, $p = .208$, $d = 0.26$) or asynchronous conditions ($t_{23} = -1.82$, $p = .082$, $d = 0.37$). Taken together, the above results suggest that the ED group showed a significant reduction in hand size estimation following induction of the illusion following both synchronous and asynchronous conditions, which is closer to their veridical hand size. Whilst the HC group also displayed a more accurate estimation of their hand width following synchronous conditions, this was not matched following asynchronous conditions. Moreover, difference scores in the ED group were more pronounced as shown by a larger effect size, which may reflect a greater malleability of body representation within this group.

Body Satisfaction

Explicit Body Satisfaction

Data from the VAS ratings were non–normally distributed across the whole sample (Shapiro-Wilk $p < .05$); therefore, a nonparametric Mann-Whitney *U* test was used to compare state body satisfaction between the ED group and HC group. As predicted, the ED group reported a significantly lower state body satisfaction (median, 15.00) compared with the HC group (median, 63.00; $U = 33.00$, $Z = -5.42$, $p < .001$).

Implicit Body Satisfaction

To directly test the hypothesis that the ED group would display lower implicit body satisfaction compared with the HC group, *D* scores from the IAT were compared between groups. Note that lower *D* scores represent lower implicit body satisfaction. Data from the IAT were normally distributed (Shapiro-Wilk $p > .05$); therefore, an independent-samples *t* test was run, which revealed a significantly lower *D* score within the ED group (mean, 0.20) compared with the HC group (mean, 0.90; $t_{35.86} = -3.06$, $p = .004$, $d = 0.43$). This suggests that ED participants displayed a reduced body satisfaction on an implicit level compared with HCs. *D* scores for both groups are shown in **Figure 4A**.

To further investigate whether ED individuals show a reduced implicit self-serving body image bias within the IAT, mean reaction times for each condition were entered into a 2 × 2 mixed-effects ANOVA, with condition (Compatible vs. Incompatible) as the within-subjects factor and group (ED group vs. HC group) as the between-subjects factor. A main effect of condition was observed ($F_{1,48} = 22.43$, $p < .001$, $\eta_p^2 = 0.32$), with significantly lower reaction times following Compatible versus Incompatible conditions. No main effect of group was observed ($F_{1,48} = 2.15$, $p = .149$, $\eta_p^2 = 0.04$). However, a significant interaction was observed between condition and group ($F_{1,48} = 9.00$, $p = .004$, $\eta_p^2 = 0.16$). Thus, Bonferroni-corrected independent-samples *t* tests (critical $\alpha = .025$) revealed a significant difference between groups following Compatible ($t_{48} = 2.52$, $p = .015$, $d = 0.36$), but not Incompatible conditions ($t_{48} = 0.04$, $p = .972$, $d = 0.01$) (**Figure 4B**). This suggests that differences in implicit attitudes between the ED and HC groups are driven specifically by weaker associations between attractiveness and the self within ED individuals.

Relationship Between Explicit and Implicit Body Satisfaction

To investigate whether explicit measures of body satisfaction related to performance on the IAT, a correlation analysis was run across the whole sample (N = 50). A Spearman's rank correlation revealed a significant positive correlation between state body satisfaction and *D* scores on the IAT across the whole sample

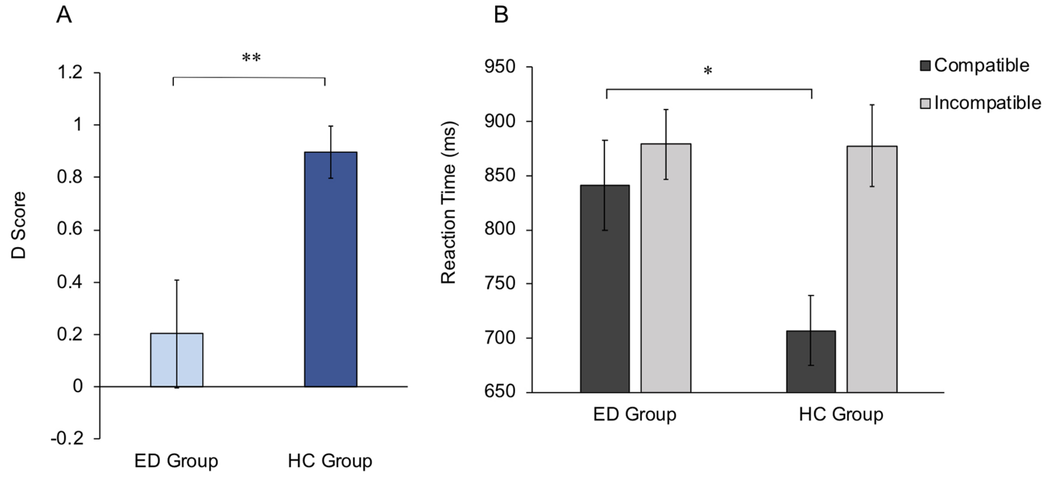

FIGURE 4 | Implicit Association Test scores. **(A)** Mean *D* scores for ED and HC groups. Higher *D* scores indicate higher implicit body satisfaction within the HC group compared with the ED group. **(B)** Mean reaction times for Compatible and Incompatible trials, for ED and HC groups. Group differences are shown to be driven by significantly slower reaction times in the ED group compared with the HC group, within Compatible trials. Error bars for both graphs show standard error. *$p < .05$, **$p < .01$.

($r = 0.46$, $p = .001$), which may suggest that those with higher explicit body satisfaction also display a higher implicit body satisfaction. Furthermore, Bonferroni-corrected Spearman's rank correlations (critical $\alpha = .025$) revealed that lower state body satisfaction is driven by performance on Compatible trials (i.e. *Self* and *Attractive* categories paired) within the IAT, with a significant negative correlation between state body satisfaction and Compatible trials ($r = -0.34$, $p = .014$) but not with Incompatible trials ($r = 0.10$, $p = .485$).

Correlational Analyses

To directly test the hypothesis that perceptual and cognitive-affective components of body image would relate with each other, measures from the mRHI (questionnaire scores, proprioceptive drift, hand size estimation) were correlated with body satisfaction measures (explicit and implicit) across the whole sample. A Spearman's rank correlation revealed a significant positive correlation between synchronous ownership questionnaire scores and IAT *D* scores ($r = 0.32$, $p = .022$), which was driven by the ED group scores (see **Supplementary Materials** for full tables). Moreover, a significant positive correlation was observed between synchronous proprioceptive drift scores and IAT *D* scores ($r = 0.30$, $p = .032$), which was similarly driven by scores in the ED group. This suggests that a stronger explicit and implicit experience of the illusion is associated with increased implicit body satisfaction, which highlights that a link does exist between perceptual and cognitive-affective components of body image. No further noteworthy correlations were observed between the above measures (see **Supplementary Materials** for full tables).

Finally, to investigate the relationship between body perception and body satisfaction with ED psychopathology, the above measures were correlated with scores from the EDE-Q across the whole sample. A Spearman's rank correlation revealed no noteworthy correlations between perceptual measures on the mRHI and EDE-Q scores across the whole sample (see **Supplementary Materials** for full tables). However, as expected, a significant negative relationship was observed between EDE-Q global scores and explicit body satisfaction ($r = -0.794$, $p < .001$), showing that those with higher ED psychopathology reported lower state body satisfaction. Interestingly, a significant negative relationship was also observed between EDE-Q global scores and *D* scores within the IAT ($r = -0.35$, $p = .012$), which suggests that those with higher ED psychopathology also display a lower implicit body satisfaction. This relationship is shown to be specifically driven by subscale scores relating to *Shape Concern* ($r = -0.47$, $p = .001$) and *Weight Concern* ($r = -0.41$, $p = .003$), which reflect body-related attitudes, rather than attitudes towards eating behaviours (i.e. *Restraint/Eating Concern*), which showed no significant relationship with IAT *D* scores (see **Supplementary Materials** for full tables).

DISCUSSION

The present study investigated the perceptual and cognitive-affective components of body image within ED individuals and healthy females. Specifically, the multisensory mRHI was used to assess body ownership and agency, alongside explicit and implicit measures of body satisfaction. Following induction to the illusion, results showed that both ED and HC individuals displayed a similar subjective experience of illusory ownership and agency towards the fake hand. Moreover, both groups initially overestimated their own hand width prior to the illusion, with a significant reduction in overestimation in ED group following both synchronous and asynchronous conditions, which was not mirrored to the same degree in the HC group. Second, ED individuals displayed significantly lower satisfaction towards their body compared with healthy females, on both an explicit and implicit level. Such implicit findings were shown to be driven specifically by a weaker association between words relating to the self and attractiveness. Finally, a significant relationship was observed between specific perceptual measures and implicit body satisfaction, which underlines the key link between body perception and body emotion. Taken together, the present findings support previous research by indicating that ED individuals have a more malleable experience of the bodily self, compared with healthy females. Moreover, novel findings show that ED individuals present with a lower implicit satisfaction towards their body that relates with perceptual experience, which may provide important implications within clinical treatment.

Using the mRHI, the present study builds upon previous multisensory integration research within ED groups (13, 24), as being the first to investigate the sense of agency and its interaction with body ownership within this population. Whilst the 'classic' RHI incorporates a three-way interaction between visual, tactile, and proprioceptive input (25), the present paradigm is supplemented by efferent, kinaesthetic information from voluntary motor actions, which elicits a sense of body ownership and agency towards a fake hand, both of which are key perceptual components within the bodily self (38). Results showed that both ED and HC groups displayed a strong sense of ownership and agency towards the fake hand following synchronous illusion conditions. However, contrary to hypotheses, the two groups displayed a comparable subjective experience of ownership and agency during the task. This finding is in contrast to previous work that has investigated subjective body ownership within the 'classic' RHI, in which ED groups displayed higher sense of ownership towards the fake hand compared with HCs (13, 24). Together, the above results suggest that the subjective sense of ownership and agency may be similar between ED and healthy groups when incorporating voluntary movement towards body representation.

Similarly, despite previous research observing differences in proprioceptive drift between the ED and HC groups (24), the present study is in line with later work that did not observe such effects between groups (13). Many researchers have widely accepted that subjective measures of embodiment following multisensory integration are dissociable from a perceived change in spatial location, which leads to proprioceptive drift (73, 74). However, the observed lack of difference between groups and indeed lack of proprioceptive drift observed from the illusion may be accounted for by a task-dependency effect. Within the present study, participants were asked to make a motor response towards the perceived location of their hand. However, previous research in healthy individuals has suggested a dissociation between perceptual body judgements and motor responses, in which participants showed susceptibility to the 'classic' RHI when making a perceptual response (i.e. verbal judgement of hand location) but showed intact proprioceptive judgement when making a motor response (i.e. a pointing movement towards hand location) (75). This suggests that the two measures denote separate body representations; therefore, future research should investigate whether such proprioceptive measures of the mRHI differ between ED and healthy groups when using perceptual, verbal responses of perceived hand location.

The present study provides a valuable foundation to further study the sense of agency within EDs, which remains a largely underresearched topic within this clinical population. Given their close association in contributing towards a coherent body representation (76), it is difficult to dissociate feelings of agency and feelings of ownership within voluntary movement, not least when sensory feedback of movement is likely to further enhance ownership (77). Within the present study, the contribution of sense of agency towards the sense of ownership — and vice versa — cannot be disentangled. Indeed, the observed lack of difference between HC and ED groups in ownership and agency may be accounted for by the enhancement of subjective ownership as a result of subjective agency following synchronous conditions within the mRHI. Thus, previous research that has observed greater plasticity in body ownership amongst ED patients within the 'classic' RHI (13, 24) may not be directly comparable to the present study, given the additional, interlinked component of agency influencing such subjective ownership. One method to overcome this in future research would be to first undertake the 'classic' RHI to determine the stability of ownership between the ED and HC groups from visuotactile integration (13), before then measuring the stability of body agency when introducing voluntary movement *via* the mRHI. Indeed, research using the mRHI has independently investigated the factors that are known to influence the sense of ownership and agency, in healthy individuals (37, 71, 78) and clinical groups (79). Specifically, anatomical plausibility of the hand and mode of movement has been manipulated, comparing active movement with passive movement (in which the experimenter moves the wooden connection, thus moving the fake hand and participant's hand). Importantly, such manipulations have been shown to dissociate the sense of agency from the sense of ownership (38). Within the present study, the total number of trials within the illusion task was intentionally limited in order to reduce extensive fatigue for ED groups; therefore, body ownership and agency were not independently manipulated.

Furthermore, results showed that whilst both ED and HC groups displayed an initial overestimation of hand width prior to the illusion, ED individuals displayed a significant reduction in their hand width estimation following both synchronous (illusion) and asynchronous (control) conditions, which was not directly mirrored in healthy females. This finding is in line with previous research (13, 26), suggesting that such perceptual changes from ED individuals occurred irrespective of the subjective experience of the illusion, which was shown to significantly differ between conditions. As previously discussed, research has suggested that greater perceptual effects within multisensory illusions amongst ED populations are associated with an increased malleability of the bodily self, in which such individuals often display a visual dominance that overrides proprioceptive input during the illusion (13, 24, 26). Therefore, an increased sensory weighting towards visual input of the fake hand may have been sufficient to change size estimations of one's own hand amongst ED individuals, irrespective of the condition. Importantly, the present results support previous research that highlights an inherent instability of perceptual body representation in ED individuals. Such findings have important clinical implications within the treatment of body image disturbance in EDs, by showing that perceptual estimation of body size can be improved within this population (80). Thus, whilst the long-term effects of improved perceptual accuracy of body size remain unknown in ED patients, a more veridical representation of one's own body is likely to positively impact upon clinical outcomes and the cognitive-affective component of body image disturbance (39, 81).

It must be noted that healthy females did also initially overestimate their hand size prior to the illusion and show a subsequent reduced hand size estimation — but following synchronous conditions only. In other words, healthy females were shown to improve their hand size estimation as a consequence of illusion conditions, which reinforces the effect of multisensory integration in inducing perceptual changes in perceived body size amongst healthy individuals (59). Importantly, the effect was different to the ED group who recorded a reduced estimation following both synchronous and asynchronous conditions, which reinforces the greater malleability of the bodily self in ED individuals compared with HCs. However, it is speculated that initial overestimation from the HC group — which occurred contrary to hypotheses — may be a consequence of higher ED psychopathology within the nonclinical range amongst the present sample. Whilst global EDE-Q scores within the HC group (median, 1.55) were below the clinical cutoff (2.80; 59), such scores appear higher than other European countries that use the EDE-Q in nonclinical samples (e.g. median = .42; 53). Indeed, six HC participants were excluded from the present study after scoring above the clinical cutoff for an EDE-Q global score. Therefore, in addition to the hand size estimation results above, such EDE-Q scores may also, in some part, explain the nonsignificant effects between the ED group and HC group on measures of subjective ownership and agency towards the fake hand. Taken together, such inflated scores amongst a healthy female sample reinforce the need to investigate ED psychopathology and vulnerability in the nonclinical population, and highlight how that EDE-Q may require assessment as a clinical measure within the UK, with regard to normative scores between nonclinical and clinical samples (82).

As shown above (i.e. hand size estimation effects), given the consistent findings in the ED literature that have shown perceptual effects of the illusion following both synchronous and asynchronous conditions, it would be informative for participants to undertake subjective and objective measures of embodiment following mere visual observation of the fake hand, with their own hand hidden from view. This would determine the degree of embodiment experienced by participants due to 'visual capture' of congruent visuoproprioceptive information alone, as a baseline measure made prior to visuomotor integration from illusory trials (83–85). As previously discussed, experiment duration was minimised for ED individuals within the present study; therefore, a visual capture measure of embodiment was not taken. However, given the apparent increased sensitivity to visual input amongst ED populations, future research should include such conditions that take such 'baseline' measures of embodiment following mere visual observation of a fake body (part), to more precisely delineate the role of altered multisensory integration within ED groups. This would be particularly interesting within an RHI set-up, as evidence has shown a greater perceptual malleability when using the RHI compared with a whole body illusion, in relation to ED psychopathology within healthy groups (83) and clinical ED groups (26).

As hypothesised, explicit measures of state body satisfaction revealed significantly lower self-reported scores in ED groups compared with healthy females. However, to the authors' knowledge, the present study is the first to investigate implicit body satisfaction in an ED sample, using the IAT. Results on the IAT showed that ED individuals displayed a significantly lower implicit body satisfaction compared with healthy females, with such differences driven by weaker associations between the self and attractiveness. These findings support previous research that suggests ED individuals lack a positive self-serving body image 'bias' (7), yet builds further by suggesting that dysfunctional attitudes towards one's self-appearance are more deeply rooted amongst ED individuals, with such implicit cognitions likely to be more resistant to change or modification compared with explicit, self-reported cognitions (43). Such findings can have important clinical implications for recovery and relapse, in assessing the implicit biases that are not influenced by a patient's compliance or pressure to report improvement in clinical outcomes following treatment (86). Indeed, recovered ED patients who explicitly self-report improvement in attitudes towards weight and shape following treatment may still be at increased risk of relapse if such cognitions are not addressed on an implicit level, which may play an important role in the prognosis of the disorder (8, 43). This is highlighted in the present study, with implicit body satisfaction shown to be associated with ED psychopathology across the whole sample. Specifically, a significant negative correlation was observed between IAT *D* scores and global EDE-Q scores, which was driven by scores on *Shape Concern* and *Weight Concern* EDE-Q subscales, and not from eating-related subscales (i.e. *Restraint*/*Eating Concern*). Importantly, it is unlikely that this significant correlation across the whole sample was driven by group differences on the above measures, given that significant differences were shown across all EDE-Q subscales between groups (**Table 1**). Therefore, such findings reinforce the link between implicit and explicit cognitions regarding body satisfaction within the pathology of EDs and the need to address both constructs within treatment to improve upon clinical outcomes.

Computer-based paradigms such as the IAT can be a cost-effective method used to assess and improve upon dysfunctional implicit cognitions within ED treatment, alongside traditional, explicit measures of clinical interviews and standardized questionnaires (86). Indeed, increasing research is showing that interventions that target such implicit processes may have clinical efficacy in improving cognitions surrounding one's body satisfaction (8). Furthermore, whilst the present study used appearance-related word associations within the IAT, it would be interesting for future research to dissociate such implicit biases from general cognitive measures such as self-esteem (87). Indeed, a dissociation between shape- or weight-related cognitions and general self-esteem would suggest that altered cognitions within this population may be specific to the body and would provide researchers and clinicians with a clearer focus within which to target treatment (86).

Finally, results revealed a relationship between perceptual and cognitive-affective components of body image across the whole sample, shown by significant positive correlations between ownership questionnaire scores and proprioceptive drift scores from the mRHI, with implicit body satisfaction from IAT *D* scores. This supports the argument that a direct link does exist between body perception and emotion, with such findings shown to be driven more specifically by ED group scores. However, the direction of such relationships was contrary to hypotheses, as it was predicted that ED individuals would display increased ownership — implicated with an instability in the bodily self — which would be associated with reduced body satisfaction. Whilst the explanation for this effect remains unclear, it could be speculated that individuals with a greater instability in their body perception (i.e. ED individuals) may have less negative implicit attitudes towards their own body because they are attaining their idealised, yet unhealthy, ultrathin body. This would be particularly relevant amongst individuals with AN, in which a strong drive for thinness is a key characteristic within such a diagnosis, with increasingly prevalent 'thinspiration' media websites positively reinforcing such aberrant weight loss (88, 89). Importantly, such findings highlight the complexity of the relationship between perceptual and cognitive-affective components of body image, in which further research is required to uncover the most salient conditions in which perceptual alterations relate to emotional bodily experience.

Given the present findings highlighting a relationship between perceptual and cognitive-affective components of body image, future research should investigate how this behavioural relationship is represented in the brain. Recent neuroscientific research has significantly increased our understanding of the neural basis of EDs, with several studies highlighting structural and functional correlates of body image disturbance (90). Specifically, alterations in posterior parietal areas, associated with the integration of sensory information, have been implicated with the perceptual component of body image disturbance amongst AN patients (91, 92). Moreover, prefrontal cortex and insula alterations have been implicated with the affective component of body image disturbance. Therefore, following neuroimaging evidence that has highlighted the interaction between perceptual and affective representations amongst healthy individuals (60), future research should investigate the functional connectivity within the brain amongst ED patients, to determine whether alterations in the communication between the above neural regions would link with the prognosis of the disorder.

The above findings must be considered within the context of limitations of the present study. Whilst a large percentage of the ED group presented with a diagnosis of AN (~70%), the heterogeneity in diagnosis (e.g. BN, BED) and treatment received (e.g. inpatient/outpatient) from ED individuals may have impacted the results within this group. Given the complexity and heterogeneity of clinical populations, this is a typical methodological issue within the ED literature. Indeed, similar research has shown effects of perceptual instability when using an ED group with varied diagnoses (23). However, the sample size within the present study was smaller than previous research that has included varied ED diagnoses; therefore, future research should undertake such work amongst larger, homogeneous samples of independent ED diagnoses.

In conclusion, the present study is one of the first to investigate the independent roles and relationship between perceptual and cognitive-affective components of body image, amongst ED and HC groups. Using a multisensory illusion paradigm that incorporated active, volitional movement, our results support previous research in highlighting the malleability of the perceptual bodily self amongst ED individuals. Second, ED individuals displayed disturbances in their cognitive-affective component of body image, shown by significantly lower body satisfaction on both an explicit and implicit level compared with healthy females, with altered implicit cognitions shown to be specifically driven specifically by weaker associations between the self and attractiveness. Finally, results highlighted an association between the perceptual and cognitive-affective components of body image, yet further research is required to determine the direct effect between these components within both clinical and nonclinical groups. Taken together, such findings can provide important clinical implications in the treatment of body image disturbance, in identifying perceptual alterations amongst this population that are possible to change, and assess more deeply rooted, negative implicit cognitions, which should be targeted alongside typical self-reported measures of recovery in EDs.

DATA AVAILABILITY

All datasets generated for this study are included in the manuscript/supplementary files.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The NHS Health Research Authority (North East – York Research Ethics Committee; Project ID: 199702) The Retreat Mental Health Care Centre, York (Research Governance Committee) Beat Eating Disorders Charity Research Ethics Committee The University of York Departmental Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MC and CP contributed to the conception and design of the experiment. MC collected and analysed the data under the supervision of CP. MC drafted the manuscript, and CP provided critical revisions. All authors approved the manuscript before submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00635/full#supplementary-material

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How Does Variation in the Body Composition of Both Stimuli and Participant Modulate Self-Estimates of Men's Body Size?

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When measured in units of body mass index (BMI), how much variation in men's self-estimates of body size is caused by i) variation in participants' body composition and ii) variation in the apparent muscle mass and muscle tone of the stimuli being judged? To address this, we generated nine sets of male CGI bodies representing low, mid, and high muscle mass rendered at low, mid, and high muscle tone, from 18.75 to 40 BMI_{hse} units. BMI_{hse} units in this study are estimates of BMI derived from calibration equations predicting BMI from waist and hip circumference, age, sex, height, and ethnicity in the Health Survey for England databases. Forty-five healthy adult men estimated their body size using a yes-no paradigm for each combination of muscle mass/tone. We also measured participants' body composition with Harpenden callipers and their body concerns with psychometric questionnaires. We show that stimulus variation in apparent muscle mass/tone can introduce differences up to ~2.5 BMI_{hse} units in men's self-estimates of body size. Moreover, men with the same actual BMI, but different body composition, showed up to ~5-7 BMI_{hse} unit differences in self-estimates of body size. In the face of such large errors, we advocate that such judgments in men should be made instead by simultaneously manipulating both the adiposity *and* the muscle mass of stimuli which are appropriately calibrated for body composition, so that the participant can match the body size and shape they believe themselves to have to the stimulus they see.

Keywords: male body image, body size estimation, body composition, muscularity, adiposity

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INTRODUCTION

Several meta-analyses support the view that body image comprises i) a perceptual component which represents the accuracy with which a person can judge the physical dimensions of their own body and ii) an attitudinal component which captures the feelings that a person has about their body size and shape (1–4). Most people with anorexia nervosa (AN) experience body image distortion (DSM-5, 2013). Perceptually, they over-estimate their body size (5–8) and attitudinally, they have negative feelings towards their body. Persistent over-estimation and disparagement of own body size predicts the long-term outcome in treatment of AN (7, 9, 10), and its continuation post-treatment is a key predictor of relapse, which can be as high as 31% (11).

In men, not only is the incidence of anorexia nervosa rising (12, 13), but an increase in a drive for muscularity can lead both to the development of anorexia nervosa (14) and the onset of muscle dysmorphia, originally termed reverse anorexia (15). The presentation of male body image disorders shows a split between men who strive for thinness and those seeking to increase muscularity (16–18). Research also demonstrates that behaviors of men and women diagnosed with an eating disorder are more comparable than previously realized (19). This emphasizes the need for an accurate method for men to estimate their own body size. However, this measurement is problematic.

Men's bodies vary in body composition (i.e., the relative proportion of total fat versus skeletal muscle mass) considerably more than women's do. Yet virtually all scales developed for self-estimation of body size, to date, focus only on shape change that depends on percentage body fat, often expressed in units of BMI. However, the BMI itself is limited as an accurate index of body size and shape because it does not explicitly distinguish between the two principal dimensions of body composition, namely adiposity and muscle mass (20, 21). Since muscles are heavier than fat, increasing muscle mass makes a body denser, i.e. weighing more at the same volume (22). Consequently, the body shapes of two individuals with the same BMI, but different body composition, one with high and the other with low muscle mass, will be different. Moreover, in terms of clinical risk, a clinician would classify a man who weighs 148 kg and who is 1.93 m tall as severely obese according to World Health Organisation (23) criteria, because he would have a BMI of 39.7. But, if this individual had a lean body mass of ~120 kg, a body fat percentage of less than 20%, and is a professional athlete, it can be assumed that he actually constitutes a low risk for obesity related disease (24).

In recognition of this measurement problem, attempts have been made to construct body scales for men which comprise systematically increasing combinations of muscle mass and adiposity. For example, Cafri and Thompson (25) constructed a line-drawn set of images based on the "somatomorphic matrix" (15). Arguably, these images lack realism in their depiction of individual bodies. More importantly, they showed low reliability on testing and the authors recommended their use should be discontinued (25). More recently Talbot, Smith, Cass, and Griffiths (26) produced a set of CGI bodies based on this image set (i.e., the new somatomorphic matrix). Although the authors found that the scores on their new measure showed good concurrent and convergent validity as a measure of male body dissatisfaction, as well as good test-retest reliability, they do not seem to have duplicated the size and shapes of these bodies in a formal, quantitative way. Specifically, there is no precisely calibrated mapping between the shape of the men in the images, and their body composition. The implication is, therefore, that while well intentioned, these somatomorphic matrices cannot currently be used to estimate body shape and size in men reliably.

THE CURRENT STUDY

Here, we set out to measure how much variation in men's self-estimates of body size (when measured in BMI_{hse} units) is caused by i) variation in participants' own body composition and ii) variation in the apparent muscle mass and muscle tone of the stimuli being judged. To anticipate, our intention was to demonstrate that the sources of error in these measurements, when expressed in BMI_{hse} units, are large. Indeed, that the errors are likely to be so large that we really should, as a research community, be seeking to solve the problem by developing stimuli that are correctly calibrated for both muscle mass and body fat for use in body-size estimation tasks. This paper *does not* represent that ideal solution. Rather it is intended as a call to action, based on the quantitative evidence we present.

To achieve this goal, we have had to use an indirect strategy, because, to our knowledge, no large-scale database exists that would allow images to be generated that are correctly calibrated for body composition. Therefore, in this study, we used 3D CGI models of men that were independently judged to have qualitatively low, middle, or high muscle mass based on visual judgments alone. For each of the three sets of models, we allowed adiposity to vary continuously from a very slim figure through to a mildly obese figure. Any given level of adiposity can be assigned a BMI_{hse} value by substituting the model's waist and hip circumference into a calibration equation derived from ~5,000 observations from the Health Survey for England datasets [see, e.g., Refs. (27, 28)]. The key point here is that across the three levels of muscle mass, qualitatively determined, we can ensure that the waist and hip values are the same at every BMI_{hse} value, and that these circumferences increase at exactly the same rate with increasing BMI_{hse}. This means that we can ask whether a participant who has a measured BMI of 26, for example, will match a stimulus to their own body that has the same BMI_{hse} across the three levels of qualitatively defined muscle mass, or different BMI_{hse} values. The possible outcomes can be explained by two alternative hypotheses.

The first hypothesis is based on behavioral and eye-movement studies of women making self-estimates of body size, which suggest that women judge BMI by estimating the width of the body in the abdominal region (29–31). Therefore, if men use the same gaze strategy when making self-estimates of body size as women, they could solve the tasks in the current study by identifying the stimuli which they believe to be a good match to their own waist and hip widths, i.e., making a match based on abdominal torso width. If this were the case, we would expect to see individuals choosing stimuli with the same BMI_{hse} values across the three levels of muscle mass reflecting the body size they believe themselves to have. Plots of the regression of BMI_{hse} on participants' actual BMI would therefore produce overlapping regression lines with, statistically, the same slopes and intercepts. Any difference, or error, between actual BMI and the body-size estimate, expressed in BMI_{hse}, should be equivalent across the three muscle mass levels.

An alternative, and we believe more likely hypothesis, assumes that men may use cues other than, or in addition to, torso edge separation (indexed by waist and hip widths), with which to make their judgments. For example, Crossley, Cornelissen, and Tovée (32) showed that males attach importance not only to the abdominal region but also the chest and the arms. Qualitative research conducted by Ridgeway and Tylka (33) questioned males about their ideal body composition and identified that as well as the upper body, males also discussed their thighs and calves as often as their shoulders and back. More recent eye tracking studies have confirmed the relevance of the chest, shoulders, and abdominal regions as areas of interest, not only when participants were looking at their own bodies, but when looking at other men (34, 35). Therefore, if men are using features like these to match the body-size/shape they believe themselves to have, then they may need, for example, to pick low muscle mass stimuli with higher $\mathrm{BMI}_{\mathrm{hse}}$ values compared to the matches they make with high muscle mass stimuli. In other words, they may need to inflate the qualitatively lower muscle mass images in order to make a convincing match to their beliefs about their own body shape and size more than they do for higher muscle mass images. In this situation, plots of the regression of $\mathrm{BMI}_{\mathrm{hse}}$ on participants' actual BMI would produce non-overlapping regression lines with different intercepts, and possibly different slopes. Were we to find such effects, this would confirm that the qualitative visual properties of a stimulus set with respect to muscle mass and tone have a strong influence on estimates of body size.

In short, calibrating our stimuli based on the HSE datasets gives a BMI index (i.e., $\mathrm{BMI}_{\mathrm{hse}}$) that is agnostic about the differential effects of muscle mass. However, because waist and hip circumferences can be held constant across the three qualitatively defined muscle mass levels, and by making sure that each participant repeats the task at each of these three muscle mass levels, we can infer something useful about the impact of stimulus muscle mass on participants' body-size judgments by comparing between measurements, and expressing these difference in $\mathrm{BMI}_{\mathrm{hse}}$ units. As a final step, we used a modestly sized body composition database of 178 men to assign plausible, quantitative muscle mass values to our stimuli, and thereby back calculate a likely real BMI value (this time sensitive to body composition) for them. We then repeated our analysis of the experimental data to test whether we converged on the same pattern of results.

In summary, we set out to measure how much error in men's self-estimates of body size (when measured in $\mathrm{BMI}_{\mathrm{hse}}$ units) is caused by i) variation in participants' own body composition and ii) variation in the apparent muscle mass and muscle tone of the stimuli being judged. Additionally, we used a battery of standard psychometric measures to index participants' psychological state and to allow us to factor this into our analysis.

METHODS

The experimental procedures and methods for participant recruitment for this study were approved by the local ethics committees at Northumbria University and the University of Lincoln. All experiments were performed in accordance with relevant guidelines and regulations set out by these organizations, and all participants gave their informed consent to take part in this study.

Participants

An opportunity sample of 53 male participants aged 18–58 (M = 24.87, SD = 9.02) was recruited from a sample of university staff and students and individuals from surrounding areas. Following participation, eight participants were excluded from our data set either because they did not complete all nine psychophysical tasks or it proved impossible to compute adequate psychometric functions from their data in at least one task. Measures retrieved from a final sample of 45 male participants aged 18–58 (M = 24.73 years, SD = 9.23) were used for data analyses, 39 of whom consented to body-site measurements with Harpenden callipers (see **Table 1** for all participant characteristics). Participants were advised that their actual BMI should fall within the range from 18 to 40 to correspond with the $\mathrm{BMI}_{\mathrm{hse}}$ range of stimuli sets. Individuals with a current diagnosis of an eating or body dysmorphic disorder were excluded from taking part in the research. There was no financial reward for taking part in the study.

Psychometric Measurements

To assess participants' current attitudes towards their body shape and size, the following questionnaires were used:

- *The Body Parts Satisfaction Scale for Men* (BPSS-M) (36). The 25-item BPSS-M asks participants to rate their level of satisfaction with their upper body, their face, and their legs on a scale from 1 to 6 (1 = *extremely dissatisfied*, 6 = *extremely satisfied*). The list of items includes both muscularity and leanness criteria, as well as an indication of an individual's overall body satisfaction. For the purposes of this study, we reverse scored all items so that higher scores index a greater dissatisfaction with body size and shape.
- *The Sociocultural Attitudes Towards Appearance Questionnaire* (SATAQ-4) (37). The 22-item SATAQ-4 evaluates the extent of internalization of appearance ideals and appearance related pressures. The SATAQ-4 measures five subscales of one's appearance: two for Internalization, consisting of thin/

TABLE 1 | Descriptive statistics for age, actual BMI, body composition and questionnaire responses (n = 45).

	M	*SD*	Range	
			Actual	Potential
Participant characteristics				
Age (years)	24.73	9.23	18.00 – 58.00	
Actual BMI (kg/m^2)	25.32	4.50	18.00 – 39.70	
Body fat (%)	19.75	3.69	13.94 – 30.37	
Skeletal muscle (%)	19.03	5.43	9.00 – 29.00	
Psychometric task performance				
BPSS-M	87.02	21.06	25.00 – 130.00	25 – 150
STQ Body fat	13.34	4.30	5.00 – 21.00	5 – 25
STQ Muscular	15.57	5.05	5.00 – 25.00	5 – 25
STQ Family pressure	7.09	3.79	4.00 – 19.00	4 – 20
STQ Peer pressure	7.84	3.25	4.00 – 16.00	4 – 20
STQ Media pressure	11.20	4.97	4.00 – 19.00	4 – 20
DMS Attitudes	26.18	9.21	7.00 – 42.00	7 – 42
DMS Behaviors	16.23	9.08	7.00 – 40.00	7 – 42
DMS Total	43.73	16.98	15.00 – 84.00	15 – 90

STQ, Sociocultural Attitudes Towards Appearance Questionnaire 4 (SATAQ 4); DMS, Drive for Muscularity Scale; BPSS-M, Body Parts Satisfaction Scale for Men.

low body fat and muscular/athletic dimensions, and three for Pressures consisting of family, peers, and media dimensions. Items are rated on a Likert scale ranging from 1 to 5 (1 = *definitely disagree*, 5 = *definitely agree*), with higher scores indicating greater internalization and acceptance of societal appearance ideals.

- *The Drive for Muscularity Scale* (DMS) (38). Participant drive for muscularity was measured using this 15-item scale, which indexes two subscales of one's muscularity drive: muscularity-oriented attitudes (7-items) and muscularity-related behaviors (7-items). The scale also provides an overall drive for muscularity score. Participants rated the items on a scale ranging from 1 to 6 (1 = *Always*, 6 = *Never*), and all items were reverse-coded so that higher composite scores indicated greater drive for, attitudes towards, and engagement in behavior to increase muscularity. Reliability testing for responses to the psychometric questionnaires across the sample showed good internal reliability.

For BPSS-M, SATAQ Body fat, SATAQ Muscular, SATAQ Family pressure, SATAQ Peer pressure, SATAQ Media pressure, DMS Attitudes, DMS Behavior, and DMS Total, Cronbach's alpha was. 96, .75, .88, .90, .82, .94, .91, .92, and .94, respectively.

Anthropometric Measurements

To assess participant's current body size and shape, we used the following measures:

- *BMI*. This was measured using the same stadiometer and calibrated scales throughout the testing period and was calculated as BMI = Weight (kg)/Height (m)^2.
- *Body Composition*. We used the Harpenden skinfold caliper as recommended by the International Standards for Anthropometric Assessment guide (ISAK) (39). Skinfold measurements (millimeters) were taken from eight key body sites: biceps, triceps, subscapular, iliac crest, abdominal, suprailium, mid-thigh, and medial calf; along with circumference measurements (cm) of the upper arm, mid-thigh, and calf, using a SECA 201 measuring tape. Body fat percentage was calculated using the final equation for men as set out by Peterson, Czerwinski, and Siervogel (40): % BF_{new} = 20.94878 + (age x 0.1166) – (height x 0.11666) + (sum4 x 0.42696) – (sum4^2 x 0.00159), where height is in centimeters and sum4 is the sum of the triceps, subscapular, iliac crest, and mid-thigh skinfold thickness. Muscle mass percentage was calculated using the final equation developed by Lee et al. (41): SM (kg) = Ht x (0.00744 x CAG^2 + 0.00088 x CTG^2 + 0.00441 x CCG^2) + 2.4 x sex – 0.048 x age + race + 7.8. This equation employed participants' height (Ht), race (Caucasian/Hispanic = 0, Asian = 1, African American = 1.1), sex (male = 1, female = 0), corrected arm (CAG), thigh (CTG), and calf (CCG) girth measurements.

Stimulus Generation

We created CGI images from the Genesis 8 male base model in a 3D modelling environment (DAZ Studio v4.8). The models stood in front of a virtual camera in three quarter view [cf. (42)]. This modelling environment allows adiposity, muscle mass, and muscle tone to be manipulated individually along separate morph dimensions. Based on pilot data, we picked three levels each for visually apparent muscle mass (low, mid, and high) and muscle tone (low, mid, and high) that 10 raters agreed constituted qualitatively distinct differences for these attributes across three BMI categories (underweight/healthy/overweight; 23). For these inter-rater judgments, the overall Kappa statistic for nominal judgment was 0.98 (SE = 0.035, Z = 28.29, p < .0001), suggesting that the qualitative differences between the three muscle mass and muscle tone renderings were indeed clear and unambiguous to participants. We then systematically manipulated the adiposity of the male model at each of the 9 muscle mass and muscle tone combinations, to produce a set of stimuli that varied in BMI_{hse} from 18.75 to 40 in 0.25 BMI_{hse} steps. We calibrated models for BMI_{hse} using the equation below, which was derived from the waist and hip circumference measurements from 5,705 Caucasian men, over the age of 18, from the HSE datasets (43). The height of the model to be entered into the calibration equation was 1.78 m [cf. (44)]. This calibration equation explains 88% of the variance relating the actual BMI of the 5,705 Caucasian men to their waist and hip circumferences, as well as their age and height:

$$BMI_{hse} = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon$$

where x_1 = waist circumference (cm), x_2 = hip circumference (cm), x_3 = height (cm), x_4 = chronological age (years), β_1 = 0.24 95% CI(0.23 – 0.25), β_2 = 0.20 95% CI(0.19 – 0.21), β_3 = -0.15 95% CI(-0.16 – -0.14), β_4 = -0.024 95% CI(-0.047 – -0.042).

Individual stimulus images were ray-traced in Luxrender. The advantages of the stimuli sets are that the images i) are high definition and photorealistic, ii) maintain the identity of the male model across a wide BMI_{hse} range, and iii) demonstrate realistic changes in BMI_{hse} dependent body shape. Examples of the stimuli are shown in **Figure 1**. However, please note that, owing to the reduced contrast and resolution of this illustration, much image detail is lost compared to the original stimuli.

Yes-No Psychophysical Task

In this study we applied classical psychophysical methods [cf. (45)] to measure two components of the participants' judgments of their own body size: i) the point of subjective equality (PSE) and ii) the difference limen (DL). The PSE is the participant's subjective estimate of their body size, in this case measured in BMI_{hse} units. The DL is an estimate of how sensitive a participant is to changes in body size and equates to the smallest difference in body size that he can detect, again measured in BMI_{hse} units. To obtain these measurements, we used the method of constant stimuli in a yes-no forced choice paradigm. This allows a psychometric function to be estimated. Here, the psychometric function is a plot of the percentage of "this image is larger than me responses" as a function of the BMI_{hse} of the stimuli presented, and the curve tends to have a sigmoidal shape. The PSE is defined from the

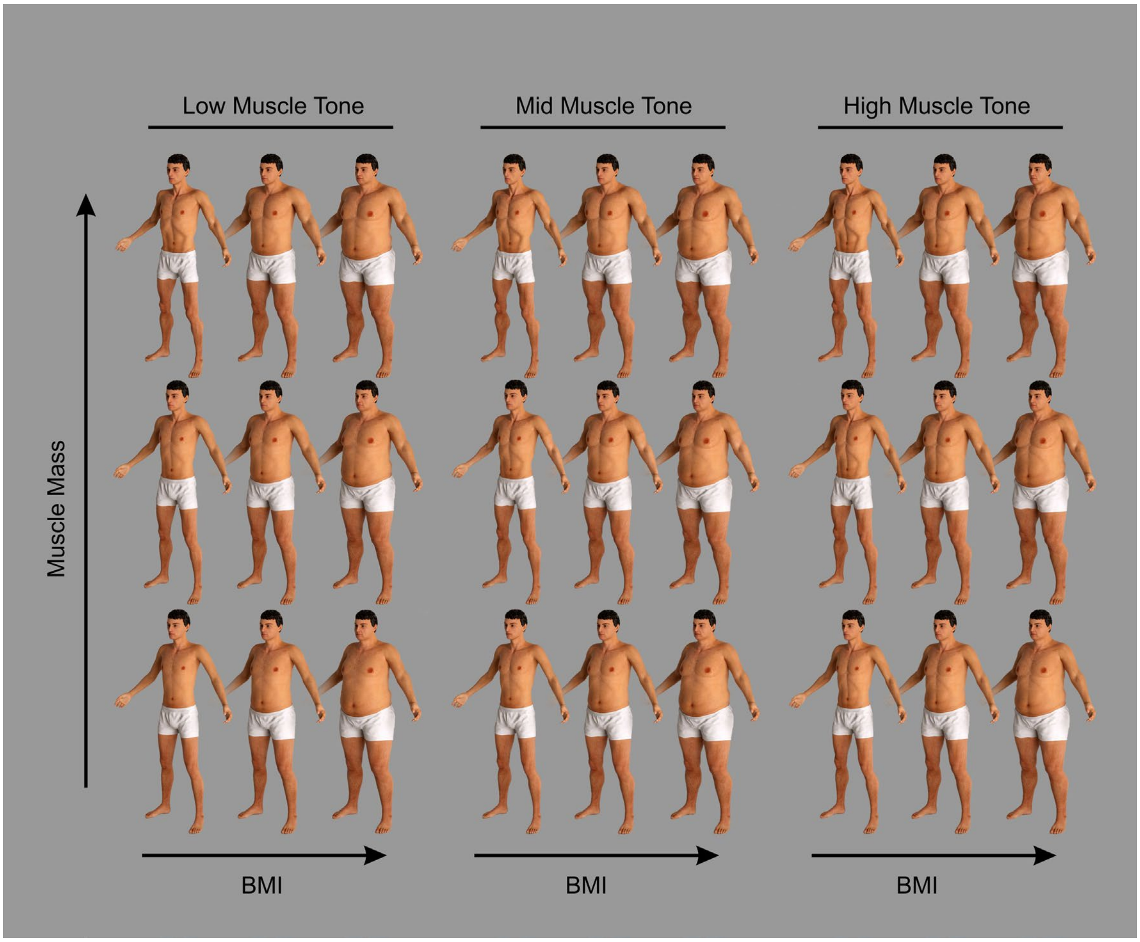

FIGURE 1 | Examples of the CGI bodies used in this study to illustrate the changes of body shape and size of the male stimuli produced by changing their body composition. The images are grouped into three columns, from left to right: low, mid, and high muscle tone. They are further divided into three rows from bottom to top: low, mid, and high muscle mass. Ten raters agreed that these groupings constituted qualitatively distinct differences for these attributes across three BMI categories (underweight/healthy/overweight; 23). The overall Kappa statistic for nominal judgment was 0.98, SE = 0.035, Z = 28.29, p < .0001.

psychometric function as the BMI_{hse} at which participants would respond "larger than me" 50% of the time. The DL is the average of the differences in BMI_{hse} of the stimuli falling between the 25% and 50% and the 75% and 50% "larger than me" response points [see (46)]. This range captures the steepness of the psychometric curve. Participants who are very sensitive to small changes in body size will have a steeper psychometric function with a correspondingly small DL. **Figure 2** shows sketch plots to illustrate how the PSE and DL are derived from the psychometric function.

Participants carried out the yes-no task nine times, once for each combination of muscle mass/muscle tone. The order of presentation of muscle mass/muscle tone stimuli was randomized for each participant. For each yes-no task, participants were presented with a randomized sequence of images of the standard CGI male body model. Across the image set, BMI_{hse} varied continuously from 18.75 to 40.0. On each trial of the task, one image was presented and participants were required to decide whether the body depicted was larger than they were and to record this decision by button press (one button for "yes" and a second button for "no"). Stimuli were presented on a 19" flat panel LCD screen (1280w x 1024h pixel native resolution, 32-bit color depth) for as long as it took participants to make a decision. At the standard viewing distance of ~60 cm, the image frame containing the male body subtended ~26° vertically and ~8° degrees horizontally. Each participant first judged seven images covering the whole BMI_{hse} range (from 18.75 to 40.0 in equal BMI_{hse} steps) presented in two separate blocks. Each stimulus image appeared 10 times in each block, and the order of presentation was randomized. Based on the responses from each block, the participants' PSE (i.e., an estimate of the BMI_{hse} they believe themselves to be) was calculated automatically by fitting a cumulative normal distribution. These two values were then averaged to give an initial estimate of the participant's PSE. On the basis of this initial estimate, the program presented a further set of 21 images (spread over a range of 5 BMI_{hse} units centered on the participant's initial PSE, at a spacing of 0.25 units per image) for the participants to judge. Each image was presented 10 times in randomized order. This final set of judgments allowed

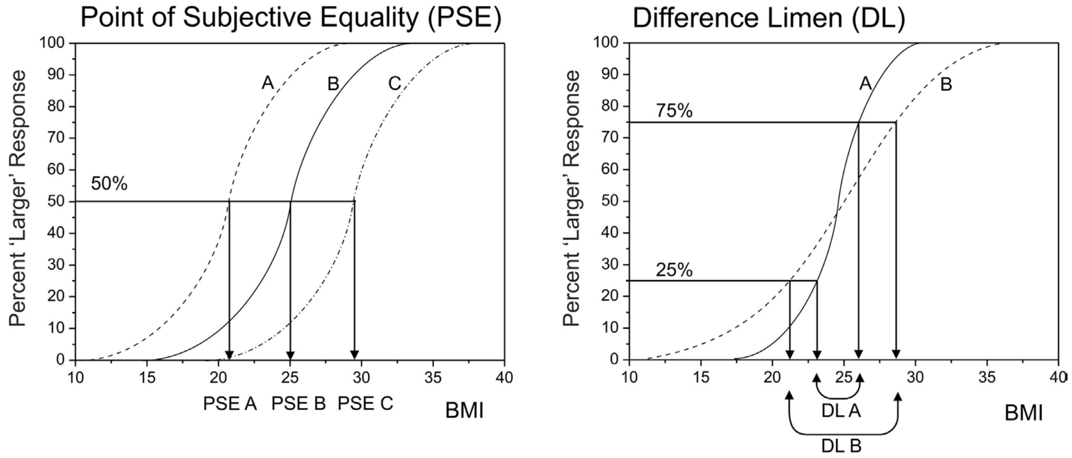

FIGURE 2 | A graphical illustration of how the psychometric function for body size estimation can be used to separate out sensory sensitivity (indexed by the difference limen, DL) from perceptual bias (indexed by the point of subjective equality, PSE). On the left, participants A, B, and C might all have the same BMI of 25. However, participant A under-estimates and participant C over-estimates their body size. On the right, participant A is more sensitive to body size change than participant B, and therefore has a steeper psychometric function, with a smaller DL.

us to plot the full psychometric function and use probit analysis off-line to calculate a definitive estimate of PSE as well as the DL (i.e., how sensitive participants are to changes in BMI_{hse}).

Timeline for Task Administration

Due to the nature of testing and the length of each task, participants were invited to take part over two testing sessions. During the first testing session, participants were invited to complete all psychometric questionnaires, before having their height and weight measured by the researcher in order to calculate actual BMI. Standardized verbal instructions were then given for the psychophysical tasks and participants were asked to complete the first four levels of the psychophysical task. Order exposure of task level was randomized. During the second session, which occurred within two weeks of the first, participants completed the remaining five levels of the psychophysical task. For participants who chose to participate, body composition measurements were also taken during the second session. Collectively, participation lasted approximately two hours.

