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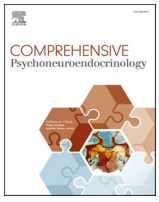

Weight-based discrimination and cortisol output: A systematic review

Maria A. Kalantzis [a,*], Daniel M. Maitland [b], Miranda Yannon [a], Christina Gaggiano [a], Jinbo He [c], Aldo Barrita [e], Lorelai Symmes [d], William H. O'Brien [a]

[a] Department of Psychology, Bowling Green State University, USA
[b] Department of Psychology and Counseling, University of Missouri Kansas City, USA
[c] School of Humanities and Social Science, The Chinese University of Hong Kong, Shenzhen, China
[d] Department of Psychology, St. Mary's College of Maryland, USA
[e] Department of Psychology, Michigan State University, USA

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ABSTRACT

Discrimination based on weight status (or weight-related discrimination/stigma) may be related to greater physical and mental health concerns via physiological and psychological phenotypes of stress. Cortisol output, a biomarker of stress, has been measured in relation to weight stigma and weight-related discrimination. This systematic review aims to synthesize existing research on the relationship between weight-related discrimination and cortisol output, evaluate methodological approaches for measuring these constructs, and identify research gaps regarding contextual factors influencing this relationship. A comprehensive search was conducted across multiple databases (PsycINFO, Scopus, ProQuest, and PubMed) from February 1 to July 1, 2024, resulting in 11 eligible studies that examined weight discrimination in relation to cortisol levels. Studies were assessed for quality using the NHLBI Study Quality Assessment Tool, and inter-rater reliability for coding was established at 90 %. The findings revealed a range of sample sizes (45–4341) and diverse participant characteristics, including variations in age, race, and body mass index (BMI). About half (N = 5) of the included studies reported a positive relation between weight stigma and cortisol output. The review also uncovered significant limitations in current methodologies, particularly concerning contextual factors and other marginalized identities, such as socioeconomic status and food insecurity, along with measuring other forms of discrimination in tandem with weight stigma, such as racial discrimination. These findings underscore the need for future research to adopt a more intersectional approach in examining the multifaceted nature of weight stigma and how it relates to a greater stress response in multiple marginalized identities, as well as including longitudinal modeling of weight stigma's impact on biomarkers for stress.

1. Introduction

Discrimination, operationalized as unfair treatment by others based upon their status and membership within a social group, such as social class, race, ethnicity, weight-status, or religion [1], is positively related to deleterious physical and mental health outcomes, such as depression, general well-being, and alcohol use [2]. Discrimination can occur on two levels: *individual* (e.g., via interpersonal interactions) and *institutional* (e.g., lack of access to necessities), and its relationship to negative health outcomes can be explained from a range of theoretical underpinnings. One theorized pathway by which discrimination impacts health posits that identity-related discrimination may be related to the inequitable distribution of institutionalized resources (e.g., fair income, food security, etc.) and unfair treatment from majority groups based upon prejudices, bias, and stereotypes. These factors may lead to lower social and personal resources to maintain well-being [3]. Furthermore, those who experience discrimination may experience a cumulative effect of hostile social interactions that may impact their ability to acquire housing, job security, and healthcare access and may directly impact health behaviors. This may be particularly salient for individuals who experience discrimination based on identities related to health, such as weight. For instance, discrimination is associated with less adherence to antiretroviral medication [4], suggesting that discrimination regarding one's social identity may result in 'medical mistrust' [5], which may then lead to non-compliance with medical care, thus resulting in adverse outcomes. It is also possible that the impact of discrimination on health

* Corresponding author. Department of Psychology, 822 East Merry Avenue, Bowling Green, OH, 43403, USA.
E-mail address: makalan@bgsu.edu (M.A. Kalantzis).

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is proximal rather than distal in nature.

