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Associations of Dispositional Mindfulness with Obesity and Central Adiposity: the New England Family Study

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Abstract

Purpose To evaluate whether dispositional mindfulness (defined as the ability to attend nonjudgmentally to one's own physical and mental processes) is associated with obesity and central adiposity.

Methods Study participants (n=394) were from the New England Family Study, a prospective birth cohort, with median age 47 years. Dispositional mindfulness was assessed using the Mindful Attention Awareness Scale (MAAS). Central adiposity was assessed using dual-energy X-ray absorptiometry (DXA) scans with primary outcomes android fat mass and android/gynoid ratio. Obesity was defined as body mass index ≥30 kg/m^2.

Results Multivariable-adjusted regression analyses demonstrated that participants with low vs. high MAAS scores were more likely to be obese (prevalence ratio for obesity= 1.34 (95 % confidence limit (CL): 1.02, 1.77)), adjusted for age, gender, race/ethnicity, birth weight, childhood socioeconomic status, and childhood intelligence. Furthermore, participants with low vs. high MAAS level had a 448 (95 % CL 39, 857) g higher android fat mass and a 0.056 (95 % CL 0.003, 0.110) greater android/gynoid fat mass ratio. Prospective analyses demonstrated that participants who were not obese in childhood and became obese in adulthood (n=154) had −0.21 (95 % CL −0.41, −0.01; p=0.04) lower MAAS scores than participants who were not obese in childhood or adulthood (n=203).

Conclusions Dispositional mindfulness may be inversely associated with obesity and adiposity. Replication studies are needed to adequately establish whether low dispositional mindfulness is a risk factor for obesity and adiposity.

Keywords Mindfulness · Obesity · Adiposity · Epidemiology · Prevention

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Introduction

Obesity and excess central adiposity are important risk factors for diseases such as type 2 diabetes and cardiovascular disease [1–3]. More than one third of US adults are obese, with increasing prevalence worldwide [4, 5]. Central obesity is associated with cardiovascular disease and type 2 diabetes independently from obesity assessed via body mass index (BMI); consequently, understanding determinants of each form of obesity is important [1–3].

High rates of obesity are expressions of many contemporary industrialized societies that provide inexpensive access to

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high caloric palatable foods in environments that promote sedentary lifestyles. Anthropologically, humans have often eaten substantial amounts when food is available, with sugar, fat, and salt of particular importance for efficient sources of calories, and regulating sodium content in the body for optimal homeostasis [6, 7]. Resting when possible has been advantageous so that energy stores are available for the many times the body is needed for activities such as hunting, migrating, protection, agriculture, and care of offspring. Energy output for modern sedentary populations is estimated to be 50–65 % of hunting-gathering lifestyles [7]. With modern technology, access to highly palatable, calorie dense foods has become easy, and factors that historically required us to exert energy greatly reduced. However, the human brain and sense organs have not had evolutionary time to change responses to these types of sense cues [6, 7]. In this context, issues of self-regulation and craving may be important modifiable factors to limit overconsumption of food, tendencies toward sedentary lifestyles, and resulting obesity. Mindfulness (here defined as the ability to attend in a non-judgmental way to one's own physical and mental processes during ordinary, everyday tasks) [8] may be a novel determinant of obesity in this setting, where it may help people better self-regulate consumption and cravings. Mindfulness-based interventions, and dispositional mindfulness, have been associated with greater self-regulation and ability to notice cravings without acting on them [8–11]. Treating emotions and physical sensations as passing events can help people tolerate cravings and overcome addictions, whether it is for cigarettes [10] or potentially for other consumption-related risks for CVD such as overconsumption of high caloric palatable foods leading to obesity or sedentary activities such as electronic screen use [12, 13].

Little is known about the relation of mindfulness with obesity and adiposity. Specifically, randomized controlled trials of mindfulness-based interventions demonstrated weight loss in some but not all studies [13–19]. However, a limitation of randomized controlled trials in this area is that interventions are fairly brief (e.g., 8-week duration), whereas longer or higher dose mindfulness interventions may be needed for substantial weight loss [13–19]. Consequently, triangulation of methods can be useful. Observational data may therefore offer an important complement to brief intervention studies, as levels of mindfulness assessed observationally may reflect longstanding patterns.