Analysis Pipeline

The main analyses of the experimental data included the following steps:

- Calculation and tabulation of univariate descriptive statistics for participants' characteristics and their psychometric performance.
- Data reduction of the psychometric responses, using principal components analysis, to produce two latent variables: i) PC1, referred to as *Participant_Fat_Att*, represents increasing body image concern, together with perceived social pressures about body image from the media, peer groups, and family; and ii) PC2, referred to as *Participant_Musc_Att*, represents perceived social pressure for and positive attitudinal responses towards increasing muscularity, combined with a drive to take part in activities that would achieve this outcome.
- Computation of three linear mixed effects models:
  - MODEL 1: Participants' PSE responses predicted from participants' actual BMI, apparent stimulus muscle mass, apparent stimulus muscle tone, participants' age, Participant_Fat_Att, and Participant_Musc_Att as explanatory variables. See **Figure 3**, upper and middle rows, for illustrated model outcome.
  - MODEL 2: Participants' PSE responses predicted from participants' percentage body fat, participants' muscle mass, apparent stimulus muscle mass, apparent stimulus muscle tone, participants' age, Participant_Fat_Att, and Participant_Musc_Att as explanatory variables. See **Figure 4** for illustrated model outcome.
  - MODEL 3: Predicted participants' DL responses using participants' actual BMI, apparent stimulus muscle mass, apparent stimulus muscle tone, participants' age, Participant_Fat_Att, and Participant_Musc_Att as explanatory variables. See **Figure 3**, bottom row, for illustrated model outcome.
- Simulation to illustrate how large the differences in body-size estimates (i.e., PSE in BMI_{hse} units) can be in individual participants who have the same actual BMI. To do this, we estimated the covariance between body fat and skeletal muscle mass in men, from a modest database of 178 Caucasian males whose body composition had been measured using a Tanita MC780MA multi-frequency segmental body composition analyzer. See **Figure 5** for illustrated model outcome.
- Simulation to illustrate the likely effect sizes of stimulus muscle mass and muscle tone that we would obtain, *if* we had stimuli that were correctly calibrated for body composition. To do this, we again used the modestly sized body composition

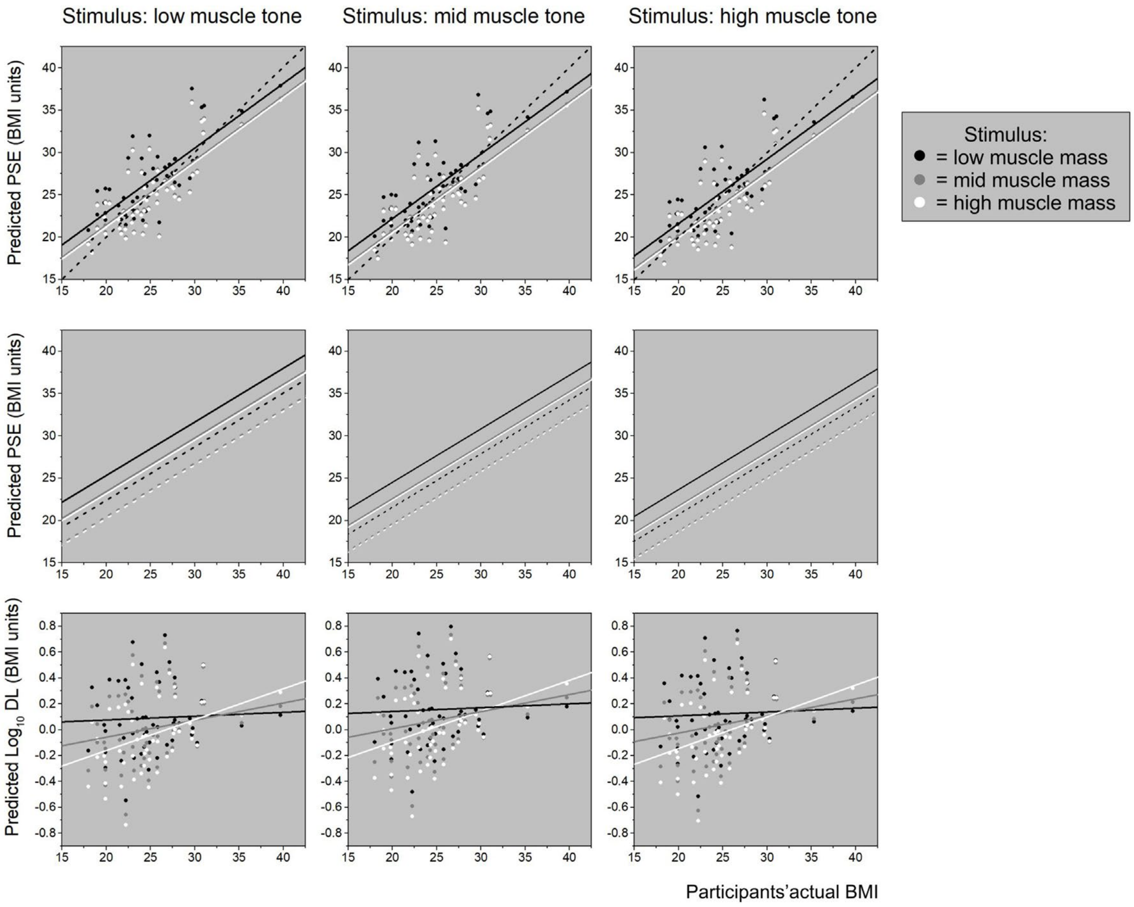

FIGURE 3 | The *top row* shows three plots of body-size estimates (PSE) predicted from the linear mixed effect model ("Model 1 for PSE" shown in **Table 4**) plotted as a function of participants' actual BMI. In each plot, low, mid, and high stimulus muscle mass is represented by black, gray, and white dots, respectively. The regression lines for each level of stimulus muscle mass follow the same color scheme. The plot on the left is for low stimulus muscle tone stimuli, the middle plot for mid stimulus muscle tone, and the plot on the right for high stimulus muscle tone. In each case, the black dashed line represents the line of equality, where body-size estimates (PSE) exactly match actual BMI. The graphs in the *middle row* show the same regressions of body-size (PSE) on actual BMI (from "Model 1 for PSE", shown in **Table 4**) at the same three stimulus muscle mass levels within each plot, separately for the three stimulus muscle tone levels across the row, from low to high. However, now each regression line is split, and plotted separately at +1 SD (solid lines) and -1 SD (dashed lines) for Participant_Musc_Att, to illustrate the independent influence of participants' psychometric performance on body size estimation. Specifically, increasingly positive attitudes and drive towards muscularity are associated with higher body size estimates. The *bottom row* shows three plots of participants' sensitivity in the body size estimation task (i.e., DL) predicted from the linear mixed effect model ("Model 3 for PSE" shown in **Table 4**) plotted as a function of participants' actual BMI. Each plot contains the predicted DL values and regression lines for low (black), mid (gray), and high (white) stimulus muscle mass as a function of actual BMI. Stimulus muscle tone changes from low, through mid, to high across the 3 plots from left to right. These graphs show that sensitivity to changing body-size systematically decreases as a function of increasing BMI, and that this effect is weakest for low muscle mass stimuli, intermediate for mid muscle mass stimuli, and strongest for high muscle mass stimuli.

database of 178 Caucasian men. This simulation converged on a qualitatively similar pattern of results, even though the sizes of the effects were reduced by ~40% for stimulus muscle mass and ~18% for stimulus muscle tone.

RESULTS

Univariate Statistics

Table 1 shows the characteristics of our 45 male participants. With respect to the World Health Organization's BMI classification scheme (23), the numbers of participants who fell into the under-weight, normal, over-weight, and obese categories were 2, 22, 15, and 6. Performance in the psychometric tasks also fell within the normal ranges for the BPSS-M (36), the SATAQ-4 (37), and the DMS (38). All raw DL scores departed markedly from a normal distribution for each condition (smallest Shapiro-Wilk's $W = 0.223$, $p < .0001$) and were therefore logarithmically transformed for further analysis.

Reliability for the yes-no task was computed by taking participant PSE scores from block 2 and block 3 of the psychophysical task output and comparing these for each task level using paired samples *t*-tests. All reliability tests were conducted retrospectively, completed following all data collection. As can be

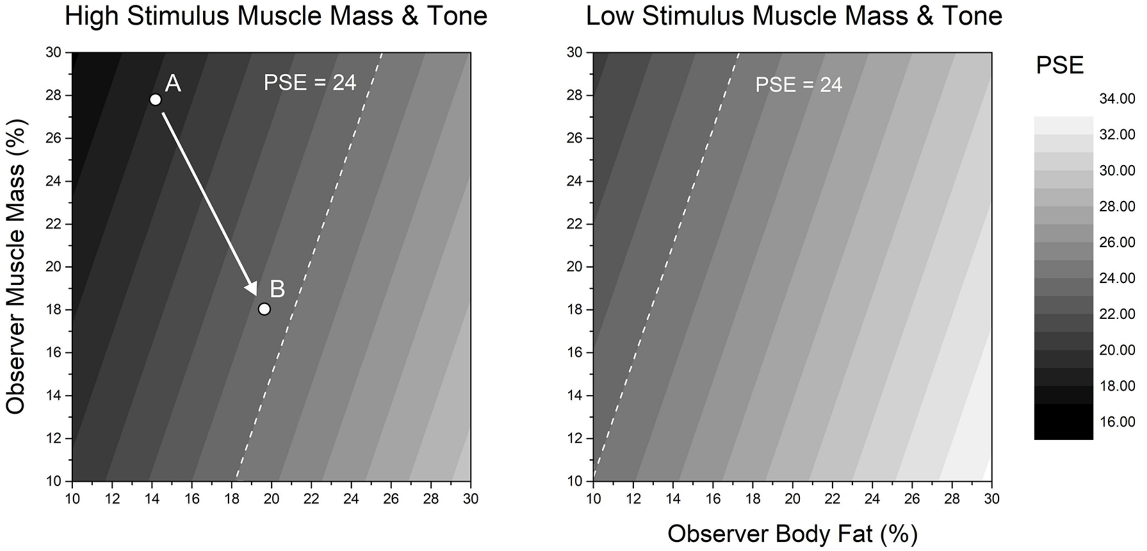

FIGURE 4 | Two contour plots of body-size estimates (PSE) predicted from the linear mixed effect model ("Model 2 for PSE" shown in **Table 4**) plotted as a function of participants' participant muscle mass (*y*-axis) and body fat (*x*-axis). Predicted body-size estimates (PSE) are represented in grey levels on the *z*-axis, from black (smaller body size) to white (larger body size). Responses from high stimulus muscle mass and high stimulus muscle tone are shown in the left panel. Responses from low stimulus muscle mass and low stimulus muscle tone are shown in the right panel. In both panels, as participants' muscle mass increases, so the size that they believe themselves to be tends to decrease. Conversely, as participants' body fat increases, so the body size that they believe themselves to have increases. Since estimated body-size changes in opposite directions for participant muscle mass and body fat, it is possible for differing body compositions to give rise to the same body size estimate. This is illustrated by the white dashed line in each plot, which corresponds to a predicted body size of 24 $\mathrm{BMI_{hse}}$. The converse of this situation is illustrated by points *A* and *B* in the left panel, which show the different muscle mass and body fat combinations from two participants in our dataset both of whom had an actual BMI ~23.

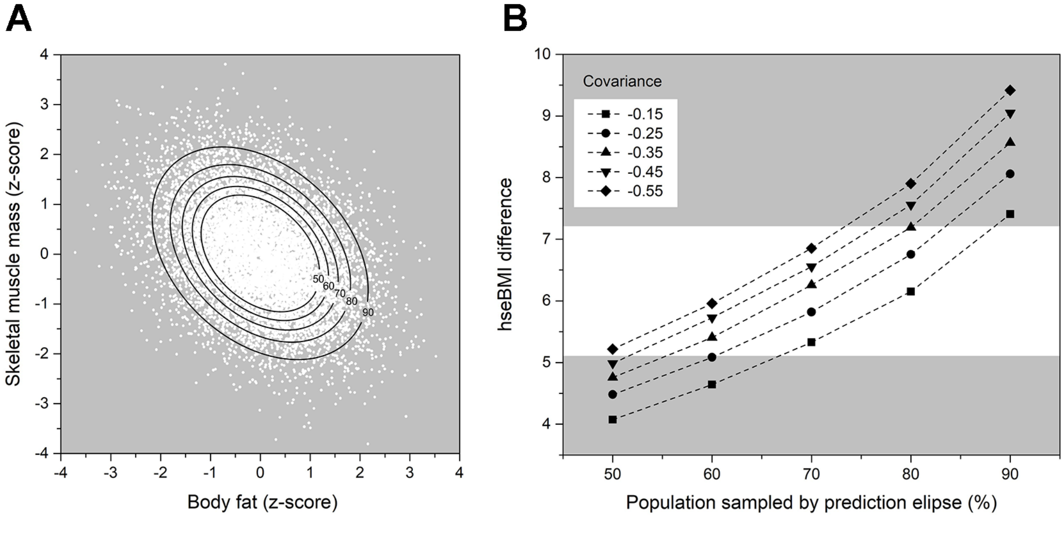

FIGURE 5 | (A) Scatter plot of the 10,000 data point bivariate normal distribution for a covariance of 0.55 between percentage muscle mass and body fat (expressed as z-scores). The black lines represent prediction ellipses that capture, respectively, 50, 60, 70, 80, and 90% of the observations in the distribution. **(B)** Differences in estimated BMI (*y*-axis) between pairs of participants who would both have the same actual BMI, but differing body compositions. The range of these differing body compositions is determined by the particular combination of the covariance between body fat and skeletal muscle mass (to produce the bivariate distribution) and the prediction ellipse (which selects how many observations are chosen from the distribution). The white band highlights the most likely combinations of covariance and prediction ellipse parameters. See text for further details.

TABLE 2 | Results of a paired samples t-tests between the mean PSE scores of block two and block three of the psychophysical task for each task level (N = 45). * = $p < .001$.

Task Level	Correlation	Mean Difference (*SD*)	*T* – value
Low Tone-Low Mass	*.901	–0.44 (2.41)	–1.227
Low Tone-Mid Mass	*.802	–1.08 (3.77)	–1.921
Low Tone-High Mass	*.830	–0.97 (3.25)	–2.004
Mid Tone-Low Mass	*.918	–0.09 (2.26)	–0.282
Mid Tone-Mid Mass	*.806	–0.59 (3.35)	–1.187
Mid Tone-High Mass	*.839	–0.43 (2.97)	–0.971
High Tone-Low Mass	*.794	0.46 (3.24)	0.948
High Tone-Mid Mass	*.787	–0.35 (3.43)	–0.686
High Tone-High Mass	*.871	–0.49 (3.16)	–1.047

seen in **Table 2**, all paired samples *t*-tests showed no sginificant differences between blocks and all correlations between the paired means were shown to be statistically significant, demonstrating good task reliability for our final sample.

Multivariate Statistics

We wanted to quantify the relationships between participants' body size estimates (indexed by BMI_{hse}), their actual BMI, their body composition, and the stimulus properties. To do this, we used PROC MIXED (SAS v9.4) to build three linear mixed effects models. Two of these models had participants' PSE as the outcome variable, and one had Log_{10} DL as the outcome. The first model for PSE and the model for Log_{10} DL used participant's actual BMI, apparent stimulus muscle mass (i.e., low, mid, and high) and apparent stimulus muscle tone (i.e., low, mid, and high) as fixed effects. In the second model for PSE, we replaced participants' actual BMI with their percentage body fat and muscle mass as fixed effects. In all three models, we wanted to control for any influence of chronological age and the psychometric variables (BPSS-M, SATAQ, and DMS).

In order to avoid the possibility of introducing substantial variance inflation, we first checked for evidence of co-linearity among the psychometric variables. **Table 3** shows the Pearson correlations for these tasks across the sample of 45 participants. **Table 3** shows several substantial and statistically significant correlations between BPSS-M and subtests of the SATAQ and DMS. Therefore, we used PROC FACTOR in SAS v9.4 (SAS Institute, North Carolina, US) to carry out a principal component analysis with rotation, in order to identify any significant latent variable(s) in the psychometric data. We used the factor scores from these component(s) in our statistical models. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (which indicates the degree of diffusion in the pattern of correlations) was 0.80 suggesting an acceptable sample. Two principal components (PC) had Eigen values greater than Kaiser's criterion of 1 (i.e., 3.35 & 2.24) which, together, explained 70% of the variance. The scree plot showed an inflexion, i.e., Cattel's criterion, which also justified retaining just two PCs. The residuals were all small, and the overall root mean square off-diagonal residual was 0.07, indicating that the factor structure explained most of the correlations. The factor loadings on BPSS-M and each of the subtests of the SATAQ and DMS for the two PCs are shown in the last two columns of **Table 3**.

PC1 loaded primarily on to BPSS-M and all SATAQ subtests excluding that for muscularity. We interpreted increasing scores on this PC (henceforth referred to as Participant_Fat_Att) as representing increasing body image concern, together with perceived social pressures about body image from the media, peer groups, and family. PC2 loaded primarily on to the muscularity dimension of the SATAQ, as well as both DMS scales. We therefore interpreted increasing scores on this PC (henceforth referred to as Participant_Musc_Att) as representing perceived social pressure for and positive attitudinal responses towards increasing muscularity, combined with a drive to take part in activities that would achieve this outcome.

Each of the three linear mixed effects models was optimized by ensuring that a) any fixed effect added to a model contributed a reduction in -2 Log Likelihood, b) fixed effects were retained in a model only if their Type III test of fixed effects was significant at p < .05. The only exceptions to this were where one non-significant fixed effect comprised part of a significant two- or three-way interaction term, in which case it was retained. In addition, we permitted individual variation at the intercept level for each participant, by including a random effect for participant. Note, as both stimulus muscle mass and muscle tone comprised

TABLE 3 | Pearson correlations for the psychometric tasks. The last two columns show the factor loadings on BPSS-M and each of the subtests of the SATAQ and DMS for the two PCs from the principal components analysis.

	STQ Med	STQ Peer	BPSS-M	STQ Fat	STQ Fam	DMS Beh	STQ Musc	DMS Att	PC1	PC2
STQ Med	–								***0.83***	0.15
STQ Peer	0.64***	–							***0.81***	0.25
BPSS-M	0.52***	0.50***	–						***0.77***	–0.05
STQ Fat	0.59***	0.58***	0.44**	–					***0.72***	0.4
STQ Fam	0.37**	0.34*	0.40**	0.18	–				***0.62***	***–0.54***
DMS Beh	0.15	0.23	-0.01	0.27	-0.34*	–			0.04	***0.89***
STQ Musc	0.25	0.35*	0.06	0.42**	-0.25	0.74***	–		0.19	***0.86***
DMS Att	0.26	0.35*	0.20	0.30*	-0.29	0.64***	0.60***	–	0.20	***0.80***
DMS Totl	0.23	0.32*	0.11	0.31*	-0.33*	0.91***	0.74***	0.90***	–	–

* = $p < .05$, ** = $p < .01$, *** = $p < .001$.

NB: STQ Fat, STQ Body Fat; STQ Musc, STQ Muscular; STQ Fam, STQ Family pressure; STQ Peer, STQ Peer pressure; STQ Med, STQ Media pressure; DMS Att, DMS Attitudes; DMS Beh, DMS Behaviors; DMS Totl, DMS Total.

three levels (high, mid, and low), we used the high level as the control when dummy coding these variables in each model. The detailed outcome of the statistical modelling is shown in **Table 4** and is illustrated graphically in **Figures 3**, **4**.

The top row of **Figure 3** shows scatterplots from the first model for PSE, the index of participants' body size estimation (in BMI_{hse} units), and corresponds to "Model 1 for PSE" as shown in **Table 4**. Stimulus muscle tone increases across the three plots from the first (left) to the third (right) column. In each graph, values of PSE predicted from the model are plotted on the *y*-axis as a function of participant's actual BMI. Within each plot, data points and their respective regression lines for PSE on actual BMI are shown for low (black), mid (gray), and high (white) stimulus muscle mass. The black dashed line represents veridical responses, i.e., where a participants' body size estimate in BMI_{hse} units would exactly match their actual body size in BMI units. Not surprisingly, participants' estimates of their own body size systematically increased with their actual BMI, as many authors have shown before (e.g., 27, 47). A second point to note is that the slopes of the regression lines are all less than 1 (F1,43 = 5.34, p = .03). This is consistent with the yes-no task producing a contraction bias effect (48), as reported previously by 27, 28. This is a perfectly normal bias seen in unanchored magnitude estimation tasks, such as our yes-no task.

The important results for the current study are the significant effects that both the apparent muscle mass and muscle tone of the stimuli have on participants' body size estimates. Specifically, stimuli that are judged subjectively to have low muscle mass give rise to significantly higher body size estimates than do those judged to have mid muscle mass (LSmean difference = 1.58 BMI_{hse} units, t = 4.61, p < .001) or high muscle mass (LSmean difference = 1.76 BMI_{hse} units, t = 5.13, p < .001). The difference between body size estimates for mid and high muscle mass stimuli was not statistically significant (LSmean difference = 0.18 BMI_{hse} units, t = 0.52, p = .6). Similarly, stimuli that are judged subjectively to

TABLE 4 | Output from the 3 linear mixed effects models.

Model Parameters	F-value (DF)	Z-value	p-value	Parameter estimate	Parameter 95% CI	-2Log likelihood
1) Model 1 for PSE						
Empty Model						2142.2
Full Model						2001.4
Fixed Effects:						
Stim_Musc_Tone	6.97 (2, 350)		<.001	1) 0.50	–0.18 – 1.17	
				2) 1.28	0.60 – 1.96	
Stim_Musc_Mass	15.92 (2, 349)		<.001	1) 0.18	–0.50 – 0.85	
				2) 1.76	1.09 – 2.44	
Participant_BMI	64.35 (1, 44)		<.001	0.67	0.50 – 0.84	
Participant_Musc_Att	9.86 (1, 44)		.003	–1.18	–1.95 – –0.42	
Participant_Age	5.40 (1, 44)		.03	0.095	0.013 – 0.18	
Random Effect:						
Subject variance		3.97	<.001	4.78		
2) Model for Log_{10} DL						
Empty Model						177.4
Full Model						141.1
Fixed Effects:						
Stim_Musc_Tone	1.61 (2, 356)		0.20	1) –0.039	–0.044 – 0.017	
			<.001	2) 0.015	–0.046 – 0.076	
Stim_Musc_Mass	12.74 (2, 356)		.07	1) 0.58	0.24 – 0.93	
			<.001	2) 0.88	0.53 – 1.23	
Participant_BMI	3.37 (1, 44.9)			0.034	0.014 – 0.054	
Participant_BMI × Stim_Musc_Mass	10.34 (2, 356)			1) –0.021	–0.034 – 0.0071	
				2) –0.011	–0.044 – 0.017	
Random Effect:						
Subject variance		4.29	<.001	0.068		
3) Model 2 for PSE						
Empty Model						2142.2
Full Model						1799.9
Fixed Effects:						
Stim_Musc_Tone	7.40 (2, 309)		<.001	1) 0.53	–0.20 – 1.26	
				2) 1.43	0.70 – 2.17	
Stim_Musc_Mass	11.83 (2, 309)		<.001	1) –0.03	–0.77 – 0.70	
				2) 1.56	0.82 – 2.29	
Participant_Body_Fat	6.56 (1, 39)		.01	0.38	0.08 – 0.68	
Participant_Musc_Mass	5.80 (1, 39.2)		.03	–0.21	–0.41 – –0.013	
Participant_Age	9.80 (1,39.1)		.003	0.16	0.06 – 0.26	
Random Effect:						
Subject variance		3.91	<.001	7.02		

NB Stim_Musc_Tone, stimulus muscle tone; Stim_Musc_Mass, stimulus muscle mass; Participant_Musc_Att, psychometric latent variable for participants' attitudes to muscularity.

have lower muscle tone give rise to higher body size estimates. The corresponding differences in the LSmeans for body size estimates were: low to mid tone = 0.78 BMI_{hse} units, t = 2.27, p = .02; low to high tone = 1.28 BMI_{hse} units, t = 3.71, p < .001; mid tone to high tone = 0.50 BMI_{hse} units, t = 1.45, p = .1.

The middle row of **Figure 3** illustrates the statistically significant and independent influence that Participant_Musc_Att had on body size estimates. This also is derived from "Model 1 for PSE" as shown in **Table 4**. The graphs in this row follow the same regime as above except that the regression lines for the three different stimulus muscle mass levels are plotted at +1 *SD* (solid lines) and -1 *SD* (dashed lines) for Participant_Musc_Att. These graphs show very clearly that increasingly positive attitudes and drive towards muscularity are associated with higher body size estimates.

The bottom row of **Figure 3** shows scatter-plots of the output from the "Model for Log_{10} DL" in **Table 4**, which indexes the smallest difference in body size that participants can detect; i.e., their sensitivity in the yes-no task. As before, stimulus muscle tone increases across the three plots from left to right and the color coding for stimulus muscle mass is the same. In each graph, predicted values of Log_{10} DL are plotted on the *y*-axis as a function of participant actual BMI. It is clear from all three graphs that sensitivity reduces (i.e., DL increases) with increasing actual BMI. This effect is systematically greater—i.e., the regression slopes are steeper—for stimuli judged to have greater muscle mass. As **Table 4** shows, this effect is statistically significant. There is, however, no significant influence of stimulus muscle tone on DL (**Table 4**). The Weber fractions (i.e., $\Delta I/I$) reduce over the range of participant actual BMI from 15 to 42.5 for low stimulus muscle mass (0.074–0.033), remain approximately constant for mid stimulus muscle mass (0.058–0.047), and increase for high stimulus muscle mass (0.030–0.081). Therefore, participants gave responses which best approximated Weber's law when viewing stimuli with mid-level muscle mass.

Figure 4 shows two contour plots derived from the second model for PSE (see **Table 4**, "Model 2 for PSE"), in which the fixed effect of actual BMI was replaced with two fixed effects together constituting body composition: percentage skeletal muscle mass and percentage body fat of the participant. As **Table 4** shows, both of these factors had statistically significant effects on participants' body size estimates, although these effects were in opposite directions: body size estimates increased with increasing participant body fat and decreased with increasing participant muscle mass. Each plot in **Figure 4** shows predicted PSE in the *z*-axis: grey levels from black to white represent low to high predicted PSE. Participants' body fat and muscle mass are plotted on the *x*- and *y*-axes respectively. The plot on the left of **Figure 4** corresponds to high stimulus muscle mass and tone. The plot on the right of **Figure 4** corresponds to low stimulus muscle mass and tone. The white dashed line in each plot corresponds to a predicted PSE of 24 BMI_{hse} units. The important point illustrated by **Figure 4** is that variable combinations of participant muscle mass and body fat (i.e., body composition) can give rise to identical estimates of body size, when measured in BMI_{hse} units. However, in order to achieve the same PSE with stimuli of lower muscle mass and tone, this regime shifts to the left.

How Big Are the Differences in Estimated Bmi_{hse} for Participants Who Have the Same Actual BMI?

The implication from **Figure 4** is that individuals who have the *same* actual BMI, but who have *different* body compositions, will estimate their body size, when indexed in BMI_{hse} units, very differently. This is illustrated by two participants from our dataset, *A* and *B*, in the left pane of **Figure 4**, both of whom have a BMI ~23. Clearly, in the context of a body size estimation task where only the adiposity of stimuli is changed, this is potentially very undesirable. Therefore, we wanted to quantify just how large this variation in body size estimation can be. In principle, we could achieve this directly if we knew how much variation there is in the body composition of the participants at different actual BMIs. Unfortunately, in our experimental dataset, there were not enough participants whose actual BMI fell within the range of a BMI unit +/- 0.5 to estimate such covariance reliably. Instead, we used a body composition database which was obtained from 178 Caucasian males (age *M* = 33.6, *SD* = 11.15; actual BMI *M* = 25.4 *SD* = 3.75; body fat *M* = 14.4 *kg*, *SD* = 7.29 *kg*; skeletal muscle mass *M* = 39.1 *kg*, *SD* = 5.7 *kg*) using a Tanita MC780MA multi-frequency segmental body composition analyzer. We used this dataset to calculate the covariance between body fat and skeletal muscle mass, at each actual BMI point (+/-0.5 BMI units) for which there were at least 15 observations—i.e., where the covariance estimate is more likely to be reliable. According to this criterion, the covariance values at BMIs 22, 23, 25, and 26 were -0.55, -0.41, -0.37, and -0.17 respectively. Moreover, we had 12 BMI points between BMIs 18–31 for which we had at least 5 data points, and the average covariance across these 12 points was *M* = -0.35, *SD* = 0.23. We then used PROC SIMNORM in SAS v9.4 (SAS Institute, North Carolina, US) to calculate 5 bivariate normal distributions, each with 10,000 data points, for a range of covariance values from -0.15 to -0.55 in steps of 0.1, consistent with the covariance values that we observed in the data at different BMIs. Next, for each of these 5 distributions, we computed prediction ellipses that captured 50%, 60%, 70%, 80%, and 90% of the possible combinations of percentage body fat and skeletal muscle mass—i.e., from about half of the range in each distribution to almost the full range, as is illustrated in **Figure 5A**. In the final step, separately for each of the five distributions, we identified from these ellipses the biggest difference in body composition at each of the prediction values (i.e., lowest body fat with highest muscle mass and vice versa) and used Model 2 for PSE (see **Table 4**) to convert these participant body composition values into self-estimates of body size, expressed in BMI_{hse}. **Figure 5B** shows plots of the difference in these pairs of BMI_{hse} estimates (*y*-axis), as a function of prediction ellipse percentage (*x*-axis). Separate lines are plotted for the five different covariances between body fat and skeletal muscle mass. The white band in the background highlights the most plausible range of BMI_{hse} differences, given that it selects prediction ellipses that capture most but not all combinations of body fat and muscle mass computed from covariance values in the middle of the range that we observed in real data. What is striking is that even a conservative evaluation of these simulations forces the conclusion that differences in body size estimation by participants who have the same actual BMI are large, typically between ~5–7 BMI_{hse} units, which is enough to leapfrog between body weight classifications in World Health Organisation, (23) criteria.

Applications of Real Skeletal Muscle Mass Values to Correct Bmi_{hse} Estimates of Body Size

As a final step in our analyses, we attempted to assign plausible muscle mass values to our stimuli (as distinct from qualitative labels) and recalculate the effects of stimulus muscle mass and tone on body size estimates. If our strategy for calibrating stimuli for BMI_{hse} is completely unrelated to reality, then we should expect to see our error estimates all but disappear. If however the analyses we present have some validity, we should expect to see similar effects once plausible muscle mass values have been assigned.

As described in the *Methods* section, we generated low, mid, and high muscle content bodies by setting the morph dimensions of muscularity and muscle tone in Daz Studio to either low, mid, or high levels. Therefore, to assign plausible low, mid, and high muscle mass values in kg to each stimulus class, we first divided the distribution of skeletal muscle mass values from our biometric database of 178 men into three ranges split at the 33rd and 67th centiles (low mid and high skeletal mass means were: M = 33.67 kg, SD = 2.48; M = 39.00 kg, SD = 3.30; M = 44.81 kg, SD = 4.20, respectively), and assigned a categorical variable with three levels to correspond to these three ranges. We then used PROC MIXED in SAS v9.4 to predict actual BMI in this database from i) the centile to which a skeletal muscle mass belonged, ii) an individuals' waist circumference, and iii) an individual's hip circumference. The fitted model thus allowed us to connect the biometric database to our experimental dataset because, for every body-size estimate in BMI_{hse} units, we know the waist and hip circumference of the corresponding CGI model. For example, for a high muscle mass, mid muscle tone stimulus, we can enter the waist and hip values that correspond to a body size estimate in BMI_{hse} units into the fitted model from the biometric database and calculate what the body size estimate would be in real BMI units. As a final step, having converted every body-size estimate from BMI_{hse} to real BMI units in this way, we re-ran model 1 in **Table 4**. We found significant Type III fixed effects for: stimulus muscle mass (F2,349 = 8.11, p < .001), stimulus muscle tone (F2, 350 = 6.63, p = .001), participant age (F1,44 = 5.41, p = .02), participant actual BMI (F1,44 = 64.36, p < .001), and Participant_Musc_Att (F1,44 = 9.86, p = .003).

Post hoc pairwise comparisons still showed that low muscle mass stimuli gave rise to significantly higher body size estimates than did mid muscle mass (LSmean difference = 0.89 corrected BMI_{hse} units, t = 3.08, p = .002) or high muscle mass stimuli (LSmean difference = 1.09 corrected BMI_{hse} units, t = 3.79, p < .001). The difference between body size estimates for mid and high muscle mass stimuli was not statistically significant (LSmean difference = 0.21 corrected BMI_{hse} units, t = 0.71, p = .5). With respect to muscle tone, the corresponding differences in the LSmeans for body size estimates were: low to mid tone = 0.63 corrected BMI_{hse} units, t = 3.08, p = .03; low to high tone = 1.05 corrected BMI_{hse} units, t = 3.62, p < .001; mid tone to high tone = 0.42 corrected BMI_{hse} units, t = 1.47, p = .1. In short, assigning plausible muscle mass values to our stimuli gave rise to a qualitatively similar pattern of results, even though the sizes of the effects were reduced by ~40% for stimulus muscle mass and ~18% for stimulus muscle tone.

DISCUSSION

The primary aim of this study was to estimate how much variation there is in men's own body size estimates, when measured in BMI_{hse} units, caused by i) variation in the participants' own body composition and ii) variation in the apparent muscle mass and muscle tone of the stimuli being judged. Our results suggest that the accuracy of male body judgments is not captured using body stimuli which only vary in adiposity, but instead needs variation in both adiposity and muscularity to accurately represent the perception of body image and reflect the variation of these dimensions in the male population.

Consistent with previous studies where women estimated their own body size or other women's body size [e.g., Refs. (27, 47, 49)], in the current study, plots of estimated body size are linearly predicted by the participant's own actual BMI, but with a slope of less than unity (see the top two rows of **Figure 3**). Lower actual BMI participants over-estimate body size, middle-range actual BMI participants' estimates are the most accurate, and high actual BMI participants under-estimate. This pattern of responses is predicted by a normal perceptual feature of magnitude estimation called contraction bias (48). It occurs when the psychophysical task is not anchored, which means that the participant does not have available to them constant reminders of the smallest and largest examples from the range of stimuli they will be presented. In this situation, body size estimation must be made by comparing the difference between the size of the stimulus presented to the body size the participant believes themselves to have with an internal reference distribution based on all the bodies that the participant has ever seen. This kind of judgment is most accurate when the participant's belief is closest to the average body size of their internal reference distribution, and increasingly less accurate as the two diverge. When there is an increasing difference between the reference and the body size being estimated, the participant makes an estimate closer to the average of the reference distribution than it should be. Hence, the term contraction bias (48).

In addition, the ability to detect a change in body size (as indexed by the DL) becomes progressively worse as the BMI_{hse} of the bodies being judged increased (see the bottom row of graphs in **Figure 3**). This is consistent with another feature of perception called Weber's law. Weber's law states that the just noticeable difference (JND) between two stimuli will be a constant proportion of their magnitude, leading to a constant Weber fraction over the stimulus range (46). This means that discriminating between higher BMI_{hse} bodies requires progressively larger differences in BMI_{hse} between stimuli (29).

Psychological Attitudes

As in previous studies with female participants, the psychological state of the participants modulates the accuracy of their self-estimates of body size [e.g., Refs. (27, 47]. In the current study, this is an effect that was statistically independent of their perceptual responses and is consistent with a multidimensional model of body image in which the size and shape someone believes themselves to be is a linear combination of attitudinal and perceptual factors [cf. (1)]. We found that men who have increasingly positive attitudes and drive towards muscularity were more likely to over-estimate their body size. However, by contrast to previous findings with female participants, body fat concerns did not influence the male participant's judgments. This may reflect a difference in the relative importance of muscularity and body fat in men and women. Body fat has been consistently identified as the central feature of body image concerns in women, whereas in men the central concern has been identified as muscularity [e.g., Refs. (19, 50–54). This is reinforced by a strong social media pressure to be both high in muscularity and low in adiposity (55, 56). Additionally, concerns about muscularity, along with concerns with adiposity, are suggested to play a key role in the development of anorexia nervosa in men (14), emphasizing the need to be able to independently index body image concerns about muscularity and adiposity to determine their separate importance in its etiology.

Apparent Muscle Mass and Muscle Tone of the Stimuli

Looking *across* the stimulus types, our results suggest that as apparent muscle mass and muscle tone *decrease* in the stimuli, so men effectively selected images with higher BMI_{hse} values to match the body size they believe themselves to have. This is an important result in several ways. First, it gives some insight into how the men may have been solving the task. Our stimulus calibration procedure is based on a multiple regression equation derived from anthropometric measurements obtained from the Health Survey for England, specifically waist and hip circumferences. This means that in our set of CGI bodies, a stimulus that has a BMI_{hse} of 25 will have exactly the same waist and hip circumference irrespective of which combination of low/mid/high muscle mass and low/mid/high muscle tone it comprises. Therefore, according to our first hypothesis, if our participants had been using the horizontal widths across the waist-hip region to match their own body size belief against the stimulus [cf. (31)], then we would not have found statistically significant differences in body size estimates between the different levels of stimulus muscle mass and tone. Given that men are more likely to deposit fat on the stomach than women (57, 58), fixating this region for estimating adiposity would be an even better strategy for men than for women. This is because the men would have reliably selected the same matches across muscle mass/tone combinations for a given belief about their own body size (i.e., they would have chosen the bodies with the same waist and hip widths). Had this been the case, graphically we would have seen the black, white, and gray regression lines in the first two rows of **Figure 3** overlie each other. But they do not. Instead the self-estimates of body size were ~2.5 BMI_{hse} units greater for the low muscle mass stimuli than either the mid or high muscle mass stimuli, and this is consistent with our second hypothesis: that men may attend to the chest and upper arms when matching stimuli to the body size/shape they believe themselves to have.

Critically, when we recalculated these effects, having attempted to assign plausible skeletal muscle mass to our stimuli, we observed the same pattern of results, albeit the effect sizes were reduced by up to ~40%. This provides convergent evidence that reinforces the need for all researchers to be running these kinds of experiments with stimuli that are correctly calibrated for body composition and BMI.

From a practical point of view, constructing a figural scale for body-size estimation where *only* adiposity changes would mean that an arbitrary choice would need to be made about the apparent muscularity of the stimuli presented to participants. The present results show that an arbitrary choice of this kind could lead to fixed errors in any survey results using such a scale. For example, suppose two figural scales were developed, one from our low muscle mass/low muscle tone images and the second from our mid muscle mass/mid muscle tone images. We would expect to see, on average, that self-estimates of BMI_{hse} would be ~2.5 BMI_{hse} units higher for the former scale, and this could lead in turn to over-estimates of obesity rates, for example. Similarly, research highlights that there is a comparable split between males who wish to lose weight, and those seeking to gain weight (16–18). Presenting a stimulus set with an arbitrary choice of visual muscularity would introduce considerable uncontrolled variability into any epidemiological study or public health assessment. In a clinical sample, e.g., men with eating disorders or muscle dysmorphia, such erratic body size estimation may even compromise the effective intervention and treatment of body image distortion (54).

Participant Body Composition

We calculated the potential variation in self-estimates of body size, when measured in BMI_{hse} units, that is attributable to the body composition of the participant. To facilitate these calculations, we needed sensible estimates of the covariance between body fat and skeletal muscle mass as a function of actual BMI. We obtained these covariance estimates from a bio-impedance database of 178 male volunteers and used them in a simulation to identify a range of maximum differences in body composition in individuals who would have the same BMIs. As a last step, we entered these body composition values into our fitted model from the experiment which predicts body size estimates in BMI_{hse} units from the body composition of the participant, and calculated the predicted differences in body size estimates. The results are illustrated in **Figure 5B**. For participants with the *same* actual BMI, the results show that self-estimates of body size can potentially vary over a range of ~5–7 BMI_{hse} units based on differences in the skeletal muscle and fat composition of the participant. This suggests a strong potential source of uncontrolled variance in body size estimation when using body scales which are designed to vary only in adiposity. Errors of this magnitude can easily move a participant's self-estimate of BMI_{hse} between BMI categories, such as from normal to overweight or even to obese.

This study strongly suggests that for men's bodies, stimuli that do not account explicitly for variation in both muscle mass and muscle tone in the stimuli, as well as measurement methods that do not take explicit account of body composition in the participant, may lead to significant errors in self-estimates of body size. This leads to the important question of whether a similar problem exists for self-estimates of body size in women. Although women's bodies tend to show a lower degree of variation in their proportion of muscle to fat than male bodies, the increase in resistance training in fitness and exercise regimes has increased this variation. Moreover, the trend towards "fitspiration," a lean and toned body rather than just a low-fat body, has created a strong media and social pressure to achieve an athletic ideal [e.g., Refs. (59, 60)]. In addition, in women with an eating disorder such as anorexia nervosa, there is significant variation in body composition linked to the severity of their condition (61, 62). Currently for women, test stimuli usually vary only in simulated adiposity, but our results suggest that this may not be a very accurate way of assessing women's perception of body size. Future studies should determine whether self-estimates of body size are affected by the female participant's body composition and whether their perception of their body size can be more accurately captured by varying the body stimuli used to index their judgment in multiple dimensions, such as adiposity and muscularity.

Is There a Solution?

In this study, healthy men made nine self-estimates of body size, expressed in units of BMI_{hse}. To do this, they used the same yes-no task nine times, but on each task run, all the stimuli for that run represented a different combination of apparent muscle mass and tone. During each task run, only the adiposity of the men in the stimuli varied. Therefore, the participants were essentially picking what level of adiposity in the stimulus, for a fixed combination of muscle mass and tone, matched the body size they believed themselves to have. We found that variation in both the apparent muscle mass and tone in the stimuli, as well as individual variation in the body composition of the participant, led to far reaching differences in body size estimation, when expressed in BMI_{hse} units. Qualitatively, we replicated these effects when we assigned plausible real muscle mass values to our stimuli. This not only confirms but also quantifies to some extent what researchers in this field have long suspected: that BMI has limited utility as a metric for body size estimation in men. So, the question is, if not BMI, then what? One obvious alternative is to have a stimulus set that represents variation in both muscle mass and adiposity parametrically. This way, participants can match the body *shape* they believe themselves to have to the stimulus on offer. Clearly, some authors have already gone down this route with the use of line-drawn images based on the somatomorphic matrix (25, 63) as well as CGI versions of the same (26). However, it is not clear that there is an accurate and calibrated mapping in these stimuli between the body shapes illustrated and the adiposity and muscle mass they are supposed to represent. One way to improve on this situation, therefore, would be to combine body composition measurements from bio-impedance or dual-energy X-ray absorptiometry (DXA) with 3D body shape scanning techniques in a large sample of volunteers. Such a dataset could be used to reveal the statistical mapping between 3D body shape change as a function of muscle mass and adiposity, and these statistical models could be used in turn to create appropriately calibrated 3D CGI models of men. Such stimuli could then be incorporated into a method of adjustment task in which both dimensions of muscle mass and adiposity could be manipulated simultaneously by mouse control. Development of such stimulus sets are vital in providing comparable measurements of the male body within size estimation tasks. Not only will the achievement of this allow for much needed progress in understanding the etiology of body image distortions in men but will provide headway in the development of gender specific interventions for men with body image disorders. Initial steps have been taken along this route in studies of body size estimation in men and women by combining 3D body shape scans with BMI measures (28, 64–66), but clearly need to be extended to allow manipulation of body composition.

In conclusion, this study suggests that the accuracy of male body judgments cannot be captured simply using body stimuli only varying in adiposity, but instead requires variation in both adiposity and muscularity to accurately index the perception of body image and reflect the significant variation in these dimensions in the male population.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the relevant guidelines and regulations set out by the local ethics committees at Northumbria University and the University of Lincoln with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the ethics committees at Northumbria University and the University of Lincoln.

AUTHOR CONTRIBUTIONS

All authors contributed to the planning, data collection, and write-up of the study.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Perceptive Body Image Distortion in Adolescent Anorexia Nervosa: Changes After Treatment

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One key symptom of anorexia nervosa (AN) is body image distortion (BID). For example, AN patients who are asked to perform body size estimation tasks tend to overestimate their body size; this is thought to indicate a distortion of the perceptive component of body image. Although BID is an important treatment objective, only few treatment approaches explicitly target body image, and even fewer target the perceptive component. Moreover, very little is known about how patients' perceptive body image changes after treatment and related weight gain. Consequently, we investigated changes of the perceptive BID in adolescent AN patients at the beginning (T1) and the end (T2) of inpatient treatment using a body size estimation task. A total of 38 AN patients performed the test for Body Image Distortion in Children and Adolescents (BID-CA) within the first 2 weeks of inpatient treatment and at the end of treatment. The results were compared to 48 healthy control (HC) participants performing the same task once. At T1, AN patients overestimated their body size more than HC, i.e., a total overestimation of 33% in AN patients *vs*. 11% in HC. At T2, AN patients overestimated their arm size to the same degree that they did at TI, but overestimations for the thigh and waist were reduced, and their overestimations for the waist no longer differed from the HC group. Thus, after treatment, AN patients were partly able to more realistically estimate their body size. Several factors may have influenced the observed changes in body size estimation, including task repetition, deliberate adjustment, growing into their preexisting perceptive body image through weight gain, as well as targeted and non-specific psychotherapeutic treatments. In conclusion, the perceptive BID in adolescent AN patients is persistent but also modifiable. Although diverse factors presumably play a role in changing BID, these findings suggest that AN patients may benefit from targeted treatment of BID.

Keywords: anorexia nervosa, body image distortion, body size estimation, adolescents, inpatient treatment

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INTRODUCTION

Anorexia nervosa (AN) is an eating disorder associated with restrictive food intake and severe underweight (1). One key symptom of AN that often motivates this detrimental dietary behavior is BID, including negative feelings and appraisals toward the body (cognitive–affective component) and body size overestimation (perceptive component). BID may be highly persistent and is known to be prognostic for both the initial manifestation (2, 3) and the short- and long-term outcomes of the disorder (4–6).

The cognitive–affective component of the body image is typically measured by self-report questionnaires or interviews. It comprises different aspects that patients are usually consciously aware of and well able to describe, including, e.g., body dissatisfaction, overvaluation of shape or weight, preoccupation with shape or weight, and fear of weight gain (7). Despite diverse methods of measurement and ongoing debates on the relative importance of different aspects, there is a consensus that the cognitive–affective component of body image is strongly affected and negatively distorted in AN (7–9); thus, the cognitive–affective aspects of body image are an important treatment objective (10). Indeed, targeted treatment leads to clear improvements in body weight and overall eating disorder psychopathology (e.g., eating concern and weight concern). Interestingly though, the improvements in the cognitive–affective aspects that are particularly related to the perception of one's own body (shape concern, feeling fat) seem to be less pronounced (5, 11).

The perceptive component of the body image is related to AN patients' tendencies to perceive their own body as bigger than it actually is. This component is less conscious in everyday life, but it can be measured by visual and metric body size estimation tasks (12, 13). In visual body size estimation tasks, images of one's own body or stylized bodies with different sizes are presented, and participants have to select or configure the picture so that it best matches their own body. In metric body size estimation tasks, AN patients first estimate the size of several body parts, and, second, these body parts are measured, e.g., using a rope or caliper. Both methods typically include the calculation of index values relating the estimated and real body sizes to indicate the amount of overestimation. A recent review and a meta-analysis of studies using such tasks (12, 13) conclude that there is clear evidence of body size overestimation in AN. Moreover, in adolescent AN patients, less body size overestimation predicted a better long-term outcome (4). This strongly suggests that the perceptive component of BID should also be a treatment objective. However, so far, only few treatment approaches directly target the perceptive component of BID.

One such treatment approach is body exposure using a mirror or video feedback. This technique targets both AN patients' tendencies to have a distorted visual perception and a negative cognitive evaluation of their body (14, 15). Indeed, this technique has been shown to reduce visual body size overestimation (16). However, it is unclear whether this visual overestimation in AN patients is due to an impaired visual perception *per se*, as several studies have reported that AN patients have intact vision (17) and visuospatial processing (18). An alternative explanation may be given based on the consideration by Molbert et al. (13) that visual size estimation tasks assess explicit (but not implicit) representations of the body. It may be argued that overestimation in visual body size estimation tasks, as well as changes in visual overestimation after treatment, are driven by explicit cognitive–affective aspects to a large part.

Another approach is hoop training (19), in which patients learn to choose and move through a hoop that best fits their body size. This technique addresses multisensory body perception, including visual, tactile, and proprioceptive perceptions. This approach works to incorporate recent findings that indicate AN involves not only visual distortion but also nonvisual multisensory impairments, including tactile and proprioceptive perception and multisensory integration (20–22). In their pilot study, Keizer et al. (19) found that hoop training specifically improved results in the hoop task, while both treatments as usual and additional hoop trainings led to improvements in visual and tactile estimation tasks. As the sample size was very small, with only 14 AN patients completing the hoop training, this approach's potential to improve multisensory body perception requires further investigation. Nonetheless, although no statistics were calculated, the results suggest that, across treatment groups, perceptive BID was persistent but less pronounced after treatment. This is further supported by similar findings in AN patients who completed eating disorder treatment (23). While treated AN patients did not differ from healthy control (HC) participants with respect to their cognitive–affective body image, their perceptive BID was persistent but less pronounced after treatment.

Overall, the treatment approaches mentioned above have aimed to address the perceptive component of body image, namely, the visual aspect (*via* the body exposure approach) or multisensory aspects (*via* hoop training) of body perception. Further, findings from these studies have shown that visual body exposure indeed improved BID in a visual size estimation task (16), and hoop training improved performance in the respective hoop task (19). Nevertheless, even though BID is a key symptom and highly relevant treatment objective in patients with AN, so far, only very few studies have investigated changes of the perceptive BID in AN, both after targeted or non-targeted treatments. Hence, little is known about how AN treatment and associated weight gain modifies the perceptive BID. Moreover, to the best of our knowledge, no studies have used a metric body size estimation task before and after treatments. Metric body size estimation tasks are considered to assess more implicit perceptive body representations (13) and are, therefore, particularly suited to capture aspects of the body image that are less conscious and, hence, perhaps difficult to change.

The aim of the present study was, therefore, to investigate changes of perceptive BID in adolescent patients with AN. To this end, AN patients completed a metric body size estimation task (Test for Body Image Distortion in Children and Adolescents; BID-CA; (24) within the first 2 weeks of inpatient treatment and at the end of treatment. Treatment comprised a phased multimodal treatment plan that included a disorder-specific body-psychotherapeutic treatment approach. We expected to replicate previous findings of body size overestimation in adolescent AN patients compared to HC participants (24–26). Based on previous findings in AN patients who received treatment targeting perceptive BID (16, 19) and in AN patients who had completed eating disorder treatment (23), we expected body size overestimation in AN patients to persist after treatment but to be less pronounced than before treatment.

MATERIALS AND METHODS

Participants

This study included female participants aged 12 to 19 years. The study protocol, including partly retrospective data collection, was approved by the ethics committee of the Medical Association of Westphalian-Lippe and the University of Münster. Participants in the HC group were recruited in secondary schools in Münster, Germany. They had to have a BMI between the 10th and 90th age percentiles and no current or prior mental illness according to structured clinical interviews, i.e., EDE-I (27) and K-DIPS (Unnewehr, Schneider, & Margraf). Patients with AN were recruited in a specialized ward for eating disorders at the Department of Child and Adolescent Psychiatry, University Hospital Münster, Germany. Patients had to have a primary diagnosis of AN or atypical AN (Eating Disorder Not Otherwise Specified; EDNOS). All comorbid diagnoses were included, except for neurodevelopmental, schizophrenia spectrum, or bipolar disorders. Diagnoses were based on clinical evaluation according to the criteria in the ICD 10. The fulfillment of the criteria in the DSM 5 was confirmed retrospectively based on the patient records and, if available, structured clinical interviews.

Inpatient Treatment

All AN patients were admitted to a specialized ward for eating disorders at the Department of Child and Adolescent Psychiatry, University Hospital Münster, Germany, and treated with a phased multimodal treatment plan. Of special importance for the results of this study, all AN patients were treated several times a week with a disorder-specific body-psychotherapeutic approach based on the Concentrative Movement Therapy (CMT; www.dakbt.de). CMT is rooted in the psychodynamic approach and operates through the stimulation of sensory motor body experience and non-verbal and verbal symbolizations. The disorder-specific body-psychotherapeutic approach used here particularly focuses on the needs of AN patients. In a bottom-up fashion, therapeutic work starts with promoting the experience of one's own body, whereby patients perform practical exercises that encourage conscious tactile, proprioceptive, and interoceptive perception (perceptive component of body image). Then, treatment goes on to integrate these perceptions with mental representations of the body and the self (cognitive–affective component of body image), and finally, AN patients are encouraged to exchange their bodily experiences with others and to solve related emotional conflicts in interpersonal relationships, e.g., in the patient group and in parent–child interaction units (interpersonal component).

Procedure and Materials

Procedure

The data analyzed in this study were collected either as part of a larger study protocol that will not be reported here (all HC subjects and 19 AN patients) or retrospectively and anonymously from patient records (19 AN patients). All participants of the larger study received written and oral study information, and the participants and their parents gave their written informed consent. At the first date of the larger study, HC participants were weighed (in underpants only) and measured (barefoot, straight posture with heels, back, head, and palms at the wall) by an investigator, in the same way that AN patients are weighed and measured by nursing staff in the ward, and completed the structured clinical interviews, the body size estimation task (BID-CA), and psychopathology questionnaires (see below). For all AN patients, data were initially collected as part of the clinical routine and were then extracted from the patient records. However, only later were structured clinical interviews included in this routine, so these interviews were not always available (see *Results*). In all AN patients, weight, height, and BID-CA were collected at two time points: first, within the first 2 weeks of inpatient treatment (T1) and, second, after treatment (T2). To test patients after the largest possible weight gain, the T2 measurement was conducted at the end of treatment in our hospital, which could be at the end of inpatient treatment or during a following day patient or outpatient treatment. The target weight was defined as a BMI at the 25th age percentile. This was not always achieved, and AN patients were included independent of their final weight status.