Researchers have developed models suggesting that the relationship between discrimination and mental and physical health outcomes as a function of stress processes [6]. Further, discrimination can be viewed as a 'stressor,' ranging from 'everyday' (e.g., being mistreated at school) to 'chronic' (e.g., living below the poverty line). Thus, discrimination can promote prolonged activation of the hypothalamic-pituitary-adrenal (HPA) axis, which can be intensified by maladaptive responses (e.g., magnification and helplessness, see Ref. [7]). The HPA axis plays an important role in the body's stress response, and over-activation has been linked to increased severity of psychotic disorders [8], eating and weight disorders [9], and cardiovascular disease [10]. While most methods to measure stress in its relationship to discrimination and health have been self-reported, researchers have examined stress using biomarker methods, such as cortisol output. Cortisol, a hormone the adrenal gland produces, plays a key role in regulating and activating the HPA axis and is one index composite allostatic load score [11]. It is theorized that cortisol works to 'counterbalance' norepinephrine and IL-1beta proinflammatory cytokine [12]. When chronic stress is present, cortisol is secreted and creates an imbalance between the endocrine and immune systems, resulting in risk for physical and mental health symptoms [13]. Currently, there are three main methods to examine cortisol dysfunction: (a) basal cortisol, which is captured by measuring cortisol during an unaroused state; (b) cortisol reactivity, which reflects the change in cortisol before and after a stress-related stimulus; and (c) diurnal cortisol, which measures the changes between the beginning and the end of the day ([14]. To this end, it is theorized that different stressors may elicit varying levels of stress responses. For instance, Dickerson and Kemeny's [15] meta-analysis found that laboratory studies inducing social-evaluative threats—where an individual's identity or part of themselves is judged by others and beyond their control—resulted in significantly higher cortisol responses compared to situations without such threats. Discrimination, as a form of social-evaluative threat, falls into this category. Empirical evidence supports this link, with studies showing that experiences of discrimination predict higher retrospective levels of cortisol in scalp hair in African Americans [16] and that perceptions of discrimination are marginally related to steeper cortisol awakening in Hispanic American youth [17].

Weight-related discrimination (or weight stigma) can be operationalized as the unfair treatment of someone due to their body size and weight status. The relationship between weight stigma and cortisol production has received significant empirical and theoretical attention. Weight stigma has also been associated with negative emotionality (e.g., 'negative, emotional experience') (Sikorski et al., 2015). Weight stigma can be directly experienced or *anticipated,* meaning a weight-stigmatizing event can create hypervigilance, or anticipation, around the next stigmatizing event, increasing psychological distress [18]. However, some scholars denote that the relationship between weight stigma, stress responses, and health is a 'vicious cycle' [19], known as the COBWEBS model. Furthermore, Hunger & colleagues [20] theorized that weight-based social identity threats cause psychological and physiological stress, which biomarkers can index. Additionally, individuals may avoid and escape environments intended to promote health behavior change (i.e., going to the gym) due to fear of weight stigma in these environments. Weight stigma can lead to negative physiological responses (i.e., maladaptive cortisol release) and negative psychological responses (e.g., binge and emotional eating to cope with stressors; [21]), which may both lead to weight gain, furthering someone's risk of weight-based stigma and discrimination.

There is a growing body of literature examining the relations between weight-related discrimination and weight stigma. Jackson and colleagues [22] found that the experience of discrimination based on weight partially explained the relation between being obese and having higher cortisol levels. Other researchers have found that those who experienced weight discrimination had twice the risk of allostatic load than those who did not (Vadiveloo et al., 2016). Panza's [2] systematic review suggests that the association between adiposity and cortisol levels complicates these relations. As such, Tomiyama and colleagues [19] found that *independent of abdominal fat*, weight stigma was significantly related to salivary and serum morning levels of cortisol [19]. Indeed, internalized weight stigma may also influence stress (Papatsaraki et al., 2024). Consistent with the COBWEBS model, a positive relation has been observed between weight-related discrimination and cortisol. However, one limitation the COBWEBS is its lack of an intersectional approach, meaning a person could be experiencing multiple, overlapping forms of stigma and discrimination (e.g., weight status and race; see Ref. [23]), which may uniquely contribute to cortisol output. To that end, there is a need for a systemic review of the current literature that critically examines studies that have investigated weight discrimination and cortisol output. Thus, we conducted a systematic review exploring the literature on weight discrimination and cortisol outcomes and aimed to identify gaps in this research field to provide recommendations for future research.