Dispositional mindfulness has been considered to be an inherent, yet modifiable, trait, where all people have varying capacities to attend and to be aware of what is occurring in the present moment [20]. Dispositional mindfulness is likely influenced by both genetic and environmental factors [21]. Consequently, it is useful to understand associations of this naturally occurring trait with obesity and adiposity. However, only one study to date to our knowledge has evaluated associations of dispositional mindfulness with adiposity. This study, by our group, demonstrated significant positive associations of dispositional mindfulness with likelihood of having normal BMI (≥18.5 and <25 kg/m^2) [11]. No study to date, to our knowledge, has investigated associations of dispositional mindfulness with obesity, waist or hip circumference, or dual-energy X-ray absorptiometry (DXA) scan-derived measures of adiposity.

The primary objectives of this study were to evaluate associations of dispositional mindfulness with DXA scan-derived assessments of central adiposity, specifically android fat mass and android/gynoid fat mass ratio, as well as with obesity obtained from the more traditionally assessed BMI. Secondary analyses evaluated associations of dispositional mindfulness with other measures of central adiposity including waist circumference and waist/hip ratio. Further exploratory analyses evaluated potential mediators of the association between mindfulness and adiposity, including depressive symptomatology, sense of control, education, perceived stress, smoking, soft drink consumption, and physical activity. In addition, prospective assessments of body mass index at ages 4, 7, and 47 years were used to evaluate the relations of change in overweight and obesity status across the life course with dispositional mindfulness.

Methods

Sample

Study participants were from the New England Family Study (NEFS), which includes 17,921 offspring of pregnant women in the Collaborative Perinatal Project (CPP), born at the Providence, Rhode Island, and Boston, Massachusetts sites (USA) between 1959 and 1974 [22]. The current NEFS substudy, named the Longitudinal Effects on Aging Perinatal (LEAP) Project, was comprised of Providence-born participants. Participants were assessed during 2010–2011. There were 1400 participants randomly selected with preference for racial/ethnic minorities, of which 796 participants were eligible for assessment (i.e., not deceased, not incarcerated, had assessments taken at age 7 years, were located, and lived within 161 km [100 mi] of the clinical assessment site). Of 796 participants eligible for assessment, we were able to establish contact with 522 (76 %) of the participants within the relatively brief 13-month data collection period and invited them to participate in the study. Of these 522 participants, 19 % (n=95) refused to participate, and a further 5 % (n=27) agreed to participate but were unable to schedule assessments within the data collection period. This left 400 participants on whom assessments were made. The following numbers of participants were available for each independent variable, dependent variable, and covariate: Mindful Attention

Awareness Scale (MAAS) score (n=391), android fat mass (n=386), android/gynoid ratio (n=386), BMI (n=399), waist circumference (n=398), waist/hip ratio (n=398), age (n=400), gender (n=400), race/ethnicity (n=400), childhood socioeconomic status (SES) (n=385), childhood intelligence (n=387), birth weight (n=400), depressive symptomatology (n=392), sense of control (n=393), education (n=392), smoking (n=399), soft drink consumption (n=380), perceived stress (n=392), and physical activity (n=376). For multivariable-adjusted regression analyses, we performed multiple imputation to allow for n=394 participants. Assuming that values are missing at random [23], we performed multiple imputation [24] to obtain valid inference for multivariable-adjusted regression analyses for n=394 participants. Six participants were excluded from the analysis, because they were too heavy for the DXA scan equipment (body weight >159 kg [350 lbs]) and were therefore excluded from the study. We performed complete case analyses (n=331) for mediation analyses using android fat mass as the primary outcome since straightforward mediation analysis methods for multiple imputed data are not available. Comparisons between participants with complete data (n=331) vs. incomplete data (n=69) showed similar values for the independent variable, dependent variables, and covariates ($p \geq 0.05$), with the exception of childhood intelligence where the full-scale intelligence quotient (FSIQ) score was 96 (interquartile range 88–106) vs. 91 (interquartile range 81–99) for participants with complete vs. incomplete data, p=0.002; Appendix Table 4). This suggested minimal important differences in values between participants with complete vs. incomplete data. The study protocol was approved by the institutional review boards at Brown University and Memorial Hospital of Rhode Island.