Questionnaire Data

Psychopathology was assessed by self-report questionnaires. Eating disorder symptoms were captured using the Eating Disorder Inventory for Children (EDI-C; German version) (28), and body dissatisfaction was assessed with the Body Shape Questionnaire (BSQ; German version) (29). Furthermore, symptoms of depression were captured with the Beck Depression Inventory 2 (BDI-II; German version) (30), and symptoms of anxiety with the Screen for Child Anxiety Related Disorders (SCARED-D; German version) (30).

Test for Body Image Distortion in Children and Adolescents (BID-CA)

The BID-CA (24) was used to assesses the perceptive component of BID. The test was conducted by the same person (body psychotherapist) in all AN patients, while HC participants were partly measured by a different trained investigator. Before the test started, participants were instructed to tune into the task by becoming aware of their own body and its form and were encouraged to palpate their body if desired to promote access to the implicit perceptive body image. Participants were then asked to estimate the size of their upper arm at the level of their armpit, their thigh at the level of their crotch, and their waist at the level of their belly button using a string. The correct positions were indicated by the investigator at her own body. The string was placed on a table, and the participants were asked to form a circle (with one end of the string connecting to the rest of the string) that equaled the size of their body parts. The length of the string needed to form the circle was determined using a tape measure (as the rope was 0.9 cm thick, the length was measured form the point where the inner part of the end of the string touched the rest of the string). Next, the actual circumference was measured using the string, and as before the length of the string that was needed to make a circle around the body part was determined using the tape measure. Three BID-Indices (arm, thigh, waist) were calculated by dividing the patient's estimated circumference by the actual circumference (in cm) and multiplying the result by 100. As a result, BID-Indices with a value of 100 reflect a perfect estimation, while deviations above or below 100 reflect the percentage of over- or underestimation, respectively.

Statistical Analyses

Statistical analyses were conducted using IBM SPSS Statistics 25. To test for group differences between AN patients and HC regarding age, body height, BMI, and psychopathology, pairwise group comparisons for age in month, body height in meters, BMI, and the global scores of all questionnaires (EDI-C, BSQ, BDI-2, SCARED-D) were conducted by independent *t*-tests. To test for group differences between AN patients and HC regarding BID-Indices at T1 and T2, respectively, two separate mixed analyses of variance (ANOVAs) were calculated with the between-subject factor being the group (AN_T1, HC, and AN_T2, HC) and the within-subject factor being the body part (arm, thigh, waist). *Post hoc* pairwise group comparisons for the BID-Indices of each body part were conducted by independent *t*-tests. As an additional statistical control for the fact that BID-Indices generally tend to increase with decreasing body size (31), one-way ANOVAs were calculated for each time point and each body part separately, with the between-subject factor being the group (AN, HC) and the measured body size being the covariate. Next, to test for changes in BID-Indices in the AN group from T1 to T2, a repeated measures ANOVA was calculated with the within-subject factors of time (T1, T2) and body part (arm, thigh, waist). *Post hoc* comparisons of T1 *vs*. T2 for the BID-Indices of each body part were conducted by dependent *t*-tests. Moreover, to investigate what drove possible BID-Index changes, the percentage change of the measured and estimated circumferences was calculated, correcting for overall size differences between body parts. Next, a repeated measures ANOVA with the factors of method (measured, estimated) and body part (arm, thigh, waist) were calculated, as were respective dependent *post hoc t*-tests. All statistical tests were corrected in the event that assumptions were violated, and the level of significance was 0.05.

RESULTS

Sample

The final study sample comprised 38 AN patients and 48 HC participants. AN patients were selected based on the study inclusion and exclusion criteria and on the availability of all BID-CA data. Of the 50 AN patients treated during the study period, 12 (24%) were excluded. Of these, two (4%) performed only the T2 measurement, because they had been admitted before the measurements started, and nine (18%) performed only the T1 measurement, because they discontinued treatment prematurely (n = 5; 10%) or changed to another hospital or practitioner (n = 4; 8%). Finally, one AN patient (2%) was excluded due to a Turner syndrome diagnosis. There were no differences between included and excluded AN patients regarding basic clinical variables (age, BMI, duration of illness, prior inpatients treatments); however, excluded AN patients had a shorter treatment duration (cf. **Supplementary Tables 1 and 2**). In the HC group, 3 of the originally 51 participants were excluded due to enhanced psychopathology. In the final sample, structured clinical interviews and questionnaire data were available only for 32 of the included 38 AN patients. AN patients (M = 189.42 months, SD = 18.31) were younger[1] than HC (M = 203,10 months, SD = 20.81), age: $t(84) = -3.191$, $p = .002$; had similar body height (AN: M = 1.68 m, SD = 0.06; HC: M = 1.68 m, SD = 0.05), $t(84) = 0.113$, $p = .91$; and, as expected, had lower BMI, $t(80{,}65) = 12.19$, $p < .001$, and higher psychopathology (**Table 1**). Most of the AN patients (N = 33; 86.8%) fully met diagnostic criteria, a majority had restrictive type AN (N = 27; 71.1%), and almost half of them (N = 18; 47.4%) had at least one comorbid disorder (**Table 2**). The average duration of illness before admission was merely 1 year (M = 11.63 months, SD = 10.47; cf. **Supplementary Table 1**). The majority of cases had their first inpatient treatment for AN (N = 27; 71.1%), but some also had one (N = 7; 18.4%) or two (N = 4; 10.5%) prior hospital stays. The average duration of inpatient treatment was approximately 5 months (*M* = 158.34 days, *SD* = 82.68), and the T2 measurement was performed between 30 days before and 98 days after discharge (M = 7.26 days, SD = 31.21). Deviations between discharge and T2 resulted from treatment extensions (N = 5) or measurements at the end of a subsequent day patient or outpatient treatment (N = 9). AN patients showed an average weight gain of nearly 11 kg (*M* = 10.97 kg, *SD* = 4.90). The average BMI_{SDS} at T2 ($M = -0.66$, SD = 0.66), corresponding approximately to the 24th age percentile, and an average increase in BMI_{SDS} of about two standard deviation scores from T1 to T2 (**Table 3**) indicate significant and clinically relevant weight gain in the AN group.

Body Image Distortion Indices

As expected, at T1, AN patients exhibited larger BID-Indices compared to the HC group (**Table 4**; **Figure 1**). The respective ANOVA revealed an interaction of group × body part, $F(2, 168) = 6.21$, $p = .002$, $\eta^2 = .07$, as well as a main effect of group, $F(1, 84) = 50.79$, $p < .001$, $\eta^2 = .38$ (cf. **Figure 1**, **Table 3**). *Post hoc t*-tests (corrected for unequal variances when necessary) revealed that the expected effect of larger BID-Indices in the AN compared to the HC group was highly significant in all parts of the body—arm: $t(84) = 4.24$, $p < .001$; thigh: $t(53.32) = 7.10$, $p < .001$; and waist: $t(58.01) = 4.69$, $p < .001$ (cf. **Table 1**). The interaction arose (at least in part) through different effect sizes, with a medium effect at the arm ($r = .42$) and large effects at the thigh ($r = .70$) and waist ($r = .52$). As an additional control, one-way ANOVAs using measured body size as a covariate confirmed higher BID-Indices in AN patients *vs*. HC when controlling for a general effect of smaller body sizes—arm: $F(1, 83) = 22.01$, $p < .001$, $\eta^2 = .15$; thigh: $F(1, 83) = 18.93$, $p < .001$, $\eta^2 = .19$; and waist: $F(1, 83) = 10.36$, $p = .002$, $\eta^2 = 0.11$. Moreover, BID-Indices differed by body part across groups, which was indicated by a main effect of body part, $F(2, 168) = 25.617$, $p < .001$, $\eta^2 = .24$.

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[1] As analyses using an age-matched HC sample (N = 35) revealed no qualitatively different results; the whole HC sample was kept.

TABLE 1 | Psychopathology questionnaires.

	AN (n = 32)		HC (n = 48)			
	M	*SD*	*M*	*SD*	*d*	*p*
BDI-II	27.75	12.11	3.25	3.30	2.43	$p < .001$
SCARED	30.41	16.40	13.35	8.59	1.17	$p < .001$
BSQ	116.06	40.72	51.55	16.25	1.85	$p < .001$
EDI-C	227.97	61.76	97.35	33.78	2.37	$p < .001$
EDI-C DT	22.06	10.03	4.04	3.95	2.10	$p < .001$
EDI-C BD	30.00	9.55	10.21	7.46	2.15	$p < .001$

(BDI-II, Beck Depression Inventory 2; SCARED-D, Screen for Child Anxiety Related Disorders; BSQ, Body Shape Questionnaire; EDI-C, Eating Disorder Inventory for Children; DT, drive for thinness; BD, body dissatisfaction).

Post hoc t-tests revealed that, across groups, BID-Indices were similar at the arm and thigh (M = 116.53, SD = 19.54 and M = 116.77, SD = 23.46, respectively), $t(85) = 0.11$, $p = .910$, $r = .01$, while overestimation was larger at the waist (M = 129.65, SD = 19.52) in comparison to the arm, $t(85) = 6.26$, $p < .001$, $r = .56$, and thigh, $t(85) = 6.10$, $p < .001$; $r = .55$.

After treatment at T2, AN patients still exhibited larger BID-Indices compared to HC on some but not all body parts. The respective ANOVA revealed again a group × body part interaction, $F(2, 168) = 7.97$, $p = .001$, $\eta^2 = .09$, and a main effect of group, but with a smaller effect size, $F(1, 84) = 14.41$, $p < .001$, $\eta^2 = .15$. *Post hoc t*-tests now revealed larger BID-Indices in AN at the arm, $t(57.11) = 3.60$, $p = .001$, $r = .43$, and thigh, $t(55.11) = 4.055$, $p < .001$, $r = .48$, but not at the waist, $t(61.66) = 1.18$, $p = .242$, $r = .15$. Again, additional control analyses using one-way ANOVAs with measured body size as a covariate confirmed the results—arm: F(1, 83) = 14.42, p < .001, $\eta^2 = .15$; thigh: F(1, 83) = 13.89, p < .001, $\eta^2 = .14$; and waist: F(1, 83) = 1.28, p = .261, $\eta^2 = 0.02$. Similar to T1, BID-Indices differed by body part across groups, indicated by a main effect of body part, $F(2, 168) = 18.78$, $p < .001$; $\eta^2 = .18$). Across groups, BID-Indices were smallest at the thigh (M = 110.76, SD = 19.19), medium at the arm (M = 117.68, SD = 24.75), and largest at the waist (M = 123.37, SD = 16.32). *Post hoc t*-tests revealed significant differences in all comparisons, i.e., arm *vs*. thigh: $t(85) = 3.50$, $p = .001$, $r = .36$; waist *vs*. arm: $t(85) = 2.56$, $p = .012$, $r = .27$; waist *vs*. thigh: $t(85) = 6.87$, $p < .001$, $r = .60$.

Longitudinally, results confirmed the expected reduction of BID-Indices in AN patients after treatment but not in all parts of the body. The ANOVA comparing AN at T1 *vs*. T2 revealed an interaction of time × body part, $F(2, 74) = 16.98$, $p < .001$, $\eta^2 = .32$), and main effects of body part, $F(2, 74) = 3.51$, $p = .035$, $\eta^2 = .09$, and time, $F(1, 37) = 8.82$, $p = .005$, $\eta^2 = .19$. *Post hoc t*-tests confirmed the expected reduction in BID-Indices from T1 to T2 at the thigh, $t(37) = 4.51$, $p < .001$, $r = .60$, and waist, $t(37) = 3.93$, $p < .001$, $r = .54$, but not at the arm, $t(37) = -0.73$, $p = .468$, $r = .12$. Moreover, BID-Indices differed by body part across both time points. Just like in the analyses at T1 across AN and HC groups, *post hoc t*-tests revealed that, across time points, AN patients' BID-Indices were comparable at the arm (M = 126.99, SD = 21.68) and thigh (M = 126.68, SD = 20.90), $t(37) = 0.12$, $p = .909$, $r = .02$, while overestimation was larger at the waist (M = 132.92, SD = 17.24) compared to the arm, $t(37) = 2.34$, $p = .025$, $r = .36$, and thigh, $t(37) = 2.29$, $p < .028$, $r = .35$.[2]

Relative Changes of Measured and Estimated Circumferences

Both measured and estimated circumferences increased longitudinally (**Table 5**; **Supplementary Figure 1**). Interestingly, reduced BID-Indices at T2 arose from a relatively lower growth of the estimated compared to the measured circumferences in some parts of the body. This was indicated by a method × body part interaction, $F(2, 74) = 15.70$, $p < .001$, $\eta^2 = .30$, and a main effect of method, $F(1, 37) = 7.34$, $p = .01$, $\eta^2 = .17$. The percentage changes of the measured and estimated circumferences were comparable at the arm, $t(37) = -0.69$, $p = .493$, $r = .06$, but they were larger for the measured *vs*. estimated circumference at the thigh, $t(37) = 4.47$, $p < .001$, $r = .47$, and waist, $t(37) = 3.56$, $p = .001$, $r = .39$. Moreover, a main effect of body part indicated that the percentage change differed by body part across methods, $F(2, 74) = 7.31$, $p < .001$, $\eta^2 = .17$. In particular, the percentage change averaged across methods was larger at the waist than on the arm, $t(37) = 3.80$, $p = .001$, and thigh, $t(37) = 2.72$, $p = .010$, with no differences between the latter two, $t(37) = 0.99$, $p = .327$.

DISCUSSION

The present study investigated changes of the perceptive BID in adolescent AN patients after inpatient treatment. Treatment comprised a disorder-specific phased multimodal treatment plan including targeted body-psychotherapeutic work on both the perceptive and cognitive–affective body images. After treatment, AN patients achieved a significant weight gain. As a main result, this study shows that the distinct body size overestimation in AN patients observed at admission (T1) was clearly reduced after treatment (T2), though not on the arm but specifically at the thigh and waist (**Figure 1**). In fact, after treatment, AN patients' BID-Indices at the waist no longer differed from HC. This indicates that perceptive BID in adolescent AN patients is modifiable and that, after treatment, AN patients were partly able to give a more realistic estimation of their body size.

We found that body size was overestimated by about 3–21% in HC participants and about 25–40% in underweight adolescent AN patients, and group differences were significant beyond effects that might be expected based on general smaller body sizes in the AN group (31). These findings are in line with previous findings using the BID-CA (24–26) and confirm the existence of a perceptive BID in AN (13). As the BID-CA is classified as a metric method of body size estimation, the relatively large effect sizes found in our study reflect the fact that metric methods yield in general larger effect sizes than depictive methods (13). Also, the observed reduction of this body size overestimation is in line with findings of reduced perceptive BID in AN patients after treatment (16, 19, 23). As

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[2] An explorative correlation analysis of the relationship between BID-Index changes and weight gain revealed no significant result.

TABLE 2 | Main and comorbid diagnoses.

Main diagnoses		Comorbid diagnoses	
Anorexia nervosa, restrictive type	27 (71.1%)	MDD	15 (39.5%)
Anorexia nervosa, binge-purge type	6 (15.8%)	Anxiety disorder	3 (7.9%)
Atypical anorexia nervosa (EDNOS)	5 (13.1%)	PTSD	1 (2.6%)
		OCD	1 (5.3%)
		Avoidant personality disorder	2 (2.6%)

(EDNOS, eating disorder not otherwise specified; MDD, major depressive disorder; PTSD, post-traumatic stress disorder; OCD, obsessive-compulsive disorder; multiple comorbid diagnoses per patient were counted separately).

TABLE 3 | Body mass index.

	BMI		BMI_{SDS}	
	M	*SD*	*M*	*SD*
HC	20.59	2.54	-0.29	0.84
AN T1	15.09	1.62	-2.83	1.28
AN T2	18.90	1.32	-0.66	0.66
AN T2–T1	3.80	1.74	2.17	1.18

(SDS, standard deviation scores).

TABLE 4 | Body image distortion–indices (BID-I).

	Arm		Thigh		Waist		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
HC	109.40	17.29	103.68	12.59	121.46	13.21	111.51	10.07
AN T1	125.70	18.71	133.48	23.50	140.02	21.45	133.07	17.82
AN T2	128.30	28.78	119.89	22.23	125.81	19.58	124.66	21.43

prior studies used tasks involving size estimations of the whole body (visual size estimation, hoop task), it is an interesting new finding that, in this study, AN patients' overestimation was improved only at the thigh and waist. Upon more closely inspecting the values underlying the calculation of BID-Indices, we found that weight regain led to a relatively even percentage increase of the measured circumferences in all body parts (12.3 to 17.6%, **Supplementary Figure 1**). However, while AN patients increased their estimations to a corresponding amount at the arm (14.5%), they only marginally changed their estimations on the thigh (6.2%) and waist (3.0%). Indeed, the significantly lower increase of estimated compared to measured circumferences at the thigh and waist apparently drove the observed reduction in the corresponding BID-Indices.

To interpret the results, a number of factors are worth considering. First, reduced BID-Indices at T2 might simply be a result of task repetition leading to training effects. However, the BID-CA is reported to have an acceptable test–retest reliability of 0.78 (25), and thus, it seems unlikely that task repetition can fully explain the results.

Second, AN patients might have deliberately reduced their estimations, even when they felt their body size was still larger, just because they became aware of their tendency to overestimate and tried to correct for it. Indeed, the results of the BID-CA were discussed with the patients, and the tendency to overestimate one's own body size was extensively worked on during therapy. And although the patients were instructed to estimate circumferences as they felt at that moment, some patients reported an attempt to correct for the expected overestimation. If this was the case, however, it is remarkable that the patients still distinctly overestimated the size of their arm and thigh at T2. At least, despite their

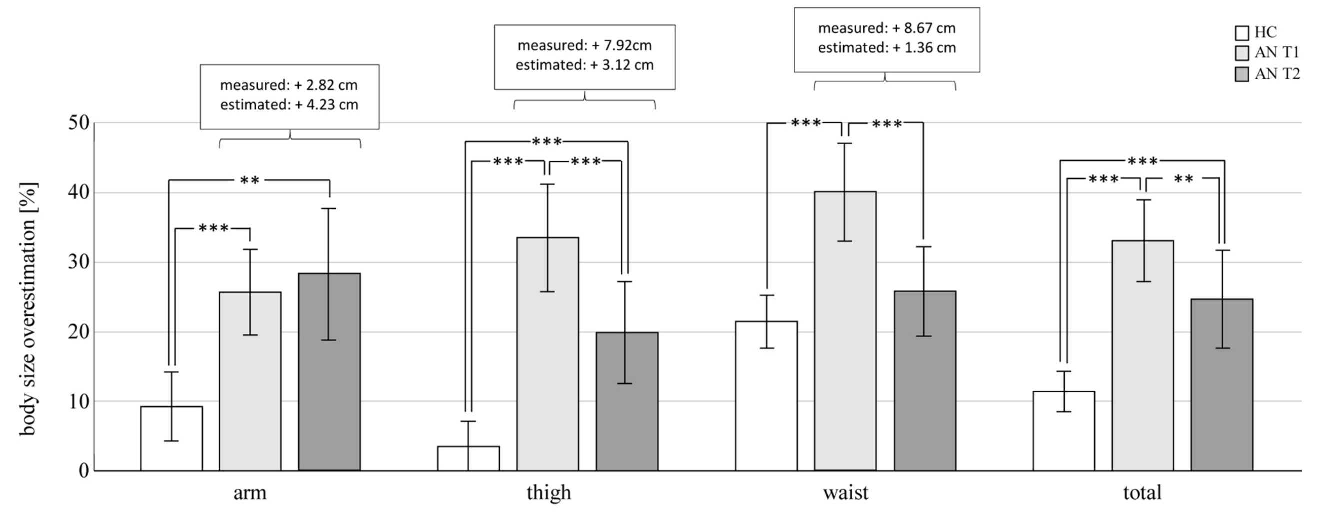

FIGURE 1 | Body size overestimation. Body image distortion–indices (BID-I) – 100 indicate the percentage of overestimation. Increases in measured and estimated circumferences (cm) in AN patients from T1 to T2 are given in the white boxes. **p < .01; ***p < .001. HC, healthy control participants; AN, patients with anorexia nervosa.

TABLE 5 | Relative changes of measured and estimated circumferences (Changes from T1 to T2, AN group only).

	Measured				Estimated			
	cm		%		cm		%	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Arm	2.82	1.59	12.29	7.46	4.23	5.76	14.46	19.77
Thigh	7.92	4.61	17.64	11.11	3.12	9.85	6.22	17.07
Waist	8.67	4.08	13.39	6.63	1.36	15.46	3.05	17.76

better knowledge, patients were not able to fully correct their tendency to overestimate.

Third, given that the estimations at the thigh and waist changed only marginally, the perceptive body image of AN patients might be considered as rather stable. Weight regain might have led the patients to grow into a preexisting perceptive body image, possibly still reflecting their body size prior to the weight loss. This idea fits with the observation that radical changes in the real constitution of the body, like limb amputation, may result in a situation where the perceptive body image is not updated, and individuals still feel a *phantom limb* (32). Such a phenomenon might be particularly prevalent in AN cases with rapid and severe weight loss. Indeed, both under- and overweight are associated with body size misperception (13, 33), suggesting that extreme weight changes might be associated with an impeded or delayed body image update. On the other hand, body size perception of a substantial proportion of overweight participants is accurate (33), and, hence, body image updates after weight gain are possible.

Finally, more realistic body size estimations and improved perceptive BID might be a result of therapeutic treatment. In particular, body-psychotherapeutic work on the perceptive component of body image, e.g., using exercises on multimodal integration, aimed to facilitate the conscious perception of the body and its boundaries. At the same time, the multimodal treatment plan also provided therapeutic work on the cognitive–affective and interpersonal component of the body image as well as on overall psychopathology. Both may have contributed to an improved body image and better task performances. Unfortunately, an analysis of the differential contributions of the diverse therapeutic treatments is not possible with the current study design.

Interestingly, although the first three points presumably all contributed to the observed results at least in part, they cannot fully explain the fact that changes of the BID-Indices are observed only at the thigh and waist. One possible explanation for this difference in body parts is that the thigh and waist, typically experienced as "problem zones" by the patients, received much more attention during (body-)psychotherapeutic treatment than the upper arm. Consequently, although this study was not designed as a clinical trial and the reasons for the observed changes may be diverse, these findings suggest that AN patients may benefit from therapeutic work targeting both cognitive–affective and perceptive aspects of BID.

Limitations of the present study concern, above all, the broad spectrum of possible factors influencing the observed BID-Index changes. To overcome this, future studies should control for test stability of the BID-CA, e.g., using a second test in HC and AN to compare changes from T1 to T2 in both groups. Moreover, the BID-CA in its original form could be better operationalized. For example, we included a short body perception exercise before the task to promote access to the implicit perceptive body image. The investigator pointed to the correct positions at each body part on her own body to improve understanding. In addition, we always measured the length of the string starting at the inner part of the end of the string touching the rest of the string, to avoid inaccuracies due to the strings' thickness. Moreover, it is difficult to be sure that all participants perform the task in the same way, as some patients verbalized a conflict between their felt body size and their desire to correct for their known tendency to overestimate body size. A further development could thus be to use two separate task instructions to clarify the difference between the felt (perceptive) body size and the known (cognitive) body size, and to compare these two conditions. Furthermore, interpreting the observed perceptive BID changes in terms of a specific treatment effect would require a randomized controlled study using different treatment arms. For example, a group of AN patients with weight regain but without any targeted treatment of perceptive or cognitive–affective body image could be compared with groups of AN patients who received different add-on treatments specifically targeting perceptive and/or cognitive–affective BID. A further limitation of this study is the varying time point of the T2 measurement due to different treatment trajectories of individual patients. To avoid this, future studies could define a fixed time point, e.g., a fixed number of weeks after T1 (accepting less weight gain in some cases), or define a fixed target weight (accepting the exclusion of the group of patients who do not achieve it) for the T2 measurement. Finally, the study included only female participants and mainly rather severe inpatient cases, which limits the generalizability of the results.

The results of the present study show that the perceptive BID in adolescent AN patients is persistent but also modifiable. The BID-CA is a comprehensive and easy-to-use test that quantifies perceptive BID and helps to make AN patients aware of their tendency to overestimate their body size. Moreover, it enables treatment monitoring and repeated work on perceptive BID. Clinical experience shows that it may be quite challenging for AN patients to update their perceptive body image and that repeated therapeutic work on this is useful. More studies are needed on the perceptive component of BID to gain a better understanding of the factors that influence and facilitate change.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by ethics committee of the Medical Association of Westphalian-Lippe and the University of Münster, Gartenstraße 210 - 214, 48147 Münster, Germany. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AD, IW and GR contributed to the conception and design of the study. AD and HF recruited the participants and collected the data. IW performed the statistical analysis and wrote the first draft of the manuscript. All authors contributed to the interpretation of the data and the manuscript revision, and read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00748/full#supplementary-material

SUPPLEMENTARY FIGURE 1 | Relative changes of measured and estimated circumferences. Comparison of the percent change of measured and estimated circumferences in AN patients from T1 to T2. *** = p < .001.

SUPPLEMENTARY TABLE 1 | Comparison of included and excluded AN patients. (BMI = Body Mass Index; SDS = Standard Deviation Scores; Duration of illness = months since begin of eating disorder symptoms estimated by AN patients and their parents at admission; Duration of treatment = Duration from admission to discharge from inpatient treatment).

SUPPLEMENTARY TABLE 2 | Main and comorbid diagnoses of excluded AN patients. (EDNOS = Eating Disorder Not Otherwise Specified; MDD = Major Depressive Disorder; PTSD = Post Traumatic Stress Disorder; OCD = Obsessive-Compulsive Disorder; multiple comorbid diagnoses per patient were counted separately).

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Cognitive-Emotional Involvement During Mirror Exposure Is Not Accompanied by Physiological Activation in Binge Eating Disorder

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Body image interventions have been shown to reduce self-reported cognitive-emotional facets of body image disturbance in binge eating disorder (BED). However, more objective assessment methods are required to evaluate the effects of these interventions. Therefore, the present study aimed at investigating the usefulness of vocally encoded emotional arousal as physiological correlate of body dissatisfaction during mirror exposure in women with BED. Women with BED (n = 60) and weight-matched controls (CG; n = 60) participated in an experimental thought-sampling procedure including a mirror exposure and a control condition in a repeated-measures design. Fundamental frequency as a vocal correlate of emotional arousal as well as negative, neutral, and positive body-related cognitions during both conditions were analyzed. In line with our hypotheses, the BED group verbalized more negative, and less positive and neutral body-related cognitions during the mirror exposure condition compared to the CG. Contrary to our hypotheses, though, there was a stronger *in*crease in physiological arousal between the control and the mirror exposure condition in the CG relative to the BED group. Furthermore, a significant negative correlation between fundamental frequency and the severity of cognitive-emotional body image disturbances emerged. The findings indicate a cognitive-emotional over-involvement with physical appearance during mirror exposure in women with BED compared to weight-matched controls in the absence of a corresponding physiological pattern. Results are discussed in terms of an impaired ability of women with BED to show adequate physiological responses to body-related stress. In addition, methodological recommendations for future research are presented.

Keywords: binge eating disorder, body image, mirror exposure, fundamental frequency, physiology

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INTRODUCTION

According to the Diagnostic and Statistical Manual of Mental Disorders (1) binge eating disorder (BED) is characterized by recurrent episodes of binge eating accompanied by feelings of loss of control in the absence of inappropriate compensatory weight regulation behavior as in bulimia nervosa (BN). BED is the most prevalent eating disorder (2) and is associated with overweight and obesity, elevated psychological and medical comorbidity, as well as psychosocial impairment. These severe consequences illustrate the need to identify and understand the core mechanisms underlying this eating disorder (3–5).

Although the diagnostic criteria for BED do not include a criterion relating to body image disturbances, there is increasing empirical evidence for the detrimental influence of a negative body image in patients with BED (for an overview see 6). Body image is a multifaceted construct, which consists of a perceptual, a cognitive-affective and a behavioral component (7). The cognitive-affective component, which comprises attitudes, cognitions, and emotions regarding one's own body (e.g., body dissatisfaction, overvaluation of shape and weight), seems to be especially relevant in distinguishing patients with BED from weight-matched individuals without an eating disorder. These results underline the assumption that body image disturbances in women with BED are not only a result of increased weight, but of eating pathology (8, 9). This assumption is furthermore supported by the fact that the level of body image disturbances observed in BED is comparable to the level of impairment observed in patients with BN (10). Besides being linked to severe functional impairment, eating disorder psychopathology, and depression in women with BED (11, 12), numerous studies emphasize the importance of body image disturbances for the development and maintenance of BED. As such, longitudinal studies have identified body dissatisfaction as a risk factor for the development of BED in adolescent females (e.g., 13, 14). Furthermore, negative mood preceding binge episodes is most frequently triggered by weight and shape related issues (15). This corroborates findings from an experimental study in which desire to binge and salivation during mirror exposure relative to a control condition were only increased in women with BED but not in weight-matched controls (16). Beyond that, overvaluation of shape and weight has demonstrated to be one of the most salient predictors and moderators for remission rates in the treatment of BED. Thereby, the presence of overvaluation of shape and weight was associated with significantly lower remission rates at the end of both a pharmacological and a cognitive-behavioral treatment (CBT) (17). Additionally, elevated levels of weight concern also negatively influenced remission rates during a 4-year follow-up period following CBT treatment in another study (18).

Mirror exposure has been shown to be a validated treatment for the improvement of body image disturbances in patients with clinical and subclinical eating disorders (19). It encompasses the systematic, repetitive viewing of oneself in a mirror under therapeutic guidance mostly including a non-judgmental description of the own body parts (19–22). In BED, two studies have shown that mirror exposure leads to significant improvements in the cognitive-affective component of body image, as well as to substantial and stable improvements in eating-disorder specific and overall psychopathology (23, 24). Finally, in one study (25), participants with BED underwent a prolonged and repeated experimental mirror exposure task without therapeutic support. Here, a decrease in negative mood and negative body-related cognitions as well as an increase in appearance self-esteem was found after two prolonged mirror exposures. This corroborates the assumption that one possible underlying mechanism of change during mirror exposure might be habituation to the discomfort and negative affect elucidated through the confrontation with one's own body (for a review see 19). Of note, though, the reported cognitive-emotional habituation effects in mirror exposure mostly rely on self-report data (22, 26, 27) and little research so far has focused on more objective, psychophysiological responses during mirror exposure in patients with BED. A more objective approach though is important as self-report measures are prone to social desirability biases which might be especially relevant in treatment evaluation (28). Second, as habituation is said to be one of the mechanisms responsible for improvements following mirror exposure therapy (19), research on physiological activation during mirror exposure warrants further attention.

Admittedly, though, results concerning changes in physiological arousal over the course of mirror exposure as measured by heart rate (variability), skin conductance, and salivary cortisol have been inconclusive despite concomitantly obtained group differences in self-reported cognitive-affective body image disturbances (29–32). For example, in the study conducted by Servián-Franco et al. (31), a greater level of arousal while focusing on thinness-related body parts like hips, buttocks, and abdomen during mirror exposure was found in both high and low body-dissatisfied women, whereas significantly higher levels of negative emotions and cognitions were observed in highly dissatisfied women compared to controls. Two studies investigating physiological changes following body image therapy also reported heterogeneous results. While Trentowska et al. (32) found no changes in psychophysiology in women with BN using heart rate (variability) and skin conductance level prior to and after mirror exposure therapy, neuroendocrine changes measured by cortisol level were found in a sample with patients with BN in a study conducted by Díaz-Ferrer et al. (30). In BED, only one study so far has investigated the effect of a mirror exposure by using both self-reported and physiological measures of stress response. While Naumann et al. (33) found women with BED and weight-matched controls to show an increase in body dissatisfaction after mirror exposure compared to no mirror exposure following a socioevaluative stress induction by means of the Trier Social Stress Test for Groups (TSST-G), this increase was significantly more pronounced in women with BED. However, no difference in physiological arousal measured by salivary cortisol was found. Given the inconclusive results concerning physiological activation during mirror exposure, further research is needed to understand the relationship between the cognitive-affective and the physiological activation during mirror exposure. Notably, physiological assessment methods used in previous studies have been criticized due to their invasiveness and visibility during mirror exposure potentially serving as visible distractor (32, 34). A recently-discussed, non-invasive way of measuring emotional arousal is the assessment of vocal fundamental frequency (35).

Fundamental frequency (f0) refers to the vibration of the vocal folds during phonation and is highly correlated with perceived pitch. During stress, higher f0 scores have been observed in simulated as well as in naturally occurring stressful situations due to the heightened tension in the involved speech muscles (36). In psychological research, f0 has already been used as a correlate of emotional arousal in research on couple therapy as well as in research on mental disorders, especially anxiety disorders (e.g., 37–42). Referring to some recent results, f0 was able to differentiate between persons with and without the diagnosis of a social anxiety disorder during a stress-provoking speech task (38). In a study on couple interactions, significant correlations between f0 and other physiological measures like heart rate variability, blood pressure, and cortisol were found, further underpinning the usefulness of f0 in psychological research (39). In the context of body dissatisfaction, only one study so far has proven the utility of vocally encoded emotional arousal as a physiological correlate of body distress. During an experimental mirror exposure, vocally encoded emotional arousal was able to differentiate between women with overweight and obesity and normal weight controls, and correlated significantly with different validated measures of body image (43). Furthermore, encouraging results have been found concerning the predictive value of f0 in treatment studies. Vocally encoded emotional arousal measured during a stress-provoking task prior to and after pharmacotherapy was able to distinguish between treatment-responder and non-responder in patients with social phobia; similarly, in couple therapy, treatment was predicted by spouses' f0 scores during a couple conflict prior to therapy (34, 44). Against this backdrop, vocally encoded emotional arousal seems to be a convincing alternative for assessing emotional arousal during a stress-provoking task in mental disorders.

Thus, this study aimed at investigating the psychophysiological and cognitive-affective reactions to an experimental mirror exposure in women with BED using vocally encoded emotional arousal during a thought-sampling procedure. We hypothesized that women with BED would show a greater increase in f0 between the control and the mirror exposure condition compared to weight-matched women without an eating disorder. In line with previous studies (e.g., 23, 45), we expected more negative (and fewer positive) body-related cognitions and more self-reported negative emotions by means of visual analogue scales (stress, insecurity, body dissatisfaction) in the BED group compared to controls during the mirror exposure relative to the control condition. Furthermore, significant positive correlations between the difference score of f0 between the two experimental conditions, and validated state and trait measure of body image were hypothesized.

MATERIALS AND METHODS

Participants

The study was approved by the Ethics Committee of the Medical Faculty of the University of Tuebingen (575/2014BO2). Females with binge eating disorder (BED; $n = 60$) and females with overweight and obesity without an eating disorder (CG; $n = 60$) were eligible for participating in this study. The BED sample was recruited from an ongoing randomized controlled trial on therapeutic mirror exposure in BED (data from the comparative RCT will be presented elsewhere). The present study was conducted as part of a baseline assessment prior to randomization to the RCT. The CG was matched to the BED group on BMI and age.

Inclusion criteria for both groups were a) age between 18 and 69, b) female gender, c) corrected or normal vision, and d) German language skills. Furthermore the CG had to have a body mass index (BMI) of > = 25 and no lifetime diagnosis of an eating disorder. Exclusion criteria for both groups consisted of the presence of a) acute psychosis, severe suicidal ideation, manic episode, or substance abuse/addiction, b) pregnancy or lactation period, c) borderline personality disorder, or d) severe physical illness. Eating disorder pathology and the present diagnosis of BED according to DSM-V (1 binge/week during the last 3 months) was assessed using the Eating Disorder Examination (EDE; German version: 46) while all other mental disorders were screened by the Structured Clinical Interview (SCID) for DSM-IV Axis I and Axis II Disorders (German version: 47). All participants were financially rewarded.

There were no differences between the two groups regarding age, BMI, and educational level (see **Table 1**). However, women with BED were less frequently in a partnership than controls. As expected, the BED group self-reported higher scores on measures of eating pathology and severity of depression. In line with previous research (3) comorbid mental disorders were more frequent in the BED relative to the CG, whereby anxiety and affective disorders were the most frequent ones (anxiety disorders: BED: 18.6%/ CG: 6.8%; affective disorders: BED: 10.2%/ CG: 3.4%).

TABLE 1 | Descriptive characteristics of demographic and psychopathological variables for women with binge eating disorder (BED) and women with overweight and obesity (CG).

	BED ($n = 60$)	**CG** ($n = 60$)	**Statistics**
	Frequency	***Frequency***	
Education level[a]			
low	16	18	χ^2 (1) = .165
high	43	41	
Marital status[a]			χ^2 (2) = 6.995*
with partner	27	41	
single	23	14	
widowed/divorced	9	4	
Comorbid diagnosis[a]	16	7	χ^2 (1) = 4.180*
	M (SD)	***M (SD)***	
Age (years)	42.2 (14.6)	40.13 (14.8)	F(1,118) = 0.575
BMI	32.8 (6.0)	30.9 (9.0)	F(1,118) = 1.868
BDI	18.9 (11.8)	7.8 (7.6)	F(1,118) = 37.404**
$\text{EDE}_{\text{global}}$	2.4 (0.9)	1.4 (0.9)	F(1,118) = 43.596**
$\text{EDE}_{\text{shape concerns}}$	3.6 (1.1)	2.1 (1.2)	F(1,118) = 55.750**
$\text{EDE}_{\text{weight concerns}}$	3.2 (1.2)	1.9 (1.2)	F(1,118) = 32.332**
$\text{EDE}_{\text{restraint eating}}$	1.4 (1.3)	0.9 (1.1)	F(1,118) = 4.736*
$\text{EDE}_{\text{eating concerns}}$	1.5 (1.2)	0.5 (0.9)	F(1,118) = 25.243**
BSQ	126.6 (25.1)	87.9 (30.8)	F(1,118) = 56.916**

BDI, Beck Depression Inventory; BMI, Body Mass Index; BSQ, Body Shape Questionnaire; EDE, Eating Disorder Examination (for detailed description see the section Questionnaires and Interviews); educational level: low ≤ secondary school; high = baccalaureate or university degree.

** $p < .05$; ** $p < .001$.*

[a] *$n = 59$ in the BED group and the CG due to missing data in questionnaire assessment.*

Measures

Experimental Thought-Sampling

A thought-sampling task was implemented to assess the occurrence of negative, neutral, and positive body-related verbalizations as well as to measure vocally encoded emotional arousal. Therefore, participants were instructed to verbalize all their concurrent cognitions and emotions in two different conditions each lasting 5 min while standing alone in a small soundproof room.

During the control condition (CC), participants stood in front of a closed mirror wearing their street wear, while during mirror exposure (ME) they wore a standardized underwear (nude panty and top) while they were standing in front of a three-winged full-length mirror. A microphone placed on the ceiling of the room recorded all verbalizations. Before starting with the two experimental conditions, participants practiced thinking aloud while the investigator was present in order to familiarize with the task.

Each condition started with a 2-min relaxation task to direct participants' attention on their concurrent feelings and thoughts. The order of the two conditions was randomized and counterbalanced between the two groups. At the beginning of the experiment as well as after each experimental condition, participants had to fill in some questionnaires measuring current stress, insecurity, and body satisfaction level as well as the motivation to follow the instructions (for further information, see section *Questionnaires and Interviews*). After the task, participants were debriefed.

Questionnaires and Interviews

1) Body dissatisfaction was assessed using the German Version of the *Body Shape Questionnaire* (BSQ; 48; German version: 49). The *BSQ* is a 34-item self-report questionnaire, which is widely used to assess weight and shape concerns over the past four weeks on a six-response scale for each item ranging from 1 (never) to 6 (always). The minimum score is 34, reflecting no shape and weight concerns, whereas the maximum score of 204 reflects extreme shape and weight concerns. The BSQ shows excellent reliability, high sensitivity, and validity (50). Internal consistency was α = .959 in our sample. 2) Severity of depressive symptoms over the last 2 weeks was measured by the German version of the *Beck Depression Inventory-II* (BDI-II; 51; German version: 52), a 21-item self-report questionnaire with a four-response scale ranging from 0 to 3, with higher scores indicating higher symptom severity. The maximum sum score is 63, with 0–13 representing no depressive symptoms, 14–19 mild, 20–28 moderate depressive, and more than 28 severe depressive symptoms. Several studies confirmed the BDI's high internal consistency, reliability, and discriminant validity (53). 3) Three 10 cm visual analogue scales (VAS) anchored "not at all" (0) and "completely" (10) implemented prior to and at the end of each experimental condition were used to assess current feelings of insecurity, stress, and body satisfaction by means of the items "At the moment, how satisfied are you with your body?" and "At the moment, how insecure/stressed do you feel?." Another 10 cm VAS anchored "*not at all*" (0) and "completely" (10) was used to assess the self-reported motivation to follow the instructions of thought-sampling by the item "Please evaluate your motivation to follow the instruction of thought-sampling."

Procedure

Participants were recruited via newspaper announcements, flyers in medical centers, and pharmacies as well as by e-mails of the local university. Interested participants were contacted for a short telephone screening to assess inclusion and exclusion criteria. Eligible participants were then invited to a face-to-face diagnostic assessment by trained psychologists at the local university to assess eating and general psychopathology by means of the EDE and SCID as wells as to fill in questionnaires on sociodemographic and (eating) psychopathological information via Unipark (Globalpark AG, Hürth), an online survey platform. Prior to the diagnostic assessment, participants were given a detailed study description and signed informed consent. An appointment for the experimental thought-sampling task was scheduled approximately one week after the diagnostic assessment. Participants then completed the above-mentioned experimental thought-sampling procedure.

Data Reduction

Quantitative content analysis: All audio files were blinded and transcribed following prescribed rules (54) and then coded by independent raters by means of valence (negative vs. positive vs. neutral) and content (body-related vs. non body-related). For the present results, only body-related verbalizations were analyzed, being quantified as the percentage of all verbalized cognitions and emotions during each condition. Verbalizations were coded as body-related when participants talked about weight, shape, physical appearance, age, as well as body-related activities such as body care or fitness. All other cognitions were rated as non-body-related. Concerning valence, body-related cognitions were coded as positive when agreement or acceptance with the own body was verbalized (e.g., "I feel like I don't have to hide my body."), and as negative when participants talked depreciative about their body (e.g., "When I look at my stomach, I feel frustrated. It's just too much!"). Verbalizations, which dealt with the participant's former body or the appearance of other persons without direct comparison to their own body as well as all other body-related descriptive verbalizations, which were neither positive nor negative, were coded as neutral (e.g., "I have wide hips."). To assess interrater-reliability, a second independent rater coded 40 randomly selected transcripts (10 transcripts of each condition of each group). Separated for contents of cognitions, raters on average agreed in 96.0% of the cases and on 89.8% concerning valence of cognitions. Overall, reliability was good with 78.3% between the two raters. As control variable, the percentage of time spoken during both conditions as well as the motivation to follow the instructions was measured.

Vocally encoded emotional arousal: For the voice analysis, the records were analyzed with Praat, a free multiple platform program for speech analysis (55). Before analyzing fundamental frequency, detection errors [background noise (e.g., closing of a window) and nonverbal speech sounds (sighing, coughing, etc.) as well as the detection of periodicity in unvoiced speech segments] were manually removed from each recording. No correction was applied when the algorithm was not able to detect periodicity in voiced segments (e.g., due to irregular phonation). Range was adapted by the method introduced by Daniel Hirst in order to restrict f0 scores to the normal range of adult speech (56). In line with previous research (e.g., 57), analysis started with the second minute of each condition. For each condition, mean f0 estimates were than obtained continuously from all voiced segments for each 25 ms using autocorrelation methods outlined by Praat, resulting in a mean f0 score per condition and person.

To account for individual differences in fundamental frequency, difference scores were calculated per person between the two conditions ($\text{Diff\_f0}_{\text{mirror-control}} = \text{mean\_f0}^{\text{mirror}} - \text{mean\_f0}^{\text{control}}$). Positive difference scores, therefore, indicate more emotional arousal during the mirror exposure relative to the control condition, whereas negative difference scores indicate less emotional arousal during the mirror exposure compared to the control condition (see **Tables 2** and **3** for descriptive statistics of the dependent variables).

Data Analysis

Statistical analyses were made using IBM SPSS Statistics (Version 25.2). We handled missing data by using mean substitution (body-related cognitions/f0: one participant per group due to technical problems in data storing; Interview assessment: one participant per group; BDI-II: three participants with BED; VAS during thought-sampling: five participants of the CG and one participant with BED). Box plot analysis outlined by SPSS were used to detect outliers, extreme outliers (> three times the interquartile range) were excluded from the analyses. Two participants in the BED group had to be excluded for the voice analysis and one participant had to be excluded concerning body satisfaction ratings during ME.

TABLE 2 | Means (M) and standard deviations (SD) for dependent variables for women with binge eating disorder (BED) and women with overweight and obesity (CG).

	BED (*n = 60*)		CG (*n = 60*)	
	M (SD)		*M (SD)*	
	ME	CC	ME	CC
% of time spoken	23.9 (12.0)	30.7 (12.5)	23.4 (13.0)	25.8 (13.3)
Motivation	3.60 (1.44)	3.71 (1.28)	3.71 (1.34)	3.63 (1.33)
$\text{Diff\_f0}_{\text{mirror-control}}$	5.7 (8.3)^{a}		9.5 (9.7)	
Body-related cognitions (BC)				
negative	58.85 (16.49)	18.35 (19.05)	38.00 (20.27)	7.25 (11.18)
neutral	22.21 (13.00)	12.49 (12.27)	33.67 (15.64)	10.19 (14.67)
positive	4.36 (4.44)	0.68 (1.61)	9.18 (9.04)	1.00 (2.28)

CC, control condition; $\text{Diff\_f0}_{\text{mirror-control}}$, difference score of f0 between the mirror exposure and control condition; ME, mirror exposure condition; motivation, self-reported motivation to follow the instructions of thought-sampling; % of time spoken, percentage of time spent talking during each condition.

^{a}n = 58 in the BED group due to the exclusion of two outliers.

Hypotheses were tested by means of a univariate analysis of variance (ANOVA) for the vocal analysis and by repeated-measures ANOVA for body-related cognitions and visual analogue scales with condition as within-subject factor (mirror exposure vs. control condition (vs. baseline for VAS)) and group as between-subject factor (BED vs. CG). *Post hoc* ANOVAS and t-tests with Bonferroni correction for multiple testing were applied when significant main effects and interactions were detected. If assumption of sphericity was not met (Mauchlys Sphericity Test: $p < 0.05$), degrees of freedom for dependent variables were corrected conservatively by Greenhouse-Geisser. Being exceedingly robust against violation of normality (58), ANOVAs were also adopted for variables not normal in distribution. Pearson product-moment correlation coefficients were computed to assess the relationship between vocally encoded emotional arousal and body-related measures. Effect sizes of the group differences and interactions are reported by partial eta squared (η_p^2), whereby values larger than 0.01 refer to small, 0.06 to moderate, and 0.14 to large effect sizes (59).

RESULTS

Manipulation Check

Percentage of time spoken: A 2 (Group: BED, CG) × 2 (Condition: ME, CC) repeated-measures ANOVA for the percentage of time spoken showed a significant main effect of Condition [$F(1,118) = 32.928$, $p < .001$, $\eta_p^2 = .218$] as well as a significant interaction of Group × Condition [$F(1,118) = 7.686$, $p = .006$, $\eta_p^2 = .061$], whereas the main effect of Group was not significant [$F(1,118) = 1.581$, $p = .211$, $\eta_p^2 = .013$]. *Post hoc* tests showed that both groups verbalized more cognitions during CC than ME [BED: $F(1,59) = 33.931$, $p < .001$, $\eta_p^2 = .365$; CG: $F(1,59) = 4.716$, $p = .034$, $\eta_p^2 = .074$]. Compared to CG, women with BED verbalized more cognitions during CC [$F(1,118) = 4.459$, $p = .037$, $\eta_p^2 = .037$], while no difference was found in the amount of verbalized cognitions in the ME [$F(1,118) = .049$, $p = .825$, $\eta_p^2 < .001$].

Motivation: A 2 (Group: BED, CG) × 2 (Condition: ME, CC) repeated-measures ANOVA for the motivation to follow the instructions of thought-sampling showed no significant main effects or interaction [all $Fs(1,118) \leq 1.654$, $ps \geq .202$, $\eta_p^2 s \leq .014$].

Fundamental Frequency

Regarding f0, a significant main effect of Group was found [$F(1,116) = 4.409$, $p = .038$, $\eta_p^2 = .037$] indicating a stronger increase in f0 from CC to ME in the CG compared to BED group (**Figure 1**).

Valence of Body-Related Cognitions

Regarding the valence of body-related cognitions, the three-way ANOVA for repeated measures (Group × Condition × Valence) revealed a significant three-way interaction (for statistics see **Table 4**). To address our hypotheses, we conducted *post hoc* ANOVAs and t-tests separately for Valence (**Figure 2**).

For negative, neutral, and positive cognitions, significant main effects for Group and Condition as well as significant interactions

TABLE 3 | Means (M) and standard deviations (SD) for questionnaire assessment during thought-sampling for women with binge eating disorder (BED) and women with overweight and obesity (CG).

	BED **(*n = 60*)**			**CG** **(*n = 60*)**		
	M (SD)			***M (SD)***		
	Baseline	**CC**	**ME**	**Baseline**	**CC**	**ME**
Visual analogue scales						
stress	4.6 (2.5)	4.3 (2.5)	6.3 (2.7)	3.0 (2.5)	2.7 (2.4)	3.7 (2.6)
insecurity	4.9 (2.7)	4.3 (2.7)	6.7 (2.8)	3.1 (2.5)	2.7 (2.3)	4.2 (2.9)
body satisfaction	2.2 (1.8)	2.0 (1.9)	0.7 (0.9)	4.5 (2.0)	4.4 (2.5)	2.7 (2.6)

Baseline, beginning of experimental procedure; CC, control condition; ME, mirror exposure condition.

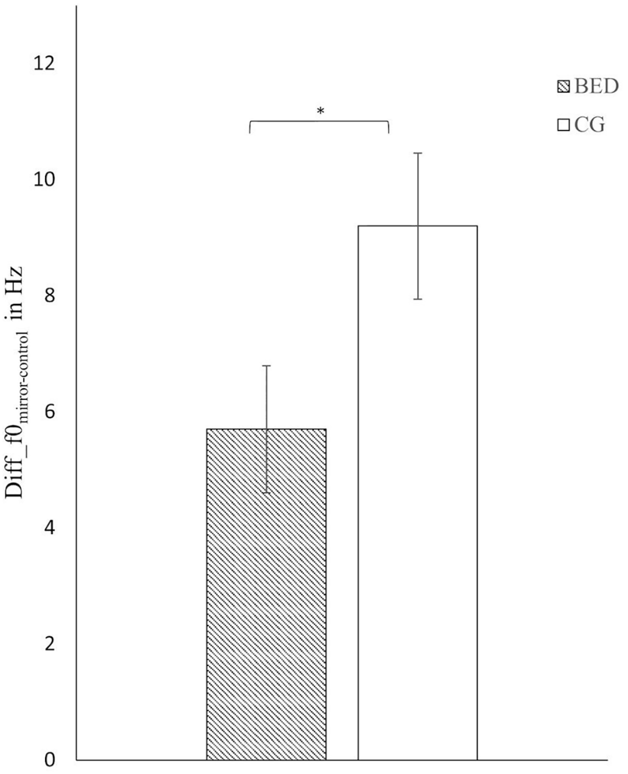

FIGURE 1 | Mean and standard error for the difference score in mean f0 between the mirror exposure and control condition in the BED and the control group (CG). *p < .05.

between Group × Condition were found [all $Fs(1,118) \geq 6.465$, $ps \leq .012$, $\eta_p^2s \geq .052$]. In both conditions, women with BED verbalized more negative body-related cognitions than the CG. However, this was more pronounced during ME than CC [ME: $t(118) = 6.182$, $p < .001$; CC: $t(118) = 3.893$, $p < .01$]. Concerning neutral body-related cognitions, no difference was found between the two groups in the CC, while during ME fewer neutral body-related cognitions were verbalized by women with BED compared to the CG [ME: $t(118) = 4.370$, $p < .001$; CC: $t(118) = .932$, $p = .353$]. The same pattern emerged for positive body-related cognitions. While no difference was found during CC, significant fewer positive body-related cognitions were verbalized by women with BED compared to weight-matched controls during ME [ME: $t(118) = 3.707$, $p < .001$; CC: $t(118) = .870$, $p = .386$].