1.1. The present review

The pervasive nature of weight discrimination or stigma is a public health concern that relates to negative mental and physical health outcomes. Central to this issue is understanding biological factors that fully or partially explain these relationships, such as cortisol output. Indeed, these relationships are complicated by weight gain and disordered eating. To that end, this review aims to 1) synthesize existing research on weight discrimination/stigma and cortisol output, 2) identify and evaluate common methodological approaches to measure weight-based discrimination and cortisol, and 3**) highlight research gaps in identifying factors across studies that may influence the relationship between weight discrimination/stigma and cortisol, including other identities or variables (e.g., race, gender, socioeconomic status) that may indirectly or directly influence this relationship.**

2. Methods

2.1. Search strategy

Electronic searches were conducted from 2/01/2024 to 07/01/2024. Studies were assessed at the title, abstract, and full-text level. The following searches were inputted into PsycINFO, Scopus, ProQuest, and PubMed: "weight" AND "discrimination" OR "prejudice," OR "stigma" OR "unfair treatment" OR "bias" OR "internalization" AND "cortisol." Given the contemporary nature of weight stigma and discrimination as a construct, there was no limitation to the date nor year. Additionally, the respective university's library databases were also assessed. Studies from previous meta-analyses and systematic reviews examining similar constructs [2,2] were also assessed for eligibility.

2.2. Inclusion and exclusion criteria

The first author and an undergraduate research assistant searched, following PRISMA guidelines (2020). To be included in the current analysis, studies had to meet the following criteria: Firstly, the study(ies) needed to be conducted in the United States (U.S.) and written in English, given the wide range of conceptualizations of discrimination across countries (Shepard et al., 2008). Secondly, the study's methodology needed to include a measure of weight discrimination, stigma, or unfair treatment (e.g., Fatphobia Scale, Robinson et al., 1993; Stigmatizing Situations Inventory, [24], lab manipulation) and validated and standardized measurement of cortisol (i.e., saliva, hair, blood; AUC, diurnal, basal). Thirdly, the study had to be peer-reviewed and report a correlational, odd-ratio, or effect-size-related statistic on the direct relationship between weight discrimination and cortisol output. Studies were excluded if they measured other forms of discrimination, such as

racial discrimination. There were no limitations regarding participant characteristics (e.g., age range, weight status). The first author and undergraduate research assistant reviewed the title and abstract for initial inclusion. Additionally, the third author screened previous systematic reviews and meta-analyses to assess for any other eligible studies. Inter-rater reliability was assessed, obtaining Kappa scores with high agreement (kappa = .77). Discrepancies were resolved between the first author and third author until the final number of studies was agreed upon. In the end, eleven studies (N = 11) were included in the current review. See Fig. 1 for the PRISMA flowchart.

2.3. Quality assessment

The NHLBI Study Quality Assessment Tool (see https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools) was used to assess the overall quality of each study (rated from poor (1) to good (3)). The first author and third author completed the checklist for each article. Disagreements were discussed and remedied.

2.4. Data extraction

Descriptives on sample characteristics, such as sample size, age, race, and SES, were collected. All results were extracted that examined the relationship between weight discrimination and cortisol and determined the statistical significance and valence of the relationship. Lastly, the frequency and range of covariates and other measured contextual factors (e.g., moderators) included in the primary study's statistical analysis were also extracted across studies.

2.4.1. Measurement quality

All studies that utilized a validated measurement of the aforementioned cortisol methods were included for review. In terms of weight discrimination, all studies included measurement of weight discrimination regardless of whether it was validated due to the newer nature of weight discrimination in the psychological health literature and whether they were self-report or lab manipulation. Studies that included a general discrimination measurement but did not tailor it to weight status were excluded.