Independent Variable

The MAAS is a 15-item questionnaire of dispositional mindfulness in which respondents indicate, on a 6-point Likert-type scale (1=*almost always* to 6=*almost never*), their level of awareness and attention to present events and experiences [20]. Sample MAAS items include "I find it difficult to stay focused on what's happening in the present," "I break or spill things because of carelessness, not paying attention, or thinking of something else," and "I could be experiencing some emotion and not be conscious of it until sometime later" [20]. A mean score is calculated (range 1–6), where higher scores reflect greater self-reported attention and awareness or "dispositional mindfulness." Please see Discussion section for further information on MAAS validity and reliability.

Primary analyses utilized a categorical exposure variable, called "MAAS score level." Participants were likely to report fairly high mindfulness levels, where the number of participants with MAAS score of 1–2, >2–3, >3–4, >4–5, and >5–6 was 7 (1.8 %), 17 (4.3 %), 59 (15.1 %), 129 (33.0 %), and 179 (45.8 %), respectively. Consequently, we utilized MAAS score-driven cut points to allow for analyses to evaluate associations of low (MAAS score<4, n=77) and medium MAAS levels (MAAS score 4–5, n=131), in relation to high MAAS levels (MAAS score >5, n=174), all with reasonable sample sizes to allow for adequate statistical power, similar to prior research [11].

Dependent Variables

DXA is considered to be one of the gold standard assessments of adiposity [3]. DXA scans were performed using the Lunar Prodigy Advance scanner (GE Healthcare, Madison, WI), and provided measures of fat in various body compartments. Central adiposity phenotypes included android fat mass (a measure of centrally located fat) and android/gynoid region fat mass ratio (a measure of central to hip-area body fat distribution). Quality control tests to monitor reproducibility and stability of DXA assessments were performed weekly using models that simulate different levels of body fat. The coefficient of variation, comparing phantom (gold standard) to the machine, was 0.31 %. Weight and height measures were obtained in participants wearing light clothing without shoes, using a calibrated stadiometer and weighing scale operated by trained nurse researchers. Heads were positioned in the Frankfurt plane. Obesity was defined as BMI ≥ 30 kg/m^2. Hip circumference was assessed at greatest gluteal perturbance, and waist circumference was assessed by the smallest horizontal circumference between the participant's ribs and iliac crest at the end of a normal expiration. Childhood weight and height were also directly assessed at ages 4 and 7 years by medical staff according to a standard protocol [25]. Childhood overweight and obesity were defined as >85th and >95th percentile, respectively, on the United States Centers for Disease Control growth charts at either age 4 or 7 years [26, 27].

Covariates

Age was directly assessed via date of birth (recorded directly in this birth cohort), subtracted from clinic visit date. Sex and race/ethnicity were self-reported in adulthood. Birth weight was directly recorded by nurse observers at delivery. Childhood intelligence was assessed with the full-scale intelligence quotient score from the Wechsler Intelligence Scale for children at age 7 years [28]. Childhood socioeconomic status (SES) was assessed from parents at offspring age 7 years, using a weighted percentile of both parents' educational attainment, occupation, and income relative to the US population [29]. Depressive symptomatology was computed as the sum of responses from the ten-item Center for Epidemiologic Studies Depression Scale (CES-D) (range 0–30) [30]. Sense of control was assessed via the Pearlin and

Schooler Mastery Scale (range 7–35) with Cronbach's α= 0.71 [31]. Educational attainment was categorized as ≤high school vs. >high school. Smoking was assessed by self-report and dichotomized as current smoker vs. nonsmoker. Soft drink consumption was assessed as frequency and quantity of usual consumption of nondiet soft drinks [32]. Self-reported physical activity was assessed using the International Physical Activity Questionnaire Short Form with validation described elsewhere [33, 34]. Findings using self-reported physical activity should be interpreted with caution as the validity of self-reported assessments are substantially less than direct assessments of physical activity [34]. Perceived stress was assessed using the four-item Perceived Stress Scale with established validity/reliability described elsewhere (range 4–20) [35].

Analytic Methods

Analyses for associations of MAAS score level with android fat mass and android/gynoid fat mass ratio used multivariable-adjusted linear regression. Analyses for obesity calculated multivariable-adjusted prevalence ratios utilizing log-binomial regression described elsewhere, given data were cross-sectional and dependent variable prevalence was >10 % [36]. Formal statistical tests of a product term between mindfulness and sex, and mindfulness and race/ethnicity, demonstrated no evidence for effect measure modification (p=0.45 and 0.48, respectively); consequently, analyses were pooled by sex and race/ethnicity. Analyses were adjusted for covariates including age, sex, race/ethnicity, birth weight, childhood SES, and childhood intelligence.