Subjective Ratings of Stress, Insecurity, and Body Satisfaction

Stress: Regarding subjective stress level during the thought-sampling procedure, a 2 (Group: BED, CG) × 3 (Condition: Baseline, CC, ME) repeated-measures ANOVA revealed significant main effects of Group [$F(1,118) = 27.557$, $p < .001$, $\eta_p^2 = .189$] and Condition [$F(2,236) = 24.701$, $p < .001$, $\eta_p^2 = .173$] as well as a significant interaction of Group × Condition [$F(2,236) = 3.686$, $p = .027$, $\eta_p^2 = .030$]. While there was no difference between baseline and CC in either group (all $ts(59) \geq 1.055$, $ps \geq .296$), both groups showed a significant increase in subjectively rated stress level between CC and ME [BED: $t(59) = 6.038$, $p < .001$; CG: $t(59) = 3.556$, $p = .002$]. The increase between baseline and ME was only significant for women with BED [BED:

TABLE 4 | Statistics for the 3-way ANOVA concerning body-related cognitions.

	F	***df***	***P***	η_p^2	**Pairwise comparisons for main effects**
Group	9.361	1,118	.003*	.073	BED > CG
Condition	535.537	1,118	<.001**	.819	ME > CC
Group × Condition	2.872	1,118	.093	.024	
Valence	195.389	2,236	<.001**	.623	negative > neutral > positive
Group × Valence	34.536	2,236	<.001**	.226	
Valence × Condition	93.652	2,236	<.001**	.442	
Group × Condition × Valence	14.519	2,236	<.001**	.110	

*BED, females with binge eating disorder; CC, control condition; ME, mirror exposure condition; CG, females with overweight and obesity. * p < .05; ** p < .001*

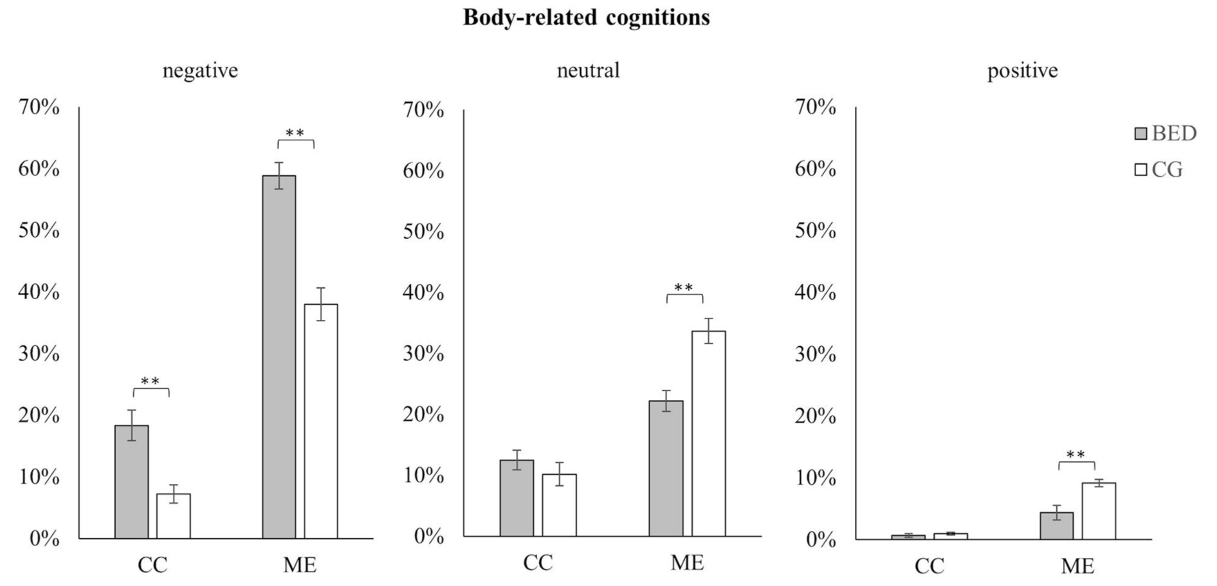

FIGURE 2 | Mean and standard error for negative, neutral, and positive body-related cognitions in women with BED and the control group (CG) during the control (CC) and the mirror exposure condition (ME).** p < .01.

$t(59) = 4.562$, $p < .001$; CG: $t(59) = 2.288$, $p = .078$]. Separated for groups, women with BED reported significantly stronger feelings of stress in all conditions being most pronounced during ME [all $Fs(1, 118) \geq 13.298$, $ps \leq .001$, $\eta_p^2s \geq .101$].

Insecurity: There was a significant main effect of Condition [$F(2,236) = 35.367$, $p < .001$, $\eta_p^2 = .231$] with higher levels of insecurity during ME compared to CC and baseline [all $ts(119) \geq 5.548$, $ps \leq .001$], while there was no difference between insecurity ratings during baseline and CC [$t(119) = 2.173$, $p = .095$]. There was further a significant main effect of Group [$F(1,118) = 24.579$, $p < .001$, $\eta_p^2 = .172$], whereby women with BED reported higher levels of insecurity compared to the CG. The interaction of Group × Condition was not significant [$F(2,236) = 2.009$, $p = .136$, $\eta_p^2 = .017$].

Body satisfaction: There was a significant main effect of Condition [$F(2,234) = 49.208$, $p < .001$, $\eta_p^2 = .296$]. Thereby, body satisfaction ratings were significantly lower during ME compared to baseline [$t(118) = 8.341$, $p < .001$] and CC [$t(111) = 8.581$, $p < .001$], while no differences between baseline and CC were found [$t(118) = .771$, $p = .442$]. There was further a significant main effect of Group [$F(1,117) = 52.217$, $p < .001$, $\eta_p^2 = .309$] with the BED group reporting lower ratings of body satisfaction. The interaction of Group × Condition was not significant [$F(2,234) = .778$, $p = .458$, $\eta_p^2 = .007$] (see **Figure 3** for all VAS).

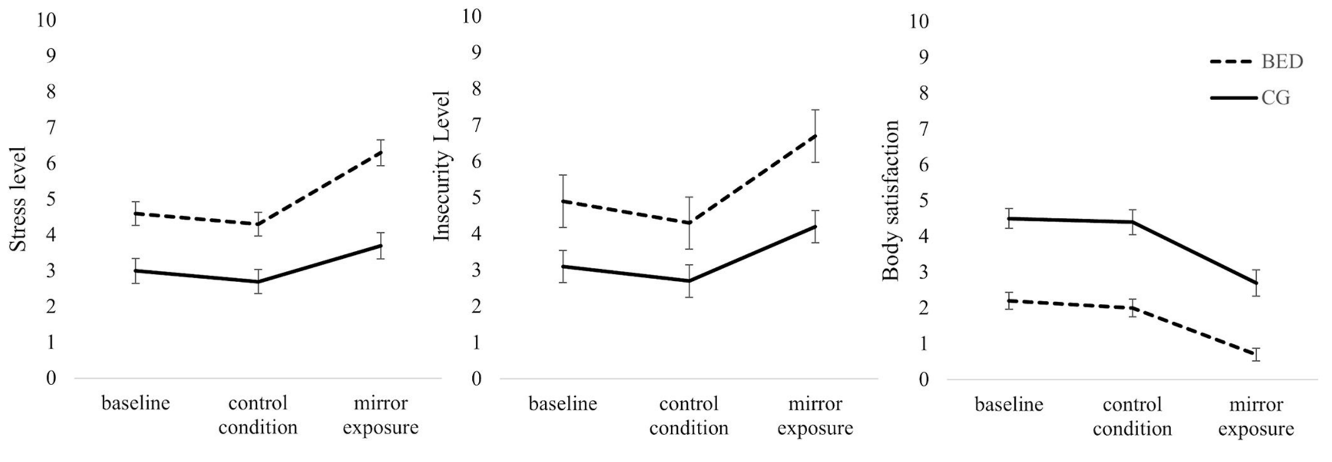

FIGURE 3 | Mean and standard error for self-reported levels of stress, insecurity and body satisfaction at the beginning of the experiment (baseline) and after the control and mirror exposure condition in women with binge eating disorder (BED) and women with overweight and obesity (CG). (Order of the two experimental conditions was counterbalanced between groups. Therefore, the figure presented does not display time sequence).

Correlations With Fundamental Frequency

No significant correlation was found between the difference score of fundamental frequency and negative body-related cognitions during ME as well as with subjective ratings of stress and body satisfaction during ME (all *r*s ≤ -.145, p ≥.118). However, there was a significant negative correlation between fundamental frequency and the BSQ (*r* = -.189, *p* = .041).

DISCUSSION

The aim of the present study was to investigate psychophysiological and cognitive-affective responses during an experimental mirror exposure in women with BED by means of vocally encoded emotional arousal. For this purpose, women with BED and weight-matched controls without an eating disorder underwent an experimental mirror exposure as well as a control condition by implementation of a thought-sampling procedure in a repeated-measures design. F0 was used to assess physiological activation as it has already been implemented as an index of emotional arousal during stress-provoking tasks in other mental disorders. In addition, vocal arousal is non-invasive and invisible to participants, and may therefore be better suited as a physiological assessment method relative to more distracting, visible measurements (38, 56, 57).

In accordance with our hypothesis, a cognitive-affective over-involvement with physical appearance was observed in women with BED compared to weight-matched controls. This was indicated by more negative as well as fewer positive and neutral body-related verbalizations as well as a stronger increase in self-reported stress level between the two conditions in women with BED. The results concerning the quantitative content analysis is in line with previous studies on psychological responses to mirror exposure in women with BED (25, 45). However, in our sample, not only differences in the frequency of negative body-related verbalizations were found, but also significant differences in the amount of neutral and positive body-related cognitions. A possible explanation for this difference might be the weight status of the investigated groups, which was substantially higher in the present sample relative to the Hilbert and Tuschen-Caffier (45) study, in which participants' BMI was only slightly above normal weight. As body dissatisfaction is increased in women with overweight and obesity (60), and significant differences between normal weight and obese persons with BED have been found (61), this may account for the significant findings relating to positive and neutral body-related cognitions in our study. Furthermore, in line with our results on positive body-related verbalizations, Svaldi et al. (62) found women with BED to be less capable of retrieving positively valenced shape-/weight-related words using an experimental recall task compared to weight-matched controls. Thus, against the backdrop of current cognitive theories of eating disorders, the activation of underlying body-related schemas (63) might not only trigger an enhanced bias for negative body-related cues, but might also impede the retrieval of positive body-related verbalizations, thereby maintaining body dissatisfaction.

In contrast to our hypothesis, the observed cognitive-affective activation in women with BED was not accompanied by increased, but reduced vocally encoded emotional arousal relative to the CG. At the same time, though, in both groups, self-reported levels of stress increased significantly from control to mirror exposure condition. Taking these findings together, a dissociation between self-reported stress level, verbalized body-related cognitions, and objectively measured physiological distress by means of f0 was found in women with BED. This was further supported by an inverse correlation between severity of self-reported body dissatisfaction and f0.

In line with previous studies, blunted physiological reactions to psychosocial stressors have been found in women with BED (33, 64) as well as in other non-clinical and eating-disordered samples during mirror exposure (e.g., 29, 31). The reason for these blunted reactions, however, is poorly understood. General changes in the psychophysiological response capability in eating disorders due to starvation and intermittent dieting are discussed (e.g., 65). Furthermore, habituation processes might be able to explain altered responses referring to the fact that females with BED are so used to these negative cognitions and emotions about their own body, that these cognitive-affective reactions do not elicit a response anymore. To clarify the specific mechanisms underlying these blunted responses, further studies are needed. So far, this dissociation between cognitive-affective and physiological reactions to body-related distress has been interpreted as an inability of body-dissatisfied persons to adaptively engage in physiological responses to body-related distress. This interpretation is based on the concept of different emotion theories (e.g., 66, 67). Accordingly, emotional coherence between experiential, physiological, and behavioral reactions helps individuals to effectively cope with environmental demands, while a lack of emotional coherence might reflect emotional dysregulation. As emotion regulation problems are a well-known phenomenon in women with BED (68, 69), the smaller increase in f0 between the two experimental conditions in participants with BED relative to controls may be attributable to their previously reported emotion regulation difficulties. This is in line with a study in which emotional coherence after a negative, positive, and neutral mood induction was stronger in response to a more functional relative to a more dysfunctional emotion regulation strategy (70). In future studies, this variable should therefore be additionally assessed when investigating the psychophysiological effects of mirror exposure.

Alternatively, the lack of coherence found in the BED group might also be attributable to the particular emotions activated during mirror exposure. Studies which have investigated emotions during mirror exposure found women with BED and BN to react with increased levels of sadness, insecurity, tension, anxiety, and disgust (25, 26). Note that for vocally encoded emotional arousal, an *increase* in mean f0 has been found for anger, joy, fear, anxiety, and stress, while a *reduction* in mean f0 has been associated with sadness, disgust, contempt, and boredom (36). Thus, our induction may have activated counteracting emotions in women with BED, which may account for the smaller increase in f0. It is important to note that not only f0 is prone to this limitation, but also other physiological assessment methods (71, 72). This might furthermore explain why associations between vocally encoded emotional arousal and the self-reported experience of stress and anxiety was more consistently found in previous studies in anxiety disorders (38, 57). Taken together, these findings point to the importance of investigating more thoroughly the different emotions activated through mirror exposure as it might be a confounding variable.

Against the backdrop of the adverse effects of a negative body image in women with BED (11, 16, 17), some important conclusions can be drawn from the present study. The high negativity of body-related cognitions during mirror exposure in the present BED sample might directly maintain binge eating, as a recent study has shown, that the negative influence of body shame on binge eating is directly mediated by enhanced self-criticism (73). Therefore, body-related interventions in BED should focus on adaptive strategies to enable a better regulation of body-related distress during exposure like displayed by the present CG. While mirror exposure has shown to be effective for the improvement of the cognitive-affective component of body image in BED (23, 24), the specific underlying mechanisms are not yet understood (19). Future studies should therefore focus on mechanisms of change which account for the observed improvements. A recent study conducted on stress-induced changes in state body dissatisfaction in women with BED found the cognitive-affective (anxiety, tension, distress, urge to leave the situation) rather than the biological stress response to be predictive for changes in body dissatisfaction (33). This underpins the importance of cognitive-affective changes during mirror exposure. However, the results on vocally encoded emotional arousal should not be neglected. Albeit unexpected, the observed blunted physiological reaction during mirror exposure in women with BED might be of predictive value for treatment outcome given the significant negative correlation with self-reported body-satisfaction. As the predictive validity of f0 has already been proven in pharmacological and psychotherapeutic treatment in other mental disorders (34, 44), future studies should focus on clarifying this relationship.

The present results should however be interpreted considering some limitations. First, the control condition used in the present study needs to be reconsidered. As a higher stress level was observed in the BED group across the two experimental conditions, future studies should implement a more suitable control condition. This notwithstanding, the anticipatory activation found in the BED group corroborates other studies on physiological arousal in eating and non-eating disordered women high on body dissatisfaction (e.g., 31, 33). In the case of the present study, this might have been because participants were informed that they will undergo a mirror exposure within the experimental session. Therefore, future studies should use authorized deception in order to avoid the activation of body-related schemas in the control condition (with the disadvantage not to be able to randomize the experimental sequence of the control and mirror exposure condition). This is important though, as the heightened stress level prior to the exposure might adversely influence vocally encoded emotional arousal. In fact, a recent study (74) found that a specific level of emotional response (in this case by means of cortisol) was necessary to observe vocal changes in reaction to stress in healthy controls. Therefore, heightened self-reported stress-levels prior to mirror exposure might have accounted for the smaller difference score in f0 in women with BED. In other words, changes in vocal arousal might have already appeared in the anticipatory control condition.

Second, even though we used a large sample with an age and weight-matched control group, no men were included in the study. As gender is said to influence body dissatisfaction (75), studies including men should be used to further understand physiological arousal during mirror exposure. Third, the coding system used in this study was only able to capture differences in frequency, but not in the intensity of body-related cognitions. That is, sentences such as “I don’t like my body” compared to “I really hate my body” were both coded as one negative body-related statement. Future studies should refine this coding system including a rating on intensity. Fourth, the VAS scales used to assess insecurity, stress, and body satisfaction over the course of the experiment might be limited in terms of their reliability. Future studies should focus on including validated questionnaires to assess negative emotions. Of note, as stated above, the differentiation between different negative emotions seems to be especially relevant in the context of investigating physiological reactions as different emotions might differentially influence these measures. Finally, there is some evidence that different physiological systems (e.g., parasympathetic, sympathetic, endocrinological system) might react dissimilar during stressful demands. In two studies on mental stress in women with BED, different changes were found for the different physiological markers used (76, 77). Hence, there is a need to include different physiological assessment methods in future studies.

To conclude, this was the first study to assess physiological arousal during mirror exposure in women with BED compared to weight-matched controls by means of vocally encoded emotional arousal. While findings on cognitive-affective over-involvement during mirror exposure were replicated, surprisingly, no coherence emerged in terms of vocally encoded emotional arousal. This might be explained by an inability of women with BED to create adequate physiological responses to body-related distress, which might adversely influence emotion regulation during confrontation. However, this interpretation should be treated with caution as a dissociation of emotional coherence might not necessarily reflect a dysregulated system (78). For this reason, future studies should take into account different physiological assessment methods besides investigating emotions and emotion regulation strategies activated during mirror exposure to control for potential confounding variables.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of the Medical Faculty of the University of Tuebingen. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JB, KK, BT-C, and JS contributed to conception and design of the study. JB and KK were responsible for data collection. JB and JS performed statistical analysis and wrote the first draft of the manuscript. KK, BT-C, and JS contributed to manuscript revision and mentoring.

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Perceived Stress Mediates the Relationship of Body Image and Depressive Symptoms in Individuals With Obesity

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Obesity is a world-wide increasing condition classified by a BMI ≥ 30 kg/m^2 that is frequently accompanied by various somatic comorbidities as well as an increased risk for mental comorbidities. Studies show associations of obesity with symptoms of depression, lower quality of life, and higher (perceived) stress compared to the general population. Body image has also been shown to play an important role in eating and weight disorders. The present study therefore aims to contribute to the understanding of the relationship of body image, perceived stress, and symptoms of depression in a morbidly obese population. *N* = 579 individuals with obesity were included upon presentation at a university clinic. The hypothesized mediating role of perceived stress in the relationship of body image dimensions and symptoms of depression could be confirmed. The results underline the importance of identifying promising stress management techniques and addressing perceived stress e.g. through mindfulness based approaches in the (lifestyle and/or weight) interventions for obesity taking into account the specific stressors of obesity affected individuals such as body image.

Keywords: obesity, body image, mediation, depressive symptoms, cross-sectional

INTRODUCTION

The prevalence of obesity has constantly increased in past years (1). The World Health Organization categorizes the severity of obesity in three classes: Having a body mass index (BMI) between 30 and 34.9 kg/m^2 corresponds to class I obesity, a BMI between 35 and 39.9 as class II obesity, and a BMI ≥40 as class III obesity (2). Obesity is often accompanied by various somatic comorbidities such as diabetes mellitus, hypertension or fat metabolism disorders (3). Additionally, there is an increased risk for mental comorbidities such as depression or eating disorders (1).

In case of the potential comorbidity of depression, the association between obesity and depressive symptoms seems to be of reciprocal nature (4). There is evidence that symptoms of depression predict the development or maintenance of obesity in the long term (5). On the other hand, there is evidence that obesity increases the risk for depression (4, 6). Some studies suggested a linear association between severity of obesity and increased risk of depression and decreased quality of life (7). Other studies, however, did not replicate this observation and suggested a more complex association (8). A possible explanation for these incoherent observations is that psychological variables rather than weight alone drive the associations between BMI and depression.

A psychological variable that is closely related to BMI is body image, i.e. the psychological representation of one's body. Body image can be defined as a construct consisting of different components: perception, attitudes, affect, and cognitions about/toward the size, shape, and form of one's own body (9–11). In early literature, it was assumed that obese people might be unaware of their excess body weight and therefore don't take countermeasures to normalize it (12). The current view is that obese people are more frequently dissatisfied with their bodies compared to normal-weight people, this difference being significantly higher in women compared to men (13) and body dissatisfaction and drive for thinness affect perceived stress in individuals with obesity (14). Reasons for higher body dissatisfaction in obesity are speculative but may originate from sociocultural factors such as current body ideals, stigmatization, or teasing by others (13). Somatic comorbidities or consequences of high weight such as restricted mobility and therefore restricted opportunities for social participation may also be of importance. Weight loss has been shown to potentially improve body image (15). Again, there does not seem to be a linear association between body dissatisfaction and severity of obesity (16), suggesting a complex modulation that takes other associated variables into account e.g. as a mediator.

One of these variables may be stress. Stress is a concept consisting of two major components: environmental conditions serving as stressors and a person's appraisal of stress (17). Since personal appraisal has been more in focus (18), we refer to perceived stress in this manuscript as opposed to e.g. a physiological stress reaction. Recent studies show that increased symptoms of depression and a lower quality of life are associated with higher (perceived) stress in individuals with obesity compared to the general population (7, 19). Associations between different types of stress (e.g. chronic stress) and higher food intake as well as subsequent weight gain could be shown: Higher stress was associated with higher food intake (20–22). A possible explanation for these findings can be increased cortisol levels due to physiological stress reactions that may lead to the selection of more calorie-dense foods and therefore increase food intake (23). Perceived stress can therefore be seen as a barrier for successful weight management in obesity, potentially contributing to further weight gain (14). It seems at hand that an association between perceived stress and body image is likely and has been shown for body dissatisfaction and perceived stress in a large sample of adolescent girls (24). To our knowledge, however, it is so far unknown how body image, perceived stress, and depressive symptoms might interact in the context of weight management.

The present study therefore aims to further investigate the relationships between stress (symptoms of), depression, and body image in a cross-sectional sample of obese individuals. Based on the above reported previous findings, obesity, and depression are related although there might not be a direct linear association. However, body image, a psychological construct closely related to BMI, has been shown to be related to obesity and perceived stress. Taken these findings together, we deem it possible that a negative/disturbed body image may be a driving factor potentially leading to the development of a comorbidity of depression in patients with obesity and that the risk for developing depressive symptoms might be dependent on the amount of stress these individuals experience. To the best of our knowledge, this has not been tested before. The investigation therefore had the following hypothesis: The relationship of body image with symptoms of depression is mediated by perceived stress in individuals with obesity.

MATERIALS AND METHODS

Sample

Individuals presenting themselves at an interdisciplinary assessment and consultation platform for patients with obesity at a tertiary university clinic were invited to participate in the study over a period of four years. Inclusion criterion was BMI ≥ 30 kg/m^2, no exclusion criterion applied other than a substantial language barrier.

Measures

The following questionnaires in paper-and-pencil versions were presented to all participants.

Perceived Stress Questionnaire (PSQ-20)

The PSQ-20 is a measure to assess perceived stress during the last four weeks (17, 25). It consists of 20 items, each scoring on one of the four subscales "worries," "tension," "joy," and "demands." An overall score describing the overall perceived stress level can be computed. The PSQ overall score is trimmed to range between 0 and 1. Internal consistency of the overall score in the present sample proved to be good with Cronbach's α = .84.

Body Image Questionnaire (BIQ-20)

The BIQ-20 is a measure to assess body image on the two subscales "negative evaluation of the body" (NEB) referring to one's negative attitude toward the own body and "perception of body dynamics" (PBD) referring to ones perception of personal vitality (26). It comprises a total of 20 items and has been validated within healthy and clinical populations (27, 28). Internal consistencies in the present sample proved to be good with Cronbach's α = .87 for the NEB scale and α = .82 for the PBD scale.

Patient Health Questionnaire—Section Depression (PHQ-9)

The PHQ-9 section of the Patient Health questionnaire assesses depressive symptoms and their severity with nine items (29). A sum score between 0 and 4 corresponds to no signs of symptoms of depression, 5 to 9 mild severity of symptoms of depression, 10 to 14 medium severity, 15 to 19 pronounced symptoms of depression and 20 to 27 severe symptoms of depression. Internal consistencies in the present sample proved to be good with Cronbach's α = 88.

Procedure

Individuals were invited to participate in the study consecutively upon presentation at the clinic. They were informed about the study and if they consented to participate, were given the questionnaires und subsequently weighed. Somatic comorbidities were retrieved from the consultation documentation. This study was carried out in accordance with the recommendations of good clinical practice. The protocol was approved by the ethics committee of the medical faculty of the University of Tuebingen (No. 727/2012BO2). All subjects gave written informed consent in accordance with the Declaration of Helsinki.

Statistical Analyses

All statistical analyses were performed in IBM SPSS Statistics (version 25). The level of significance for all analyses was set at $\alpha = .05$. Means, standard deviations, and percentages are reported for sample descriptions. Since most of the variables are not normally distributed, Spearman rho correlations are reported for the associations between variables. The mediation analysis was performed according to the approach by Hayes (30) utilizing the PROCESS macro for SPSS (version 3.1). Direct and indirect effects are quantified using ordinary least square (OLS) regression-based path analysis. Inference about the indirect effect is determined by bootstrapping, reporting 95% bootstrap confidence intervals [95% BCa CI]. The number of bootstrap samples was set at 10,000. Effects of the mediation analysis are reported as unstandardized effects (b).

RESULTS

A total of $N = 663$ individuals agreed to participate in the study. After omitting data sets with missing values for one of the investigated measures, $n = 579$ participants were included in the final analyses.

Descriptive Statistics

For an overview of the descriptive statistics, see **Table 1**. Notably, with a mean at the top of the mild severity range, our study sample shows more depressive symptoms compared to the German population norms ($M = 3.56$, $SD = 4.08$, 31). This applies to the PSQ-20 overall score and the BIQ subscales as well. The mean scores of NEB and PBD ranged around the 99th and 14th-21st percentile respectively, compared to representative German population norms (27). The PSQ-20 overall score was also higher than the reference value of $M = 0.33$ of healthy adults (17).

Most of the study population classified as class III obesity. This probably results from the clinical setting participants were recruited: Presenting oneself at a university hospital to seek consultation and/or treatment for obesity often implies psychological strain because of the weight status. Psychological strain is more likely for severely obese individuals who experience more comorbidities and possible impairments (**Table 1**).

TABLE 1 | Demographic characteristics of the study population (N = 579).

Variable	M (SD)	%
Gender		70.3 female 20.9 male
Age (years)	41.68 (12.21)	
BMI (kg/m^2)	45.52 (8.19)	
Obesity		7.1
- Class I		18.3
- Class II		74.6
- Class III		
Comorbidities		
- Type 2 diabetes		31.4
- Arterial hypertension		54.9
- Hyperlipidemia		30.8
- Hyperuricemia		12.0
- Hypothyroidism		24.3
PHQ-9/symptoms of depression	9.43 (6.12)	
BIQ-20		
- NEB	37.48 (8.54)	
- PBD	26.09 (6.86)	
PSQ-20		
- Overall score	0.48 (0.20)	
- Worries	0.44 (0.25)	
- Tension	0.49 (0.24)	
- Joy	0.45 (0.24)	
- Demands	0.42 (0.22)	

BIQ-20, Body Image Questionnaire; BMI, body mass index (kg/m^2); PHQ-9, Patient Heath Questionnaire-9 (section depression); PSQ-20, Perceived Stress Questionnaire.

TABLE 2 | Spearman rho (r_s) correlations of investigated variables.

Variable	Stress	NEB	PBD	BMI
Depressive symptoms (PHQ-9)	.722**	.456**	−.460**	−.015
Stress (PSQ-20)	—	.477**	−.355**	−.064
NEB (BIQ-20)	—	—	−.356**	.175**
PBD (BIQ-20)	—	—	—	−.169**

***$p < .01$; BIQ-20, Body Image Questionnaire; BMI, body mass index (kg/m^2); NEB, negative evaluation of the body; PBD, positive body dynamics; PHQ-9, Patient Health Questionnaire (section depression); PSQ-20, Perceived Stress Questionnaire.*

Correlations

For the complete correlation matrix, see **Table 2**. Correlations were found in the expected directions: Perceived stress and depressive symptoms do not correlate with BMI whereas there are significant but small correlations for BMI and both body image dimensions (**Table 2**).

There is also a significant correlation between perceived stress and depressive symptoms. Both constructs are a sort of psychological distress and therefore associated but not the same construct. Stress may increase the risk for developing depressive symptoms.

Mediation Model

The total effects model for NEB and symptoms of depression proved to be significant [$F(1,577) = 138.42$, $p < .001$, $R^2 = 0.19$]. In line with the found correlations, NEB and symptoms of depression are positively associated, indicating that a more NEB is associated with higher symptoms of depression. This relationship explained about 19% of variance in symptoms of depression. The mediation model with perceived stress as the mediator between

NEB and symptoms of depression also proved to be significant [$F(2,576) = 304.52$, $p < .001$, $R^2 = 0.51$] indicating a significant mediation. The direct effect of NEB on symptoms of depressions is still a significant pathway, although to a smaller degree (total effects model: $b = 0.32$, mediation model: $b = 0.09$). The indirect effect [$b = 0.23$, (95% BCa CI) (0.19; 0.27)] depicts the influence of NEB on symptoms of depression mediated by perceived stress and proved to be significant. The mediation model explained about 51% of variance (**Figure 1**).

The mediation analysis for PBD showed similar results. The total effects model proved to be significant [$F(1,577) = 159.38$, $p < .001$, $R^2 = 0.22$] indicating a negative association between the two variables. Hence, a higher perception of one's vitality is associated with less symptoms of depression. The mediation model with perceived stress as a mediator between PBD and symptoms of depression was also significant [$F(2,576) = 349.61$, $p < .001$, $R^2 = 0.55$]. Similar to the first mediation model, the direct effect of PBD on symptoms of depression remained significant but to a smaller degree (total effects model: $b = -0.42$, mediation model: $b = -0.21$). The indirect effect proved significant as well [$b = -0.21$, 95% BCa CI (−0.26; −0.16)]. This mediation model accounted for 55% of variance.

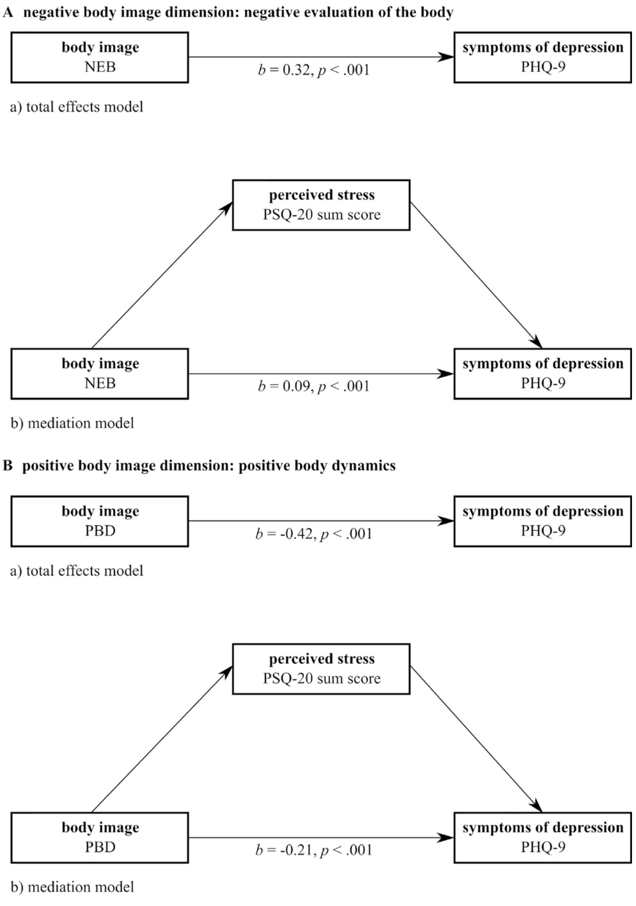

FIGURE 1 | Graphical illustration of the mediation analyses. NEB, negative evaluation of the body; PBD, positive body dynamics; PHQ-9, Patient Health Questionnaire (section depression); PSQ-20, Perceived Stress Questionnaire.

In consideration of potential gender differences in our analysis, we computed the examined correlations and mediation analyses separately for the male and female subgroups. The only difference in correlations was a non-significant correlation for BMI and PBD in the male subgroup. All other correlations corresponded to the correlations of the whole group. The mediation analyses for the male and female subgroup both corresponded to the mediation analysis for the whole group.

DISCUSSION

To the best of our knowledge, this is the first study to explore the mediating role of perceived stress in the relationship of body image dimensions and symptoms of depression in individuals with obesity. We found perceived stress to be a significant mediator for negative dimensions of body image (i.e. negative evaluation of the body) as well as positive body image dimensions (i.e. perception of body dynamics). The mediation model explained a good portion of variance of the relationships of body image dimensions, perceived stress and symptoms of depression in our obese study population.

In line with a review by Schwartz and Brownell (12), we found a linear association of BMI with the perception of body image dimensions in our study sample. Schwartz and Brownell concluded in their review that this association applies to the whole population of obese individuals and may not apply in subgroups such as obese women seeking weight loss. According to the authors, there was not sufficient evidence to comment on men. Looking only at the male subgroup in our study, linear associations between BMI and body image were significant for the negative dimension of body image (NEB) but not for the positive dimension of body dynamics. We can therefore expand existing research concerning this regard.

With regard to the confirmed mediation model, we found similar results before in individuals with anorexia nervosa for the NEB in a longitudinal design (32). In this study, because patients underwent treatment at the time of the perceived stress assessment, increased stress could have been a result of gaining weight during treatment. However, this explanation does not seem sufficient since we found similar patterns in obesity. There are similar patterns concerning other aspects of body image between individuals with obesity and with anorexia nervosa as well: Recent studies examining body image in individuals with obesity found evidence that obese individuals are not generally biased in estimating their own body size but cognitive-affective factors are likely to play an important role (33). Obese children and adolescents did also not differ in their body size estimation from normal weight children and adolescents (34). To the best of our knowledge, possible common mechanisms have still to be determined.

Concerning the treatment of obesity related body image disturbances, studies predominantly show an effect of weight loss and/or lifestyle interventions for the improvement of body image and symptoms of depression (15, 35, 36). Since long-term weight management in obesity remains difficult (37), evidence for identifying relevant variables and developing more specialized treatments is essential. The results of our study suggest that two important aspects should be addressed in order to help prevent the development of depressive symptoms: body image at first instance and also perceived stress.

Only few studies so far directly addressed body image in obese individuals in their intervention: Cognitive behavioral body image therapy lead to an improved body image (38), but did not lead to more improvement in body image when it was added to a weight control program (39). A pilot study showed an increase in body satisfaction in obese adolescents following a mirror exposure intervention (40). Given current research on mirror or body exposure interventions in the field of eating and weight disorders, it might be a recommended intervention for individuals with body image disturbances with and without an eating disorder (41).

In case of perceived stress, successful and specific (body image directed) stress management techniques for obese individuals are missing (22). From our point of view, mindfulness based strategies seem promising. They encourage a mindfulness, non-judgmental stance toward one's body, include body related exercises (e.g. body scan) and reduce perceived stress (see 42 for a systematic review).

A further consideration for this study would have been subgroup analysis for individuals with a binge eating disorder as it has been indicated before that this population shows especially pronounced body image disturbances (43, 44). In our sample, about 25% of participants screened positive for binge eating (episodes). However, as it was only a written screening and no structured and standardized assessed diagnosis, we deemed it not valid to make a subgroup analysis but would plan for a standardized clinical assessment in future studies.

Other studies indeed showed associations between binge eating, perceived stress, and symptoms of depression (12) and determined that binge eating patients are a distinct subgroup of the obese population considering these variables. In this study, we could show that these associations might also apply to the whole obese population, at least the severely obese (class III obesity). One might hypothesize that body image is an important aspect in obesity as well as binge eating. Perceived stress could therefore be an important factor deciding if or to what extent e.g. body image dissatisfaction has a negative impact on symptoms of depression in both entities.

There are three specific limitations to our study we want to address. First, it is a cross-sectional study. We therefore cannot deduct causal relationships between the investigated variables. However, considering the big sample size and robust effects, longitudinal validation of the presented associations (e.g. 32 for patients with anorexia nervosa), would be the next step.

Second, the investigated study population may not be representative for all patients with obesity. Due to the recruitment at a specialized unit for obesity at a university clinic, patients were at least seeking consultation (if not treatment) for obesity. Thus, our study population was more likely to be discontent with their weight and wanting to change it (either through bariatric surgery or conservative programs). The mean BMI of our study population reflects this as well: nearly 75% classified as class III obesity. However, somatic causes of obesity (such as hypercortisolism) could not be included as exclusion criterion in the present study, as well as chronic psychotic (e.g. mild delusional symptoms) or personality disorders. This could potentially bias the results. Considering the comparatively low prevalence of these causes and symptoms and our large sample size, such a bias does not seem likely, but could be controlled for in future studies.

Third, we used a measure for body image that operationalizes body image in a broad way on a two-dimensional score. One subscale represents a negative dimension of body image similar to body dissatisfaction and one dimension represents a positive dimension of body image such as body satisfaction or satisfaction with body appearance. Since this was the first study exploring the mediating role of perceived stress, we think this broader defined measure of body image was adequate but would encourage further research to assess more specific aspects of body image. It can help to understand which aspects of body image have the greatest impact on the here examined relations.

Further directions of research on this topic could include the whole weight spectrum from underweight to obesity determining if these findings can be replicated. If these findings cannot be replicated, there might be e.g. a U-shaped association between body image, perceived stress and/or symptoms of depression if the whole weight spectrum is taken into account as shown by Martin-Rodriguez et al. (8) for the association of BMI at baseline and new-onset of depression. In this case, the mediation model confirmed in this study would not be applicable in the normal weight range. This would point at (not-normal-ranged) weight as an important part of the underlying mechanisms of the found results. Subgroup analyses according to a manifested eating disorder would also be beneficial. Additionally, identifying the most promising stress management techniques, incorporating them or e.g. mindfulness based approaches into lifestyle interventions for obesity and verifying its efficacy for the specific target group of individuals with obesity remains an important challenge.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the ethics committee of the medical faculty of the University of Tuebingen. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KZ, CF, SCB, KEG, MT, SZ, and FJ contributed to the conception and design of the study. SB, E-MS, and IM substantially contributed to the acquisition of data for the study. KZ performed the statistical analysis and wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Body Dissatisfaction, Importance of Appearance, and Body Appreciation in Men and Women Over the Lifespan

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Body image disturbance is associated with several mental disorders. Previous research on body image has focused mostly on women, largely neglecting body image in men. Moreover, only a small number of studies have conducted gender comparisons of body image over the lifespan and included participants aged 50 years and older. With regard to measurement, body image has often been assessed only in terms of body dissatisfaction, disregarding further aspects such as body appreciation or the importance of appearance. The aim of this cross-sectional study was to explore different aspects of body image in the general German-speaking population and to compare men and women of various ages. Participants completed an online survey comprising questionnaires about body image. Body dissatisfaction, importance of appearance, the number of hours per day participants would invest and the number of years they would sacrifice to achieve their ideal appearance, and body appreciation were assessed and analyzed with respect to gender and age differences. We hypothesized that body dissatisfaction and importance of appearance would be higher in women than in men, that body dissatisfaction would remain stable across age in women, and that importance of appearance would be lower in older women compared to younger women. Body appreciation was predicted to be higher in men than in women. General and generalized linear models were used to examine the impact of age and gender. In line with our hypotheses, body dissatisfaction was higher in women than in men and was unaffected by age in women, and importance of appearance was higher in women than in men. However, only in men did age predict a lower level of the importance of appearance. Compared to men, women stated that they would invest more hours of their lives to achieve their ideal appearance. For both genders, age was a predictor of the number of years participants would sacrifice to achieve their ideal appearance. Contrary to our assumption, body appreciation improved and was higher in women across all ages than in men. The results seem to suggest that men's and women's body image are dissimilar and appear to vary across different ages.

Keywords: body image, body dissatisfaction, body appreciation, importance of appearance, gender comparison, age, lifespan

INTRODUCTION

Many people are concerned about at least one part of their body (1). A negative cognitive evaluation of one's body can be an expression of a negative body image (2). Body image is conceptualized as a multidimensional construct, which encompasses a behavioral component involving body-related behaviors (e.g. checking behaviors), a perceptual component involving the perception of body characteristics (e.g. estimation of one's body size or weight), and a cognitive-affective component involving cognitions, attitudes, and feelings toward one's body (3–6).

Negative thoughts and feelings about one's body are defined as body dissatisfaction (7), which is considered to be the most important global measure of stress related to the body (4). Body dissatisfaction has been found to be a predictor for the development of an eating disorder (8) and occurs in individuals with different mental disorders, such as binge eating disorder or social anxiety disorder (e.g. 6, 9), as well as in healthy persons (e.g. 10–12). It represents one of the two poles of the satisfaction-dissatisfaction continuum of body image disturbance (4), which encompasses measures of satisfaction (e.g. being satisfied with particular body areas; e.g. 13) and dissatisfaction (e.g. weight or muscle dissatisfaction; e.g. 14, 15).

Another construct which is related to both the cognitive-affective and the behavioral component is the importance of appearance, also termed appearance orientation, which reflects the cognitive-behavioral investment in one's appearance as an expression of the importance people place on their appearance (16, 17). This construct was shown to be distinguishable from the construct of appearance evaluation (18), which also represents a measure of body satisfaction/dissatisfaction.

Besides negative body evaluation and the importance of appearance, a positive appraisal of one's body also forms part of the cognitive-affective component. For instance, body appreciation is defined as accepting, respecting, and having a favorable opinion of one's own body, as well as rejecting unrealistic body ideals portrayed by the media (19). Body appreciation was shown to predict indices of well-being beyond other measures of body image (19) and occurred simultaneously with body dissatisfaction, highlighting the independence of the two concepts (20).

In the past, studies have investigated the impact of gender and age on body features related to the cognitive-affective component. Specifically, research on body dissatisfaction has shown that girls and female adolescents (e.g. 21–24), and women of all ages (e.g. 12, 25, 26) report body dissatisfaction. While some studies revealed that the level of body dissatisfaction varied across different age groups (27, 28), others found that body dissatisfaction remained quite stable across the adult lifespan in females (20, 25, 29, 30). Studies examining other aspects of the satisfaction-dissatisfaction continuum, such as weight dissatisfaction (15, 31) or satisfaction with particular body parts (13, 32), also found body dissatisfaction in women. Frederick and colleagues (33) estimated that 20% to 40% of women are dissatisfied with their bodies. Nevertheless, body dissatisfaction is also reported in men, suggesting that 10% to 30% of men show body dissatisfaction (33) or 69% of male adolescents to be dissatisfied with their bodies in terms of their weight (34). Frederick and colleagues (14) even reported that 90% of male US students in their sample described themselves as being dissatisfied with respect to muscularity. In terms of body evaluation, striving for increased muscularity, referred to as drive for muscularity (35), has emerged as a central issue for boys and men (e.g. 35–38). It was shown to be distinct from body dissatisfaction (39). However, although previous studies reported that body dissatisfaction does not differ across age in women, it remains unclear whether the level of body dissatisfaction changes across age in men.

While body dissatisfaction seems to remain stable across age in women, studies suggest that the importance of appearance appears to decrease with age (40). In line with Pliner and colleagues, Tiggemann and Lynch (41) found in a group of females aged 20 to 84 years that the importance of appearance was lower in older than in younger women. For men, only one study has examined the importance of appearance, and found that it varied between age groups and reached a peak at age 75 years and older (42). To our knowledge, no other study has examined the importance of appearance in men over the lifetime. Thus, it remains relatively unclear whether the importance of appearance remains stable or changes over the lifetime in men.

With respect to body appreciation, Tiggemann and McCourt (20) demonstrated higher body appreciation in older than in younger women. Furthermore, high body appreciation was found to be protective against the negative effects of media exposure to thin models in women (43). Other studies reported that body appreciation in men and women was associated with a low level of consumption of Western and appearance-focused media (44) and correlated negatively with internalization of sociocultural ideals (45). However, studies focusing on age differences regarding body appreciation in males are lacking.

Previous studies on body image have mostly considered age-related changes in either men or women, or in particular age groups (e.g. college students, adolescents). Only a limited number of studies have compared men and women with respect to the aforementioned aspects of body image. These studies generally found greater body dissatisfaction in females than in males (e.g. 29, 30, 46–49). Men (vs. women) seem to place less importance on their appearance (42, 50, 51) and report slightly higher levels of body appreciation (e.g. 45, 52–54). Tylka and Wood-Barcalow (55) also reported higher body appreciation in college men (vs. college women), but were unable to replicate this effect in a community sample. In contrast to this latter result, Swami and colleagues (53) reported higher body appreciation in men than in women in a sample from the general Austrian population. However, these studies comparing men and women did not analyze their data with respect to the impact of age.

Only a small number of studies have investigated the effect of age and gender on body dissatisfaction, importance of appearance and body appreciation. In a two-year longitudinal study, Mellor and colleagues (56) found that body dissatisfaction was higher in females than in males and higher in younger than in older participants. In another longitudinal study, Keel and colleagues (15) examined men and women over a period of 20 years. As men aged, the authors observed increasing weight and increasing weight dissatisfaction, while weight dissatisfaction decreased in women despite analogous increases in weight. The authors concluded that women appear to be more accepting of their weight as they age (15). Unfortunately, the mean age at the 20-year follow-up was only 40 years, meaning that conclusions could not be drawn about the whole adult lifespan. Similarly, in a large sample of men and women aged 18 to 49 years, Ålgars et al. (46) found that overall body dissatisfaction was higher in women than in men, but that only in women was age associated with decreasing body dissatisfaction, while in men, body dissatisfaction changed across the different age groups (46). However, these results have to be interpreted with caution, as the sample consisted of twins and was thus not representative of the general population.

Other studies found higher levels of body dissatisfaction (28) and lower levels of satisfaction with certain body areas (29) in women than in men. However, the latter study did not find any gender- or age-related effect on overall body dissatisfaction (29). Concerning the importance of appearance, Öberg and Tornstam (42) found that women placed more importance on their appearance than did men, and that this factor remained stable across different age groups in women but varied in men. These results are contrary to the findings of Tiggemann and Lynch (41) and Pliner et al. (40), who found that the importance of appearance decreased with age in women. However, this discrepancy may be due to the assessment method in the study by Öberg and Tornstam, as they used a single item to evaluate the importance of appearance. Hence, the development of importance of appearance in men and women across the lifespan remains unclear.

Although, as mentioned above, some studies have found that women place less importance on their appearance as they age (40, 41), this aspect has not been examined in a large population sample comprising different age groups in relation to the impact of gender and age. Furthermore, studies comparing body appreciation between men and women across different age groups are lacking. To our knowledge, no previous study has examined body dissatisfaction, importance of appearance and body appreciation in the general population including men and women aged 16 to 50 years and older. Therefore, the present study aims to fill this research gap by analyzing these negative and positive aspects of body image in a general population sample considering gender and age.

First, based on the previous findings outlined above, we predicted that body dissatisfaction would be higher in women than in men (Hypothesis 1) and would remain stable across age in women (Hypothesis 2). As no previous study has investigated body dissatisfaction across the whole lifespan in men, we aimed to examine a potential influence of age on body dissatisfaction in men.

Second, we hypothesized that women would place more importance on their appearance than men (Hypothesis 3), but that in line with the aforementioned studies, across age, older women would report lower levels of importance than younger women (Hypothesis 4). Given the lack of corresponding studies in men, we intended to investigate the importance of appearance and its relation to age in men in an exploratory analysis. Furthermore, appearance orientation assesses the importance of appearance in terms of the extent of investment in one's appearance (e.g. grooming behaviors) and in terms of the attention one pays to one's appearance. However, it does not quantify how many hours or years people would be willing to invest in their appearance to look the way they want to. Therefore, as a measure of the importance of appearance, we additionally assessed the number of hours men and women would be willing to invest per day to achieve their ideal appearance, and the number of years of their life they would sacrifice to achieve their ideal appearance.

Third, we predicted that body appreciation would be higher in men than in women (Hypothesis 5). As the aforementioned studies examined gender differences without analyzing the impact of age, we aimed to investigate potential changes in body appreciation across age in an exploratory manner.

Fourth, to take into account the well-documented increase in BMI over the lifetime (e.g. 46, 57, 58) and its potential association with the outcome variables, we examined these relations as a control analysis by calculating correlations between the subjective evaluations of body image and BMI.

MATERIALS AND METHODS

Participants

Inclusion criteria were age 16 years and older, sufficient German-language skills, and internet access. Data were collected from N = 1,338 persons. From the original data set, n = 4 participants had to be excluded due to ambiguous details about their age or invalid responses to questions. Moreover, n = 7 persons were excluded as they did not fit into the binary gender categories male or female. The final study sample comprised n = 942 women and n = 385 men, aged 16 to 88 years (total sample: n = 1,327).

Measures

Demographic Data

All participants completed a questionnaire assessing demographic data such as gender, age, height and weight, educational level, relationship status, sexual orientation, and number of children. The item on sexual orientation was optional. Self-reported weight and height were used to calculate the body mass index (BMI, kg/m^2).

Multidimensional Body-Self Relations Questionnaire–Appearance Scales

The Multidimensional Body-Self Relations Questionnaire–Appearance Scales [MBSRQ-AS; (16); German-language version: (17)] is a self-report questionnaire consisting of 34 items and five subscales to assess different appearance-related aspects of body image. The MBSRQ-AS has been validated for participants aged 15 years and older and for both men and women (16). For the purpose of this study, the *Appearance Evaluation Scale* (seven items) and *Body Areas Satisfaction Scale* (nine items) were used to assess body dissatisfaction, and the *Appearance Orientation Scale* (12 items) was applied to examine the importance people place on their appearance. According to Cash (16), the *Appearance Evaluation Scale* measures overall satisfaction/dissatisfaction with one's appearance and physical attractiveness, with high scores indicating body satisfaction and low scores indicating body dissatisfaction. Furthermore, the *Body Areas Satisfaction Scale* (nine items) assesses satisfaction/dissatisfaction with particular body areas; high and low scores are analogous to the Appearance Evaluation Scale. The *Appearance Orientation Scale* (12 items) evaluates the investment in one's appearance, with low scores indicating that people do not place importance on or invest much effort into being "good-looking". All items are rated on a 5-point Likert scale with different response labeling (*Appearance Evaluation Scale* and *Appearance Orientation Scale*: 1 = definitely disagree to 5 = definitely agree; *Body Areas Satisfaction Scale*: 1 = very dissatisfied to 5 = very satisfied). While the English-language version has been validated in both men and women (16), the German-language version has only been validated for females (17). In the German validation, all subscales showed good internal consistency (α = .78–.90; 17). In the current sample, high internal consistencies were found (*Appearance Evaluation Scale:* α = .88; *Appearance Orientation Scale:* α = .85; *Body Areas Satisfaction Scale*: α = .81), both for men (*Appearance Evaluation Scale:* α = .87; *Appearance Orientation Scale:* α = .85; *Body Areas Satisfaction Scale*: α = .80) and women (*Appearance Evaluation Scale:* α = .89; *Appearance Orientation Scale:* α = .86; *Body Areas Satisfaction Scale*: α = .81).