2.5. Note on coders

Two researchers (Masked) independently searched for studies at the search term and abstract level. Inter-rater reliability was assessed at the abstract level; researchers agreed 90 % of the time, which was deemed adequate agreeability [25]. Discrepancies were then discussed to determine if the study met criteria based on the inclusion and exclusion criteria. Coding was finalized with mutual agreement from all researchers.

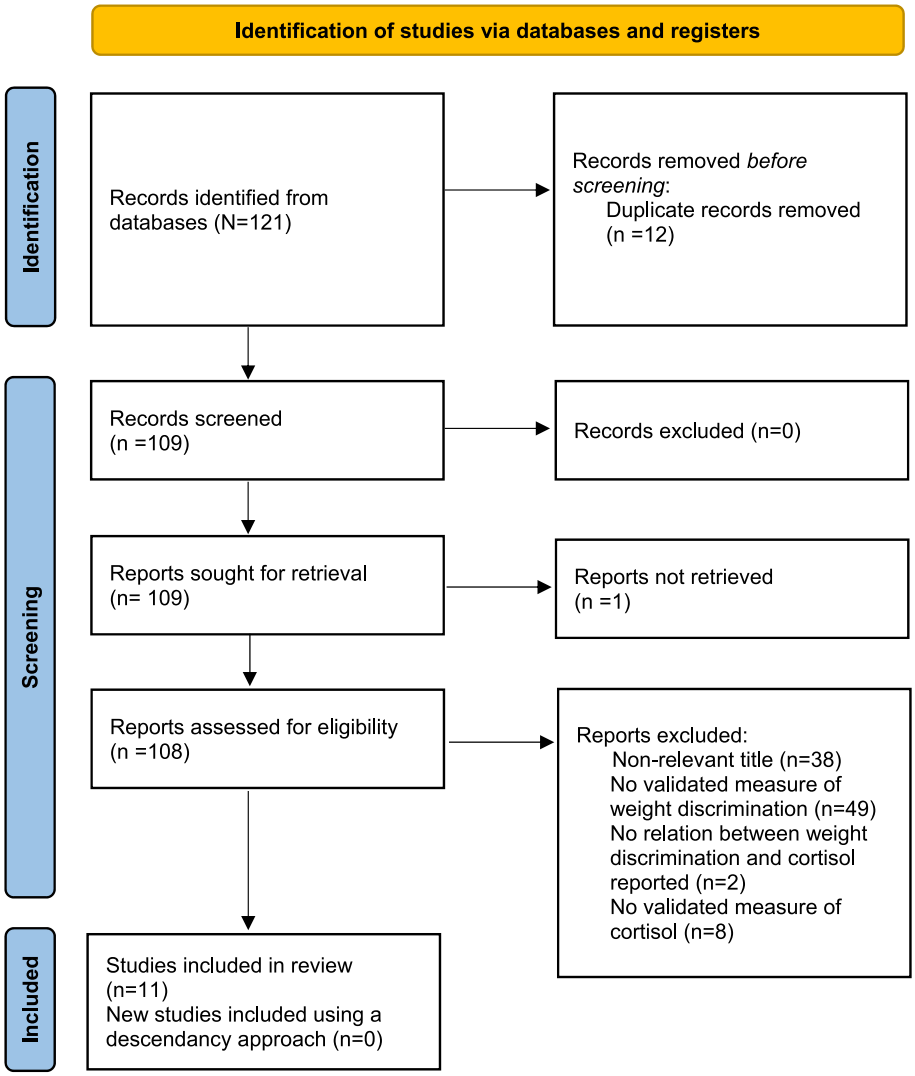

Fig. 1. PRISMA flowchart.

3. Results

We examined the characteristics of studies examining the relationship between weight-related discrimination and cortisol. See Table 1 for study year, sample size, BMI, mean age, racial/ethnic breakdown, covariates/moderators, cortisol measurement, weight discrimination measurement, study design, analysis type, and results summary.