Multiple imputation was used for regression analyses in order to reduce biases that may arise from missing values. Variables that informed the multiple imputation included all variables shown in Table 1 and variables obtained prenatally (number of prenatal visits, household crowding, mother's nonverbal intelligence), at birth (gestational age, public financial assistance such as welfare), age 8 months (Bayley mental and motor scales of infant development), age 1 year (number of chronic medical conditions), age 4 years (Stanford Binet intelligence quotient score), age 7 years (SES, mother's marital status, number of chronic medical conditions), and adult variables assessed at median age 47 years (systolic blood pressure, diastolic blood pressure, total cholesterol, HDL cholesterol, maximum carotid intima media thickness, fruit and vegetable consumption), where many of the early life variables are described in more detail elsewhere [37]. One hundred multiply imputed datasets were generated using the method of chained equations as implemented in IVEware [38]; all analyses were conducted separately within each imputed dataset, and results combined across datasets using the MIANALYZE procedure in SAS version 9.2 (Cary, NC) which accounts for sampling variability across imputations.

Exploratory mediation analyses assessed whether there were potential mediators of the association between mindfulness and android fat mass using formal mediation methods based on the counterfactual framework, which allows for decomposition of a total effect into direct and indirect effects, even in models with interactions and nonlinearities [39]. Examining indirect effects provides evidence of whether mindfulness may exert its effects uniquely through any of the potential mediators examined in this study. Percentile based 95 % confidence limits were estimated via bootstrapping with 1000 samples with replacement. We utilized linear regression analyses evaluating associations of MAAS level, and each potential mediator, with android fat mass. Using simulations from Fritz and MacKinnon [40], for 80 % power to detect a small- or medium-mediated effect (standardized-mediated effect sizes of 0.14 or 0.39, respectively), 667 and 90 participants, respectively, will be needed based on the Sobel first-order test with alpha=0.05. The sample size in this study for mediation analyses is 331, suggesting adequate power for detecting medium-mediated effect sizes.

Results

There were significant associations of MAAS level with android fat mass, age, sex, depressive symptoms, sense of control, smoking, and perceived stress in unadjusted analyses (Table 1). Further descriptive characteristics are shown for covariates stratified by android fat mass tertile, which showed significant associations of android fat mass with sense of control, education, and physical activity (Table 2).

Multivariable-adjusted log-binomial regression analyses demonstrated prevalence ratio (PR) of 1.39 (95 % CL 1.06, 1.83) for associations of low vs. high MAAS level with obesity, adjusted for age, sex, and race/ethnicity. Further adjustment for early life covariates including SES, intelligence, and birth weight resulted in PR=1.34 (95 % CL 1.02, 1.77) (Fig. 1). There was some evidence of a threshold effect, where medium MAAS levels (score range 4 to 5) showed similar prevalence ratios (PR=1.03, CL 0.78, 1.37) to the referent high MAAS level (PR=1.00; score range >5 to 6), and it was only low MAAS levels (score range 0 to <4) that showed a modest and significant effect size (PR= 1.34, 95 % CL 1.02, 1.77; Fig. 1). Similarly, participants with low vs. high MAAS level had 448 (95 % CL 39, 857) g higher android fat mass and 0.056 (0.003, 0.110) greater android/gynoid fat mass ratio (Table 3). Comparable point estimates in terms of the direction of association were found for waist/hip ratio and waist circumference; however, the corresponding 95 % confidence

Table 1 Participant characteristics for entire sample (overall) and stratified by Mindful Attention Awareness Scale (MAAS) level