Body Appreciation Scale-2

The Body Appreciation Scale-2 (BAS-2; 55; German-language version: Steinfeld, unpublished manuscript) assesses body appreciation in a gender-neutral manner using 10 items rated on a 5-point Likert scale (1 = never to 5 = always). High internal consistency (α = .96) was found for the BAS-2 in an English-speaking sample of men and women (55). In our sample, internal consistency was high (α = .94), both in males (α = .92) and females (α = .94).

Investment in One's Appearance

To investigate the amount of time which men and women would be willing to invest in and sacrifice for their own appearance, participants were asked the following two questions: "How many years of your life would you be willing to sacrifice if you could look the way you want?", "How many hours a day would you invest in your appearance if you could look the way you want?"

Single-Item Self-Esteem Scale

The Single-Item Self-Esteem Scale (SISE; 59) measures self-esteem using the item "I have high self-esteem," which is rated on a 5-point Likert scale (1 = not very true of me to 5 = very true of me). It has shown high correlations with the Rosenberg Self-Esteem Scale and a high test-retest reliability after four years (r_{tt} = .75) (59).

Depression Anxiety Stress Scales–Depression Subscale

The Depression Anxiety Stress Scales–Depression Subscale (DASS-D) (60; German-language version: 61) consists of seven items assessing depressive mood over the past week on a 4-point Likert scale (0 = never to 3 = always). For the German version of the DASS-D, high internal consistency has been found (α = .88) (61). In the present study, internal consistency ranged from α = .89 for men to α = .91 for women (total sample: α = .90).

Study Procedure

Participants were recruited via social media, mailing lists, press releases, advertisements, and flyers and were asked to take part in a short online survey comprising different questionnaires about body image. To access the study website, they could either scan a barcode or use a web link. The online survey was set up using the software Unipark (Version EFS Winter 2018; 62). Participants were informed about the purpose of the study and were asked to provide their informed consent by clicking a button next to a declaration asserting that they agree to the processing of their personal data according to the given information. The survey began once participants had provided consent and took approximately 10 min to complete. Participants were offered no financial compensation for study participation. The research project was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of Osnabrück University.

Data Analysis

Data analysis was performed using the software SPSS Statistics (version 25; IBM 63) for descriptive statistics, correlation analysis, and general linear models and the software R (version 3.5.3; R 64) with the DHARMa package (version 0.2.4; 65), the glmmTMB package (version 0.2.3; 66), and the MASS package (version 7.3–51.3; 67) for generalized linear models. As we intended to explore homogenous hypotheses in terms of body dissatisfaction, the power was set at a significance level of $p = .10$ for the variable age.

For group comparisons on demographic and descriptive variables (**Table 1**), we calculated Mann-Whitney U Tests, as our data were not normally distributed (except BMI). Since inferential statistics for simple comparisons are massively overpowered in such large samples, we additionally report effect sizes. For better interpretability, U-values were converted into correlation coefficients r (68, 69). For correlations between BMI and the body image variables (**Table 3**), Spearman's rank correlations were calculated due to non-normally distributed data.

For linear and generalized linear models, gender was dummy-coded, with men as the reference category. Age was centered to simplify the interpretation of the model coefficients. Due to missing data on single items within the questionnaires, the sample sizes for the initial model estimations varied, since participants were only included in the respective data analysis if they answered all items of a scale. To examine the individual impact of gender and age for each dependent variable, we started with the general linear model and inspected the residual distributions, tested statistically and by visual inspection for normality, and tested for homogeneity of

TABLE 1 | Descriptive statistics and group comparisons regarding age, height, weight, BMI, depression, and self-esteem.

	Total sample			**Women**			**Men**			**Test Statistics**		
	M (SD)	***N***	**Min; Max**	***M (SD)***	***N***	**Min; Max**	***M (SD)***	***N***	**Min; Max**	***U***	***p***	***r***
Age	33.05 (14.09)	1,327	16; 88	31.40 (13.33)	942	16; 83	37.08 (15.08)	385	16; 88	134,235	***	0.2
Height	173.01 (9.04)	1,322	150; 212	169.15 (6.46)	938	150; 188	182.45 (7.33)	384	160; 212	31,581.5	***	0.65
Weight	72.61 (16.89)	1,319	40; 175^{+}	67.73 (14.75)	936	40; 155	84.55 (15.85)	383	55; 175^{+}	63,599	***	0.51
DASS-D	1.60 (0.62)	1,319	1; 4	1.62 (0.64)	937	1; 4	1.56 (0.57)	382	1; 4	187,904.50	n.s.	0.04
SISE	2.84 (0.76)	1,327	1; 4	2.77 (0.76)	942	1; 4	3.01 (0.72)	385	1; 4	151,165.50	***	0.14
										T	***p***	***r***
BMI	24.15 (4.88)	1,314	15.43; 62.75^{+}	23.65 (4.93)	932	15.43; 49.01	25.37 (4.55)	382	17.32; 62.75^{+}	5.88	***	0.18

*Age in years; height in centimeters; weight in kilograms. DASS, Depression Anxiety Stress Scale–Depression Subscale; SISE, Single-Item Self-Esteem scale; BMI, Body Mass Index; M, mean; SD, standard deviation; N, sample size; Min, minimum; Max, maximum; U, Mann-Whitney U test; t, t value; p, p value; r, correlation coefficient. ***p < .001; n.s., nonsignificant; + = one man reported this extreme but still realistic value regarding weight and BMI. In all general linear models and all generalized linear models, outlier detection marked him as an outlier and did not include him in the analyses.*

variance as well as for skewness, kurtosis, and outliers (Mahalanobis and Cook's distance, Leverage). While Cook's distance should be smaller than 1 (70) and Leverage for large samples $<3k/N$ (71), a value was identified as an outlier if the Mahalanobis distances were above the critical χ^2 value exceeding the probability of 0.01 (72) and if studentized deleted residuals were larger than 3 standard deviations. The highest number of outliers was detected for the Body Areas Satisfaction Scale, with 3.36%. Comparisons of the models with and without outliers revealed no substantial differences; hence, we report the models without potential outliers, as power issues were not expected for such a large sample size and precision of estimates was prioritized. Final sample sizes are reported for each model (**Tables 4** and **5**).

For the Body Areas Satisfaction Scale, the assumption of homogeneity was violated. Therefore, a general linear model was calculated, using the HC3 method for robust estimation of the standard errors. Furthermore, due to skewness and non-normal distribution of the data, responses to the Body Appreciation Scale-2 were inverted and a generalized linear model with a gamma distribution and identity link function was used. The analyses of hours people would invest in their appearance and years people would sacrifice from their lives indicated severe violations of the assumptions of the general linear model, since their distributions were similar to zero-bounded count data. Therefore, the numbers of hours and years were rounded to integer values to enable us to calculate several Poisson and negative binomial regression models, which are suitable for count data. The fit of each model was assessed by tests for overdispersion and zero inflation, as well as by tests of residual fit using the DHARMa package. As a final model for the analyses of the years people would sacrifice from their lives, we used a negative binomial regression with a log-link and linearly increasing variance (73) and adjustment for zero inflation for the intercept using the glmmTMB package. For the analyses of the hours people would spend on their appearance, we used a negative binomial regression with the log-link function using the MASS package.

RESULTS

Sample Characteristics

Descriptive statistics and group differences are shown in **Table 1**. Men and women differed significantly in terms of age, height, weight, BMI, and self-esteem. Compared to women, men were slightly older, taller, and heavier and had a higher BMI. This is in line with data from the German Federal Statistical Office (57), which reported a mean weight of 68.7 kg, a mean height of 166 cm and a mean BMI of 25.1 in German women, and a mean weight of 85.0 kg, a mean height of 179 cm and a mean BMI of 26.1 in German men. As indicators of psychopathology, men and women did not differ regarding depressive mood over the past week ($p = .152$), whereas self-esteem was higher in men than in women.

Information about educational level, relationship status, number of children, and sexual orientation is reported in **Table 2**. Of the total sample, $n = 29$ participants (of whom $n = 23$ were female) refused to answer the question regarding sexual orientation, and $n = 3$ participants (of whom $n = 1$ was female) did not state whether they had children. A recent study on the proportion of Lesbian, Gay, Bisexual, and Transgender (LGBT) persons in Europe reported that 7.40% of the German population identify themselves as LGBT (74). In our sample, 10.17% reported a sexual orientation other than heterosexuality, which is slightly higher than the reported value for the German population, but can be still considered as representative.

The Spearman's rank correlations of BMI with body dissatisfaction, importance of appearance, the number of hours per day participants would invest and years they would sacrifice to achieve their ideal appearance, and body appreciation are displayed in **Table 3**.

General and Generalized Linear Models

Table 4 presents the descriptive statistics for appearance evaluation, body areas satisfaction, appearance orientation, hours of investment, and years of sacrifice, as well as body appreciation, separated for total sample, men, and women. The results of the general and the generalized linear models are displayed in **Table 5**. Regarding body dissatisfaction, gender emerged as the only significant predictor of appearance evaluation ($t = -2.012$, $p = .044$) and body areas satisfaction ($t = 4.282$, $p < .001$), indicating lower appearance evaluation and lower body areas satisfaction in women than in men. Age (appearance evaluation: $t = -1.489$, $p = .137$; body areas satisfaction: $t = -1.605$, $p = .109$) and the interaction of age ×

TABLE 2 | Numbers and percentages regarding educational level, relationship status, and sexual orientation for total sample, women, and men.

	Total sample (N = 1,327)		Women (N = 942)		Men (N = 385)	
	N	%	*N*	%	*N*	%
Achieved level of education						
No educational attainment	6	0.45	4	0.42	2	0.52
Secondary school certificate	22	1.66	9	0.96	13	3.38
General secondary or extended secondary school certificate	123	9.27	85	9.02	38	9.87
Advanced technical college certificate	88	6.63	62	6.58	26	6.75
General qualification for university entrance	451	33.99	358	38.00	93	24.16
Polytechnic degree	147	11.08	85	9.02	62	16.10
State examination/university degree	464	34.97	320	33.97	144	37.40
Other	26	1.96	19	2.02	7	1.82
In a relationship	836	63.0	582	61.8	254	66.0
Sexual orientation						
Heterosexual	1,163	87.64	820	87.05	343	89.09
Homosexual	44	3.32	23	2.44	21	5.45
Bisexual	79	5.95	66	7.01	13	3.38
Other	12	0.90	10	1.06	2	0.52
Children	376	28.33	246	26.11	130	33.77

N, sample size; %, percentage regarding the respective sample. In terms of sexual orientation, 29 participants (23 female) did not answer; regarding children, three participants (one female) did not answer.

gender (appearance evaluation: $t = 1.630$, $p = .103$; body areas satisfaction: $t = 1.257$, $p = .209$) did not reach statistical significance. In terms of the importance of appearance, gender ($t = 6.597$, $p < .001$), age ($t = -3.636$, $p < .001$), and the interaction of gender × age ($t = 3.194$, $p < .001$) significantly predicted appearance orientation, revealing that women placed more importance on their appearance than did men, whereas age only influenced the importance of appearance in men. The number of hours which participants would spend on their appearance if they could achieve their ideal appearance was predicted by gender ($z = 2.037$, $p = .042$) and age ($z = -4.654$, $p < .001$), indicating that women would invest more hours than men, but that with higher age, both genders would invest fewer hours in their appearance. The interaction of gender × age ($z = 0.428$, $p = .67$) was not significant. Age was the only predictor of the number of years participants would be willing to sacrifice to achieve their ideal appearance ($z = -5.828$, $p < .001$), revealing that with higher age, men and women would sacrifice fewer years for their ideal appearance. Neither gender ($z = -0.526$, $p = .60$) nor the interaction of gender × age ($z = 1.015$, $p = .310$) had a significant impact on the number of years. Furthermore, gender ($t = 2.828$, $p = .005$) and the interaction of gender × age ($t = -2.186$, $p = .029$) were significant predictors of body appreciation, insofar as with higher age, women reported higher body appreciation than men, while body appreciation in men remained stable with higher age. Age ($t = 0.127$, $p = .899$) did not reach statistical significance.

DISCUSSION

The aim of the present study was to investigate potential gender differences and the impact of age on body dissatisfaction, importance of appearance, the number of hours per day participants would invest and the number of years they would sacrifice to achieve their ideal appearance, and body appreciation in the general population.

As predicted in our first hypothesis, we found an effect of gender on the Appearance Evaluation Scale and the Body Areas Satisfaction Scale, suggesting that women were significantly more

TABLE 3 | Spearman's correlations between BMI and the scores on the scales Appearance Evaluation, Body Areas Satisfaction, Appearance Orientation, the number of hours per day participants would invest to achieve their ideal appearance, and the number of years participants would sacrifice to achieve their ideal appearance and Body Appreciation for total sample, women, and men.

BMI	Appearance evaluation	Body areas satisfaction	Appearance orientation	Hours	Years	Body appreciation
Total sample	−.375***	−.344***	−.063*	.064*	.028	−.198***
N	1,290	1,295	1,291	1,289	1,306	1,293
Women	−.419***	−.399***	−.006	.092**	.074*	−.228***
N	915	920	919	913	927	919
Men	−.327***	−.318***	−.058	.116*	−.096	−.199***
N	375	375	372	376	379	374

*BMI, body mass index. *p < .05; **p < .01; ***p < .001.*

TABLE 4 | Descriptive statistics regarding the scores on the scales Appearance Evaluation, Body Areas Satisfaction, Appearance Orientation, hours of investment, and years of sacrifice, as well as Body Appreciation for total sample, women and men used in the final models.

	Total sample			Women			Men		
	M (SD)	**Min; Max**	***N***	***M (SD)***	**Min; Max**	***N***	***M (SD)***	**Min; Max**	***N***
Appearance evaluation	3.49 (0.77)	1.14; 5.00	1,261	3.47 (0.79)	1.14; 5.00	913	3.55 (0.73)	1.29; 5.00	348
Body areas satisfaction	3.49 (0.64)	1.56; 5.00	1,264	3.44 (0.65)	1.56; 5.00	918	3.60 (0.59)	1.78; 5.00	346
Appearance orientation	3.11 (0.64)	1.25; 4.92	1,303	3.20 (0.62)	1.50; 4.92	929	2.91 (0.64)	1.25; 4.42	374
Hours	0.97 (1.47)	0.00; 24.00	1,294	1.04 (1.60)	0.00; 24.00	919	0.79 (1.07)	0.00; 6.00	375
Years	1.60 (3.94)	0.00; 40.00	1,317	1.64 (3.97)	0.00; 40.00	936	1.52 (3.88)	0.00; 35.00	381
Body appreciation	2.42 (0.77)	1.00; 4.90	1,306	2.46 (0.79)	1.00; 4.90	929	2.32 (0.72)	1.00; 4.80	377

M, mean; SD, standard deviation; N, sample size; Min, minimum; Max, maximum; Hours, number of hours per day men and women would invest to achieve their ideal appearance; Years, number of years men and women would sacrifice to achieve their ideal appearance.

TABLE 5 | General linear models for the prediction of Appearance Evaluation, Body Areas Satisfaction and Appearance Orientation as well as generalized linear models for the prediction of Body Appreciation, the number of hours per day participants would invest to achieve their ideal appearance, and the number of years participants would sacrifice to achieve their ideal appearance, with gender and age as predictors.

	b	***SE (b)***	**95% CI**		***P***
			LL	**UL**	
Appearance evaluation (*N* = 1,261)					
Constant	3.562	0.042	3.497	3.644	***
Gender	−0.099	0.049	−0.196	−0.002	*
Age	−0.005	0.004	−0.012	0.002	n.s.
Gender × age	0.007	0.004	−0.001	0.015	n.s.
Body areas satisfaction (*N* = 1,264)					
Constant	3.444	0.022	3.402	3.487	***
Gender	−0.168	0.039	−0.244	−0.091	***
Age	−0.004	0.002	−0.009	0.001	n.s.
Gender × age	0.004	0.003	−0.002	0.010	n.s.
Appearance orientation (*N* = 1,303)					
Constant	2.939	0.033	2.873	3.005	***
Gender	0.259	0.039	0.182	0.336	***
Age	−0.008	0.002	−0.012	−0.004	***
Gender × age	0.008	0.003	0.003	0.014	**
Hours (*N* = 1,294)					
Constant	−0.195	0.068	−0.329	−0.064	**
Gender	0.162	0.079	0.007	0.318	*
Age	−0.024	0.005	−0.035	−0.014	***
Gender × age	0.003	0.006	−0.009	0.014	n.s.
Years (*N* = 1,317)					
Constant	0.398	0.102	0.199	0.597	***
Gender	−0.058	0.110	−0.273	0.158	n.s.
Age	−0.046	0.008	−0.062	−0.031	***
Gender × age	0.0097	0.010	−0.009	0.029	n.s.
Body appreciation (*N* = 1,306)					
Constant	2.315	0.039	2.241	2.394	***
Gender	0.132	0.047	0.039	0.222	**
Age	0.0003	0.003	−0.005	0.005	n.s.
Gender × age	−0.007	0.003	−0.013	−0.001	*

*b, regression weights; SE(b), standard errors of the regression weights; CI, 95% confidence interval with LL, lower limit and UL, upper limit; p, p value; Hours, number of hours per day men and women would invest to achieve their ideal appearance; Years, number of years men and women would sacrifice to achieve their ideal appearance. Appearance evaluation: $R^2 = .005$; body areas satisfaction: $R^2 = .013$; appearance orientation: $R^2 = .052$; hours: AIC = 3,418.6; years: AIC = 3,800.1; body appreciation: AIC = 2,907.8. n.s., nonsignificant; *p < .05; **p < .01; ***p < .001.*

dissatisfied with their bodies than men. This is in accordance with the results of several studies (e.g. 28, 30, 46, 56), which likewise reported higher levels of body dissatisfaction in women than in men. In line with our results, Fallon and colleagues (29) found that women (vs. men) reported higher levels of body dissatisfaction on the Body Areas Satisfaction Scale, but contrary to our study, the authors did not find an effect of gender on the Appearance Evaluation Scale. Keel et al. (15) even found higher weight dissatisfaction in men than in women, which is also in contrast to previous findings. Therefore, it might be possible that women may be more satisfied with their weight while still reporting more body dissatisfaction.

Additionally, we found that body dissatisfaction on the Appearance Evaluation Scale and on the Body Areas Satisfaction Scale was not influenced by age or by the interaction of gender and age, indicating that body dissatisfaction remains stable across all ages for both genders. For women, this finding confirms our second hypothesis, which assumed that body dissatisfaction would not be influenced by age, and also supports previous findings (e.g. 20, 25, 29, 30). One study by Öberg and Tornstam (42) found that body satisfaction was higher in older than in younger women, which is also in contrast to our findings, as we found no influence of age on body dissatisfaction. For men, our results indicate that body dissatisfaction remains stable across different ages. This is in contrast to Ålgars and colleagues (46), who found that body dissatisfaction varied across different age groups in men. However, the latter finding might be attributable to artificial grouping strategies, as the authors investigated the impact of the continuous variable age as a categorical variable through the use of age groups. Moreover, Ålgars and colleagues (46) only assessed participants between the age of 18 and 49 years. The present study included men and women aged from 16 to 88 years, thus covering a broader proportion of the lifespan in Germany; according to the German Federal Statistical Office (75), the average life expectancy lies at 78.4 years for men and 83.2 years for women. To sum up, body dissatisfaction seems to remain relatively stable across different ages, both for men and for women.

In line with our third hypothesis that women would place more importance on their appearance than men, we found a significant effect of gender on the Appearance Orientation Scale, indicating that women indeed place more importance on their appearance compared to men. This finding corroborates previous studies (42, 50, 51). Moreover, age was a significant predictor of appearance orientation, as was the interaction of gender and age. Although age and the interaction of gender and age reached statistical significance, only in men did higher age bring about a lower importance of appearance. For women, the regression weights of age and the interaction of gender and age cancelled each other out. Therefore, gender was the only factor to impact appearance orientation in women, and the importance of appearance was not affected by age in women. This is in contrast to our fourth hypothesis that older women would report lower levels of importance of appearance than younger women. It also conflicts with previous findings (40, 41), as we found that appearance orientation remained stable across all ages in women. In line with our finding, Öberg and Tornstam (42) also reported that the importance of appearance remained stable in women of different ages. They further found a small variation of the importance of appearance across different age groups in men, with the level of importance being more pronounced from the age of 45 years and older (42). However, we observed that older men seem to place less importance on their appearance than do younger men.

As the construct of importance of appearance does not reflect the extent to which people are willing to invest time in order to reach their ideal appearance, we additionally assessed the amount of hours per day participants would invest, and the number of years of their lives they would sacrifice, in order to achieve their ideal appearance. We found an effect of gender and age on the number of hours spent on appearance, but only an effect of age on the number of years which participants would sacrifice for their appearance. Women were more likely to spend more hours per day on their ideal appearance than men. However, older men and women would invest fewer hours than their younger counterparts. Concerning the number of years people would be willing to sacrifice to achieve their ideal appearance, we found no effect of gender, but found age to be a significant predictor, meaning that older men and women would sacrifice fewer years from their lives for the sake of their ideal appearance. This indicates that in terms of their behavioral investment regarding the importance of appearance, men and women may be more similar than hitherto assumed. Apparently, women might find it easier to relinquish a small number of hours per day to be invested in their appearance compared to men, but regarding lifetime investment, both genders might be unwilling to sacrifice years of their lives for the sake of their appearance.

Furthermore, we examined the impact of gender and age on body appreciation, and found gender and the interaction of gender and age to be significant predictors. The significant effect of gender suggested that women showed less body appreciation than did men. This is in line with our fifth hypothesis that women would show lower levels of body appreciation than men, and is also in accordance with other studies (45, 53, 76). However, the significant interaction of gender and age indicates that with higher age, women report higher levels of body appreciation compared to men. This is in contrast to the aforementioned studies (e.g. 45, 53, 76), but may provide an explanation for the lack of a gender effect in an English-speaking community sample in the study by Tylka and Wood-Barcalow (55). Interestingly, compared to our study, Tylka and Wood-Barcalow (55) reported slightly higher values (from 3.22 to 3.97) for their samples for both genders. Furthermore, the significant interaction in our study suggested that body appreciation also improves in women across age, and older (vs. younger) women report higher levels of body appreciation. This is in line with Tiggemann and McCourt (20), who found greater body appreciation in older than in younger women. Regarding men, as pointed out above, no previous study has investigated the impact of age on body appreciation. In our study, the level of body appreciation remained quite stable across different ages in men, and was lower compared to that of women. An explanation might be that men are possibly more affected by restrictions of their body's functionality due to aging processes (27), whereas women may cherish their body and the remaining functionality.

With respect to the associations between BMI and the aspects of body image, we found significant negative correlations between BMI and the Appearance Evaluation Scale and Body Areas Satisfaction Scale for men and women, insofar as with increasing BMI, values on both scales decreased (= higher body dissatisfaction). This is in line with previous research, which found that BMI was positively associated with body dissatisfaction in both genders (e.g. 77–81). Body appreciation was found to be negatively correlated with BMI for both genders, which is partially in line with previous research: One study found this association for women but not for men (53), while other studies yielded mixed findings, reporting either a negative association between BMI and body appreciation (e.g. 82, 83) or no significant results (e.g. 44). Concerning the importance of appearance, we found no significant association with BMI for either gender. In line with our results, some previous studies found no association between the importance of appearance and BMI in both men and women (13, 84), while others reported a positive correlation for women but no significant association for men (85). The latter may be explained by the differentiation between the importance of appearance and the investment of time in appearance, as we found that BMI was positively associated with the number of invested hours for both genders, but was only associated with the number of years participants would sacrifice to achieve their ideal appearance in women. These findings emphasize the distinction between the evaluative perspective of the importance of appearance (How essential are my looks to me)? and the behavioral perspective of the extent of investment in appearance (How many hours/years am I willing to invest in my appearance)?. For instance, a person may place importance on his or her appearance, but as appearance is less important than years of his or her life, he or she is unwilling to invest much effort in appearance. As shown in our study, women reported quite stable, higher levels of importance across age than did men. Consequently, it might be assumed that they have to invest more time in order to achieve their ideal appearance. Nevertheless, as older men and women would invest fewer hours and sacrifice fewer years, the extent of investment or sacrifice is evidently not expressed by the importance of appearance. These results underline the need to differentiate between the importance of appearance and the investment of time in one's appearance.

Although in the present study, women reported a higher degree of body dissatisfaction than did men, men's and women's responses on average lay slightly above the value of 3 on the 5-point Likert scale (**Table 4**). This indicates, on average, neither agreement nor disagreement on the two scales (3 = I neither agree nor disagree) and possibly reveals a more neutral to slightly positive evaluation of one's body. These results are in line with those of Cash (16) and Fallon et al. (29), who reported similar values on both scales for men and women. Therefore, on average, men and women may be neither particularly dissatisfied nor particularly satisfied with their bodies.

In consideration of all of the aforementioned research, one has to raise the more general question of whether the absence of body dissatisfaction is synonymous with the presence of body satisfaction in terms of a continuum model as proposed by Thompson et al. (4). Another possibility lies in an alternative model, in which body satisfaction and body dissatisfaction coexist alongside one another. For instance, it may be possible for a person to report high levels of overall body dissatisfaction, while simultaneously reporting high levels of body satisfaction with certain areas (e.g. "In general, I am dissatisfied with my body, but I like my legs, my cheeks and my hair."). This could result in neither agreement nor disagreement on a continuum scale. Further research is needed to investigate a possible coexistence of both concepts.

Some limitations have to be mentioned when interpreting the results of the present study. Although several coefficients turned out to be significant, they contribute only a minimum of change to the dependent variables. In addition, according to the conventions of Cohen (86), we found very small values for the R^2s, as the R^2s in the present study explained only 0.5% (appearance evaluation) up to 5.2% (appearance orientation) of the total variance. Due to our total sample size of N = 1,327, the significance of the coefficients therefore might be attributed to the study's power. Moreover, as was the case for most of the previous studies (except for 15 and 56), we did not investigate age effects in a longitudinal design. Therefore, it is not possible to disentangle the effects of age and birth cohorts. The effects found in this study may be related to different birth cohorts, the way in which people were brought up and socialized, or different ideals of beauty and fashion. Longitudinal studies including different age cohorts of men and women are therefore required.

Another limitation may lie in the assessment method. As younger people use the internet more frequently than older people (87), it cannot be excluded that this could have led to a stronger selection bias in older participants. Further, the online assessment may not be representative for the general population (88). Thus, there was no control regarding the implementation conditions of participation (e.g. whether there were distractions while participating) or regarding who was participating (88). False answers on variables such as weight, height, and age seem to be easier to notice in the laboratory. However, false statements concerning the variables of body image may be just as difficult to detect in the laboratory or in paper-and-pencil examinations as in online assessments. Our calculation of correlations between BMI and the outcome variables may be seen as a control analysis, as the participants' answers on BMI were associated with our dependent variables, in line with aforementioned research.

Furthermore, our sample included more women than men. This may reflect the fact that women are more likely to participate in studies than men (e.g. 89, 90). Although general and generalized linear models are able to control for different sample sizes, men and women differed significantly regarding age, height, weight, and self-esteem. While the differences in weight and height could be explained by natural gender differences, men were slightly older than women. As a further limitation, the assessment was restricted to certain body-related aspects and omitted other concepts such as the drive for muscularity (35) or drive for thinness (91). We only included appearance-related aspects of body image and body appreciation in order to shorten the length of our study and to decrease the burden of our survey on respondents. Therefore, we concentrated on more general aspects related to the cognitive-affective component of body image. Future studies need to investigate the impact of gender and age on other components of body image, such as perceptual estimation of body size (e.g. 92) or checking behaviors (e.g. 93). Although some studies have already investigated body image regarding genders other than the distinct categories of male and female (e.g. 94, 95), we did not analyze these persons in the present study due to the insufficient sample size ($N = 7$). Moreover, we did not investigate the relation between sexual orientation and body image, although previous studies have found indications of an influence of sexual orientation on body image (96–99). Therefore, future research should investigate the impact of age on body image for different sexual orientations.

In conclusion, the present study is one of the first to examine body dissatisfaction, importance of appearance, the number of hours participants would be willing to invest per day to achieve their ideal appearance and the number of years they would sacrifice to achieve their ideal appearance, and body appreciation in relation to gender and age. Body appreciation was higher in older than in younger women and women reported higher levels of body appreciation compared to men. While the importance of appearance was lower in older than in younger men and remained stable in women, neither gender was willing to relinquish a large amount of time for the sake of their appearance. Although we found higher body dissatisfaction for women than for men, both genders seem to be neither satisfied nor dissatisfied with their bodies on average. Eating disorder prevention programs, or therapeutic approaches for several mental disorders, could benefit from a more functional perspective on the absence of body satisfaction, as this does not necessarily equate with the presence of body dissatisfaction.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics committee of Osnabrück University. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

HQ, SV, AH, and UB planned and conducted the study. RD and HQ analyzed the data. HQ wrote the first draft of the manuscript. All authors contributed to the compilation of the manuscript and read and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Body Image and Body Avoidance Nine Years After Bariatric Surgery and Conventional Weight Loss Treatment

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Recently, there has been an increasing focus on body image dissatisfaction (BID), both as a motivational factor for seeking bariatric surgery and as a factor influencing weight loss outcome after surgery. Although associations have been reported between BID, emotional distress and successful weight loss, conclusions are limited due to methodological issues such as non-weight-specific assessment tools for body image and neglect of behavioral components (e.g. body avoidance, BA). The present study seeks to report on BID and BA 9 years after bariatric surgery using a cross-sectional data set from the 9-year follow-up assessment of the Essen–Bochum Obesity Treatment Study (EBOTS). In total, N = 291 participants of the original EBOTS sample were included in the present analyses (N = 78 bariatric surgery patients, SURG; N = 124 patients of a conventional treatment program, CONV; and N = 83 individuals with obesity not seeking treatment, OC). Current body image facets (BID and BA) were captured at the 9-year follow-up assessment *via* silhouette scales adapted for use in samples with obesity. Moreover, BID was assessed retrospectively to obtain baseline attitudes. Possible influences of eating disorder symptoms and depression/anxiety were controlled for and assessed *via* standardized self-report measures. The results imply an improvement in BID in the SURG group, but not in the CONV and OC groups. The level of BA in relation to clothing was significantly higher in the CONV group compared to both the SURG and OC group. Current BID as well as BA were positively associated with current body weight as well as depression, anxiety, and levels of disinhibited eating. A positive change from baseline to current levels of BID was associated with successful weight loss, independently of treatment. The findings emphasize the role of the different components of body image after surgery for mental health features, and suggest a robust relationship between BID and weight loss (success). Thus, it might be helpful to address BID in treatment. However, further research, particularly in the form of prospective studies, is necessary to determine the direction of influence.

Keywords: obesity, bariatric surgery, body image, body avoidance, weight loss, eating pathology

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INTRODUCTION

Obesity [defined as a body mass index (BMI) ≥30 kg/m^2] is a clinical disease with a high risk of chronicity. As such, prevention and management of obesity have become important public health issues. Bariatric surgery has received increased attention, in particular for the treatment of individuals with severe obesity, as it successfully reduces weight, with major physiological benefits also in the long term (1). However, reports regarding mental health and course of weight after surgery have shown less favorable outcomes in some patients (2–5). In this regard, research has recently begun to focus on body image dissatisfaction, both as a motivational factor for seeking bariatric surgery (6, 7) and as a factor influencing weight loss outcome after surgery (8).

Body image needs to be considered as a multifaceted construct, which encompasses perceptual deficits (e.g. seeing oneself as fatter than one is), cognitive-affective/attitude distortion (e.g. thinking negatively about one's body), and dysfunctional body-related behaviors such as checking and avoidance behaviors [e.g. (9–11)]. Body image disturbances are common among young people, and especially among females [e.g. (12)], and are core symptoms of eating disorders such as anorexia or bulimia nervosa (13). However, over the last decade, robust evidence has emerged that body image disturbances also occur in individuals with obesity. Study findings have emphasized associations between obesity and cognitive/attitudinal components of body image, indicating a relation between higher dissatisfaction/low appearance evaluation and increasing weight. Moreover, heightened body avoidance and checking behaviors are also common among this patient group [e.g. (8, 14, 15)]. There is also some evidence regarding the misperception of body size (14, 16), as well as robust evidence that body image dissatisfaction (BID) in individuals with obesity seeking bariatric surgery is related to increased distress (17). In particular, depression, anxiety, and suicidality have been associated with BID pre-surgery, and interestingly, emotional eating served as a mediator between BID and psychological stress (18).

Given that a negative body image is a motivational factor to undertake weight loss efforts and is related to the level of physical activity, dietary control strategies, and caloric intake, etc. (14), changes in body weight might be associated with enhanced body image. Indeed, several studies showed improvements in body dissatisfaction after conventional, non-surgical weight loss treatments that were associated with weight loss outcome [e.g. (19–21)]. Moreover, in samples of individuals with severe obesity undergoing bariatric surgery, a positive body evaluation after bariatric surgery was associated with greater weight loss (22, 23) and better quality of life (8), whereas poor weight loss outcome after gastric banding was associated with persistently negative body image (24). A negative body perception following surgery was associated with the presence of psychopathology, such as higher depression or anxiety (8).

Despite this preliminary evidence supporting an association between body image and weight change after conventional and surgical weight loss treatment, some methodological issues have to be considered, which probably limit the generalizability of these findings: For instance, most studies relied on non-weight-sensitive assessment tools such as questionnaires that were developed and validated within the normal-weight general population and thus do not consider differences in attitudes and experiences between normal-weight and individuals with obesity (25, 26). Furthermore, most studies did not control for eating disorder symptomatology, although it has been shown that the presence of an eating disorder is linked to greater BID among individuals with obesity (16). In addition, most studies neglected the multifaceted nature of body image by focusing only on cognitive-attitudinal components (27). As behavioral aspects of body image, such as avoidance and checking behaviors, are known to maintain a negative body image and are also related to eating pathology in bariatric surgery patients (28), it seems important to include these components when investigating weight loss outcome and body image in individuals with obesity seeking bariatric surgery. However, to our knowledge, there is only one recent study that included body avoidance and checking behavior besides attitudinal aspects in a pre- to 6-month post-surgery assessment (29). The results showed that body dissatisfaction, feelings of fatness, and body avoidance were significantly reduced 6 months after surgery, with the largest reduction being found for body avoidance.

In summary, body image features seem to be associated with the course of weight after bariatric surgery and might be accompanied by eating disturbances (emotional eating) and psychological distress (e.g. higher depression or anxiety scores). Current evidence is limited to questionnaire-based, non-weight-sensitive assessments and mostly neglects the multifaceted nature of body image. Moreover, comparisons between conventional and surgical procedures for weight loss and non-treatment-seeking individuals with obesity, as well as investigations with long-term outcome monitoring, are lacking. Consequently, further research is warranted to better understand the associations between body image and its different facets, and the changes therein following bariatric surgery. The present study therefore seeks to report on body image attitudes and behaviors 9 years after surgery using a cross-sectional data set from a 9-year follow-up assessment during the Essen–Bochum Obesity Treatment Study (EBOTS). A conventional treatment group as well as individuals with obesity who did not seek weight loss treatment acted as control groups. As the weight loss should be higher in those who underwent surgery, we assume a greater reduction in perceived body size and body dissatisfaction and lower avoidance-related behaviors in this group compared to both control groups. We also assume that the reduction in perceived body, body dissatisfaction, and body-related avoidance behavior will be associated with the amount of weight loss. Finally, we seek to explore the differential impacts of these components on successful weight loss while considering factors that might also be related to body image features and weight loss (eating disorder symptoms, depression and anxiety levels).

METHOD

Design and Procedure

The present cross-sectional analysis is part of a large controlled multicenter study (initiated in 2000) that aimed to prospectively investigate predictors of the short- and long-term course of weight after surgical and non-surgical weight-loss treatment. As the main research questions as well as detailed information concerning design and procedure have been published elsewhere (4, 30–38), only the most important information is summarized here: In 2000, the study began with a cross-sectional assessment comprising individuals with obesity seeking non-surgical and surgical weight loss treatment as well as controls with obesity. The control group was originally recruited from a random selection of the residents list (all citizens in Germany are legally required to register their place of residence) of the city of Essen (about 600,000 inhabitants) and matched for age and weight. Bariatric surgery patients were recruited from six surgery departments in Germany and were assessed on the day of hospital admission. Participants in the conventional treatment group had undergone the Optifast® program which included a multidimensional therapy approach (nutritional counseling, behavioral modification) with weekly group sessions over 1 year. During the initial 12 weeks of Optifast®, a liquid meal replacement was applied. The following exclusion criteria were applied for all participants: pregnancy, chronic, non-obesity-associated diseases or disabilities, or a diagnosis of psychotic disorder or dementia. In addition, participants of the population-based control group with obesity who reported that they were currently trying to lose weight were excluded.

All participants with obesity were approached at five assessment time points (baseline, 1, 2, 4, and 9 years after the intervention). At the 9-year assessment, participants were contacted by telephone and, after providing informed consent, were sent the self-report questionnaires. In addition, they either came to the treatment center or were visited at home to be interviewed with two clinical structured interviews by one of four trained clinical psychologists, who were monitored throughout the study. Body weight and height were measured under controlled conditions after the removal of shoes and heavy clothing. At the 9-year assessment, all participants received a reimbursement (120€). For the present study, data from both treatment groups as well as the control group with obesity were analyzed if data on body image variables assessed at the 9-year follow-up were available.

Participants

Of the original baseline sample (n = 529), 55% of the participants took part in the 9-year follow-up assessment and provided information on body image (N = 291). Of these, N = 78 participants belonged to the *Bariatric surgery group* [SURG; 51% of the original baseline sample (N = 152)]. Most of the participants in this group had received restrictive procedures such as vertical gastroplasty or gastric banding. In total, 35% reported reoperations following the initial surgery in 2000.

N = 130 participants of the *Conventional treatment group* (CONV) provided the relevant questionnaires for the present analyses. Of these, six participants reported bariatric surgery before the 9-year follow-up assessment and therefore had to be excluded from the analyses; thus, N = 124 data sets were available for the CONV group [50% of the original baseline sample (N = 249)].

N = 83 participants with *obesity* of the *control group* (OC, individuals with obesity not initially seeking treatment) could be included in the analyses, corresponding to 68% of the original sample.

Reasons for dropouts were related to health problems (chronic illness) or death, pregnancy, or contact unknown, no response/refusal to participate. Differences between those who dropped out and those who participated at the 9-year follow-up related to relationship status and BMI, with dropouts being more likely be single and to have a lower baseline BMI. No further differences on clinical and sociodemographic values were found. A detailed overview of reasons for dropout and detailed sample characteristics was provided in (4).

Ethics Statement

The study was approved by the ethics committee of the ethical board of the Medical Faculty of the Ruhr-University Bochum. The study protocol was conducted in accordance with the Declaration of Helsinki (revised 1983). Written informed consent was provided by all participants, who were aware that they could withdraw from the experiment at any time without further consequences.

Assessment

The following areas of interest/assessment instruments applied at the 9-year follow-up were incorporated in the present analyses: 1) Body image was assessed with the Body Image Assessment for Obesity (BIA-O) and the Body Image Avoidance Questionnaire (BIAQ); 2) Eating pathology was assessed with the short version of the Structured Interview for Anorexic and Bulimic Disorders (SIAB-EX) and the Three-Factor Eating Questionnaire (TFEQ); and 3) General psychopathology was assessed with the Hospital Anxiety and Depression Scale (HADS). In addition, clinically relevant mental disorders were assessed with structured clinical interviews.

Body Image Assessment for Obesity

To measure body image in overweight adults, silhouette scales adapted for use among individuals with obesity (39) were applied. These silhouettes include the nine body silhouettes from the original version of this last scale, which range from underweight to overweight, plus nine body silhouettes that reflect different degrees of overweight to extreme obesity, in total 18 increments. Participants rated which silhouette corresponds best to their current body shape, thus representing the perceptual component of body image. This is labeled as "perceived shape" throughout the manuscript. Next, participants were asked to choose the silhouette which best reflects the shape they realistically would like to achieve in the future. This is labeled as "desired shape". Finally, participants were asked to rate the silhouette that represents their ideal shape. The results for this last scale are reported in the **Supplementary Materials** see **Table S1**. In the current study, the three ratings had to be performed twice: a) retrospectively concerning the shape before the start of the weight loss intervention (baseline), and b) concerning the current shape. In addition, a discrepancy score indicating the degree of body dissatisfaction was calculated by subtracting the perceived shape from the desired shape.

Body Image Avoidance Questionnaire

The 11 items of the German version of the BIAQ (40) measure body-related avoidance behavior within the dimensions "clothing", "social activities", and "eating-related control behavior". The items were rated on a 5-point scale from "not at all" (= 0) to "always" (= 4).

Three-Factor Eating Questionnaire

The German version of the Three-Factor Eating Questionnaire [TFEQ, (41)] was applied. The TFEQ measures behavioral correlates of dysfunctional eating along the dimensions "cognitive restraint", "disinhibition", and "feelings of hunger". In the present analyses, only the disinhibition subscale was considered.

Hospital Anxiety and Depression Scale

The German version of the Hospital Anxiety and Depression Scale [HADS, (42)] was administered to assess anxiety and depressive symptoms. A score of >10 indicates clinically relevant symptoms.

Composite International Diagnostic Interview, M-CIDI/DIA-X

To assess the prevalence of mental disorders 9 years after treatment, the CIDI (43) was applied. The CIDI is a reliable structured clinical interview based on criteria of ICD-10 and DSM-IV. "Current diagnosis" refers to symptoms reported for the past 2 to 4 weeks. Reliability and validity of the M-CIDI/DIA-X have been confirmed in several investigations.

Structured Interview for Anorexic and Bulimic Disorders

The short version of the SIAB-EX (44) was used to assess eating disorder symptoms and diagnoses according to DSM-IV criteria. The reliability and validity of the structured interview in patients with eating disorders is well documented (44). Data from the SIAB in the present analyses concern the assessment of binge eating disorder as well as the presence of objective binge eating.

Sociodemographic characteristics and weight

Sociodemographic information was provided by all participants, and weight and height were assessed in light clothing without shoes. Successful weight loss (maintenance) was defined as the maintenance of at least 5% weight loss from the baseline weight. The percentage weight loss was calculated as baseline weight minus weight at 9-year follow-up divided by baseline weight, and the result was multiplied by 100: [KG(Base) − KG(9y)/KG(Base)] × 100. Then, a nominal variable was created to evaluate whether the percentage weight loss was lower or higher than 5%.

As definitions for successful weight loss for surgery patients differ markedly from those applicable for the conventional weight loss treatments, in line with the recommendations, the successful weight loss variable for the SURG group was created based on percent excess BMI loss {%EBMIL = [change in BMI/(Initial BMI − 25)] × 100}, an equivalent to %EWL according to the definition of the American Society for Metabolic and Bariatric Surgery [ASMBS (45)]. For those in the surgery group, 50% EBMIL is considered as representing a successful amount of weight loss (46). If this criterion was fulfilled, the participant was categorized as successful weight loser. We then collapsed the information on successful weight loss for both groups and created a single variable (successful weight loss) that reflects information whether a participant was categorized as successful weight loser 9 years after surgery or conventional weight loss treatment respectively.

Statistical Analyses

All analyses were performed using IBM® SPSS version 24. Differences between all three groups regarding baseline characteristics were calculated using univariate or multivariate ANOVAs or χ^2 tests. Changes in body image perception and attitudes assessed with the BIA-O were analyzed by repeated measures analyses of covariance with sex and age as covariates. A power analysis using G*Power3 (47) to test the difference in change between the three groups from baseline to 9-year follow-up with repeated measures ANCOVA assuming a medium effect size (f = 0.25), and an alpha of 0.05, revealed that a total sample of 66 participants was required to achieve a power of 0.95. Group differences in avoidance behavior (BIAQ subscales) were calculated using multivariate analyses of covariance, taking into account the influence of sex and age. Partial eta square (η_p^2) is reported to evaluate effect sizes of the results. In general, η_p^2 is the ratio of variance associated with an effect, taking into account the effect itself and its associated error variance. η_p^2 effects of 0.01 are seen as small, effects of 0.09 are evaluated as medium, and effects of 0.25 and higher are considered as large effects (48). Correlation analyses to test for associations between current BID features and eating/general psychopathology as well as weight (loss) were performed using Pearson product–moment correlation. Finally, a stepwise hierarchical logistic regression analysis was performed with sex and age (first step), psychopathological features such as disinhibited eating, depression, and anxiety (second step), and body image variables (third step) as predictors of successful weight loss. Analyses were performed separately for each treatment group.

RESULTS

Sample Characteristics

Most of the participants were females (N = 205, 70.4%). There was no difference in the distribution of gender between the groups, whereas level of school education differed significantly between the groups, with the CONV group comprising the highest percentage of individuals with a higher-track school-leaving certificate. Moreover, as at baseline, there was a significant difference in age at the 9-year follow-up assessment: Individuals in the SURG group were significantly younger than those in the CONV group. Note that at the baseline assessment, there was a significant and large difference in body weight and BMI between all three groups, with the SURG group showing the highest BMI [means for BMI are displayed in **Table 1**, for more details see (30)]. Nine years after the start of the project weight and BMI did not differ between the treatment groups (SURG and

TABLE 1 | Sample description.

		Group			Test statistics			
		SURG (N = 78)	**CONV (N = 125)**	**OC (N = 83)**	**χ^2/ANOVA**	***p***	**η^2**	**Post-hoc/*p***
Gender (female)					χ^2(2,284) = 0.924	0.630		
	N	54	91	56				
	%	69.2	73.4	67.5				
School education					χ^2(6,269) = 24.061	0.001		
Low-tracker school diploma								
	N	30	30	25				
	%	38.5	25.8	30.1				
Middle-tracker school diploma								
	N	32	30	29				
	%	41	25.8	34.9				
High-tracker school diploma								
	N	10	55	23				
	%	12.8	44.4	27.7				
No school graduation								
	N	1	2	2				
	%	1.3	1.8	2.4				
Age (years)					*F*(2,285) = 4.528	<0.001	0.031	CONV>SURG
	M	46.19	50.78	49.45				0.009
	SD	9.59	10.88	11.11				
Weight baseline (kg)					*F*(2,285) = 9.350	<0.001	0.395	SURG<CONV>OC
	M	146.74	116.32	98.99				0.002/<0.001/<0.001
	SD	27.02	23.96	14.46				
Weight follow-up (kg)					*F*(2,285) = 9.350	0.012	0.062	SURG = CONV > OC
	M	113.85	114.84	100.27				0.002/ < 0.001
	SD	26.52	28.88	17.53				
BMI Baseline (kg/m^2)					*F*(2,285) = 136.901	<0.001	0.493	SURG > CONV > OC
	M	50.41	39.76	34.27				< 0.001/ < 0.001/ < 0.001
	SD	7.15	6.86	4.23				
BMI follow-up (kg/m^2)					*F*(2,285) = 10.535	<0.001	0.070	SURG = CONV > OC < 0.001/0.001
	M	39.27	39.13	34.69				
	SD	8.75	8.12	17.53				
Δkg					*F*(2,285) = 86.212	<0.001	0.379	SURG > CONV = OC < 0.001/ < 0.001
	M	32.97	1.48	−1.27				
	SD	25.31	17.97	9.86				
%WL					*F*(2,285) = 73.816	<0.001	0.344	SURG = CONV > OC
	M	21.42	1.18	−1.26				0.002/ < 0.001
	SD	15.0	14.02	9.73				
SWL					χ^2(2,285) = 3.199	0.202		
	N	32	44	23				
	%	41	35	28				

SURG, bariatric surgery group; CONV, conventional treatment group; OC, obese control group. School education according to the German school system (Hauptschule, Realschule, Fachabitur/Abitur), BMI, body mass index; Δkg = baseline weight in kg minus actual weight in kg at 9-year follow-up assessment, note that positive scores represent weight loss, whereas negative scores indicate weight gain; %WL = percentage weight loss calculated as follows: [(baseline weight in kg − weight at 9-year follow-up in kg)/(baseline weight)] × 100; SWL, successful weight loss maintenance, indicates the number of individuals who did regain not more than 5% of the lost weight over the 9-year follow-up period or still report 50% of excess BMI loss (%EBMIL) in the SURG group respectively.

CONV), but were still significantly higher in the treatment groups compared to the OC group. The SURG group achieved a significant and large weight loss over the 9-year period, compared to only marginal weight loss in the CONV group. OC participants slightly gained weight over the 9-year period. In total, about 41% of the SURG group met the definition of successful weight loss (%EBMIL still 50% or more)[1] after the 9-year period, whereas 35% of the CONV group met the criterion of 5% weight loss maintenance.[2] In the OC group, 28% reported 5% less weight compared to baseline weight. There was no significant difference in the number of successful weight loss (maintainers) between the groups. Details of these sample descriptions are presented in **Table 1**.

Regarding psychopathology at the 9 year follow-up, the largest number of individuals with an Axis I mental disorder were in the SURG group, followed by the CONV group and the OC group. However, the prevalence of binge eating disorder was

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[1] One year after surgery, N = 36 participants (46%) reached the criteria of 50% EBMIL.

[2] After 1 year of CONV treatment, N = 95 participants met the 5% reduction criteria (77%). Further information on weight loss success after treatment is available in 36.

rather low and did not differ between the groups. On the other hand, inhibition scores of the TFEQ subscale were significantly higher in the CONV group compared to the SURG and OC groups. Average depression and anxiety scores, assessed with the HADS, were below the cut-off and not of clinical relevance; however, both subscale scores were higher in SURG patients compared to CONV and OC patients. Detailed information regarding mean scores and standard deviations of the described characteristics as well as test statistics are displayed in **Table 2**.

Perceptual Component of Body Image

The evaluation of the *perceived shape* using the BIA-O silhouettes revealed a significant time × group interaction: The perceived shape was largest in the SURG group for both baseline and current body image, but at the same time, changes in the perceived BI were only significant for this group (for details see **Table 3**). Both covariates, sex and age, exerted a significant influence on the estimation of the perceived body size, insofar as higher age reduced the effect and female gender increased it [F (2,270) = 11.804, $p = 0.001$, $\eta_p^2 = 0.042$ and (F(2,270) = 12.402, $p = 0.001$, $\eta_p^2 = 0.044$ respectively].