		MAAS level[a]			
	Overall	Low	Medium	High	p[b]
Adiposity measures					
Android fat mass (g)	2870 (1892–3939)	3375 (2221–4107)	2675 (1760–3915)	2729 (1734–3733)	0.04
Android/gynoid fat mass ratio	1.037 (0.921–1.192)	1.032 (0.926–1.220)	1.062 (0.909–1.207)	1.043 (0.940–1.187)	0.96
Body mass index, kg/m^2	29.2 (25.2–34.1)	30.5 (27.0–35.5)	28.6 (24.8–34.5)	29.0 (25.0–33.7)	0.07
Waist circumference	96.8 (87.0–110.0)	100.6 (90.8–108.8)	95.9 (82.8–110.6)	96.4 (86.4–110.6)	0.24
Waist/hip ratio	0.904 (0.836–0.964)	0.913 (0.843–0.967)	0.903 (0.831–0.964)	0.903 (0.839–0.958)	0.66
Confounders					
Age, years	47 (46–48)	47 (46–48)	47 (45–48)	47 (46–49)	0.03
Sex, % female	47.0	46.7	46.8	47.2	0.04
Race/ethnicity, % white	56.5	63.3	57.9	52.5	0.25
Childhood socioeconomic index	40 (25–57)	39 (23–58)	39 (24–54)	44 (28–58)	0.31
Childhood FSIQ, score	95 (87–105)	94 (86–102)	96 (86–106)	96 (88–106)	0.51
Birth weight, g	3232 (2608–3742)	3118 (2750–3685)	3232 (2495–3742)	3260 (2693–3799)	0.55
Potential mediators					
Depressive symptoms, CESD score	6 (3–10)	12 (8–17)	7 (4–11)	4 (2–8)	<0.0001
Sense of control, score	14 (12–18)	17 (14–22)	14 (13–18)	14 (10–16)	<0.0001
Education, % ≤high school	70.3	73.1	69.9	69.3	0.83
Smoking, % current smoker	36.2	49.4	35.3	30.9	0.02
Soft drink consumption, % >1 serving/day	13.9	16.2	16.5	10.8	0.30
Physical activity, % low activity	35.8	46.8	30.8	34.6	0.06
Perceived stress, score	9 (6–12)	12 (9–13)	9 (7–11)	7 (5–10)	<0.0001

Point estimates represent median (interquartile range) or percentage

BMI body mass index, *CESD* Center for Epidemiologic Studies Depression Scale, *FSIQ* full-scale intelligence quotient

[a] MAAS levels represent the following MAAS scores (range 1–6): low <4, medium 4–5, and high >5

[b] p Values are derived from chi-squared tests (categorical variables) or Kruskal–Wallis tests (continuous variables)

intervals included the null for fully adjusted models (Appendix Table 5).

Mediation analyses demonstrated no significant evidence of mediation by any tested variables. There was weak evidence that soft drink consumption may be a potential mediator of associations between MAAS and android fat mass; however, 95 % confidence limits for the indirect effect included the null. In these analyses, effect sizes represent change in android fat mass (g) for low vs. high MAAS level. Specifically, the total effect of low vs. high MAAS level on android fat mass was 619 (95 % CL 192, 1046) g, adjusted for age, race/ethnicity, gender, birth weight, childhood SES, and childhood intelligence. The indirect effect for soft drink consumption was 43 (95 % CL −7, 136) g for low vs. high MAAS level. This demonstrated that 43 of the 619 g total effect may be mediated through soft drink consumption for low vs. high MAAS level. There was less evidence of mediation effects for sense of control (indirect effect 88 g, 95 % CL −95, 275), depressive symptoms (indirect effect −80 g, 95 % CL −358, 207), education (indirect effect −10 g, 95 % CL −94, 55), smoking (indirect effect 8 g, 95 % CL −70, 89), physical activity (indirect effect 21 g, 95 % CL −36, 100), or perceived stress (indirect effect −25 g, 95 % CL −235, 186), where all indirect effects are for low vs. high MAAS level.

In order to take advantage of prospective assessments of adiposity in childhood (ages 4 and 7 years) and adulthood (mean age 47 years), participants who were not obese in childhood and became obese in adulthood (n=154) had 0.21 (95 % CL −0.41, −0.01; p=0.04) lower MAAS scores than those that were not obese in both childhood and adulthood (n=203). Further analyses found those who were overweight/obese in childhood but not obese in adulthood (n=40) had 0.12 (95 % CL −0.22, 0.46; n=40) higher MAAS scores than those who were not overweight/obese in childhood and not obese in adulthood (n=175). Furthermore, those who were overweight/obese in both childhood and adulthood (n=50) had 0.27 (95 % CL −0.58, 0.03; n=50) lower MAAS scores, compared to participants who were not overweight/obese in childhood and not obese in adulthood (n=175).

Table 2 Participant characteristics stratified by sex-specific android fat mass tertile

	Android fat mass tertile			
	Low	Medium	High	*p*
Confounders				
Age, years	48 (47–49)	47 (45–48)	47 (46–49)	0.12
Sex, % female	57.0 (48.3–65.7)	56.6 (47.9–65.3)	56.6 (47.9–65.3)	1.00
Race/ethnicity, % white	67.2 (58.9–75.4)	61.2 (52.7–69.8)	66.7 (58.4–74.9)	0.54
Childhood socioeconomic index	21 (16–35)	44 (29–64)	39 (24–54)	0.06
Childhood FSIQ, score	96 (88–109)	94 (85–105)	95 (86–101)	0.27
Birth weight, g	3274 (3005–3997)	3189 (2637–3799)	3232 (2523–3685)	0.96
Potential mediators				
Depressive symptoms, CESD score	5 (3–10)	6 (3–10)	7 (4–13)	0.07
Sense of control, score	14 (11–18)	14 (12–18)	16 (13–19)	0.005
Education, % ≤high school	62.1	74	77.2	0.02
Smoking, % current smoker	38.3	31.8	43	0.18
Soft drink consumption, % >1 serving/day	11.3	10.8	19.5	0.09
Physical activity, % low activity	52.0	38.0	27.7	0.0005
Perceived stress, score	9 (6–11)	8 (6–12)	9 (7–12)	0.50

Point estimates represent median (interquartile range) or percentage. *p* Values are derived from chi-squared tests (categorical variables) or Kruskal–Wallis tests (continuous variables)

CESD Center for Epidemiologic Studies Depression Scale, *FSIQ* full-scale intelligence quotient

Discussion

Summary of Findings

This study found significant inverse associations of high vs. low dispositional mindfulness with obesity, android fat mass and android/gynoid fat mass ratio, adjusted for age, sex, race/ethnicity, birth weight, childhood SES, and childhood intelligence. Participants who were not obese in childhood and became obese in adulthood had significantly lower MAAS scores than those that were not obese in both childhood and adulthood, suggesting that dispositional mindfulness may relate to obesity trajectories across the life course. These analyses of observational data do not provide evidence of causation but do offer preliminary support for the potential role of mindfulness in the development of obesity and adiposity.

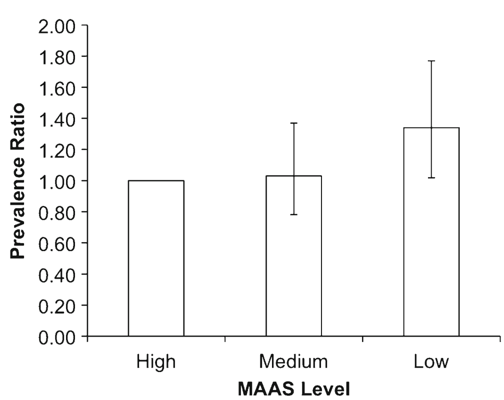

Fig. 1 Prevalence ratios (95 % confidence limits) of obesity (BMI≥ 30 kg/m^2) according to mindfulness level, adjusted for age, sex, race/ethnicity, childhood socioeconomic status, childhood intelligence, and birth weight. Mindfulness attention awareness scale (MAAS) levels represent the following MAAS scores (range 1–6): low <4, medium 4–5, and high >5

Prior Literature

Associations of dispositional mindfulness with obesity and adiposity to our knowledge have been investigated by only one other study. This study, by our group, demonstrated significant positive associations of dispositional mindfulness with likelihood of having normal BMI (≥18.5 and <25 kg/m^2), where those with high mindfulness had a prevalence ratio of 2.17 (95 % CI 1.16, 4.07) greater likelihood of having normal BMI vs. those with low mindfulness [11]. The current study complements these findings by demonstrating significant associations of high vs. low dispositional mindfulness with obesity, android fat mass, and android/gynoid fat ratio. Several studies evaluated impacts of mindfulness interventions on weight loss. Overall, the types of mindfulness interventions have varied, and weight loss has been shown in some but not all studies. A recent systematic review stated that nine of ten mindfulness-based intervention studies demonstrated weight loss or stabilized weight [13]. However, inclusion criteria for this review