Attitudinal Component of Body Image

Regarding the *desired shape,* no significant time × group interaction emerged. However, a main effect of group [F(2,270) = 4.033, $p = 0.019$, $\eta_p^2 = 0.029$] was found, indicating that SURG patients chose slightly larger silhouettes compared to CONV and OC. Moreover, there was a significant main effect of time [F (2,270) = 7.491, $p = 0.007$, $\eta_p^2 = 0.027$] indicating a decrease over time above all in the SURG group. However, overall, at baseline, most of the participants chose a silhouette between 6 and 7, which corresponds to the higher range of normal weight/ borderline overweight. Furthermore, the choice of the currently desired shape was also represented by the silhouettes numbered 6 and 7 (for details see **Table 3**). A significant effect emerged for

TABLE 3 | Mean Scores and standard deviation for body image-related features.

Body image assessments	Group			Test statistics (for ANOVA interaction effects time × group)			
	SURG N = 77	CONV N = 118	OC N = 81	ANOVA	df	p	ηp^2
Desired shape				1.557	2,271	0.273	
Baseline score							
M	7.03	6.27	6.11				
SD	1.83	1.91	1.61				
Current score							
M	6.65	6.25	6.21				
SD	2.02	1.78	1.63				
Perceived shape				39.435	2,270	<0.001	0.226
Baseline score							
M	15.05	11.51	9.28				
SD	2.52	2.86	2.20				
Current shape							
M	10.55	11.09	9.47				
SD	3.28	3.35	2.51				
BIAQ, 9 years ago							
Clothes							
M	5.86	6.79	4.38				
SD	4.51	4.12	3.54				
Social							
M	2.22	1.46	1.33				
SD	2.86	2.15	2.95				
Eating control							
M	3.45	3.72	3.36				
SD	1.82	1.82	2.06				

Actual body shape and desired body shape were measured with the BIA-O (Body Image Assessment for Obesity); BIAQ, Body Image Avoidance Questionnaire.

TABLE 2 | Psychopathology compared between groups.

	Group			Test statistics			
	SURG (N = 78)	*CONV* (N = 125)	OC (N = 83)				
				χ^2/ANOVA	p	η^2	Post-hoc/p
Presence Axis I diagnoses				χ^2(2,267) = 4.777	0.092		
N	52	63	40				
%	66.6	50.8	48.19				
BED				χ^2(2,285) = 1.670	0.796		
N	2	5	3				
%	2.6	4.0	3.6				
Disinhibited eating (TFEQ)				F(2,285) = 15.688	<0.001	0.104	CONV > SURG = OC
M	6.93	8.87	6.60				< 0.001/ < 0.001
SD	3.83	3.42	3.95				
HADS—Depr				F(2,285) = 6.291	<0.001	0.044	SURG > OC
M	6.55	5.35	4.19				0.001
SD	4.98	3.75	3.88				
HADS—Anx				F(2,285) = 6.291	<0.001	0.034	SURG > OC
M	7.47	6.61	5.42				0.006
SD	4.48	4.23	3.35				

Diagnoses for Axis I disorders were assessed with the Composite International Diagnostic Interview (CIDI); BED, binge eating disorder, assessed with the structured interview for anorexic and bulimic disorders (SIAB); TFEQ, Three-Factor Eating Questionnaire; HADS, Hospital Anxiety and Depression Scale; Depr, depression subscale; Anx, Anxiety subscale.

sex as covariate (($F(2,270) = 5.746$, $p = 0.017$, $\eta_p^2 = 0.021$), indicating that overall, women chose more slender silhouettes than did men. Moreover, a significant time × age interaction emerged [$F(1,271) = 8.872$, $p = 0.003$, $\eta_p^2 = 0.032$], with the chosen silhouettes becoming larger with increasing age.

Regarding the degree of *body dissatisfaction* captured as the discrepancy score of current perceived shape estimation minus desired shape estimation, a significant time × group interaction emerged [$F(2,269) = 55.849$, $p < 0.001$, $\eta_p^2 = 0.293$], indicating the highest improvement in the SURG group, compared to no changes in the OC and CONV group. We also found a main effect of group [$F(2,269) = 35.064$, $p < 0.001$, $\eta_p^2 = 0.207$], such that SURG patients reported overall higher body dissatisfaction compared to OC and CONV. However, regarding only the current level of body dissatisfaction (at the 9-year follow-up) in individuals who had undergone bariatric surgery, body dissatisfaction was lower in SURG compared to CONV ($p > 0.001$) and comparable to that of OC ($p = 1.0$). Details are provided in **Figure 1**. Moreover, sex and age had a significant influence on the level of body dissatisfaction [main effects—sex: $F(2,269) = 4.966$, $p = 0.027$, $\eta_p^2 = 0.018$; age: $F(2,269) = 23.209$, $p < 0.001$, $\eta_p^2 = 0.079$]: Higher age was associated with lower dissatisfaction and female gender was associated with higher dissatisfaction.

Behavioral Component of Body Image

A multivariate ANCOVA was performed to detect differences between the current level of body image avoidance between the three groups. For the subscale "clothing", a significant difference between the groups emerged [$F(2,285) = 8.597$, $p < 0.001$, $\eta_p^2 = 0.058$]. Sex as a covariate exerted a significant influence on avoidance behavior relating to clothing [$F(2,285) = 7.680$, $p = 0.006$], whereas age had no impact [$F(2,285) = 2.230$, $p = 0.136$]. Post hoc tests revealed that CONV reported higher avoidance behavior compared to OC ($p < 0.001$), whereas the level of behavioral avoidance did not differ between SURG and OC ($p = 0.108$) or between SURG and CONV ($p = 0.251$). For the subscales "social activities" and "eating control", no significant difference between the groups emerged [$F(2,285) = 2.658$, $p = 0.072$ and $F(2,285) = 0.653$, $p = 0.521$ respectively]. For details, please see **Table 3**.

Association of Body Image Features With Eating Psychopathology and General Psychopathology

The results of the correlation analyses revealed overall significant associations (all ps ≤ 0.001) of both the current level of body dissatisfaction (BIA-O differences score) and the subscale score for clothing on the BIAQ with anxiety ($r_{BIA-O} = 0.200$, $r_{BIAQ} = 0.320$) and depression scores ($r_{BIA-O} = 0.380$; $r_{BIAQ} = 0.533$), eating disinhibition ($r_{BIA-O} = 0.441$, $r_{BIAQ} = 0.468$) as well as weight status (current BMI; $r_{BIA-O} = 0.650$, $r_{BIAQ} = 0.354$) and percentage of weight loss ($r_{BIA-O} = 0.650$, $r_{BIAQ} = 0.354$). Moreover, a moderate association was found for body dissatisfaction and avoidance behavior ($r = 0.451$).

Impact of Body Image Features on Successful Weight Loss Maintenance

Finally, we employed hierarchical binary logistic regression analyses to categorize successful and unsuccessful weight loss maintenance separately for each group, in order to identify the impact of body image features on weight loss when controlling for the influence of eating disturbances and psychological features. Details of the final model (step 3 including all variables) for all three regression analyses are presented in **Table 4**.

In the *SURG group*, sex and age were not significant predictors in the first step. When depression, anxiety, and

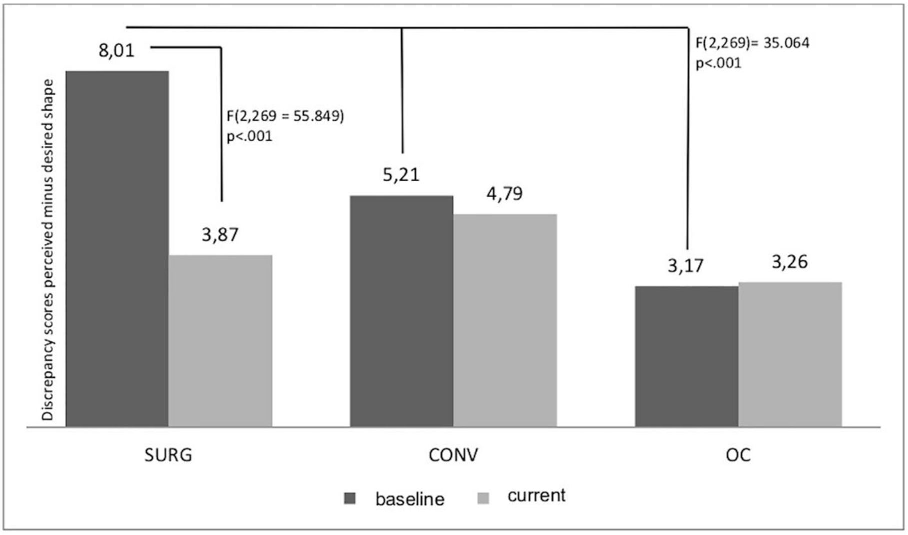

FIGURE 1 | Discrepancy in current versus baseline body image dissatisfaction.

disinhibition were added as control variables, 30.7% of the variance was explained, with 75% of cases correctly classified, based on anxiety as well as depression scores as significant predictors (β = 0.335, *Wald* = 10.164, *p* = 0.001 and β = −0.280, *Wald* = 5.349, *p* = 0.021). The final, third step (adding change in body dissatisfaction, avoidance behavior subscales clothes and social activities) increased the explained variance to 57.3%, with 86.1% correctly classified cases. Anxiety and change in body dissatisfaction emerged as significant predictors, whereas depression was no longer significant. Avoidance behavior (subscale clothing) failed to reach statistical significance. All other variables had no statistically significant influence.

In the *CONV group*, sex emerged as a significant predictor in the first step (β = 1.146, *Wald* = 4.948, *p* = 0.026), but only explained 8.6% of the variance and with only 65.2% of correctly classified cases. Adding psychopathological variables in the second step increased the explained variance to 24.7%, with 68.8% of correctly classified cases. Sex remained a significant predictor (β = 1.305, *Wald* = 5.330, *p* = 0.021), and disinhibition emerged as significant (β = −0.176, *Wald* = 5.421, *p* = 0.020). In the third step, the model explained 51.2% of the variance, with 78.6% of correctly classified cases. Again, sex remained a significant predictor, and change in body dissatisfaction also emerged as a significant predictor, whereas avoidance behavior (social activities) failed to reach statistical significance and disinhibition lost its significant impact.

In the *OC group*, in the first step, neither sex nor age was significant. Adding psychopathological variables in the second step increased the explained variance (24.7%) and lead to 70% of correctly classified cases based on disinhibition as the only significant predictor. Anxiety was only of marginal statistical significance. In the third step, body image variables were entered. This final model explained 42.1% of the variance, and 85% of cases were correctly classified; here, change in body dissatisfaction was the only significant predictor, whereas disinhibition lost its statistical significance when change in body dissatisfaction was entered in the final step of the regression.

DISCUSSION

The main aim of this article was to explore the associations of different body image facets with weight loss outcome after bariatric surgery, and to compare these findings with conventional weight loss treatment outcomes and weight status among individuals with obesity who initially did not seek weight loss treatment. The data were derived from a larger prospective study, but body image assessment was captured solely at the 9-year follow-up, both for the current body image and for the (retrospectively evaluated) body image at baseline. The main results of the analyses revealed that solely the SURG patients reported a difference between the baseline and the current body image, suggesting an improvement in body satisfaction. Moreover, SURG patients reported lower levels of body avoidance in relation to clothing compared to CONV. No significant difference emerged between SURG and OC. The current level of body dissatisfaction as well as body avoidance behavior were associated with a range of psychopathological features, e.g. higher levels of depression and anxiety as well as disinhibited eating, higher body weight, and less weight loss. Regarding the role of body image in successful weight loss and the maintenance thereof, a positive change from baseline to current levels of body dissatisfaction was significantly associated with successful weight loss and the maintenance thereof, independently of the type of treatment. Several aspects need to be discussed in light of these results.

Body Perception

On average, SURG participants retrospectively reported a larger baseline silhouette compared to the current one, which seems to reflect their change in weight. The SURG group lost the most weight and was able to maintain a larger proportion of the lost weight over the 9-year follow-up period compared to the CONV group and the OC group. These findings are in line with recent meta-analyses and systematic reviews (1, 8, 49). Nevertheless, more than half of the SURG group did not achieve/maintain the possible excess weight loss and was therefore not classified as successful according to the recommended definitions. This might

TABLE 4 | Third step regression analyses for weight loss maintenance.

Predictor	Group								
	SURG			CONV			OC		
	β	Wald	*p*	β	Wald	*p*	β	Wald	*p*
Sex	1.012	1.344	0.246	1.520	4.480	0.034	0.615	0.729	0.393
Age	−0.063	1.979	0.160	0.023	0.818	0.366	0.032	1.075	0.300
RSES	−0.130	0.617	0.432	−0.082	0.490	0.484	−0.006	0.002	0.966
TFEQ	0.044	0.180	0.671	−0.100	1.220	0.269	−0.197	3.610	0.057
HADS—Anx	0.234	4.046	0.044	−0.038	0.175	0.675	0.181	2.190	0.139
HADS—Depr	−0.224	2.471	0.116	−0.119	0.982	0.322	0.007	0.003	0.960
BIAQ_clothes	−0.231	3.480	0.062	−0.049	0.290	0.590	−0.120	0.822	0.365
BIAQ_social	0.085	0.269	0.604	0.266	3.369	0.066	0.039	0.133	0.715
change_dissatisfaction	0.532	12.140	<0.001	0.619	15.743	<0.001	0.723	10.648	0.001

SURG, bariatric surgery group; CONV, conventional treatment group; OC, obese control group; RSES, Rosenberg Self-esteem Scale; TFEQ, Three-factor Eating Questionnaire; disinhibition subscale; HADS, Hospital Anxiety and Depression Scale; Anx, anxiety; Depr, depression; BIAQ, Body Image Avoidance Questionnaire; subscale clothing.

be due to the restrictive nature of bariatric surgery procedures. CONV and OC participants showed no differences in baseline and current weight, which might reflect the lack of significant difference between the two chosen silhouettes. These results point toward a valid and reliable recall of body image at baseline. However, it has to be considered that body size estimations may be biased. There is some empirical evidence suggesting misperceptions in body size depending on BMI. For example, Thaler and colleagues (50) showed that women with a higher BMI tend to overestimate their shape. However, there is also evidence that women with obesity perceive their own body much more accurately than do normal-weight (51) and overweight women (52).

Body Image Attitudes

Regarding the desired shape, the chosen silhouettes were in the normal-weight to borderline overweight range in all patients [silhouettes 6 and 7; see (39, 53)], but slightly higher in the SURG group compared to the OC group. However, among all patients, there was a shift toward normal-weight silhouettes from retrospectively reported baseline to 9 years later in terms of the desired shape. In line with previous findings of higher body dissatisfaction among women compared to men (26, 54), women in the present study indicated generally smaller silhouettes for their desired shape compared to men. This may reflect the general sociocultural influence on body image (55) and the negative portrayal of overweight and obese bodies that has become almost normative in the media (56).

Given that body dissatisfaction to some degree results from the experienced discrepancy between one's own weight and the weight that is idealized or desired to be achieved through weight reduction [e.g. (26, 55)], it is not surprising that the perceived shape differed largely from the desired shape among all participants. As individuals with obesity are confronted daily with anti-fat attitudes and experience discrimination due to their weight (56, 57), their desire to lose weight and achieve a normal weight is high. In most cases, despite high investments, this goal is not realistic, leading to a possible decline in well-being following initial weight loss. This is also supported by recent evidence that shows associations between emotional distress and body dissatisfaction as well as depressive symptoms (6, 18, 58). Moreover, it is also in line with the correlational results from the present study: Both components—body dissatisfaction as well as avoidance behavior—were related to deficits in other areas of mental health (e.g. depression, anxiety), emphasizing the impact of body image on psychological functioning. Moreover, our results in relation to body avoidance behaviors showed no group differences regarding social activity and eating control, but higher scores for the CONV group in relation to clothing, which was also associated with higher dissatisfaction. From eating disorder research, it is known that body avoidance might maintain the negative body image and serve an anxiolytic function [e.g. (10, 59)]. However, body avoidance did not impact weight loss outcome. Further research is warranted to better understand this component of body image in individuals with obesity.

Body Dissatisfaction and Its Association With Weight Loss

With regard to body dissatisfaction, we found a significant difference from recalled baseline to current body dissatisfaction only in the SURG group. This might be associated with the achieved weight reduction. In the CONV and OC group, the level of dissatisfaction did not change, which might be due to the lack of significant weight reduction. However, as we did not include prospective data, we cannot draw any conclusions regarding the direction of the association. Further research is required in order to elucidate the interaction between body image and weight loss. What has not been considered so far is that more than 90% of these individuals with severe obesity suffer from negative consequences of the fast and massive weight loss: “Hanging” skin arises and sometimes causes infections, as well as other distressing and non-aesthetic conditions (60–62). Whereas a large proportion of bariatric surgery patients seek skin-contouring surgery, only a small number of them actually receive it due to substantial barriers such as non-refundable surgery costs [e.g. (61)]. Recently, it was shown that skin correction surgery reduces depressive symptoms and improves body image (58). Moreover, it was reported that individuals who underwent body-contouring surgery after bariatric surgery showed more positive body image features compared to those who did not (60). Thus, as we did not include questions relating to these aesthetic complications and the wish for skin correction surgery, we do not know how these factors may have impacted body image features and weight loss after surgery.

Strengths and Limitations

A strength of the present study lies in the application of a weight-specific assessment tool for body image in individuals with obesity, which captures different facets of body image across different treatment approaches, as well as the addition of an instrument that reflects behavioral components of body image. A further strength is the long-term follow-up, which allowed us to capture body image in surgery patients after their weight had stabilized or possibly increased again. However, several limitations of the present study also need to be considered: 1) The instruments for body image were added to the original study at the 9-year follow-up. Consequently, the baseline evaluation of body perception, desired shape, and ideal shape had to be made retrospectively, which may have biased the reported results. 2) The BIA-O does not assess dissatisfaction with specific body parts or loose skin and may therefore lack to capture the real level of body dissatisfaction as it may not only depend on the silhouette, but also on other features such as hanging or loose skin. As we did not ask whether body-contouring surgeries due to hanging or loose skin were wished, were necessary or were performed, following bariatric surgery, we cannot be sure that this might have biased body image evaluations [e.g. (61)]. 3) The sample assessed at the 9-year follow-up did not include those participants who dropped out of the study, meaning that the results might not be representative for all of the study participants. 4) Moreover, the BIA-O assesses body dissatisfaction using a difference score, which is not without criticism (63). 5) The number of SURG patients that report successful weight loss was remarkably low also at the 1 year follow-up which might reflect the problems of restrictive procedures. However, as up to 60% reductions of the excess weight (EWL, calculated as kilograms of weight above BMI 25 kg/m² as excess weight) can be reached depending on the surgical procedure (49), the present results have to be considered with care. Further research should therefore take into account the surgical procedure when addressing body image in bariatric surgery. 6) Finally, the use of different definitions for successful weight loss might bias the results. Replication of the presented results in larger, prospective trials is necessary to further our understanding of body image preceding and following bariatric surgery.

CONCLUSION

The present study adds to the existing evidence by emphasizing the role of the different components of body image after surgery in mental health features and course of weight. A robust relationship between BID and weight loss, independently of weight loss approach, is implied and suggests the need to acknowledge body image in the aftercare of bariatric surgery as well as in conventional treatment [e.g. (19, 20, 28)].

DATA AVAILABILITY STATEMENT

The datasets generated for this study will not be made publicly available. At the time of the investigation, it was not usual to share data sets publicly and therefore the informed consent did not include such a statement. Therefore, participants did not give their consent to share the data sets publicly. However, if there are any requests, we will try to be responsive.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Board of the Medical Faculty of the Ruhr-University Bochum. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SH and TL conceived the study concept and design (9-year assessment), SH and TL supervised data collection (9-year assessment), TL analyzed data and drafted the article. All authors (SH, AM, MZ and TL) were involved in interpreting and discussing the results, revising the article critically for important intellectual content, and had final approval of the submitted and published versions.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00945/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Trait-Based Emotional Intelligence, Body Image Dissatisfaction, and HRQoL in Children

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Background: Body image dissatisfaction (BID) is related to an increased risk for various health issues including descreased health-related quality of life (HRQoL), the development of problematic eating behaviors and obesity. Previous research indicates that emotional intelligence is one important factor related to BID in adults. Whether this is the case in children, remains yet unknown. Taking this into consideration, the aim of this study was to explore the relationship between BID and trait-based emotion intelligence (TEI) as well as HRQoL in female and male primary school children.

Materials and methods: TEI and BID were assessed via self-reports as well as HRQoL via parental reports in a large sample of 991 primary school children (429 girls) within the "Baden Württemberg Study", which evaluated the effectiveness of the health prevention programm "Join the Healthy Boat" in Southwestern Germany.

Results: Our findings demonstrated the interrelation between higher levels of TEI and lower levels of BID among girls and boys. Positive associations were found between better HRQoL, better intrapersonal and stress management abilites (subscales of TEI) and lower BID, as reflected by parental and self-reports.

Conclusions: Our results reveal an interconnectivity between TEI, BID, and better HRQoL in female and male primary school children. Although the observed correlations were rather small, they nervertheless support the idea that TEI consists a key-factor for the self-regulation of health-related behavior. Prevention programs could benefit from including processes, that sough to improve aspects of emotional intelligence such as intrapersonal, interpersonal abilities, and adaptability, as an effort of preventing problematic habits or lifestyles that could lead to disordered eating behaviors as well as to obesity in middle childhood.

Keywords: emotional intelligence, body image dissatisfaction, body image, health-related quality of life, childhood

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Abbreviations: TEI, trait based emotional intelligence; HRQoL, health-related quality of life; BID, body image dissatisfaction; BMI, body-mass index; VAS, visual analogue scale.

INTRODUCTION

A thin body ideal is predominant in different cultures, especially in western countries, whilst body image dissatisfaction (BID) in young women is common, causing in some cases disordered eating attitudes and behaviors (1). While the prevalence of these disorders is rising, especially among girls (2), their onset is gradually dropping (3). In this way, school-age children demonstrate discontentment with their body shape (4, 5), something that is often reinforced by the bidirectional dynamic between society and media, in which a thin ideal that rarely fits with reality, is being promoted (6–13).

Body image is a multidimensional construct, which involves perceptions, behaviors, cognitions, and emotions related to individual's body, that are also connected to the degree of one's own body image satisfaction and perceptual accuracy (5, 14–16). Furthermore, when trying to understand how body dissatisfaction occurs and evolves through the developmental spectrum, it is worth taking into consideration that body image is strongly related to the holistic experience of embodiment (awareness that my body belongs to me), which reflects the attunement between the inner states (emotions, cognitions etc.) and the body (17–20) and has been found to be present even in early childhood (17, 21). Embodiment can also be regarded as a precondition for social relatedness (22, 23), which plays a central role in children's developing healthy lifestyle (24). Bearing this in mind, another important characteristic for social relatedness is emotional intelligence [IE; (25)]. More specifically, Mayer and Salovey [(26), pp. 5] define emotional intelligence (EI) as: "the ability to perceive accurately, appraise and express emotion; the ability to access and/or generate feelings when they facilitate thought; the ability to understand emotion and emotional knowledge; and the ability to regulate emotions to promote emotional and intellectual growth."

In addition, EI not only entails the constellation of personality traits connected to emotions, that include affective personality dispositions, which are determinable *via* self-reports [trait EI (TEI)], but also the self-perceived emotional ability, which can be assessed *via* performance tests [ability EI (AEI); (27–30)]. Accordingly, higher levels of EI are associated with more positive attitudes, more successful relationships, greater adaptability, higher orientation towards positive values as well as less difficulties in expressing, evaluating, and regulating emotions (31–33). Aspects of psychological well-being, such as life satisfaction and happiness, have been found to be related to EI (34), as well as higher levels of subjective physical health (35). Cuesta-Zamora and colleagues (36), demonstrated that low TEI predicted body dissatisfaction as well as eating disorders symptoms in preadolescents and adolescents. At the same time, it was demonstrated that deficits in different aspects of emotional intelligence are positively related to binge eating, body-weight, and body-shape concerns; therefore suggesting an indirect interaction between emotion processing and body perception/image (36).

Moreover, health-related quality of life (HRQoL) describes individual's perceived quality of life in physical, psychological, and social aspects of health (37), as well as is strongly related to individuals' subjective well-being (38). Farhat and colleagues (39) found out that girls who overestimated their body-weight, reported at the same time poorer HRQoL than those with accurate body-weight estimations; Although there is a great research interest concerning HRQoL in various children populations suffering from somatic diseases, such as leukemia, paraplegia, heart failure etc. (40–42), little do we know regarding HRQoL and its related psychological parameters.

Bearing these in mind, scope of the current study was to examine the relationship between BID and TEI among 991 primary school children, as well as their interaction related to HRQoL. Based on previous research, we hypothesized that TEI would be associated with lower BID and better HRQoL in children. As BID is known to be more prevalent among girls (43, 44), we sought to lay focus of our analyses also on possible gender differences and thus hypothesized more profound levels of BID among girls.

MATERIALS AND METHODS

Participants and Procedure

After legal guardians provided their written informed consent, 1047 children in the age of 9.59 (*SD* = 0.63) years, were recruited from primary schools (third to fourth grade) in the federal state of Baden-Württemberg (south western Germany) and participated in the Baden-Württemberg Study, which evaluated the health promotion program "Join the Healthy Boat—Primary School" which focuses mainly on the prevention and promotion of a healthier lifestyle among primary school children, in order to increase awareness regarding overweight and obesity (45–48). A more detailed study's protocol and design have been previously described (45). Study's approval was obtained from the Ministry of Education as well as from the University's Ethics Committee.

From the main sample, complete children's data sets derived from 991 participants; 492 girls (49.6%) and 499 boys (50.4%) with a mean age of 9.58 years (*SD* = 0.62; age ranged from 8 to 11 years). Due to missing data 56 children were excluded from our sample. Finally, there were 787 corresponding parental reports.

Subjective Reports

For the assessment of trait based emotion intelligence, we used the Bar-On EQi-Youth Version. It is consisted of four subscales: *intrapersonal* (e.g. understanding one's own feelings) and *interpersonal abilities* (e.g. feeling for someone), *adaptability* (e.g. adjusting one's behaviors to changing situations), and *stress management* [e.g. resisting an impulse; (49)]. Due to practical reasons including shortening measurement's duration we used the shortened version of the Bar-On Emotional Quotient Inventory (EQi)-Youth Version [(49); adapted by (50)]. Good psychometric properties were found by Koch and Pollatos (50) for the German adapted shortened version (CFIs = 1.0, RMSEAs < .001, SRMRs < .001. On the other hand, body image perception was assessed using the Body Silhouette Chart by Collins (51) for preadolescent children. Test-retest reliability coefficient ranged as high as .91 (51). Lastly, parents gave information about their children's HRQoL [Parent's Questionnaire KINDL^{R}; (52)], by providing information regarding the following aspects: physical well-being (e.g., “my child felt sick”), emotional well-being (e.g., “my child felt insecure”), self-esteem (e.g. “my child didn’t feel much like doing anything”), family (e.g. “my child got on well with us parents”), well-being related to friends/peers (e.g. “my child got along with friends”), and school-related well-being (e.g. “my child was afraid of getting bad grades”). Internal consistency ranges from 0.54 to 0.73 for all subscales and 0.82 for the total score (53).

Anthropometric Measures

Body mass index (BMI) was calculated (kg/m^2) and converted to BMI percentiles (BMIPCT) based on national reference data for German children (KIGGS).

Statistical Analyses

All statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS, version 25). A normality test was performed in order to determine if there was a normal distribution using the Kolmogorov–Smirnov Test. Because of the normal data distribution, parametric tests were carried out. A two-sample t-test was run to compare mean and standard deviation of continuous variables. For the investigation of the relationship between emotional intelligence, BMI, and body image satisfaction as well as HRQoL, there were used regression analyses, Pearson correlations, and partial correlations coefficients. No adjustment for multiple testing was made because of the explorative nature of this study. *p* Values less than 0.05 were considered significant.

RESULTS

Sample Descriptives and Questionnaire Data

Sample characteristics on all variables of interest as well as mean scores in trait emotional intelligence, body image dissatisfaction (discrepancy between the real self and the ideal figure) and HRQoL (mean scores, transformed to 0–100) are shown in **Table 1**.

TEI and BMI in Boys and Girls

T-tests for independent samples revealed that girls had significantly higher TEI scores in the subscales intrapersonal [$t(989) = -3.40$, $p < 0.01$], interpersonal [$t(989) = -7.77$, $p < 0.001$] and stress management [$t(989) = -3.76$, $p < 0.001$], while boys scored higher on adaptability [$t(989) = 3.58$, $p < 0.001$] (**Figure 1**).

We observed small, but significant inverse correlations between BMI and trait-based emotional intelligence total score ($r = -0.12$, $p < 0.001$; boys: $r = -0.15$, $p < 0.001$; girls: $r = -0.09$, $p < 0.05$), suggesting that a higher relative body weight was associated with lower emotional intelligence. We therefore controlled for BMI differences in all subsequent analyses.

TEI and BID in Boys and Girls

Both girls and boys reported on average a thinner ideal body image than their real self. The distributions of the BID scores demonstrated that 42% of girls and 34% of boys wish to have a thinner body (BID < –0.5). There was a significantly higher BID in girls as compared to boys [see **Figure 2** and **Table 1**; $t\ (981) = 2.60$, $p < 0.01$].

In a next step we transformed the BID scores into absolute values, with higher scores indicating greater BID. For all further analyses we used absolute scores. We conducted partial correlations between BID and trait-based emotional intelligence (total score) that revealed inverse correlations for both girls ($r = -0.18$, $p < 0.001$) and boys ($r = -0.15$, $p < 0.01$) after controlling for BMI differences. Lower emotional intelligence was therefore associated with higher BID difference scores, thus higher body dissatisfaction.

HRQoL, Trait-Based Emotional Intelligence and BID

Girls and boys were compared in all aspects of HRQoL except for school-related well-being (girls: mean, 55.36; boys: mean, 58.75; $t\ (779) = -2.98$, $p < 0.001$). Furthermore, we conducted partial

TABLE 1 | Sample characteristics and independent samples t-test regarding all variables of interest (total sample: N = 991, respectively N = 787 for parental reports of HRQoL).

	Total sample	Boys	Girls	Boys x Girls	
		M (SD)		*t*	*Cohen's d*
Age (years)	9.58 (.62)	9.61 (0.62)	9.57 (0.62)	—	—
BMI (kg/m^2)	17.33 (2.57)	17.16 (2.74)	17.10 (2.72)	$p > 0.05$	—
BMIPCT	48.04 (27.58)	—	—	—	—
TEI total	9.48 (1.61)	9.25 (1.70)	9.70 (1.46)	**$^{**}p < 0.01$**	**0.28**
TEI intrapersonal	1.63 (0.66)	1.56 (0.68)	1.70 (0.60)	**$^{**}p < 0.001$**	**0.21**
TEI interpersonal	2.22 (0.59)	2.08 (0.62)	2.36 (0.51)	**$^{***}p < 0.001$**	**0.24**
TEI adaptability	2.02 (0.66)	2.10 (0.67)	1.94 (0.63)	**$^{***}p < 0.001$**	**0.24**
TEI stress management	3.60 (0.75)	3.51 (0.78)	3.69 (0.70)	**$^{***}p < 0.001$**	**0.24**
Body Image Dissatisfaction	–0.38 (0.82)	–0.31 (0.83)	–0.45 (0.81)	$p > 0.05$	—
HRQoL emotional well-being	79.16 (11.37)	77.03 (13.10)	77.23 (13.10)	$p > 0.05$	—
HRQoL self-worth	47.67 (13.87)	47.42 (14.27)	48.21 (13.56)	$p > 0.05$	—
HRQoL well-being in the family	67.40 (12.20)	67.22 (12.34)	67.41 (12.56)	$p > 0.05$	—
HRQoL well-being related to friends/peers	61.80 (12.80)	61.64 (14.00)	61.70 (11.66)	$p > 0.05$	
HRQoL school-related well-being	57.05 (15.96)	55.28 (17.78)	59.25 (13.70)	**$^{***}p < 0.001$**	**0.25**

All values are mean ± SD unless stated otherwise; BMI, Body Mass Index; BMIPCT, BMI percentiles; SD, Standard Deviation; $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

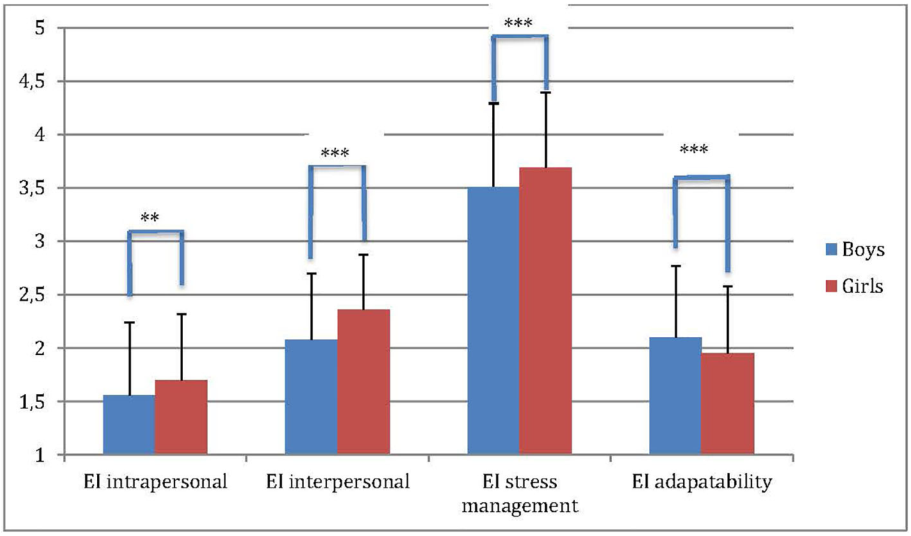

FIGURE 1 | Emotional intelligence scores contrasting boys and girls ($^{**}p < 0.01$; $^{***}p < 0.001$).

correlations between HRQoL (total score) and emotional intelligence (total score) that revealed a positive relationship ($KINDL_{total\ score} = 0.13$, $p < 0.001$) after controlling for BMI differences. Lower emotional intelligence was associated with lower HRQoL (in all three HRQoL measures). To visualize these effects, we compared high and low emotional intelligence groups. As depicted in **Figure 3**, children with higher emotional intelligence had higher HRQoL [$KINDL_{total}$: high EI: 65.8 vs. low EI: 64.0; $t(777) = -2.77$, $p < 0.01$].

We finally carried out a multiple regression analysis (forward selection) to predict HRQoL measures ($KINDL_{total\ score}$) from the four subscales of trait based emotional intelligence as well as from BID. HRQoL was explained by better stress management ($T = 3.80$, $\beta = .12$, $p < 0.001$), better intrapersonal abilites ($T = 2.70$, $\beta = .09$, $p < 0.01$, and lower BID ($T = 2.00$, $\beta = 0.06$, $p < 0.05$); ($F(5,985) = 7.81$, $p < 0.001$, $R = 0.19$, $R^2 = 0.04$).

DISCUSSION

The present study aimed to elucidate the relationship between trait based emotional intelligence, body image disatisfaction as well as HRQoL in primary school children. In accordance with our hypotheses higher TEI was associated with lower BID in both girls and boys, and these effects remained significant after controlling for BMI. Moreover, HRQoL was predicted by highler levels of stress management, better intrapersonal abilites, as well as by lower BID. However, we did not observe any gender differences concerning HRQoL and its associations to TEI.

These findings are in accordance with prior research, in which it was demonstrated that different dimensions of TEI, but also EI, were closely connected to subjective psychological and physical well-being (27, 34, 35). Likewise, this interaction between EI and body image was indicated in several studies among young athletes, as well as young adults (54–56), but up to now there was no direct evidence among children. Additionally, the observed inverse correlation between TEI and weight status found in this study, is in accordance with prior research showing that obesity is related to disturbed emotion regulation processing among children (57–59).

Taking these into consideration, the close link found between the dimensions of TEI, BID and BMI, ephasizes the need of improving such emotion abilities in schools, as in this way this could have a positive impact on children's overall HRQoL and well-being. This can be achieved by e.g. integrating, in early interventions, methods in learning how to improve intrapersonal and interpersonal abilities, as well as adaptability; as an effort of preventing both problematic eating attitudes (e.g. obesity) as well as the development of eating disorders in childhood.

There are limitations in our study referring to the fact that our data are the result of a correlational, cross-sectional design, where different causality directions cannot be ruled out. Therefore, longitudinal study designs are necessary to clarify the direction and causal chain of the observed interrelations. Furthermore, the observed correlations were rather small, reflecting the fact that other factors like e.g. emotional regulation abilities associated with TEI might also play a role. As a further shortcoming should be regarded the fact that we used the shortened version of the Bar-On Emotional Quotient Inventory (EQi)-Youth Version adapted by Koch and Pollatos (50) due to practical reasons including minimizing measurement's duration. Moreover, it has been demonstrated in prior research that the dimensional structure of the EQi- short form is not robust in young people (60). Additionally, the fact that we used parental reports [Parent's Questionnaire $KINDL^R$; (52)] in order to assess HRQoL should be considered as a further

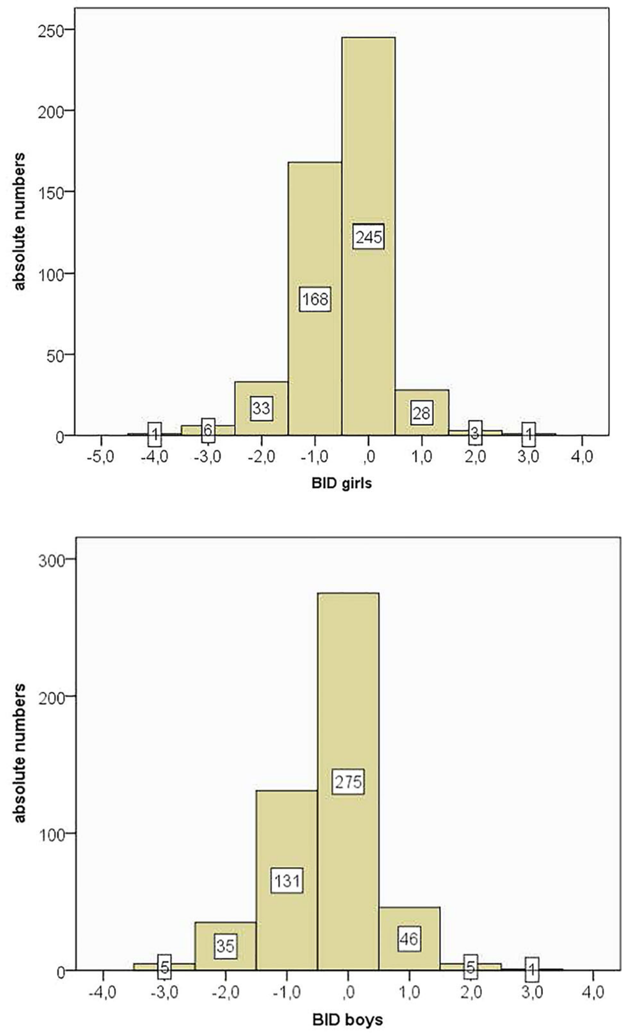

FIGURE 2 | Body image dissatisfaction scores—distribution in boys and girls.

shortcoming, which could have led to biased results. Lastly, BID was only assessed *via* the body silhouette chart (51) and not *via* a suitable self-report validated for children in this age group, like for example subscales of the Child Eating Disorder Examination Questionnaire [ChEDE-Q; (61)], that would have been more informative.

In view of these, future longitudinal studies should include further self-report questionnaires with a focus on emotional characteristics associated with both dimensions of emotional intelligence (trait based but also ability based) in children and their interaction to BID and overall well-being. It would be also important to examine in this way further variables, such as emotional intensity or emotional lability as well as other mediation and moderation effects (62). At the same time, data concerning proclivity to mental disorders (such as the SDQ—Strengths and Difficulties Questionnaire) or general cognitive ability should be also taken into account.

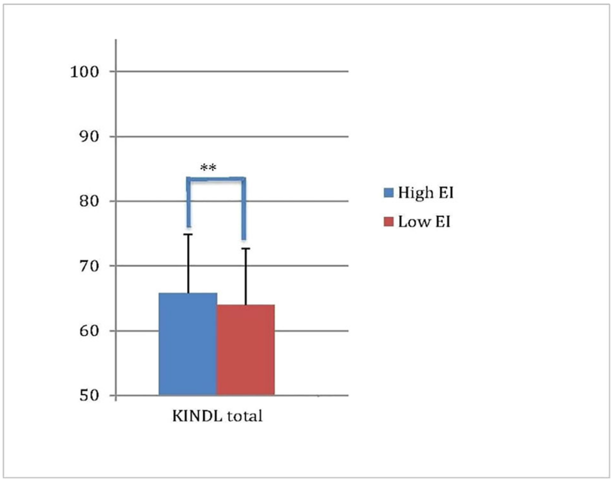

FIGURE 3 | Children's HRQoL (as assessed via the KINDL) in high vs. low emotional intelligence (** $p < 0.01$).

To sum up, our study demonstrated for the first time that dimensions of TEI are associated with lower BID and better HRQoL in female and male primary school children. This is the first evidence that shows that already in middle childhood the development of emotional intelligence is related to body image perception. Therefore, more longitudinal studies are needed addressing the developmental pathways of BID not only in childhood but also in adolescence, by taking into consideration emotional intelligence and HRQoL.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The Ministry of Education, as well as Ulm University's ethics committee (https://www.uni ulm.de/einrichtungen/ethikkommission-der-universitaet-ulm/) had approved the study. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

OP, SK, AS, EG, and JS participated in the design of the study. SK, AS, JD, and JS carried out the study. OP, EG, and JD performed the statistical analyses. OP and EG drafted the manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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An Investigation of Lower Limb Representations Underlying Vision, Touch, and Proprioception in Body Integrity Identity Disorder

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Individuals with Body Integrity Identity Disorder (BIID) have a (non-psychotic) longstanding desire to amputate or paralyze one or more fully-functioning limbs, often the legs. This desire presumably arises from experiencing a mismatch between one's perceived mental image of the body and the physical structural and/or functional boundaries of the body itself. While neuroimaging studies suggest a disturbed body representation network in individuals with BIID, few behavioral studies have looked at the manifestation of this disrupted lower limb representations in this population. Specifically, people with BIID feel like they are overcomplete in their current body. Perhaps sensory input, processed normally on and about the limb, cannot communicate with a higher-order model of the leg in the brain (which might be underdeveloped). We asked individuals who desire paralysis or amputation of the lower legs (and a group of age- and sex-matched controls) to make explicit and implicit judgments about the size and shape of their legs while relying on vision, touch, and proprioception. We hypothesized that BIID participants would mis-estimate the size of their affected leg(s) more than the same leg of controls. Using a multiple single-case analysis, we found no global differences in lower limb representations between BIID participants and controls. Thus, while people with BIID feel that part of the body is foreign, they can still make normal sensory-guided implicit and explicit judgments about the limb. Moreover, these results suggest that BIID is not a body image disorder, per se, and that an examination of leg representation does not uncover the disturbed bodily experience that individuals with BIID have.

Keywords: xenomelia, body integrity dysphoria, lower limbs, body perception, multisensory, body ownership

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INTRODUCTION

Body Integrity Identity Disorder (BIID) is a rare, non-psychotic condition characterized by a persistent and strong desire to acquire a physical disability (1). This can include the (lesser known) variant which involves the desire for deafness (2) or blindness (3), but most reported cases of BIID involve the desire to amputate or paralyze one or more healthy limbs [e.g. (2–12)]. People with this variant of BIID (who will be the focus of the current report) presumably experience a mismatch between their internal mental image of the body and the external physical and functional boundaries of the body itself (4, 13). The condition is not a product of any apparent brain damage, most often manifests before adolescence, is more prevalent in males than females, and is reported more often for the lower limbs than for the upper limbs [see (14–17) for reviews]. While these individuals have normal sensory feedback (like vision, touch, and proprioception) from and about the affected limb (5, 11), they feel overcomplete with that limb, and that it is redundant in the bodily experience. Instead, they feel that removing the limb [or at least removing the functional abilities of the limb(s)] will make them feel complete, such that the external physical body would then match their, presumably innate, internal image of how the body should be. In other words, people with BIID likely experience an incongruence between their biological body and internal body representation.

Therefore, is BIID a product of a disturbed internal body representation? Neuroimaging evidence suggests that this may be the case. Specifically, individuals with amputation-variant BIID [i.e. those who desire amputation of a limb, also known as xenomelia (10)] have structural and functional alterations (compared to healthy control participants) in the body-representation network, specific to the superior parietal lobule (SPL), primary somatosensory cortex (SI), secondary somatosensory cortex (SII), supplementary motor area, and the paracentral lobule (which contains the SI leg representation), premotor cortex (PMC), and insula, and also other subcortical areas, perhaps more involved in sensorimotor control, like the cerebellum, putamen, caudate nucleus, pallidum, thalamus, and basal ganglia (11, 18–21). In addition, people with BIID show a reduction in activity of the SPL (10) and PMC (20) when being touched on the affected compared to the unaffected leg and to the legs of control participants. These brain areas are critical for integrating sensory input and maintaining models of the body, specifically for feeling ownership over a body part (22–25). So, although they can *feel* tactile input on their legs, there seems to be some fault at registering that information with a higher-level leg representation in the brain. Recently, Oddo-Sommerfeld and colleagues (12) found differential brain activity specific to most of the aforementioned body representation regions when individuals with BIID viewed images of themselves modified to look like a lower-limb amputee (desired body type) compared to controls viewing the same modified image of themselves (non-desired body type). Specifically, brain activity accurately predicted group membership, i.e. whether the participant belonged to the BIID group or control group. In addition, they found (unexpected) differential activation of lower- and higher-visual areas in the occipital lobe too. These studies indeed reveal an underlying disturbed body-representation network that could manifest as (or contribute to) an incongruence between the perceived internal representation of the body and the actual body. In line with this, many BIID researchers suggest that BIID might be indicative of "an inability of the brain to "map" or integrate sensation from the limb into [higher-order] body maps" (26) on page 3, (10, 20, 21, 27). Specifically, these higher-order body maps underlying visual and sensorimotor (like somatosensory, proprioceptive) information might be disrupted, such that they are incomplete or underdeveloped, in BIID.

Yet, few behavioral studies have investigated the manifestation of this disordered body representation in BIID individuals. We know that, at least for the amputation-variant, these individuals have an implicit preference for amputated versus intact bodies (7), have a more vivid rubber foot illusion for the affected foot (8), show impaired temporal-spatial processing of tactile stimuli for the affected leg (5), have an increased skin conductance response (SCR) to stimuli contacting the affected (but not the unaffected) limb (9, 28), and a reduced SCR response to stimuli *approaching* the affected limb (28). These studies, in conjunction with the neuroimaging results, do suggest that the origins of BIID might be a consequence of disturbed integration of bottom-up information (like vision, touch, proprioception) with top-down information, like higher order model(s) of the affected body part. What remains unknown, however, is how these models underlying sensory input for the affected body parts look in BIID. Is BIID a body representation disorder (specifically, is the perception of the affected leg distorted)? And if it is a problem with primary sensory input reaching the higher order representation(s), at which source does it start to falter? The one that underlies vision, or touch, or proprioception, if any? This urges one to investigate leg representations underlying these sensory modalities in BIID. We wanted to investigate this not only in those desiring amputation of their leg(s), but also in those with the paralysis-variant of BIID, since no studies, to our knowledge, have yet investigated body representations in people with paralysis-variant BIID.

One way to tap into the representation of the body is by asking people to make judgments about the size and shape of their body parts. Several investigations have revealed that healthy people have a distorted representation of their bodies, and this is dependent (at least partly) on the most reliable and dominant source of sensory information available when making judgments about that body part. People consistently overestimate the width of their hands when asked to make more implicit judgments about the body, like to localize points on their unseen hand (proprioceptive feedback) and underestimate tactile distances applied lengthwise on the hand (tactile feedback) but are accurate when asked to explicitly judge the shape of the hand when looking at pictures of it [visual feedback, i.e. the more conscious body image (29)]. The metric body representation of the lower limbs, however, has been much less studied (30–33). Though recently, we investigated the role that vision, touch, and proprioception play in making estimates about the underlying body representation of the lower limbs (33). Healthy participants made judgments about the size, shape, and location of landmarks on the legs while relying on different sensory input, and results revealed that body representations of the leg are also distorted. When asked to localize points on the leg while relying on its unseen position in space, participants perceived the upper legs to be longer/thinner than they are, but the lower legs to be squatter/shorter than they are. Distortions also ensued when asked to judge unseen tactile distances on the legs: tactile distances applied length-wise were underestimated more than those applied width-wise. Furthermore, when presented with different images of their legs onscreen, participants slightly overestimated their widths (length estimates were not tested). Thus, the underlying leg representations, underlying different weights of sensory input, show systematic distortions in healthy people.

Specifically, it has been proposed that perceiving the distance between two (tactile) points applied to a body part or localizing an unseen landmark on the body requires reference to a higher-order representation, i.e. the body model (34, 35). That is, the raw tactile and proprioceptive afferent information (e.g. about joint angle or skin stretch) is not informative about the size of the body part per se, so in order to estimate these tactile distances or localize one's position in space, the brain needs to refer to and integrate with a higher-order representation of the size and shape of the body (34–36). We suspect that these higher-order representations (or the connections to them) could be underdeveloped in BIID. On the other hand, however, visual estimates about perceived body size, specifically when judging (distorted) pictures of the body, tend to be veridical in healthy individuals [e.g. (29, 37)], suggesting a distinction between (more implicit) somatosensory and (more explicit) visual representations of the body (29, 36, 38). In clinical conditions, estimates of body part size tend to mimic one's internal and external experience of the body. For example, individuals with anorexia nervosa overestimate the distance between two tactile points on the body (39–41) but also overestimate body size when making more explicit judgments about images of their own body [e.g. 38,39; see (42) for review]. Similarly, individuals with complex regional pain syndrome (CRPS) overestimate body size in a template-matching task (43), reflecting their feeling that the limb feels bigger than it is. Yet, stroke patients who are asked to complete more implicit judgments about the affected body part, like localize the midpoint of their unseen arm, tend to underestimate its length (44). Individuals with BIID feel "overcomplete" on the outside, but like an amputee or paraplegic individual on the inside. Therefore, one might wonder whether these aforementioned tasks can shed lighten the hypothesized disturbances in body representations in BIID.

Therefore, in the current study, we explored leg representations underlying somatosensory and visual information about the body in a group of people with amputation- and paralysis-variant BIID. We employed the same tasks as used in Stone et al. (33). We hypothesized that participants with BIID would:

1. overestimated their disowned/affected leg(s) more than the/affected leg(s) more than the same leg(s) of controls when making conscious, visually-guided estimates about leg shape, reflecting the ever-present "overcomplete" feeling of being in one's own body, but
2. underestimate their disowned/affected leg(s) (unilateral-desire) or both (bilateral-desire or paralysis-desire) legs more than that same leg of controls during the more implicit, tactile or proprioceptively guided tasks, reflecting the possibly incomplete or underdeveloped higher-order representation of the limb.

That is, if the sensory input has problems cross-referencing with a model of the legs in the brain, judgments about bodily dimensions and its position in space might be reflective of only a portion of the (total possible) input about one's body configuration if visual input is not there to correct for it. Understanding the perceived internal configuration of the legs in BIID might provide insight into the incongruent experience they have, and eventually move towards modulating these representations to better close this gap between the perceived body and the actual body [e.g., (44–46)].

METHODS AND PROCEDURES

Participants

BIID Participants

Ten participants with lower-limb BIID took part. One participant (female desiring paralysis of her legs) was removed due to motivational issues during the experiments. Therefore, nine participants were included in the current experiments. Participants were recruited via collaboration with another BIID researcher and through online BIID support group forums (https://groups.yahoo.com/neo/groups/fighting-it/info and https://forum.biid.ch/). Participants (8 biologically male) ranged in age from 19 to 68 years of age (mean = 43.1, SD = 13.5). Highest level of education completed was as follows: primary school (*n* = 1), secondary school (*n* = 1), higher education (*n* = 5), university level (*n* = 2). Two individuals desired left leg amputation, two desired right leg amputation, one desired bilateral amputation, and 4 desired bilateral paralysis of the legs. Participants had normal or corrected-to-normal vision. Tactile sensitivity was reported to be normal.

Participants took part in a telephone interview with a psychiatrist prior to their participation to confirm the desire to change the body arose from having BIID and was not a product of another psychiatric condition. We used the criteria from First and Fisher (1) to determine if the individual had BIID. In addition, questions were asked about the history of the BIID, any psychiatric illnesses, and whether they had normal tactile sensitivity and vision. See **Appendix 1**. All contacted participants were eligible for participation. For a more thorough assessment of the individual's psychiatric profile, a trained neuropsychologist administered the Structured Clinical Interview for the DSM-5 Axis I and Axis II disorders (SCID-5) on the day of testing in Utrecht. Psychiatric profiles were overall normal for most participants. Three individuals had diagnoses prior to participation, including one with PDD-NOS, one with borderline personality disorder and post-traumatic stress disorder, and another with gender identity dysphoria (male desired to be female) which were confirmed during the clinical interview. Characteristics for each participant are included in **Table 1**.

TABLE 1 | Characteristics of BIID sample. General characteristics of BIID sample. For the participant column: RA, right amputation desire; LA, left amputation desire; BA, bilateral amputation desire; P, paralysis desire. The number preceding the code is randomly assigned participant number. For the sex and gender columns: M = male, F = female. For the current comorbid conditions column: PDD-NOS, pervasive developmental disorder-not otherwise specified; BPD, borderline personality disorder; PTSS, post-traumatic stress symptoms.

Participant	Sex	Gender	Age (years)	Highest level of education obtained	Desire (lower limbs only)	Desire since age	Current comorbid conditions
1—RA	M	M	40	Higher education	Right knee disarticulation	10	PDD-NOS
2—RA	M	M	42	Secondary school	Right above knee amputation	6	none
3—LA	M	M	51	Higher education	Left above knee amputation	6	none
4—LA	M	M	42	University degree	Left above knee amputation	7	none
5—BA	M	M	38	Higher education	Bilateral above knee amputation	6	none
6—P	F	F	19	Primary school	Paralysis	6	BPD, PTSS, Dysthymia
7—P	M	F	35	Higher education	Paralysis	20	Gender Dysphoria
8—P	M	M	68	Higher education	Paralysis	6	none
9—P	M	M	51	University degree	Paralysis	10	none

Controls

Approximately two sex- and age-matched (± ~5 years) control participants were tested per BIID participant, so the total control group consisted of 21 participants (17 males) between the ages of 21 and 71 (mean = 44.9, SD = 15.2). Highest level of education completed was as follows: secondary school (*n* = 4), higher education (*n* = 9), university level (*n* = 8). Participants reported normal tactile sensitivity and normal or corrected-to-normal vision. All participants reported no past/current psychiatric illnesses, and this was corroborated by our screenings with the Modified MINI-screen (47) and a SCID-V questionnaire for personality disorders (48). Participants were recruited via online study participant websites, Utrecht University's intranet, and word of mouth.

All participants gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the internal ethics committee of the Faculty of Social and Behavioral Sciences at Utrecht University (protocol number: FETC 17-004) before participation. Participants were naïve to the purposes of the study.

Questionnaires

Demographics and Medical History

Control participants completed a general questionnaire which included questions about the demographics (e.g. age, sex, ethnicity) and medical history (e.g. presence of psychiatric or chronic medical disorder).

BIID participants completed a more extensive version of the questionnaire with additional questions about their BIID, which was a modified version of the BIID Phenomenology Questionnaire (4). These questions were administered to provide a richer understanding of the history, experience, and description of the individual's condition.

12-Item Zurich Xenomelia Scale

This scale was given to BIID participants only. This has been described by us in the supplementary material elsewhere (49). The 12-item Zurich Xenomelia Scale (ZXS) (5), consists of 3 subscales regarding 1) the strength of the participant's amputation (or paralysis) desire, 2) the participant's erotic attraction to amputees/being an amputee, and 3) the extent to which the participant engages in pretending behaviors (i.e. simulated the bodily state of being amputated or paralyzed). Participants rated their agreement with each statement from 1 (strongly agree) to 6 (strongly disagree). Items 1 (reverse-scored), 2, 5 (reverse-scored), 10 are part of the "pure amputation (paralysis) subscale," items 3, 6(reverse-scored), 9 (reverse-scored), 12 are part of "erotic attraction" and items 4, 7, 8 (reverse-scored), 11 (reverse-scored) are part of the "pretending behavior" subscale. We modified the ZXS to accommodate all participants, i.e., "amputation" was replaced with "paralysis" for participants who desire paralysis.

Sheehan Disability Scale (SDS)

Note: this was given to BIID participants only.

The SDS is a scale which assesses functional impairment in work/school, social, and family life due to having a disability or impairment, in this case BIID (50). Participant rated their agreement [from 0 (not at all) to 10 (extremely)] with three statements about the extent to which their BIID symptoms have disrupted work/school, social life, and family life in the past week. The number of days in the past week that were lost and that were underproductive were also recorded.

Body Representation Tasks

Methods were similar to Stone et al. (33). Order of tasks was counterbalanced between participants with the BIID group. Participants in the control group received the same task order as the BIID participant they were matched to.

Template Matching Task (Visual Body Representation)

Body representations about the visual properties of the legs were assessed using a Template Matching Task (29, 33, 51). Participants made judgments about the length/width of their body parts in a custom-made MATLAB program. Photographs were taken of the participants' bare legs (mid-thigh to ankle), which were then entered into a custom-made MATLAB program. The program generated fifteen images ranging in size from 65% to 135% (in increments of 5%) of the image's length *or* width. These images were displayed, one at a time, on a vertically positioned computer monitor (27 L × 34 W; resolution: 1280 ×

1024). For the images that were stretched horizontally, participants indicated, by clicking one of two onscreen buttons, whether the image of the leg shown onscreen was wider or more slender than he/she felt the shape of his/her own leg was. For images that were stretched vertically, participants were asked to choose whether image of the leg shown onscreen was shorter or longer than he/she felt the shape of his/her own leg. The program used a staircase procedure to determine the participants' perceived leg width/length [described in greater detail in (33)]. The average value of the last five reversals was taken as the perceived size (range of values 0.65–1.35). For example, an average value of 1.22 on the length estimates would indicate that the participant perceived his leg to be 122% of its actual image size, or 22% longer. Starting condition (length right, length leg, width right, width left) was counterbalanced between participants. See **Figure 1A** for visualization of an example trial.

Tactile Distance Estimation Task (Tactile Body Representation)

Body representation underlying tactile distances was assessed using the tactile distance estimation task (33, 39). A digital caliper was used to apply two points with a pre-specified distance (for legs: 50, 60, or 70 mm; for arms: 40, 50, 60 mm) to the participant's body part in the horizontal (width-wide, medio-lateral) or vertical (length-wise, proximo-distal) direction. The difference in distances were due to the 2-point discrimination threshold for the shin [e.g. 45 mm, (52)] and the small size of some individuals' arms (i.e. applying 70 mm extends the width of some people's arms). The reason for this directional manipulation was to assess biases in tactile direction estimates, which have been shown before (33, 53, 54). While blindfolded, participants estimated the distance between those two points by mimicking the distance with their right thumb and index finger and placing it on an ACER Aspire 10-inch tablet. A custom-made program (TouchTest, programmed in MATLAB) recorded the responses. As in Stone et al. (33), each distance was applied three times per location (shin, forearm, thigh), side (right, leg), and direction (horizontal, vertical). In total, 18 stimuli were applied per body part. Starting condition based on location and direction were counterbalanced between participants. See **Figures 1C, D** for example of setup and response.

Controls

Stimuli were applied to all six parts (left shin, right shin, left thigh, right thigh, left forearm, right forearm). However, it is important to note that only participant 5-BA received the task on his thighs, and therefore is the only participant compared to this condition.

BIID Participants

Amputation Variant. To assess tactile distances on affected versus unaffected parts of the body, stimuli were applied to two parts (right shin, left shin). In all unilateral-desire cases, one shin was coded as an affected part. Participant 5-BA, who desired

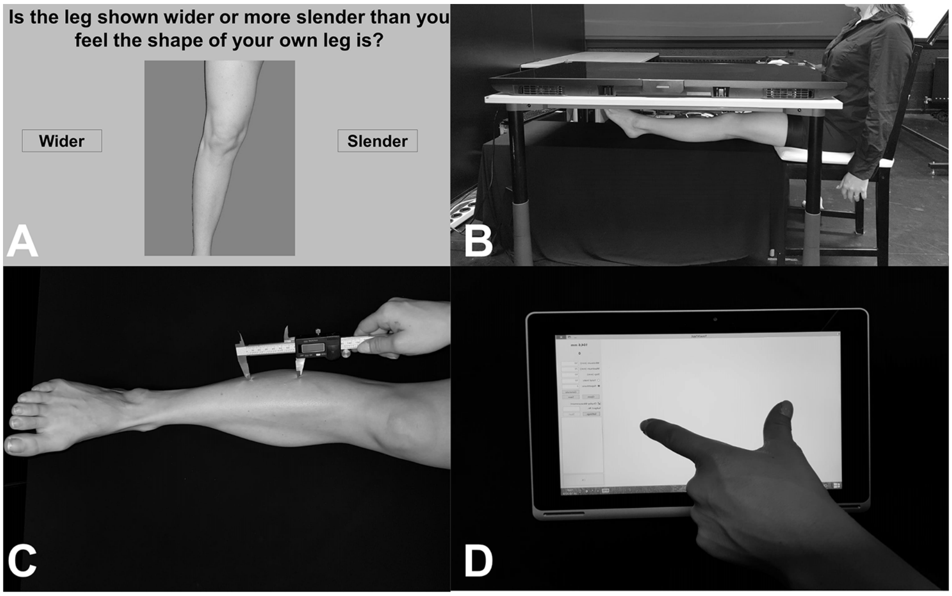

FIGURE 1 | (A) Image showing an example trial from the Template Matching Task. Participants were presented with distorted images of their own legs and asked to judge whether the leg was wider/slender (or longer/shorter, not pictured here) than their own leg by clicking one of the buttons on either side of the image. **(B)** Image showing setup for localization task, in an example trial of the Real condition. Participants placed their legs under a television screen and were asked to click-to-indicate (using a mouse in their right hand, not pictured here) the position of different leg landmarks. **(C)** Image showing an example trial from the tactile distance estimation task. Two unseen points were applied to the leg in the vertical (pictured here) or horizontal direction. **(D)** Image showing example response for the tactile distance estimation task. While blindfolded, participants judged the distanced between the two applied points (e.g. as shown in **C**.) using their thumb and index finger on a touchscreen tablet.

bilateral amputation, received tactile stimuli above (thigh) and below (shin) the demarcation line, such that the shins constituted the affected parts.

Paralysis Variant. As participants desired paralysis of their legs from the waist down, we used the forearm as an "unaffected" body part. Distances were thus applied to the four parts (left shin, right shin, left forearm, right forearm). In all cases, both shins were coded as affected parts.

Localization Task (Proprioceptive and Other Body Representations)

Leg representations underlying proprioception, proprioceptive imagery, and visual memory were assessed using the Leg Localization Task (33), employed several times for the hands: [e.g. (13–15, 18, 19)]. The widths of the participants' knees, ankles, and mid-thighs (mid-point between the groin and knee) and the lengths of the participants' upper legs (mid-thigh to knee) and lower legs (knee to ankle) were measured with a Vernier caliper (brand: MIB, 300 mm), measuring tape, and a curved caliper. Marks were made at these same locations (inner/outer mid-thigh, inner/outer knee, inner/outer ankle) using a washable marker to familiarize the participant with these landmarks.

Participants sat with their torsos centrally aligned at the short edge of a 55-inch SONY KDL-55W805C television (screen dimensions: 68.5 cm W (short edge) × 121.5 cm L (long edge); resolution: 1920 × 1080) which lay horizontally on a tabletop (120 L × 80 W × 70 H cm). Text indicating 1 of 6 landmarks (inner mid-thigh, outer mid-thigh, inner knee, outer knee, inner ankle, outer ankle) was presented adjacent to the participant on the other end of the screen for each trial. Using a mouse in the right hand (positioned at the same height as the table), participants moved the cursor to the perceived location of the presented landmarks and clicked to indicate its position under the following conditions:

a) Real: participants outstretched their legs on a tabletop (100 L × 60 W × 44.5 H cm) located 30 cm below the television, rendering it out of sight. To prevent movement during each block, the heel was positioned to rest on a foam pad. Participants were asked to indicate the felt position of that landmark by left-clicking directly above where they *felt* (i.e. relying on proprioceptive feedback) that part of their leg to be. This was completed twice, once for each leg. See **Figure 1B** for example of this condition.

b) Imagine: participants were instructed to "imagine as though your leg is extended under the table" while sitting normally at the setup (legs bent at 90 degrees). Participants therefore relied on proprioceptive imagery (33, 55), rather than proprioceptive feedback, to complete the task. This was completed twice, once for each leg.

c) Mannequin: participants were instructed to indicate the same landmarks on a mannequin leg. They studied a right mannequin leg, with the same marked landmarks as their own legs, for 30 s and were urged to memorize its shape and landmarks. The mannequin leg was then placed under the television screen on the lower tabletop. Participants sat normally, as in the Imagine condition.

A custom-made MATLAB program was used to display the text and record the data. Participants completed 60 randomized trials (10 trials per landmark) per condition. Starting condition (real right, real left, imagine right, imagine left, mannequin) was counterbalanced between participants. To familiarize participants with the task, a short 12-trial practice block was completed before the experiment started (data not included in analysis). See **Figure 1B** for example of setup.

Data Analysis

Template Matching Task

The average value for each image was taken as the last 5 reversals across both staircases for each image. Average values could range from 0.65 to 1.35 as images shown were between 65% to 135% of the length or width of the body part's image. For controls, a one-sample t-test comparing the values to 1 (veridical performance) was used to examine whether participants over- or under-estimated the shapes of their legs/feet.

The average estimates for each part were individually compared between BIID participants and controls.

Tactile Estimation Task

For controls, the average estimates per distance were calculated by taking the average of the three trials per distance. Separate repeated measures ANOVA with distance and body as the within-subject factors were conducted to examine if participants estimated larger distances for 70 mm vs 50 mm vs 60 mm, for example for each part. There was a main effect of distance, showing that participants estimated distances as larger as the applied distance was indeed larger. There was no interaction between distance and body part. Therefore, we collapsed across distance estimates, and converted it to a percent mis-estimation for each body part and direction (i.e. % mis-estimation = (perceived distance-actual average distance)/ actual average distance). To compare performance, distances were collapsed for BIID participants as well. See supplementary material (**Figures S1–S4**) for plots displaying judgments per distance, per participant for controls and BIID participants.

Comparison to Amputation Variant: Percent mis-estimations for the affected and unaffected shins were compared to the shins of controls. For participant 5-BA (bilateral-amputation desire), percent mis-estimations for the affected shins (both) and the unaffected (thigh) were compared to the shins and thighs of controls.

Comparison to Paralysis Variant: Percent mis-estimations for the shins (both affected) were compared to the shins of controls. Percent mis-estimations for the forearms (both unaffected) were compared to the forearms of controls.

Localization Task

On-screen coordinates were compared to the actual dimensions of the leg. Each pixel on screen represented 0.63 mm. For each landmark, the average x/y coordinates of the 10 clicked points per landmark was calculated. Points > 2 SDs from the average clicked location were removed.

The perceived distance between the two points (e.g. inner knee to outer knee) were calculated using the equation:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

To convert from pixels to mm, "d" was multiplied by 0.63 (due to screen size and resolution). The perceived and actual shapes of the lower legs were calculated in order to compare the BIID legs to control legs (33). This is a measure of the overall aspect ratio of an object/body part (34, 56), which can be calculated as 100 * width/length. As at least one lower leg (knee to ankle) was affected in all BIID participants, we calculated lower leg (perceived and actual) SIs using the following equation:

$$SI = 100 * average\ of\ ankle\ and\ knee\ widths\ (in\ mm)/\ length\ from\ knee\ to\ ankle\ (in\ mm)$$

A value of 100 would suggest that width is equal to length (i.e. a square shape). A value > 100 would suggest that width > length (i.e., a shape that is shorter than it is long) and <100 would suggest that width < length (i.e. a shape that is longer than it is wide). Importantly, actual SIs for the lower leg are <100 as the width of the ankle and knees are always less than the length of the shin bone in normal legs. However, perceived SIs can entertain all possible outcomes (e.g. I could perceive my leg to be shorter than it is long). To compare across conditions in the localization task, we used these actual and perceived SIs to then calculate a *normalized* shape index (NSI = perceived SI/actual SI) to use as an outcome measure for each participant and condition. Values of 1 indicated that participants accurately perceived the shape of the leg part. Values > 1 indicated that the perceived shape of the leg was shorter and/or wider than the actual shape (i.e. the perceived proportion of width to length is higher than the actual proportion of width to length, or in other words, a foreshortened leg length with respect to its width). Conversely, values < 1 indicated that the perceived shape of the leg was longer and/or thinner than the actual shape (i.e. the perceived proportion of width to length is lower than the actual proportion of width to length, or in other words, a lengthened leg with respect to its width). NSIs were compared between BIID participants and controls.

BIID versus Controls: Due to the heterogeneity of the BIID sample (e.g. sex, affected body part, variant of BIID, age), we took a multiple single-case approach, comparing each BIID participant separately to the control group. Outcomes for each task were compared between BIID subjects and controls using Crawford-Garthwaite Bayesian single-case t-tests (57) in R using the psycho package (58), one-sided (as we hypothesized an *under*estimation of leg size for the localization (NSIs > 1) and tactile distance estimations (% mis-estimation < 0), but an *over*estimation of leg size for the template matching task compared to controls). Bonferroni-corrections for multiple comparisons were used when necessary. Microsoft Excel 2016 was used to process and visualize the data. IBM SPSS Statistics 23.0 for Windows (IBM Corp., Armonk, N.Y., USA) and JASP [version 0.9.2.0, (59)] were also used for analysis/further visualization of the data. For clarity, only the lowest *p* value is stated for the multiple single case comparisons. Tables including all *p* values, credible intervals, and effect sizes for each BIID participant on each outcome measure per task in comparison to controls is included in the **Supplementary Material**.

Outlier Analysis: In total, control participants with scores > 2.5 SDs from the mean score were removed from the analysis. One control participant was removed from the tactile estimation task and two control participants were removed from the localization task. One participant did not complete the arm trials for the tactile estimation task but completed the task for the legs. Analyses were done within tasks.

RESULTS

Questionnaires

12-Item Zurich Xenomelia Scale

Average scores ± standard deviations for each subscale were as follows: 5.4 ± 0.6 (pure amputation/paralysis desire), 3.2 ± 1.3 (erotic attraction), and 4.7 ± 0.6 (pretending behaviors). Total average score was 4.4 ± 0.8 out of a possible 6. These scores are in line with previous studies using this scale to describe their BIID sample [e.g. (5, 11, 21)]. See **Table 2**.

Sheehan Disability Scale (SDS)

Average scores ± standard deviations for each subscale (out of a total possible score of 10) were as follows: 6.5 ± 2.6 (work/school life), 6.6 ± 1.9 (social life), 5.1 ± 2.9 (family life). Values between 6 to 7 reflect *moderate to marked* disruption. Values between 5 to 6 reflect *marked* disruption (50). The average number of days lost due to BIID was 0.4 ± 0.7 days. The average numbers of underproductive days due to BIID was 1.6 ± 2.0.

TABLE 2 | 12-item Zurich Xenomelia (ZXS) scores per BIID participant.

Participant	ZXS: Total Score	Pure amputation/ paralysis desire subscale	Erotic attraction subscale	Pretending behaviors subscale
1 - RA	4.42	4.75	3.5	5
2 – RA	4.83	5.5	4.25	4.75
3 – LA	3.83	5.5	1.5	4.5
4 – LA	5.50	6	5	5.5
5 – BA	4.75	6	4.75	3.5
6 – P	4.25	6	2	4.75
7 – P	3.92	4	2	5.75
8 – P	4.08	5.5	2.25	4.5
9 – P	4.75	5.75	4	4.5

The total score is the average of all scores. Scores could range from 1 to 6, with higher scores indicating stronger BIID symptomatology.

Body Representation Tasks

Template Matching Task

Controls

Controls were accurate in making judgments about right leg width ($t(20) = 1.5, p = 0.2$), right leg length ($t(20) = 1.8, p = 0.08$), left leg length ($t(20) = 1.6, p = 0.1$), and left leg width ($t(20) = 1.8, p = 0.07$) as revealed by a series of one-sample t-tests comparing the scores to 1 (i.e. veridical performance).

A repeated-measures ANOVA with side (left, right) and direction of distortion (width, length) as within-subjects factors conducted on the average scores revealed no main effect of side ($F(1,20) = 0.3, p = 0.5$, η2 = 0.01), direction ($F(1,20) = 0.08, p = 0.7$, η2 = 0.004), and no interaction between side and direction ($F(1,20) = 0.005, p = 0.9$, η2 < 0.0001). Controls were overall accurate in making judgments about the length and width of images of their legs, regardless of side. See **Figure 2**.

Comparison to BIID Participants

Right. *Width*. There was no difference between BIID participants and controls ($p \geq 0.1$ for remaining comparisons). *Length*. No differences between BIID participants and controls emerged ($p \geq 0.07$ for remaining comparisons, and $p = 0.04$ for participant 3-LA due to underestimation but irrelevant due to one-tailed testing).

Left. *Width*. No differences between BIID participants and controls emerged ($p \geq 0.1$ for remaining comparisons, and $p = 0.01$ for participant 7-LA due to underestimation but irrelevant due to one-tailed testing). *Length*. No differences between BIID participants and controls emerged ($p \geq 0.1$ for remaining comparisons). See **Figure 2** for individual results.

Therefore, our hypothesis that participants with BIID would overestimate the size of their affected legs more than the same leg of controls, mimicking the conscious experience of being "overcomplete," was not confirmed. See **Tables S1.1–S1.4** in supplementary material for all p-values, confidence intervals, and effect sizes for BIID participants compared to controls.

Tactile Estimation Task

Controls (Raw Estimated Values)

Shin. A repeated-measures ANOVA with distance (50, 60, 70 mm), side (left, right), and direction (horizontal, vertical) revealed a main effect of direction, indicating that participants judged distances applied in vertical direction as smaller than those same distances applied in the horizontal direction ($F(1,19) = 28.0, p < 0.0001$, η2 = 0.5). There was a main effect of distance, indicating that participants judged larger distances as larger, e.g. 60 mm > 50 mm ($F(2,38) = 43.3, p < 0.0001$, η2 = 0.6). There was no main effect of side, indicating that estimates were similar for left and right legs ($F(1,19) = 0.1, p = 0.7$, η2 = 0.008). No interactions were significant ($p \geq 0.3$ for all comparisons).

Arm. A repeated-measures ANOVA with distance (40, 50, 60 mm), side (left, right), and direction (horizontal, vertical) revealed a main effect of direction, indicating that participants judged distances applied in vertical direction as smaller than those same distances applied in the horizontal direction ($F(1,18) = 51.5, p < 0.0001$, η2 = 0.7). There was a main effect of distance, indicating that participants judged larger distances as larger, e.g. 60 mm > 50 mm ($F(2,36) = 48.8, p < 0.0001$, η2 = 0.7). There was no main effect of side ($F(1,18) = 1.6, p = 0.2$, η2 = 0.08). The interaction between distance and direction was significant ($F(1.4, 26.8) = 5.7, p = 0.01$, η2 = 0.2). Paired samples t-tests (where the critical Bonferroni-correct $p = 0.016$) revealed that 60 mm were judged as larger than 50 mm (and 50 mm larger than 40 mm) for the horizontal directions

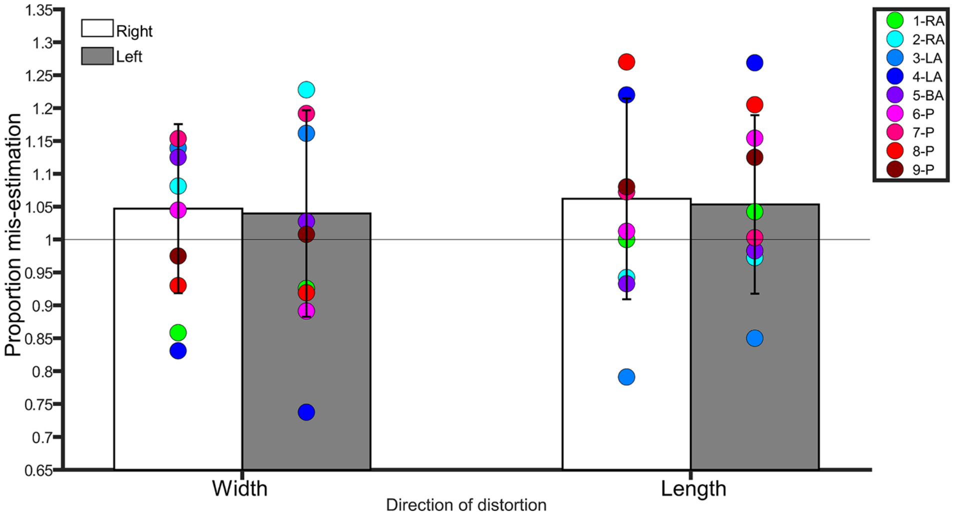

FIGURE 2 | Bar graph showing proportion mis-estimation (1 is veridical) for judgments of images distorted width-wise or length-wise in the Template Matching Task. The white bars represent estimates of the right leg in controls. The grey bars represent estimates of the left leg in controls. Error bars represent standard deviation. The horizontal line positioned at y = 1 denotes veridical performance on this task. Each colored point represents a BIID participant. RA, right amputation; LA, left amputation; BA, bilateral amputation; P, paralysis in the legend. The preceding numbers denotes participant number.

($p < 0.0001$ for all), but 60-mm distances applied in the vertical direction failed to be judged as larger than 50-mm distances in the vertical direction, thereby showing a slightly less pronounced upward step in distance estimates ($t(18) = -2.3$, $p = 0.057$). No other interactions were significant ($p \geq 0.2$ for all comparisons).

Thigh. A repeated-measures ANOVA with distance (50, 60, 70 mm), side (left, right), and direction (horizontal, vertical) revealed a main effect of distance, indicating that participants judged larger distances as larger ($F(1.5,27.0) = 39.4$, $p < 0.0001$, $\eta 2 = 0.6$). There was no main effect of side ($F(1,18) = 1.5$, $p = 0.2$, $\eta 2 = 0.07$) or direction ($F(1,18) = 0.6$, $p = 0.4$, $\eta 2 = 0.03$). No interactions were significant ($p \geq 0.5$ for all comparisons).

For clarity's sake, we collapsed across the variable "distance" for both "sides" and "directions" for the arm, thigh, and shin separately. Percent mis-estimations for each side and direction were calculated as: (average estimated distance – average applied distance)/(average applied distance) * 100. These values were used to compare to BIID participants for each condition.

Controls (Percent Mis-Estimation Values)

Shin. A repeated measures ANOVA on the percent mis-estimation values with side and direction as within-subject factors revealed a main effect of direction ($F(1,19) = 28.0$, $p < 0.001$, $\eta 2 = 0.5$), indicating that controls underestimated distances applied in the vertical direction (−19.5% ± 23.5 SD) more than those applied in the horizontal direction (−4.9% ± 24.7 SD). There was no main effect of side ($F(1,19) = 0.1$, $p = 0.7$, $\eta 2 = 0.008$). The interaction between side and direction was not significant ($F(1,19) = 0.2$, $p = 0.6$, $\eta 2 = 0.01$). One-sample t-tests comparing the values to 0 (Bonferroni-corrected $p = 0.01$) for each condition revealed that distances applied to the right ($t(19) = -4.0$, $p < 0.001$) and left ($t(19) = - 3.1$, $p = 0.005$) shins in the vertical direction were significantly different from 0, suggesting that these distances were underestimated. Distances applied in the horizontal direction were not different from 0 ($p \geq 0.3$ for both comparisons). See **Figure 3**.

Arm. A repeated measures ANOVA on the percent mis-estimation values with side and direction as within-subject factors revealed a main effect of direction ($F(1,18) = 51.4$, $p < 0.001$, $\eta 2 = 0.7$), indicating that controls underestimated distances applied in the vertical direction (−4.3% ± 21.3 SD) more than those applied in the horizontal direction (8.9% ± 21.1 SD). There was no main effect of side ($F(1,18) = 1.6$, $p = 0.2$, $\eta 2 = 0.08$). The interaction between side and direction was not significant ($F(1,18) = 2.9$, $p = 0.1$, $\eta 2 = 0.1$). One-sample t-tests comparing the values to 0 (Bonferroni-corrected $p = 0.01$) for each condition revealed no difference from 0 (i.e. veridical performance, $p \geq 0.4$ for left horizontal, left vertical, and right vertical, $p = 0.029$ for right horizontal). See **Figure 4**.

Thigh. A repeated measures ANOVA on the percent mis-estimation values with side and direction as within-subject factors revealed no main effect of direction ($F(1,18) = 1.5$, $p = 0.2$, $\eta 2 = 0.07$), no main effect of side ($F(1,18) = 0.6$, $p = 0.4$, $\eta 2 = 0.03$), nor an interaction between side and direction ($F(1,18) = 0.2$, $p = 0.6$, $\eta 2 = 0.01$). One-sample t-tests comparing the values to 0 (Bonferroni-corrected $p = 0.01$) was significant for all comparisons (right horizontal: $p = 0.002$, left horizontal: $p = 0.01$, right vertical: $p < 0.001$, left vertical: $p = 0.006$).

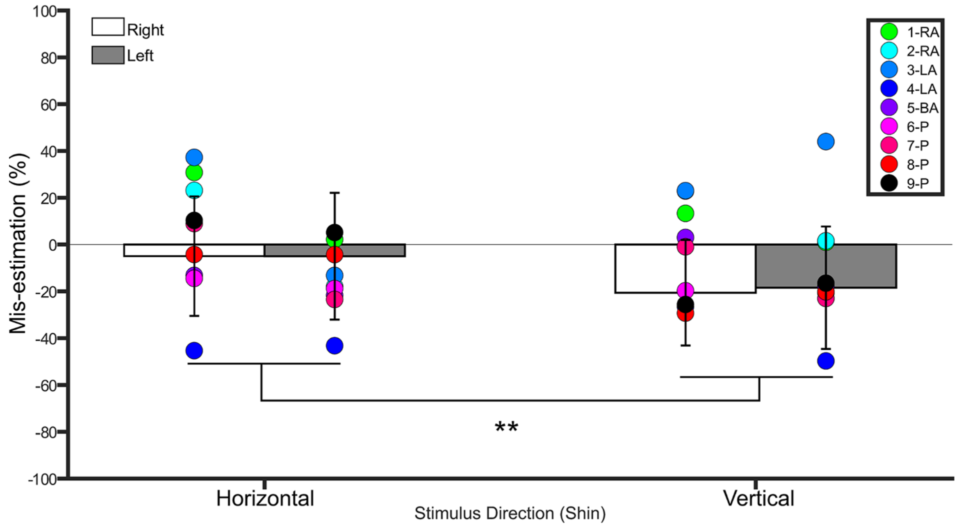

FIGURE 3 | Bar graph showing percent mis-estimation of distances applied horizontally (width-wise) and vertically (length-wise) to the shins. The white bars represent percent mis-estimation for the right shin in controls. The grey bars represent percent mis-estimation for the left shin in controls. Error bars represent standard deviation. Negative values suggest under-estimation of distances applied and positive values suggest over-estimation of distances applied. Individual colored point represents percent mis-estimations for each BIID participant. RA, right amputation; LA, left amputation; BA, bilateral amputation; P, paralysis in the legend. The preceding numbers denotes participant number. Note that some estimations were so similar in BIID participants that their points overlapped. **$p < 0.001$ and denotes that control participants overestimated more for distances applied horizontally versus vertically.

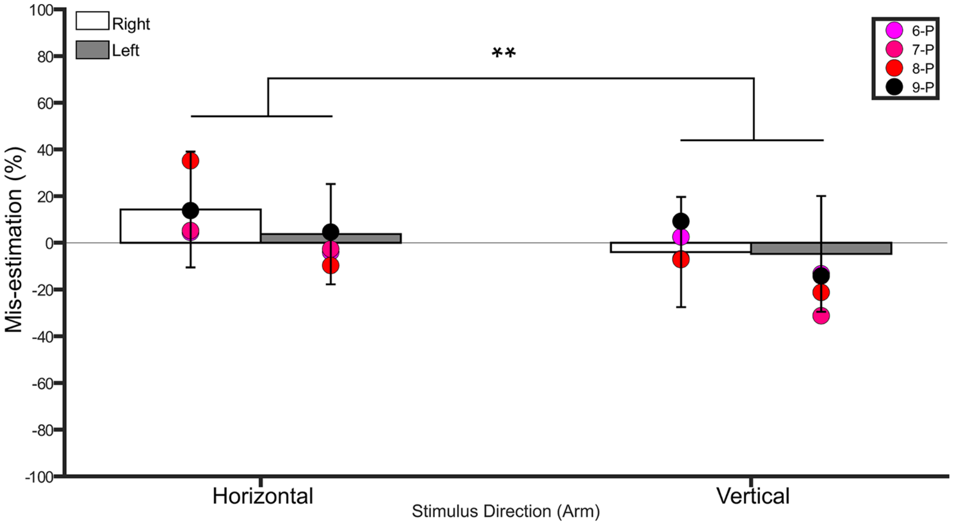

FIGURE 4 | Bar graph showing percent mis-estimation of distances applied horizontally (width-wise) and vertically (length-wise) to the forearms. The white bars represent percent mis-estimation for the right forearm in controls. The grey bars represent percent mis-estimation for the left forearm in controls. Error bars represent standard deviation. Negative values suggest under-estimation of distances applied and positive values suggest over-estimation of distances applied. Individual colored point represents percent mis-estimations for each BIID participant. P = paralysis in the legend. The preceding numbers denotes participant number. Note that some estimations were so similar in BIID participants that their points overlapped. **$p < 0.001$ and denotes that control participants overestimated more for distances applied horizontally versus vertically.

Comparison to BIID

Shin. The shins were tested on all participants. Both shins were "affected" in paralysis-variant participants and the bilateral-amputation desire participant. One shin was "affected" in unilateral amputation desire participants (i.e. 2 left, 2 right). See **Figure 3** for individual results.

Right. *Horizontal*. BIID participants did not significantly underestimate distances more than controls ($p \geq 0.06$ for all comparisons). *Vertical*. BIID participants did not significantly underestimate distances more than controls ($p \geq 0.08$ for all remaining comparisons, except $p = 0.04$ for participants 2-RA and 3-LA but in the opposite direction, i.e. overestimation, irrelevant due to one-tailed testing).

Left. *Horizontal*. BIID participants did not significantly underestimate distances more than controls ($p > 0.09$ for all comparisons). *Vertical*. BIID participants did not significantly underestimate distances more than controls ($p \geq 0.1$, except $p = 0.02$ for participant 3-LA but in opposite direction, i.e. overestimation, irrelevant due to one-tailed testing).

Therefore, our hypothesis that participants with BIID would underestimate distances applied to their affected parts more than controls was not confirmed. See **Tables S2.1–S2.4** in supplementary material for all p-values, confidence intervals, and effect sizes for BIID participants compared to controls.

Arm. The arms were only tested on participants who desired paralysis, as the arms served as the unaffected part. See **Figure 4** for individual results.

Right. *Horizontal*. No differences between BIID and control participants emerged ($p \geq 0.2$ for remaining comparisons). *Vertical*. No differences between BIID and control participants emerged ($p \geq 0.3$ for all comparisons)

Left. *Horizontal*. No differences between BIID and control participants emerged ($p \geq 0.3$ for all comparisons). *Vertical*. No differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons).

See **Tables S2.5–S2.8** in supplementary material for all p-values, confidence intervals, and effect sizes for BIID participants compared to controls.

Thigh (Unaffected Site for Participant 5-BA)

Right. *Horizontal*. There was no difference between participant 5 (7.0%) and controls (−20% ± 25 SD; $p = 0.1$). *Vertical*. There was no difference between participant 5 (−33.8%) and controls (−21.3% ± 23.2 SD; $p = 0.3$).

Left. *Horizontal*. There was no difference between participant 5 (−21.9%) and controls (−16.4% ± 24.7 SD; $p = 0.4$). *Vertical*. There was no difference between participant 5 (0.5%) and controls (−20.2 ± 28.0 SD; $p = 0.2$).

See **Tables S2.9–S2.12** in supplementary material for all p-values, confidence intervals, and effect sizes for BIID participants compared to controls.

Localization Task

NSIs were compared between BIID and control participants for the lower legs (knees to shins).

Controls

Comparison to 1 (Veridical Performance). NSIs for all conditions were significantly different from 1 ($p < 0.001$ for all comparisons), such that they were greater than 1. Importantly, an NSI >1 indicates that the participant perceives the proportion of width to length of the lower leg as *larger* than the actual proportion, suggesting a foreshortened leg shape.

Own legs. A 2 (leg) × 2 (condition) repeated measures ANOVA on lower leg NSIs revealed a main effect of condition ($F(1,18) = 4.9$, $p = 0.03$, $\eta^2 = 0.2$), indicating that NSIs were higher for the Real (1.77 ± 0.50 SD) condition than the Imagine (1.62 ± 0.54 SD) condition. There was no main effect of Leg ($F(1,18) = 0.006$, $p = 0.9$, $\eta^2 < 0.001$), nor an interaction between condition and leg ($F(1,18) = 0.9$, $p = 0.3$, $\eta^2 = 0.04$). See **Figure 5**.

Comparison with mannequin condition. To compare to the mannequin leg condition (for which we only tested a right mannequin leg), we collapsed across side for participants' own legs and ran a repeated measures ANOVA on condition (real, imagine, mannequin). There was a main effect of condition ($F(1.2,22.7) = 5.8$, $p = 0.01$, $\eta^2 = 0.2$). Bonferroni-corrected pairwise comparisons revealed a significant difference between Mannequin (2.1 ± 0.8 SD) and Imagine conditions ($t(19) = 2.88$, $p = 0.01$), but not Mannequin and Real ($t(18) = 1.9$, $p = 0.07$). The difference between Real and Imagine was also significant ($t(19) = 2.2$, $p = 0.03$). See **Figure 5**.

Comparison to BIID

Each condition (Right Real, Left Real, Right Imagine, Left Imagine, Mannequin) were compared to BIID participants separately. See **Figure 5** for individual results.

Right. *Real.* No differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons). *Imagine.* Participant 1-RA scored significantly higher than controls (NSI = 86.9, $p < 0.0001$). No other differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons).

Left. *Real.* No differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons). *Imagine.* Participant 1-RA scored significantly higher than controls (NSI = 20.8, $p < 0.0001$). No other differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons).

Mannequin. No differences between BIID and control participants emerged ($p \geq 0.1$ for all comparisons).

Therefore, our hypothesis that participants with BIID would have a higher NSI (more distorted, foreshortened perceptual representation of the affected leg(s)) was not confirmed. See **Tables S3.1–S3.5** in supplementary material for all p-values,

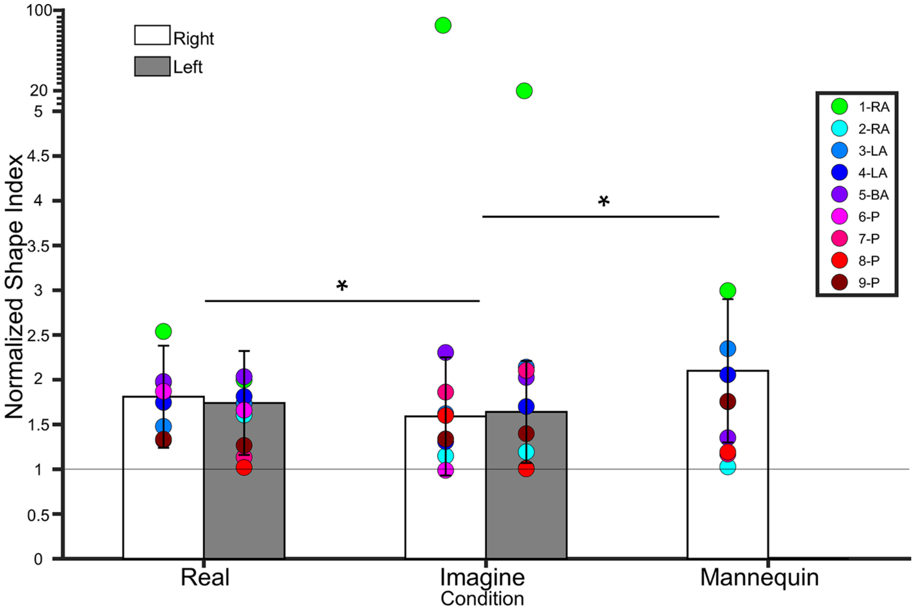

FIGURE 5 | Bar graph showing lower leg normalized shape indices (NSI). The white bars represent NSIs for the right shin in controls. The grey bars represent NSIs for the left shin in controls. Error bars represent standard deviation. The grey horizontal bar at y = 1 denotes veridical shape perception of the lower leg. Individual colored point represents lower leg NSIs for each BIID participant. RA, right amputation; LA, left amputation; BA, bilateral amputation; P, paralysis in the legend. The preceding numbers denotes participant number. Note that some estimations were so similar in BIID participants that their points overlapped. *$p < 0.05$ and denotes that, for control participants, NSIs in the Real condition were significantly higher than NSIs in the Imagine condition, and NSIs in the Mannequin condition were significantly higher than NSIS in the Imagine condition (regardless of leg). Note: miniature y-ticks following NSI of 5 each correspond to a value of 5 in order to display extremely high NSIs from participant 1 (i.e. NSI Right leg Imagine = 86.9; NSI Left leg Imagine = 20.8).

confidence intervals, and effect sizes for BIID participants compared to controls.

DISCUSSION

In the current study we behaviorally investigated lower limb representations in individuals with and without Body Integrity Identity Disorder (BIID), a rare condition wherein individuals desire to be disabled (1). Most commonly, this involves the desire to amputate or paralyze one or more perfectly healthy limb(s) (4). In a series of behavioral tasks, participants with and without the desire to amputate or paralyze their legs were asked to make judgments about the size and shape of their legs when relying chiefly on vision, touch, or proprioception. We replicated previous findings in our control sample, such that healthy participants were overall accurate at making judgments about visual representations of their legs, but showed systematic distortions for estimating the metrics underlying the tactile and proprioceptive representations of the legs (27, for hands see: 33, 37, 60). We hypothesized that individuals with BIID over/underestimate the metric representations of their legs more than healthy controls, as their internal representation of their legs, at some level of multimodal integration, seems to be stunted/missing (but paradoxically, at the same time people with BIID feel "overcomplete"). Using a multiple single-case analysis, we found no global differences between BIID participants and controls on any of the leg perception tasks. This suggests that despite the mismatch between the (internal) felt image of the legs and the (external) actual physical presence of the legs, individuals with BIID exhibit normal (albeit also distorted) perceptions of their legs.

Visual perception of the lower limbs was tested by asking participants to make visually-guided judgments of the length/width of distorted images of their own legs onscreen. All participants were accurate in making judgments about the size and shape of legs. These findings are in line with others that have shown accurate performance in making explicit judgments about body size when visual feedback is available [(e.g. 33)]. These results also validate the non-delusional nature of BIID, such that these individuals *know* what their legs look like, they *know* that they are part of the body, and they *know* that the desire to structurally or functionally abolish them is bizarre, but nevertheless *feel* a longstanding wish to do so (28). This logic is borrowed from Romano et al. (28) who hypothesized (and subsequently found) that although people with amputation-variant BIID could judge the limb as part of oneself, they had a reduced skin conductance response to painful stimuli approaching the unwanted limb (reflecting its internal underrepresentation). Our results, at least partly, confirm their hypothesis insofar that people with BIID can distinguish between the judgment of and (on the contrary) the feeling of what constitutes the boundaries of their bodily selves. Our results might also suggest that BIID is not a (psychiatric) body image disorder, per se, like anorexia nervosa, bulimia nervosa, and body dysmorphic disorder show distortions in making conscious judgments about body size and shape (42, 61). Noteworthy though is that in these disorders, body size or appearance is the critical factor that drives the underlying desire to modify the body. People with BIID do not feel that their leg is too big or that there is something wrong with the appearance of it. However, they do report that they feel "overcomplete" in the current body. This overcomplete feeling is not reflected in the conscious visual perception of the legs, however. Our data demonstrates that BIID individuals have a normal visual percept of their legs, thereby suggesting that the wish to amputate or paralysis the limb is not due to a distorted visual body image. Noteworthy, however, is that we did not include a control body part (e.g. hand) for those who desired paralysis or bilateral amputation. Given that the data for both the affected and unaffected limbs of the unilateral-desire participants fell within range of controls, we have reason to believe that it would be similar for the unaffected body parts of others. Nevertheless, these results should be considered with caution and might best serve simply as a starting point for understanding visual body perception in BIID.

Tactile perception of the affected (and unaffected) parts of the body was tested by asking participants to make judgments about the distance between two simultaneously applied tactile points on the legs, and for some participants, the arms. In this task, judging the distance between these points not only relies on primary tactile input (i.e. contact with the skin), but the reference to and communication with a mental model of the leg itself (37, 62, 63). In the tactile estimation task, participants must first 1) detect the two stimuli, and 2) refer to an internal (higher-order) model of the body that houses the model of the limb and 3) shape the hands to reflect the perceived distance. One study showed that participants with amputation-variant BIID have reduced PMC activity to tactile stimuli on the affected, but not the unaffected, leg (20). Moreover, another study showed decreased SPL activity when tactile stimuli was applied to the legs (regardless if it was the affected or unaffected leg) in individuals with BIID compared to controls (10). These results suggest that there might be issues with integrating primary tactile input on the lower body into a coherent body representation in BIID. In line with this, Aoyama and colleagues (5) showed that individuals with amputation-variant BIID show exaggerated attention to tactile stimuli on the affected part – that is, for two vibro-tactile taps to be perceived as simultaneous on the legs, the vibration had to be applied to the unaffected part first. Again, these findings might speak to an altered higher-order tactile representation of the limb. So, how might this affect tactile distance estimates on the affected body part? Previous studies have used the tactile estimation task to test this higher-order tactile representation in individuals with a disrupted or unhealthy bodily experience (39, 40, 64). Individuals with Anorexia Nervosa, for example, overestimate distances between two unseen tactile points on body, reflecting an internal oversized model of the body (39, 40). If the internal model of the leg in higher-order representations is missing in BIID, then distance estimates might rely on an earlier stage of processing touch, like in SI. In SI, cortical area devoted to the leg is much smaller than for more sensitive body parts, like the hand (65, 66).

These "homuncular" distortions are corrected for, to some extent, by a visual representation of the body (i.e. tactile-visual remapping), such that the size of the body part, if properly represented in a higher-level stage of processing [(presumably posterior parietal areas), should reduce the distortion (for review see 67)]. The leg is physically much larger, though less sensitive, than the hand, and so one would assume that these more "proportional" maps of the legs in the higher-order areas could counteract this. In BIID, we might expect that if distances are judged without this correction factor, they might be perceived as much smaller than we would see in controls. However, we found that tactile distance perception for BIID participants was within range of normal controls. As discussed above, visual representations of the body in BIID participants were unimpaired compared to controls, which might account for the null results here. Our findings regarding directional distortions (for the arm and shin) are also in line with previous reports – such that stimuli applied in the vertical direction are underestimated more than those applied in the horizontal direction (33, 53, 54, 68). This mimics the underlying geometry of the, presumably oval-shaped, tactile receptive fields on the hairy skin (68–70). Therefore, these findings also reiterate that the impairment in BIID is not at the primary somatosensory level [in line with previous studies, (5)], as all participants were able to detect the tactile stimuli on the body.

In fact, our findings regarding somatosensory-related aspects of body representation complement the existing literature on BIID. Other studies have already shown that BIID is not likely caused by an underlying deficit related to the somatosensory representation. For example, symptoms of BIID are not diminished after caloric vestibular stimulation (CVS). CVS is a technique where cold water is irrigated through the ear canal in an attempt to modulate [higher-order somatosensory) representations of the body, e.g. (71–73)]. CVS has proven useful in correcting other aberrant experiences of the bodily self, such as in somatoparaphrenia [e.g. (74)], where a body part is experienced as foreign following stroke in the right hemisphere (75). Furthermore, people with BIID show exaggerated physiological responses to painful stimuli contacting the unwanted limb (9, 28), and they have a more vivid rubber foot illusion for the unwanted foot (8). In other words: stimulating the vestibular system does not change the symptoms, touch is still processed (albeit in a more exaggerated way) on the affected limb, and they can still temporarily experience a rubber foot as their own via multisensory (visuo-tactile) integration. While these somatosensory-related representations may be altered at a behavioral (5, 8) and a neural (10, 20) level, they do not seem to be deficient. Our data further exemplifies this.

Body representations underlying proprioceptive input and imagery were tested by asking participants to localize unseen landmarks on their legs. As the lower part of the legs (i.e. knee to shin) were affected in all BIID participants, we compared the perceived shape of this part in BIID participants to controls. Control participants judged the shins to be shorter than they are in reality, consistent with our previous report (33), and also consistent with judgments of tactile distance on this part of the body. We expected BIID participants to exhibit an even shorter/squatter perception, as this part of the body seems to be "missing" in the internal image of the self in BIID. We found no differences between BIID participants and controls on this task. However, in this case, participants could rely on sensory feedback (proprioceptive input) to judge the location of these points on the leg. Sensory feedback is overall normal in individuals with BIID, therefore it is plausible that this information compensates and/or overrides the internal disturbed model of the legs to facilitate judgments about the locations, similar to what we might have observed in tactile distance estimates. Thus, we also included a condition where participants were asked to imagine their legs outstretched under the display screen and to judge where these landmarks would be (33, 55). Therefore, instead of integrating proprioceptive input with a stored model of the body, one must therefore use proprioceptive imagery to localize these landmarks. In such a case, participants have to rely on an imagined model of the limb (55). Localizing landmarks on the imagined leg yielded similar distortions in BIID participants as controls (and also similar to the Real condition, when the leg was under the screen). In line with this, we recently showed that individuals with BIID perform similarly to intact controls and lower-limb amputees during mental rotation of feet (Stone et al. (76), *preprint*), a task which involves mentally rotating your limb to match the posture of the pictured limb in order to make a judgment. Therefore, the findings of the current study support a preserved ability to imagine the lower limbs in a different posture than the current one in individuals with BIID. One participant (2-RA, right leg amputation desire) did elicit extremely high NSI scores on the Imagine condition for both legs. Inspection of the data revealed that this was a product of localizing the knee and ankle in (nearly) the same location, almost as though the shape mimicked that of an amputated/underdeveloped lower leg. However, as we did not see this in all of the BIID participants, and it was not specific to his (right) to-be-removed leg, we do not suspect that this was reflective of BIID, per se. Noteworthy is that this participant had PDD-NOS, a form of Autism Spectrum Disorder (77) in addition to BIID, which might have influenced imagery of one's own body position (78–80). It is also possible, unfortunately, that the participant simply misunderstood the Imagine condition instructions. Finally, participants were also asked to localize landmarks on an unseen corporeal object (mannequin leg). Judgments about the fake leg did not differ between BIID participants and controls. Thus, while individuals with BIID might report having an incongruent physical and mental body representation, it does not seem to interact with the implicit perception of the configuration of the leg, whether it be their own legs, or a foreign leg.