Table 3 Multivariable-adjusted regression analyses showing change (95 % confidence intervals) in android fat mass (g) and android/gynoid fat mass ratio according to Mindfulness Awareness Attention Scale (MAAS) level

		Model adjustment	
Adiposity outcome	MAAS level	Age, sex, race/ethnicity	Age, sex, race/ethnicity, childhood SES, childhood intelligence, birth weight
Android fat mass (g)	Low	487 (79, 895)	448 (39, 857)
	Medium	64 (−285, 4140)	30 (−320, 380)
	High	0	0
Android/gynoid ratio	Low	0.057 (0.004, 0.111)	0.056 (0.003, 0.110)
	Medium	0.035 (−0.010, 0.081)	0.034 (−0.012, 0.080)
	High	0.000	0.000

High MAAS level is referent category. MAAS levels represent the following MAAS scores (range 1–6): low <4, medium 4–5, and high >5

SES socioeconomic status

allowed studies without control groups, resulting in reasonable risk for bias. Another recent systematic review of randomized controlled trials and observational studies found significant weight loss in 13 of 19 studies [19]. This review noted that many studies did not report whether the interventions influenced mindfulness levels and recommended that measures of mindfulness be included in future studies to provide evidence that the mindfulness intervention is operating via improvements in mindfulness. Randomized controlled trials with higher quality methods and longer durations of follow-up will provide more robust evidence on the potential for mindfulness-based interventions in weight loss. Future studies should consider the potential for floor effects in participants who are not obese [17] or currently attempting to lose weight [18] due to evidence of null effects related to these conditions [17, 18].

With regard to plausible mechanisms by which mindfulness could influence obesity and adiposity, there have been a number of studies with control groups that showed positive impacts of mindfulness-based meditation practices on diet-related behaviors including food cravings [41–43], diet composition [44, 45], and eating disorders, including binge eating [46] and stress-related eating [17]. Systematic reviews have demonstrated generally consistent protective effects of mindfulness-based intervention on eating disorders [13, 47]. In the current study, none of the evaluated mediators were statistically significant. As described in the Methods section, power simulations from Fritz and MacKinnon [40] suggest adequate statistical power in this study for detecting medium to large mediation effects but not small mediation effects. The estimates of indirect effects for soft drink consumption missed the 5 % significance threshold and thus may be a mediator with small effect size. This finding should be replicated in a larger study.

The assessment of mindfulness is without a gold standard, and there is current debate on the accuracy of self-reported mindfulness, including using the MAAS used in the current study [48, 49]. The MAAS has been shown to have a single-factor structure [20] and appears to emphasize an element related to dissociation and absent-mindedness [50]. The scale exhibits good internal consistency (Cronbach's α=0.82–0.87) and high test–retest reliability over a 1-month period (intraclass correlation=0.81, p<0.0001) [20, 50]. The MAAS score has been shown to be positively related to long-term meditation experience, where Zen meditators were shown to have higher MAAS scores than age- and sex-matched community members [20], and Thai monks showed higher MAAS scores than Thai or American students [51]. A systematic review and meta-analysis showed randomized controlled trials that evaluate impacts of mindfulness training on self-reported mindfulness scores, including the MAAS, show overall improvements in self-reported mindfulness in relation to wait-list control groups, but not in relation to active control groups [48], which is somewhat concerning. Some active control groups may increase self-awareness and mindfulness; however, further work is needed to determine reasons for lack of improvements in mindfulness for randomized controlled trials using active control groups. The convergent and discriminant validity of the MAAS has been evaluated, and it appears to tap a single construct where higher scorers on the MAAS tend to be more aware of and receptive to inner experiences and are more mindful of their overt behavior [20]. High MAAS scorers are more aware of their emotional states and able to alter them and are more likely to fulfill basic psychological needs [20]. Furthermore, higher MAAS scorers are less likely to be self-conscious, socially anxious, and ruminative than low scorers [20]. Thus, while these tools should be considered tools of a developing science, they have attained psychometric properties that justify their use in associational studies at this time

[52]. Further validation and exploration of gold standard measures of mindfulness could be very fruitful to help the mindfulness research field advance in methodologically rigorous ways.

Limitations and Strengths

Limitations of the study included that the independent variable, potential mediators, and dependent variables were measured at the same time point for most analyses, which limits causal inference. Furthermore, while studies have shown that abdominal fat mass measured by DXA and well-respected computed tomography (CT) is highly correlated, DXA systematically underestimates the CT-derived abdominal fat mass [3]. This likely resulted in more conservative estimates biased toward the null.