It is worth noting that the overall perceived configurations of the lower legs in all conditions were indeed distorted, insofar that distances between estimated landmarks in the length direction, compared to the actual distance between the landmarks, were underestimated more than the (average of) those in the width direction (made evident by the NSIs > 1, representing a leg that is wider than it is long). This replicates our previous study (33) and is also in line with how individuals perceive the internal configuration of their hands (29, 34, 51, 67, 81–84). Our current findings therefore suggest that leg representations in BIID, albeit distorted with respect to their physical size, are overall "normal" in this population. This could be informative for clinicians, insofar that tests of leg perception in BIID should yield normal results. If not, then another factor might be at play in the wish to amputate or paralyze the limb.

The tasks employed in the current study were mainly perceptual in nature. Specifically, they involved making judgments about the properties of the body, providing us with a description of the leg representation. There is an ongoing discussion regarding the dissociation between types of body representations (37, 85–89). Longo (36, 38) has proposed that there are not necessarily clear distinctions between body representations, but rather that they exist along a continuum, with implicit (e.g. distorted body model underlying tactile/proprioceptive information) and explicit (visually-based veridical) ones on opposite ends of the continuum. It is thus the "different weightings" of these models of the body that underlie body representations on the continuum [page 386, (36)]. People with BIID desire non-action (and consequently no somatosensory/proprioceptive feedback) of the affected part, either by completing removing the limb or paralyzing it. It could be that body representations that tap more into the function of the limb (perhaps somewhere in the middle of Longo's proposed continuum), rather than the perception, would better capture the breakdown (if there is one) of body representation underlying BIID.

These action- and perception-related aspects of body representations might be better considered under the (somatosensory) dorsal-ventral stream model proposed by Dijkerman and de Haan (85). They suggested that somatosensory processes have functional and anatomical "what/ventral" and "how/dorsal" pathways (similar to that in vision). That is, the dorsal pathway processes aspects of the body representation for the guidance of action, while the ventral pathway is related to perception and memory about the body. Our tasks involved making spatial localization/metric perceptual judgments about the body (e.g. localization and tactile estimation tasks) using responses (e.g. index finger-thumb separation) that were similar to those used to assess ventral stream functions in the visual domain (90). In this way, results were probably reflecting the (perceptual) ventral representation. Tasks that tap chiefly into dorsal stream functions, whether it be underlying somatosensory (85) or visual (91) input about the limbs might be more informative in BIID. For example, tasks involving motor control of the legs, such as locomotion (92, 93), obstacle avoidance (94), object interaction (e.g. football), proprioceptive matching (95), postural manipulations, or kinematics of goal-directed "reach-to-touch" movements (i.e. because the lower limbs do not "grasp"). However, since many people with BIID spend a lot of time pretending to be in the body they desire [i.e. by binding up the leg to simulate an amputation, or using a wheelchair (1, 6, 96)], they use their leg(s) much less, which might in and of itself affect outcomes on body representation tasks related to body action [e.g. (97, 98)]. Also noteworthy is that immobilizing the limb affects plasticity of sensorimotor brain areas (99), so it is possible that some of the body representation network disturbances revealed in neuroimaging studies of BIID participants could be partly due to long-term pretending behaviors (11), i.e. a product of behavior rather than a cause of BIID. Therefore, future studies should explore action-related leg representations in BIID, while carefully considering pretending behaviors too.

Finally, this is the first study, to our knowledge, that has tested amputation- and paralysis-variant BIID participants involving behavioral measurements. All of the behavioral studies on BIID, to date, have been in those who desire amputation (5, 7, 8, 100). A few questionnaire-based investigations of BIID have included paralysis-variant participants (4, 6, 101) and only one neuroimaging study included paralysis-variant participants (n = 2) in addition to amputation-desire participants (n = 6; 12). The questionnaire data suggested that the only major difference, besides the desired body type, between amputation- and paralysis-variant BIID individuals seems to be a higher prevalence of women who desire paralysis versus amputation. One of our paralysis-variant participants was indeed female, but we had another who was biologically male but desired to be female in addition to desiring paraplegia. The parallels between Gender Dysphoria and BIID have been discussed elsewhere (14, 96). Whether the desire to paralyze the legs is intertwined with the desire to modify the gender could probably only be confirmed after surgical intervention addressing one of the two conditions. Neuroimaging data including paralysis-variant BIID participants showed structural alterations in the premotor cortex and posterior cerebellum, compared to controls, but the data could not be analyzed separately for each variant of BIID because there were only 2 paralysis-variant participants included. While we also could not conduct a group-level analysis comparing the two variants (due to sample size limitations), our single-case analysis did not suggest that the paralysis- and amputation-variants differed in task performance. Specifically, our findings suggest that the amputation- and paralysis-variants are similar in their perception of the affected parts of their body, so if a dissociation between the two variants exists, it does not lie in how one perceives the size/shape of the legs. However, larger-scale studies comparing (and correlating task performance with) the two variants might provide a more thorough understanding of the mechanisms that underlie BIID.

In conclusion, body perception is a combination of central, presumably stable, representations of the body and peripheral input, which are more transient in nature (102). These results suggest that the peripheral input, seemingly superfluous for people with BIID, preserves perceptions of the body that are like the general population. Our data cannot confirm or deny the presence of an atrophic representation of the affected body part (s) in BIID but does suggest that lower limb perception is not disturbed in this population. The finding that the perception of the leg size/shape is normal might align with the fact that the limb itself is healthy and functions normally. Thus while people with BIID feel that part of the body is foreign, they can still make normal sensory-guided implicit and explicit judgments about the limb, two components of the bodily experience that may be dissociable in nature [e.g. (103)].

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of 'name of guidelines, name of committee' with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol (number: FETC 17-004) was approved by Utrecht University's local ethics committee.

AUTHOR CONTRIBUTIONS

KS contributed to experimental design, data collection, data analysis, and writing/editing of manuscript. KS wrote the manuscript with input from all authors. CK and ME assisted with data collection and editing of manuscript. RB assisted with participant recruitment, provided feedback on the experimental design, and edited the manuscript. AK and HD contributed to experimental design, writing, and editing the manuscript. AK and HD also supervised the project. All authors read and approved of the final manuscript.

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SUPPLEMENTARY MATERIALS

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2020.00015/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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APPENDIX 1

BIID Screening – Criteria

Must meet the following criteria (1):

A) An intense and persistent desire to become physically disabled in a significant way (e.g., major limb amputee, paraplegic, blind), with onset by early adolescence
B) Persistent discomfort or intense feelings of inappropriateness concerning current nondisabled body configuration
C)The desire to become physically disabled results in harmful consequences, as manifested by either (or both) of the following:

1. The preoccupation with the desire (including time spent pretending to be disabled) significantly interferes with productivity, with leisure activities, or with social functioning (e.g., person is unwilling to have a close relationship because it would make it difficult to pretend)
2. Attempts to actually become disabled have resulted in the person putting his or her health or life in significant jeopardy

D)The desire to become disabled is not primarily motivated by sexual arousal or by any perceived advantages of becoming disabled
E)The disturbance is not a manifestation of a psychotic process (e.g., desire to amputate a limb because of delusional conviction that the limb belongs to another person), is not due to a primary neurological condition such as post stroke neglect syndrome and is not better accounted for by another mental disorder such as Body Dysmorphic Disorder or Factitious Disorder

Subtype based on predominant desired disability

Amputation type

Paraplegia type

Other type

Unspecified type

Other:

- Normal tactile sensitivity (e.g. no excessive scarring on affected body part(s) which might influence tactile sensitivity)
- No body image disorder (i.e. no eating disorders or BDD)

Further questions:

1. At what age did your BIID start?
2. Can you describe your BIID?
3. What is the primary reason you want to change your body?
4. Does your BIID interfere with your everyday life? If so, can you describe in what ways?
5. Have you ever visited a psychiatrist?
6. Have you been diagnosed with a psychiatric or somatic disorder?
7. Are you currently using any medications?
8. Do you currently use drugs or alcohol?
9. Have you ever had a head injury? If so, can you describe when and how it happened?
10. Do you have any scars on the affected body part(s)? If so, can you describe their locations exactly?
11. Do you have trouble detecting touch sensations on any part (s) of your body? If so, where exactly?
12. Do you have normal vision? If not, has your vision been corrected with lenses, glasses, surgery, etc.?

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SYSTEMATIC REVIEW
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Influence of Physical Activity Interventions on Body Representation: A Systematic Review

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Distorted representation of one's own body is a diagnostic criterion and corepsychopathology of disorders such as anorexia nervosa and body dysmorphic disorder. Previousliterature has raised the possibility of utilising physical activity intervention (PI) as atreatment option for individuals suffering from poor body satisfaction, which is traditionallyregarded as a systematic distortion in "body image." In this systematic review,conducted according to the PRISMA statement, the evidence on effectiveness of PI on body representation outcomes is synthesised. We provide an update of 34 longitudinal studies evaluating the effectiveness of different types of PIs on body representation. No systematic risk of bias within or across studies were identified. The reviewed studies show that the implementation of structured PIs may be efficacious in increasing individuals' satisfaction of their own body, and thus improving their subjective body image related assessments. However, there is no clear evidence regarding an additional or interactive effect of PI when implemented in conjunction with established treatments for clinical populations. We argue for theoretically sound, mechanism-oriented, multimethod approaches to future investigations on body image disturbance. Specifically, we highlight the need to consider expanding the theoretical framework for the investigation of body representation disturbances to include further body representations besides body image.

Keywords: body image, body representation, physical activity, eating disorders, body dysmorphic disorders

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INTRODUCTION

Disturbances in body representation have been identified as the crux of many debilitating psychiatric disorders, such as body dysmorphic disorder (1), body integrity identity disorder (2), somatoparaphrenia (3), and asomatognosia (4). It has also been proposed as a core psychopathology of eating disorders [e.g., (4–9)]—especially in anorexia and bulimia nervosa. Heightened body dissatisfaction has been interpreted as a predisposition indicator in subclinical populations.

Individuals with body image concerns are reportedly more vulnerable to developing eating and dieting pathologies (10–13). As yet, however, mechanisms of change in body representation are still poorly understood, limiting mechanism-oriented interventions for prevention and treatment of disturbed body representation.

Previous literature has suggested that regular physical activity has beneficial effects on thephysical health of the body, as well as a significant impact on the level of satisfaction with whichthe body is perceived [e.g., (14–16)]. This is surprising, insofar as cross-sectional studies in individuals withhigh levels of physical activity suggest decreased rather than increased body satisfaction (17). However, it is important to note that there has been little critical appraisal of the existing studies. Previous systematic reviews and meta-analyses on the topic of physical activity and its potential interactions with body satisfaction have been conducted from an outcome-centric perspective [e.g., (14, 15, 18–20)]—focusing on evaluating the effectiveness of physical activity as an intervention for the improvement of individuals' body satisfaction—with an emphasis on the affective and cognitive aspects (i.e., body image). Nevertheless, the question of which potential mechanisms might be responsible for the apparent shift in body image after the introduction of physical activity has not been inadequately addressed.

Despite the lack of a unified consensus on its exact nature, the term body image has been widelyused in research across psychology, neuroscience, and psychiatry. Body image can roughly becharacterised as the conscious, predominantly visual, mental representation of one's own body,which in turn provides a basis upon which perceptual, cognitive, and affective attitudes toward thebody are assigned (21, 22). However, it is important to note that the current literature largely concurson the use of the term body image as a measure of body satisfaction—in that body image as anoutcome measure is interpreted as the degree with which individuals are satisfied with various aspects of themselves that is influenced by the visual aspect of their body (e.g., appraisal of body shape information). In this review, we therefore adopt the term body representation when referring to the broad range of mental representations of one's own body, whereas body image only refers to cognitive-affective appraisal of the body. The fact that body image investigations in health research has so far been conducted from an almost exclusively perceptual-affective perspective is worth discussing.

Longo (23) argued that higher level representations of thebody are unlikely to emerge from abstract cognition alone. Rather, they are constructed through theinterplay of multiple distinct body representations. Not only do individuals have immediateknowledge of their body from within (i.e., bodily awareness through interoception), they are alsoable to objectively reflect on their own body from an external perspective, in the same way thatexternal objects are cognitively assessed (with regards to their shape, size, location, aesthetics, et cetera). Relying on neuroscientific evidence, Longo's framework of body perception consists of multiple distinct body representations that are informed by different sensory modalities and can be arranged along two orthogonal axes: explicit vs. implicit & perceptual vs. conceptual. However, most empirical data concerning body image has been based on self-report or visual body size judgments, which effectively leads to the underrepresentation of other somatically driven/sensory inputs when considering the potential mechanism underlying the concept of body image (24). Although these subcomponents of body representation have been demonstrated to have distinct underpinning neural networks [see (25) for review], the mechanisms responsible for the development and regulation of these subcomponents are still very much unexplored (e.g., the idea that body satisfaction, or the lack thereof, could be socially and/or somatically driven—or the product of their interactions). As such, it is not at all clear why the body image should remain the sole focal point when investigating how individuals mentally represent their own body, and the potential distortions therein.

In this systematic review, we aim to synthesise existing literature investigating longitudinal interaction between physical activity and body image. Our purpose is to synthesise the empirical evidence from previous studies with a focus on effects, broader potential, and eventual impact mechanisms of PI on body representation. Specifically, our research questions were:

i. Are there systematic effects of PI on body representation?
ii. Are previous studies informative with regard to prevention or treatment of sub-clinical or clinically relevant body image disturbance?
iii. Are there specific mechanisms of how long-term engagement in structured PI that influence thedynamics of individuals' body representations?

METHOD

The systematic review process was conducted according to the PRISMA statement (26). Methods of analysis and inclusion criteria were specified in advance and documented in a protocol.

Literature Search

Studies were identified *via* searching the following electronic databases: PubMed, Web of Science and SPORTDiscus. The search was weekly updated until January 2020.

The specific search terms are as follows: ("body image" OR "body representation" OR "body dissatisfaction" OR "body satisfaction" OR "body image disturbance") AND ("physical activity" OR "physical exercise" OR "exercise intervention" OR "endurance training" OR "exercise training" OR "exercise intervention" OR "aerobic exercise" OR "aerobic training" OR "anaerobic exercise" OR "anaerobic training" OR "motor activity" OR "resistance training" OR "resistance exercise" OR "strength training" OR "weight training" OR "weightlifting" OR "cardio training" OR "cardio" OR "athletic sports" OR "exercise program" OR "fitness training" OR "cardiovascular training" OR "interval training" OR "intermittent training" OR "interval exercise" OR "intermittent exercise" OR "sprint training" OR "sprint exercise" OR "high intensity interval training" OR "high intensity interval exercise" OR "moderate intensity training" OR "moderate intensity exercise" OR "exercise/psychology" OR "exercise therapy/methods" OR "resistance training/methods").

Additionally, reference lists of included articles were hand searched.

Eligibility Criteria and Study Selection

Each step of the eligibility assessment was performed independently by two reviewers according to the PICOS criteria (27). Only articles in English were considered.

Studies had to fulfil the following criteria:

Population: a sample of adult participants,

Intervention: include a longitudinal physical activity intervention (PI; no lifestyle counselling; specific targeting of body image/body representation not compulsory),

Comparison/Control: include a validated measure of body image/body representation, a control group was not required,

Outcome: at least one pre & post measurement of a validated self-report or experimental body image/body representation measure, and

Study Type: published as a peer-reviewed original article.

Exclusion criteria were as follows:

i. samples younger than 18 years old, and
ii. no inference statistics performed.

The first author (DS) applied the search terms to three databases, extracted the search results and removed duplicates. DS and LW screened titles to identify relevant records. Abstracts and full texts of the identified records were subsequently screened by DS and SB. All studies included in the qualitative synthesis were rated according to the eligibility criteria by DS and SB. Interrater reliability between DS and LW for title screening was good (κ = 0.61; 94.2% agreement). Articles were included in the full-text screening if one reviewer rated it as a potential match. Interrater reliability between DS and SB for the subsequent steps was very good (κ = 1.0 for abstract screening; κ = 0.94 for full-text screening). Disagreements between the reviewers were solved by discussion and, when in doubt, articles were included. DS extracted relevant data from the included studies (i.e., sample characteristics, PI types and dosage, measure of fitness level, measures of body composition, measures of body image/body representation, and results).

Risk of Bias in Individual Studies

To assess the risk of bias in individual studies, DS and SB conducted a quality rating. The Qualitative Assessment Tool for Quantitative Studies by the Effective Public Health Practice Project (28, 29) is recommended by the Cochrane Handbook for Systematic Reviews of Interventions to be used for assessing any quantitative study design (30) and was judged a suitable tool for systematic reviews of effectiveness (31). The tool consists of component ratings for the following categories: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Components were rated according to the accompanying dictionary. Studies received ratings of either "strong", "moderate", or "weak" for each category. A global rating was assigned at the end of the process *via* the summarisation of the number of categories rated as "weak". Disagreements between the reviewers were solved by discussion.

RESULTS

Study Selection

The searches yielded a total of 3,318 results. Duplicates were discarded (n = 602), leaving 2,716 records for title and abstract screening. During this process, 2,659 studies were discarded, and the remaining 57 studies were identified for full-text analysis. Subsequently, 34 studies were included in the systematic review. For the PRISMA flow chart, see **Figure 1**.

Study Quality

The overall study quality within the current review showed a slight majority for "weak" (55.88%; n = 19), followed by "moderate" (41.17%; n = 14). Only 1 study (2.94%) included in the review qualified for the global "strong" rating. The detailed components ratings are included in **Table 1**.

Notably, included studies only received weak (n = 26) and moderate (n = 8) ratings for the selection bias category. The main reason for depreciation was the recruitment in sports classes or from community samples; thus producing a selection bias favouring highly motivated, sports-oriented participants. In the same vein, most studies qualified for moderate rating in the study design category (n = 27). This is due to the lack of randomisation in the selection as well as group allocation process, as participants often conducted the PI of their choice. This limits explanatory power regarding general recommendations of effective types of training. To summarise, there is a possibility for risk of bias in the studies included in the current review.

Study Characteristics

The study characteristics of included studies are detailed in **Table 1**. All studies employed a longitudinal design, as defined by the inclusion criteria. Of the total 34, 6 studies were described as quasi-experimental. Twenty-three studies included control groups in their experimental design, while the remaining 11 did not. Within the 23 controlled studies, 18 studies included "no intervention" comparison groups, while the remaining 5 studies included participants who performed low to moderate exercise as controls. Eight studies included clinical and/or sub-clinical groups. The remaining 26 studies had healthy samples. Eleven studies aimed to compare different types of PIs and their impact on body image/body representation of participants. Most studies (n = 27) did not have a randomised participant selection and/or group allocation process.

Physical Activity Interventions

The most commonly investigated types of PI were weight/strength training (n = 14), as well as aerobics/cardiovascular training (n = 13). Three studies implemented the combination of

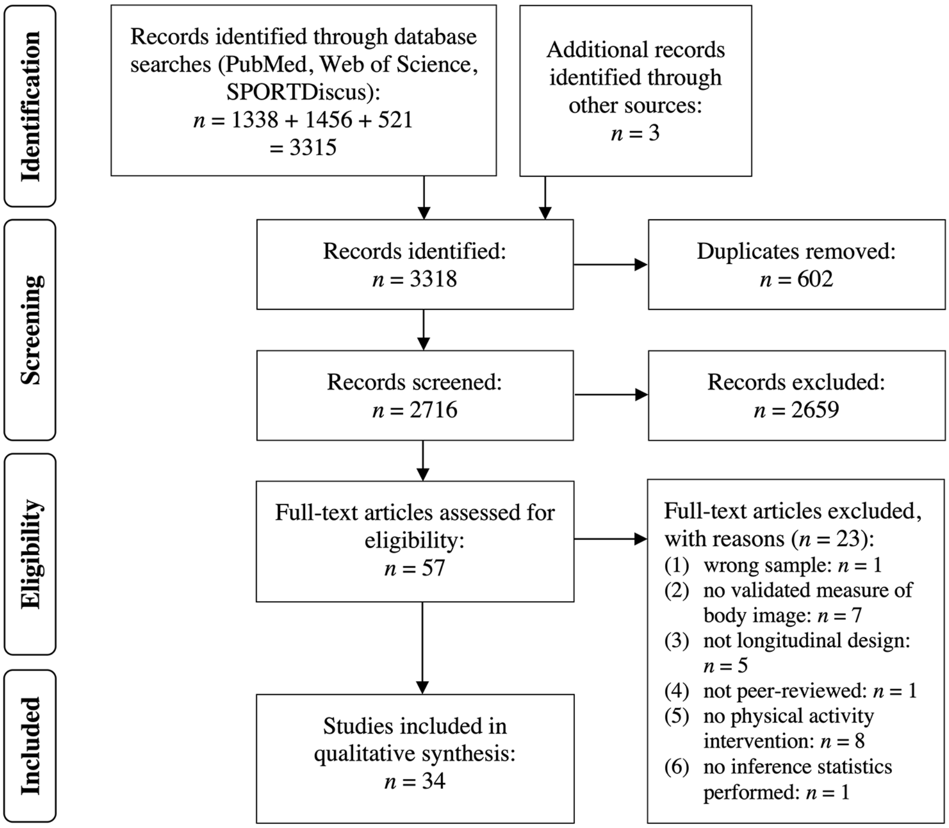

FIGURE 1 | PRISMA flowchart for study selection.

both types as a singular intervention. Dancing (n = 3) was also investigated. Other PIs included walking, running, swimming, cycling, pilates, hydrogymnastics, yoga, fascial fitness, and functional training. The mean length of time for the implementation of the PI was 13.29 (SD = 8.45) weeks, with the maximum of 52 weeks (1 year) and the minimum of 2 weeks. The median for PI duration was 12 weeks.

VO_2max was used as a measure of fitness in 9 studies. Eleven studies conducted strength tests as a marker of fitness level (i.e., variations of maximum repetition test). Heartrate was also measured as a marker of fitness level (n = 4). Twelve studies did not report any measure of physical fitness.

Outcome Measures

Studies were homogeneous in terms of the operationalisation of body image/body representation measures. Almost all studies exclusively implemented validated questionnaires assessing body image. Only 3 studies additionally implemented more visual-oriented measures (i.e., Stunkard Scale of Silhouette, Figure Rating Scale)—though nevertheless still affective/subjective in nature. No study used experimental assessments of body representation (e.g., depictive/metric body size and visual estimation tasks). As such, the domains of visual, tactile and affordance perception of body representation were not at all investigated.

The most commonly employed scales were MBSRQ (Multidimensional Body Self-Relations Questionnaire; (66) and PSPP (Physical Self-Perception Profile; (67) at 23.53% (n = 8) each. The Body Cathexis Scale was also frequently implemented in earlier studies (n = 7; 20.59%; (68).

Systematic Effects of PI on Body Representation

PI was considered effective if significant improvement in body representation measures was reported at post-test among the intervention group, relative to the control group. The overall results are as follows: 5 studies (14.71%) observed no significant improvement in both control and PI groups across all body image measures; 3 studies (8.82%) observed significant improvement in both control and PI groups across all body image measures; 10 studies (29.41%) reported significant improvement in PI group across all body image measures; 16 studies (47.06%) reported partial significance effect in PI groups (i.e., not all improvement in scores measured in the subscales of the implemented questionnaires reached significance).

However, due to the low number of clinical and sub-clinical studies (n = 8) included in this systematic review, we cannot reliably synthesise significant evidence with regard to utilising long-term PI (structured or otherwise) as a treatment measure for clinically relevant groups.

TABLE 1 | Overview on main characteristics and findings of included studies.

Study	**Sample characteristics**	***n***	**Physical activity intervention & dosage**	**Measure of fitness level**	**Measure of body composition**	**Measure of body image/ representation**	**Main findings**	**Quality rating:**				**Strong ○ Moderate ◍ Weak ●**		
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
Folkins (32) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 0% ※At high-risk of coronary heart disease	18	Unspecified 36x *n. r.* minutes over 12 weeks	VO_2max	N/A	BCS	**PI & Control Groups** • There were no significant changes in BCS scores post-test for both groups.	○	◍	◍	○	◍	○	○
	Controls: no intervention	18												
Tucker (33) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 0%	60	Weight training 32x 50 minutes over 16 weeks	N/A	N/A	TSCS	**PI Group** • Showed significant increase from pre to post PI on all TSCS indices except Social Self. • Scored significantly higher than control group in the Total Positive, Identity, Behaviour, Physical Self, and Personal Self indices of TSCS post PI. **Control Group** • There were no significant changes in TSCS scores post-test. ※PI and control groups did not differ significantly in Moral-Ethical Self, Self-Satisfaction, Family Self, or Social Self indices post-test.	◍	◍	◍	●	◍	○	○
	Controls: no intervention	45												

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:						Strong ○ Moderate ◍ Weak ●
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
Tucker (34) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 0%	142	Strength (weight) training 32x 50 minutes over 16 weeks	Strength test	N/A	BCS, TSCS	**PI Group** • Scored significantly higher than control group for both BCS and TSCS measures post PI.	●	◍	◍	●	◍	○	●
	Controls: no intervention	130					**Control Group** • There were no significant changes in BCS and TSCS scores post-test.							
Tucker (35) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 0%	114	Weight training 32x *n. r.* minutes over 16 weeks	1-RM strength test		BCS	**PI Group** • Scored significantly higher than control group for BCS post PI.	◍	◍	◍	◍	◍	○	●
	Controls: no intervention	127					**Control Group** • There were no significant changes in BCS scores post-test.							
Caruso and Gill (36) ◊	Study 1 M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 100%	13 15	Weight training Aerobic training 30x 50 minutes over 10 weeks	1-RM strength test, VO_2max	Body fat % (skinfold measures at 3 sites)	PSPP, PIP, BCS	**PI & Control Groups** • PSPP, PIP and BCS scores improved post-test (significance not calculated) but did not significantly differ between groups.	●	●	◍	●	◍	○	●
	Controls: physical education activity class	6												
	Study 2 M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 45.2%	42	Weight training 30x 50 minutes over 10 weeks	Max. repetition strength test	Body fat % (skinfold measures at 3 sites)	PSPP, PIP, BCS, BES, Stunkard Scale of Silhouette	**PI & Control Groups** • PSPP, PIP, BCS, BES scores and Body Size Drawings revealed no							

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating: Strong ○ Moderate ◐ Weak ●						
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
	Controls: non-fitness activity	23					significant changes post-test for both groups.							
Tucker and Maxwell (37) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 100% **Controls:** exercised 2.9 ± 2.2 days/week; no weight training	60 92	Weight training 30x 45 minutes over 15 weeks	1-RM strength test	Body fat % (skinfold measures at 3 sites)	BCS	**PI Group** • Scored significantly higher than control group for BCS post PI (after controlling for pre-test differences). • Showed significantly greater improvement than control group from pre-test to post-test on BCS scores. **Control Group** • Showed no significant improvement from pre-test to post-test on BCS scores.	●	◐	◐	●	◐	○	●
Tucker and Mortell (38) ◊	M_{age}: 42.5 ± 4.2 M_{BMI}: *n. r.* % Female: 100% **Controls:** none	30 30	Weight training Walking program 36x *n. r.* minutes over 12 weeks	Max. repetition & 1-RM strength test, 1 Mile Walk test	N/A	BCS	**PI Groups** • Both groups showed significant improvement in BCS scores post PI. • Weight-trainers scored significantly higher than walkers on BCS scores post PI.	●	●	◐	●	◐	○	○
McAuley et al. (39) ◊	M_{age}: 54.5 M_{BMI}: *n. r.* % Female: 50.6%	83	Aerobic training	VO$_2$max	Body fat % (skinfold measures at 3 sites)	PSPP, PIP	**PI Group** • Significant improvements were found in the	◐	●	◐	◐	◐	○	◐

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:						Strong ○ Moderate ◍ Weak ●
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
	Controls: none		60x 40 minutes over 20 weeks				following subscales of PSPP: Physical Self-Worth & perceptions of Physical Condition. • Attractive Body subscale of PSPP rating showed no significant effect post-test.							
McAuley et al. (40) ◊	M_{age}: 66.71 ± 5.35 M_{BMI}: *n. r.* % Female: 71.8% **Controls:** none	85 89	Aerobic training Toning exercise 72x 40 minutes over 24 weeks	VO$_2$max, heartrate	Body fat % (TOBEC)	PSPP	**PI Groups** • Latent growth curve analyses showed a curvilinear pattern of growth with significant increases at all levels of PSPP measure upon completion of PI. • Significant declines were shown at 6 months post PI in both groups.	◍	●	○	◍	◍	○	○
Williams and Cash (41) ◊	M_{age}: 21.7 ± 3.8 M_{BMI}: 23.9 ± 4.4 % Female: 69.2% **Controls:** no intervention	39 39	Weight training 1x 180 minutes over 6 weeks	1-RM strength test	N/A	MBSRQ, SPAS	**PI Group** • Showed significant improvement post PI in SPAS scores, as well as Appearance Evaluation and Body Area Satisfaction subscales of MBSRQ. **Control Group** • Reported no significant changes	●	●	◍	●	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating: Strong ○ Moderate ◍ Weak ●						
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
							on all measures post-test. ※After adjusting for pre-test score differences, significant group differences were found for Appearance Evaluation, Body Area Satisfaction and Social Physique Anxiety post-test.							
Aşçı (42) ◊	M_{age}: 22.15 ± 1.87 M_{BMI}: *n. r.* % Female: 52.9% **Controls:** no intervention	70 68	Step dance 30x 50 minutes over 10 weeks	N/A	N/A	PSPP	**PI & Control Groups** • PI group showed significantly greater improvement than control group from pre-test to post-test on all PSPP subscales except for Sport Competence.	●	●	○	●	◍	○	○
Aşçı (43) ◊	M_{age}: 21.35 ± 0.88 M_{BMI}: *n. r.* % Female: 100% **Controls:** no intervention	20 20	Aerobic training & step dance 30x 50 minutes over 10 weeks	N/A	N/A	PSDQ	**PI & Control Groups** • Participants in the PI group showed significant improvement in Physical Activity, Coordination, Sport Competence and Flexibility subscales of PSDQ as compared the control group post-test.	●	●	○	●	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:				Strong ○ Moderate ◍ Weak ●		
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
Depcik and Williams (44) ◊	M_{age}: 22.13 ± 5.51 M_{BMI}: *n. r.* % Female: 100% ※Pre-existing body image disturbance (109.0 mean group score on BSQ) **Controls:** exercised 2.23 ± 2.02 days/ week; no weight training	15 15	Resistance (weight) training 52x 50 minutes over 13 weeks	1-RM strength test	N/A	BCS, BSQ	**PI & Control Groups** • Mean BCS scores significantly increased for weight trainers as compared to control group post-test. • The groups differed significantly in body image disturbance (BSQ scores) post-test. Weight trainers experienced a greater reduction in body image disturbance than control group post-test.	●	●	◍	●	◍	○	○
Annesi (45) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 100% **Controls:** no intervention	48 30	Cardiovascular training 36x 30 minutes over 12 weeks	N/A	N/A	BES	**PI & Control Groups** • Scores on the Physical Condition subscale of BES significantly increased post-test for the exercise group, but not the control group. • Scores on the Sexual Attractiveness subscale of BES did not significantly change post-test for both groups.	◍	●	◍	◍	◍	○	○
Annesi and Westcott (46) ◊	M_{age}: 46.3 ± 13.4 M_{BMI}: *n. r.* % Female: 50.6%	35	Weight & cardiovascular training	Heartrate	N/A	PSPS	**PI Group** • PSPS scores significantly improved post PI.	●	●	◍	●	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:						Strong ○ Moderate ◍ Weak ●
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
	Controls: none		30x 60 minutes over 10 weeks											
Ginis et al. (47) ◊	M$_{age}$: 21.57 ± 2.47 M$_{BMI}$: *n. r.* % Female: 36.4% **Controls:** none	44	Strength (weight) training 60x *n. r.* minutes over 12 weeks	1-RM test	Body fat % (DXA)	SPAS, BASS, DMS	**PI Group** • Participants experienced significant increases in BASS and decreases in SPAS scores post PI. • Only male participants experienced a significant decrease in muscularity dissatisfaction (DMA score) post PI.	◍	◍	◍	●	◍	○	○
Hős (48) ◊	M$_{age}$: 48.9 ± 5.6 M$_{BMI}$: *n. r.* % Female: 100% **Controls:** no intervention	25 28	Aerobic dance 52x 60 minutes over 52 weeks	N/A	N/A	TSIT	**PI Group** • Showed significant increases post PI on Total Self-Image (all subscales of TSIT, except for Family Self-Image). **Control Group** • There were no significant changes post-test on Total Self-Image (all subscales of TSIT, except for Social Self-Image). ※There were significant differences between	●	●	◍	●	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating: Strong ○ Moderate ◍ Weak ●						
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
							both groups on all subscales of TSIT post-test, except for Social Self-Image.							
Henry et al. (49) ◊	M_{age}: 19.24 ± 1.43 M_{BMI}: 22.85 ± 3.39 % Female: 100% **Controls:** low to moderate exercise (3.24 days/week)	23 28 21	Aerobic training Interval cuircuit (weight) training 36x 50 minutes over 12 weeks	Step test (VO_2max), bench press test (muscular strength & endurance)	Body fat % (skinfold measure at 3 sites)	BSIQ	**PI & Control Groups** • Interval circuit training group improved significantly post PI in overall Appearance Evaluation and Health/Fitness Evaluation & Influence, as well as significantly reduced Negative Affect subscales of the BSIQ as compared to control group.	●	●	◍	●	◍	○	○
Opdenacker et al. (50) ◊	M_{age}: 66.65 ± 4.16 M_{BMI}: 27.08 ± 19.11 % Female: *n. r.* **Controls:** no intervention	46 49 46	Lifestyle PI Structured exercise 33x 60-90 minutes over 11 weeks	VO_2max	N/A	PSPP	**PI & Control Groups** • Immediately after PI, the lifestyle group showed significant improvements in Self-Perceived Physical Condition, Body Attractiveness, and Physical Self-Worth subscales of PSPP. In the structured group, significant effects were found on only on Physical Condition. • One year after PI, the lifestyle group had significant	◍	●	◍	◍	◍	○	◍

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:				Strong ○ Moderate ◍ Weak ●		
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
							effects on Body Attractiveness while the structured group showed significant improvements in Physical Condition and Body Attractiveness. ※There were no significant differences between PI groups for both short and long-term results.							
Özdemir et al. (51) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 0% **Controls:** no intervention	11 11 11 12	Swimming Cycling Running 36x 40 minutes over 12 weeks	VO_2max	Body fat % (DEXA), muscular strength (isokinetic dynamometer),	PSPP	**PI & Control Groups** • All groups revealed no statistical improvement in PSPP scores post-test.	◍	◍	○	●	◍	○	○
Cruz-Ferreira et al. (52) ◊	M_{age}: 41.08 ± 6.64 M_{BMI}: *n. r.* % Female: 100% **Controls:** no intervention	38 24	Pilates 48x 60 minutes over 24 weeks	N/A	N/A	PSCS	**PI Group** • Showed significant improvement between baseline and 6 months post PI in Perception of Physical Appearance, Functionality and Total Physical Self-Concept. **Control Group** • No significant differences were observed over time.	◍	●	○	◍	○	○	◍

(Continued)

TABLE 1 | Continued

Study	**Sample characteristics**	***n***	**Physical activity intervention & dosage**	**Measure of fitness level**	**Measure of body composition**	**Measure of body image/ representation**	**Main findings**	**Quality rating:**						**Strong ○ Moderate ◍ Weak ●**
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
							※No significant differences in PSCS scores were observed between groups at all time points.							
Moore et al. (53) ◊	M_{age}: 20.2 ± 2.02 M_{BMI}: *n. r.* % Female: 30.8% **Controls:** none	120	Resistance (weight) training 24x *n. r.* minutes over 12 weeks	1-RM strength test	N/A	PSPS, PSAQ	**PI Group** • Significant improvements were observed across all measures post PI.	●	●	◍	●	◍	○	○
Van Puymbroeck et al. (54) ◊	M_{age}: 58.67 ± 9.82 M_{BMI}: *n. r.* % Female: 100% ※≥9 months post breast cancer treatment **Controls:** light exercise	18 12	Hatha yoga 16x 75 minutes over 8 weeks	Tests for flexibility, strength, abdominal muscular endurance, agility & dynamic balance	N/A	Body Image Scale for use with cancer patients	**PI & Control Groups** • PI group reported significantly more positive body image as compared to control group at pre and post-test. • There were no statistical differences for the changes in body image scores over time for both groups.	●	●	◍	●	◍	○	◍
Appleton (55) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 52.9% **Controls:** within-subjects,	34 34	Cardiovascular training 12x 40 minutes over 2 weeks	N/A	Body weight, waist & hip circumferences	MBSRQ	**PI Group** • There were significant increases in the following subscales of MBSRQ: Appearance Evaluation, Fitness	◍	●	◍	◍	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:						Strong ○ Moderate ◍ Weak ●
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
	no intervention (12x 40 minutes reading over 2 weeks)						Evaluation, Fitness Orientation, Health Evaluation, Illness Orientation and Body Areas Satisfaction; Self-Classified Weight significantly decreased post PI. **Control Group** • Appearance Evaluation and Body Areas Satisfaction subscales of MBSRQ significantly decreased during no PI condition. ※Appearance Orientation, Health Orientation and Overweight Preoccupation subscales of MBSRQ were unaffected by PI.							
Hatipoglu et al. (56) ♦	M$_{age}$: 45.63 ± 8.12 M$_{BMI}$: 33.2 % Female: 18.2% ※Acromegaly patients **Controls:** no intervention	11 9	Cardiovascular, strength, balance & stretching training 36x 75 minutes over 12 weeks	N/A	BMI	MBSRQ	**PI Group** • Significant improvement in MBSRQ scores was observed post PI. **Control Group** • No significant changes in MBSRQ scores were reported post-test.	●	●	◍	◍	◍	○	●

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating: Strong ○ Moderate ◍ Weak ●						
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
Pearson and Hall (57) ♦	M_{age}: 33.4 ± 7.6 M_{BMI}: 29.02 ± 4.71 % Female: 100% ※Obesity patients (BMI >25 kg/m^2) **Controls:** none	37	Cardiovascular training 54x 45 minutes over 18 weeks	VO$_2$max	Waist circumference, body weight & fat % (DXA)	MBSRQ	**PI Group** • Significant improvements occurred between baseline and week 6 as well as week 18 post PI for Appearance Evaluation, Fitness Orientation and Body Areas Satisfaction subscales of MBSRQ.	●	◍	◍	●	◍	○	●
Seguin et al. (58) ◊	M_{age}: 62 ± 12 M_{BMI}: *n. r.* % Female: 100% **Controls:** none	341	Strength (weight) training 20x 60 minutes over 10 weeks	N/A	N/A	MBSRQ	**PI Group** • Significant improvement occurred post PI for Health Orientation, Subjective Weight, Fitness Orientation, Fitness Evaluation, and Health Evaluation subscales of MBSRQ. • There were no significant changes in Weight Preoccupation subscale of MBSRQ post PI.	◍	●	◍	○	◍	○	◍
Zarshenas et al. (59) ◈	M_{age}: 26 ± 6.9 M_{BMI}: *n. r.* % Female: 100% ※Pre-exisiting self-reported mild to severe depressive symptoms (BDI-II score of ≥14)	41	Aerobic training *n. r.*x 65 minutes over 4 weeks	Heartrate	N/A	MBSRQ	**PI Group** • MBSRQ scores across all subscales significantly improved post PI. • Significant improvement was found in Appearance Evaluation,	●	●	◍	◍	◍	○	●

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:				Strong ○ Moderate ◐ Weak ●		
								Global rating	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection methods**	**Withdrawal and dropouts**
	Controls: no intervention	41					Appearance Orientation, Health Orientation, and Illness Orientation subscales of MBSRQ post PI as compared to control group. **Control Group** • There were no significant changes in MBSRQ scores post-test.							
Ginis et al. (60) ◊	M_{age}: 21.5 ± 2.93 M_{BMI}: 22.96 ± 3.89 % Female: 100% ⋇Pre-existing body image concerns (≥27 score on SPAS & ≤3 on BASS) **Controls:** none	17 23	Aerobic training Strength training 24x 45 minutes over 8 weeks	VO_2max, 10-RM strength test	BMI, waist-hip ratio	SPAS, AE, BASS, PSDQ	**PI Groups** • Both PI groups revealed significant improvements across all measures post PI. • Aerobic training group yielded significantly greater improvements in SPAS as compared to strength training group post PI.	◐	●	◐	◐	◐	○	○
Mendonça et al. (61) ◊	M_{age}: *n. r.* M_{BMI}: *n. r.* % Female: 100% **Controls:** no intervention	25 28 21 25	Strength (weight) training Dance Hydrogymnastics 48x 60 minutes over 16 weeks	8-RM strength test, heart rate	N/A	SPA, Stunkard Scale of Silhouette	**PI and Control Groups** • Significant improvements in SPA scores were found regardless of the program, with the greatest effect shown by the strength training group post PI. • No significant differences were found for body image	●	●	○	●	◐	○	●

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating: Strong ○ Moderate ◍ Weak ●						
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
							perception and bodily dissatisfaction post PI. • All PI groups showed significant improvements across all measures when as compared to control group post-test.							
Vurgun (62) ◊	M_{age}: 40.5 ± 12.1 M_{BMI}: *n. r.* % Female: 100% **Controls:** no intervention	12 20	Aerobic training 42x 60 minutes over 14 weeks	Heartrate	BMI, waist-hip ratio, body density and fat ratio (skinfold measured at 9 sites)	BISQ	**PI and Control Groups** • BISQ scores were significantly improved post PI as compared to control group.	◍	●	◍	◍	◍	○	○
Baur et al. (63) ◊	M_{age}: 37.9 ± 9.2 M_{BMI}: *n. r.* % Female: 52.8% ※Suffers from non-specific back pain **Controls:** none	17	Fascial* fitness 3x 60 minutes over 3 weeks	N/A	N/A	FKB-20	**PI groups** • Fascial fitness group showed significant improvement only for negative body image post PI.	●	●	◍	●	◍	○	○
Megakli et al. (64) ♦	M_{age}: 32.70 ± 7.26 M_{BMI}: 35.84 ± 4.59 % Female: 100% ※ Obesity patients (BMI >30 kg/m^2) **Controls:** no intervention	18 19	Aerobic & resistance training 36x 30 minutes over 12 weeks	N/A	Waist & hip circumferences	PSPP	**PI and Control Groups** • PI group showed significant increases post PI for all PSPP subscale scores except for Perceived Body Attractiveness as compared to control group.	◍	●	○	○	◍	○	○

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	*n*	Physical activity intervention & dosage	Measure of fitness level	Measure of body composition	Measure of body image/ representation	Main findings	Quality rating:				Strong ○ Moderate ◍ Weak ●		
								Global rating	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawal and dropouts
Aukštuolytė et al. (65) ◊	M$_{age}$: 35.58 M$_{BMI}$: *n. r.* % Female: 100%	15	Functional training	N/A	Body fat % (skinfold measure at 4 sites)	BSQ, Figure Rating Scale	**PI Groups** • Body shape dissatisfaction was significantly reduced for functional training group after PI, but not for Zumba group.	●	●	◍	●	◍	○	●
		16	Zumba 16x 60 minutes over 8 weeks											
	Controls: none													

Symbols: *[♦] Clinical sample; [⬖] Sub-clinical sample; [◊] Non-clinical sample.*

Abbreviations: *Not Applicable (N/A); Not Reported (n.r.); Physical Activity Intervention (PI).*

Abbreviated Measures: *Appearance Evaluation (AE) sub-scale of MBSRQ; Beck's Depression Inventory-second edition (BDI-II); Body Areas Satisfaction (BASS) sub-scale of MBSRQ; Body Cathexis Scale (BCS); Body Esteem Scale (BES); Body Image Satisfaction Questionnaire (BISQ); Body Self-Image Questionnaire (BSIQ); Body Shape Questionnaire (BSQ); Drive for Muscularity Scale (DMS); Fragebogen zum Körperbild (FBK-20 aka. Body Image Questionnaire (BIQ)); Multidimensional Body Self-Relations Questionnaire (MBSRQ); Perceived Importance Profile (PIP); Physical Self-Attribute Questionnaire (PSAQ); Physical Self-Concept Scale (PSCS) subscale of the TSCS; Physical Self-Description Questionnaire (PSDQ); Physical Self; Perception Profile (PSPP); Physical Self-Perception Scale (PSPS) subscale of the TSCS; Satisfaction with Physical Appearance Scale (SPA); Social Physique Anxiety Scale (SPAS); Tennessee Self Concept Scale (TSCS); Tennessee Self Image Test (TSIT).*

**The Structural Integration group from (63) is not taken into consideration, as structural integration is not considered as a physical activity intervention, rather a form of physical therapy.*

Mechanisms Underpinning the Interplay Between PI and Body Representation

All studies included neither explicitly addressed/proposed a form of a mechanistic interplay between PI and body representation, nor provided evidence to support one. As such, the question of which potential mechanisms might be responsible for the apparent shift in body representation after the introduction of physical activity remain inadequately addressed.

DISCUSSION

In this systematic review, we synthesised the empirical findings from longitudinal intervention studies on effects of structured PI on body representation. Overall, the studies suggest that the implementation of structured PI is associated with improved body image. Effects on other body representations were not investigated. To our knowledge, this review is the first to demonstrate such an effect in longitudinal settings. The effectiveness of these interventions seems promising for future research and possible development of prevention interventions. However, we argue that due to the quality of existing studies, further research is highly necessary to investigate whether the positive effects of PI can be generalised across healthy (active or sedentary), sub-clinical as well as clinical populations, and to capture a more complete sense of body representations that allows for exploring potential mechanisms of change.

Based on the evidence available, PI can be cautiously regarded as a potentially effective option regarding body image related outcomes. Notably, the studies included in the review examined predominantly volunteer groups (i.e., people who were generally open to the idea of engaging in physical activity), even if they were previously sedentary. It remains unclear whether positive effects of PI would also generalise to the voluntarily sedentary population who are physical-activity-reluctant. From a clinical perspective, these groups would be very relevant, since they are at higher risk for cardiovascular diseases and obesity. Thus, from the current studies, it remains unclear whether PI can be recommended as a general treatment to people suffering from poor body image.

Based on our systematic review, it would not be responsible to simply conclude that PI might be a promising treatment option for sub-clinical and/or clinical populations whose core psychopathology is centred around body dissatisfaction and distorted representation of one's own body. Despite the fact that a general improvement in measures of body representations can be observed, the percentage of clinical and sub-clinical studies included within the systematic review is too low to draw such a conclusion (23.53%). Additionally, there is no clear evidence regarding an additional or interactive effect of PI when implemented in conjunction with established treatments for clinical populations. More importantly, a previous meta-analytic review of stand-alone interventions to improve body image by Alleva and colleague (18) has provided evidence which cautioned against discussing physical activity with patients, as it was significantly associated with poorer body image outcomes. The meta-analysis proposed that by discussing physical activity as an intervention, patients may inadvertently have their attention drawn to their own weight and appearance, as well as the associated societal standards for physical fitness and physical attractiveness. Further, it was also not reported to be significantly associated with larger intervention effects on body image. Until the literature on the underlying mechanism between physical activity and body representation is further investigated, physical activity-related interventions targeting body image/representation should therefore be exclusively kept to psychologically healthy populations or be closely embedded in an overall treatment concept.

Notably, objective improvements in bodily composition and physical fitness brought about by PI are inconsistently related to changes in body image. This is surprising, insofar as people typically assume that their body image is based on an objective evaluation and comparison of their body. Instead, it appears that complex appraisal processes, eventually involving perceived improvements in physical capacities or more intense somatosensation experiences during PI may play a more important role. PI interventions could serve to improve body image/body representation by allowing individuals to redirect their attention more toward the functionality of their body and less on their appearance, or by increasing their sense of physical efficacy (69, 70). In this sense, the previous literature supports the need for a comprehensive, multisensory assessment of body representation as suggested by the Longo framework.

Strengths and Methodological Considerations

To our knowledge, this review is the first to provide a comprehensive systematic review on the topic of the longitudinal interactions between PI and body representation —the definition of which we have updated and adapted to fit the more complex theories and discussions which have arisen over the years.

Methodological limitations of this review arise from our study selection process as well as fromthe included studies. As we only searched for published results, a publication bias towardsignificant effects cannot be excluded. Further, as terminology in the field is very heterogeneous,it is possible that despite our broad search strategy, a few relevant articles may have been missed.Notably, some of the included studies had small sample sizes and may have been underpowered. Thecurrent systematic review is also potentially limited by biases within studies. Although nosystematic risk of bias across or within studies were identified, 97% of the included studies wereconsidered at risk with regards to selection bias and study design. More importantly, all studiesare lacking in the variety of validated outcome measures. Only self-report questionnaires wereimplemented, and the main component of body image addressed here was body satisfaction or the lackthereof. Additional visual scales implemented were used to measure the disparity between participants' subjective ideal versus actual body shapes, which, once again, only measured participants' attitudinal/conceptual issues of their own body image. Moreover, the two studies whose results also reported long-term effects of PI on body image were shown to be in direct contradiction (40, 50). One possible explanation for the contrasting results might be the difference in the type and dosage of the PIs implemented. As such, it remains unclear whether PI-induced body image improvement is indeed sustainable.

Perspectives and Future Directions

Our systematic review revealed that evidence on PI as a means to change body representation is still limited. A major challenge for future research is not only to reduce selection bias in the investigated samples, but also to explore potential mechanisms of body image improvement *via* PI through adopting a broader perspective on body representation. Based on our review, we argue for a more comprehensive view that takes various sources of information about the body into account (71, 72). In pursuit of a mechanism-oriented intervention, it is imperative to have a solid grasp on the understanding of how body image/body representation are constructed and which aspects drive changes in how individuals mentally represent their body.

The assessment of multisensory body representation is challenging. However, an increasing number of experimental paradigms have been developed in recent years to assess such concepts as: interoception [e.g., (73–75)], implicit knowledge of body dimensions (76–78) and multisensory integration (24). Despite reports of potentially disturbed multisensory integration and interoception in eating disorders (24, 79, 80), these measures have so far been largely neglected in clinical research. We expect that a broader use and further development of these methods in body representation assessment could give rise to a more informed understanding of the mechanisms of disturbed body representation and its malleability.

To this end, it is important to undertake future research on (i) identifying valid tasks to investigate different body representations (e.g., through combining actual body measures with tasks assessing body size estimation, interoceptive abilities or affordance estimates with questionnaires assessing cognitive-affective appraisal of the body), and (ii) investigate the malleability and interactions between different body representations.

AUTHOR CONTRIBUTIONS

DS, KG, SB, SZ, and AT conceptualized the project. DS, SB, and L-MW performed the literature review. DS wrote the first draft of the manuscript. SB, KG, HW, and AT critically reviewed the manuscript with respect to their areas of expertise: body image and eating disorders (KG, SB, SZ); philosophy and cognitive science of body perception (HW); and sports science (AT).

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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