Strengths of the study included prospectively assessed covariates including childhood SES, childhood intelligence and birth weight, as well as prospectively assessed body mass index at ages 4, 7, and 47 years. Furthermore, there were direct assessments of major measures of adiposity (android fat mass, android/gynoid ratio, waist circumference, waist/hip ratio) and obesity (body mass index).

Conclusions

The current study observed associations of low dispositional mindfulness with greater obesity, android fat mass, and android/gynoid ratio, compared with high mindfulness. This research extends early findings in randomized controlled trials of mindfulness-based interventions that show effects on eating behaviors [13, 17, 41–47] and preliminary evidence for impacts on weight loss in some but not all studies [13–18]. However, this field is still very new, and high-quality prospective studies are needed to firmly evaluate whether dispositional mindfulness is related to obesity and adiposity and the potential contributions of mindfulness-based interventions to weight loss in those who are overweight or obese.

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Compliance of Ethical Standard

Conflict of Interest Eric B. Loucks, Willoughby B. Britton, Chanelle J. Howe, Roee Gutman, Stephen E. Gilman, Judson Brewer, Charles B. Eaton, and Stephen L. Buka declare that they have no conflicts of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Appendix

Table 4 Characteristics for participants with complete data (n=331) vs. incomplete data (n=69)

	Participants with complete data	Participants with incomplete data	
	Median (interquartile range) or percentage	Median (interquartile range) or percentage	p
MAAS score	4.93 (4.15–5.47)	4.96 (4.33–5.59)	0.70
Adiposity measures			
Android fat mass (g)	2871 (1928–3915)	2870 (1829–3989)	0.77
Android/gynoid fat mass ratio	1.042 (0.922–1.200)	1.003 (0.898–1.148)	0.53
BMI, kg/m^2	29.2 (25.2–33.9)	29.5 (25.2–36.7)	0.46
Waist circumference, cm	96.7 (86.4–109.5)	98.0 (90.6–112.4)	0.18
Waist/hip ratio	0.903 (0.839–0.965)	0.911 (0.833–0.957)	0.47
Confounders			
Age, years	47 (46–48)	47 (46–49)	0.38
Sex, % female	57.4	53.6	0.56
Race/ethnicity, % white	67.1	55.1	0.06
Childhood socioeconomic index	41 (26–57)	35 (24–53)	0.08
Childhood FSIQ score	96 (88–106)	91 (81–99)	0.002
Birth weight, g	3260 (2608–3770)	3090 (2551–3685)	0.33
Potential mediators			
Depressive symptoms, CESD score	6 (3–11)	6 (4–9)	0.92
Sense of control, score	14 (12–18)	16 (13–19)	0.18
Education, % ≤high school	70.1	72.1	0.75
Smoking, % current smoker	36.3	38.2	0.76
Soft drink consumption, % >1 serving/day	86.1	89.8	0.48
Physical activity, % low activity	36.9	44.4	0.32
Perceived stress, score	9 (7–11)	9 (6–12)	0.94

Point estimates represent median (interquartile range) or percentage. p Values are derived from chi-squared tests (categorical variables) or Wilcoxon Mann–Whitney tests (continuous variables)

Table 5 Multivariable-adjusted regression analyses demonstrating change (95 % confidence limits) in waist/hip ratio and waist circumference according to Mindfulness Awareness Attention Scale (MAAS) level

		Model adjustment	
Adiposity outcome	MAAS level	Age, sex, race/ethnicity	Age, sex, race/ethnicity, childhood SES, intelligence, birth weight
Waist/hip ratio	Low	0.021 (0.001, 0.042)	0.018 (−0.002, 0.039)
	Medium	0.002 (−0.016, 0.019)	−0.001 (−0.019, 0.017)
	High	0.000	0.000
Waist circumference (cm)	Low	4.3 (0.1, 8.5)	3.8 (−0.4, 8.0)
	Medium	0.0 (−3.5, 3.6)	−0.4 (−4.0, 3.1)
	High	0.0	0.0

High MAAS level is referent category. MAAS levels represent the following MAAS scores (range 1–6): low <4, medium 4–5, and high >5

SES socioeconomic status

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