3.1. Participant characteristics

A total of 11 studies were included in the final review, with sample sizes ranging from 45 to 4341. The mean age of participants varied across studies, with one study (see Huynh et al., 2016) focusing on young adolescents (M_{age} = 16.39), while all others (i.e., N = 10; See Table 1) were from adults (Age range, 19.26–67.7 years) Indeed, individuals 'with overweight/obesity' were included as the target sample in a majority of studies (N = 7; See Table 1), with 1 study being a 'simulated' experience of with overweight/obesity (i.e., participants wore a "fat-suit," see Rodriguez et al., 2016). All but one study (see Huynh et al., 2016) reported BMI (Range across studies: 22.03–35.9 kg/m2). Additionally, four studies (N = 4) focused on recruiting women ([32]; Incollingo et al., 2019; [19]; and Himmelstein et al., 2014). Lastly, race/ethnicity varied significantly across studies. Three studies recruited virtually all White/Caucasian participants (e.g., 98 % White in Ref. [26]; 100 % White in Nicolau et al., 2023; and 98.8 % White in Ref. [22]). Other studies, such as Himmelstein and colleagues (2015), reported diverse sample sizes and were the only study to include Arab/MENA individuals (1.8 %) [19], was the only study to include Pacific Islander participants (19.1 %). Himmelstein et al. (2015) and Shvey et al. [19] were the only two studies to include Native American participants (.9 % and 3.9 %, respectively). The complete details of each study's participant characteristics are provided in Table 1.

3.2. Study design

There was meaningful methodological variability across studies. Five studies employed a longitudinal design (N = 5), examining multiple time points of cortisol in relation to weight discrimination. For example, Tomiyama et al. [19] collected cortisol samples across four days at multiple time points. Incollingo and colleagues (2019) measured cortisol at six months and 1-year postpartum. Two studies (N = 2) directly employed a cross-sectional approach, measuring a single timepoint of cortisol and retrospective reports of weight discrimination.

Four studies (N = 4) utilized an experimental approach to cortisol change as it relates to weight discrimination. Indeed, all studies included an experimental and control group. For example, Jung et al. (2020) were subjected to a series of experimental tasks while their internalized weight bias was being measured. Himmelstein (2015) exposed an experimental group to a 'shopping activity,' where the confederate told participants that 'their size and shape are not ideal for this style of clothing … ', adapted from Goffman's framework (Goffman, 1963). Notably, this was the only study to also measure perceptions of weight in addition to 'objective' BMI. Lastly, one study was conducted where participants experimentally manipulated their perceived body size by the experimental group wearing a 'fat-suit.' Cortisol was measured pre- and post-account across all studies.

3.3. Measurement of cortisol

3.3.1. Timing of cortisol measurement

Various measurements of timing for cortisol were utilized across studies. Firstly, a couple of studies (N = 2; [19]; Huynh et al., 2016) utilized diurnal saliva sampling. Three studies (N = 3) utilized specific time points of cortisol measurement in relation to the study design. For example, Nicolau et al. (2023) measured cortisol at 8:00 a.m. via plasma after an overnight fast, and Jung et al. (2020) and Schvey et al. [32] measured cortisol before and after experimental tasks/videos. Lastly, Jackson et al. [26] and Hackett et al. (2023) measured hair cortisol, which tends to measure cortisol levels across time (Sharpley et al., 2011). For example, cortisol levels found in 2 cm of hair would represent a two-month interval when hair grows 1 cm per month.

3.3.2. Type of cortisol measurement

There was no methodological consensus around cortisol measurement. The most common measurement of cortisol was saliva (N = 7), followed by hair (N = 3) and plasma (N = 1). In terms of the various ways in which cortisol output can be calculated, four studies utilized a diurnal approach (N = 2, i.e., multiple time points), single timepoint of cortisol (N = 3), and area under the curve (N = 1; Huyn et al., 2016).

3.4. Measurement of weight discrimination

Researchers overwhelmingly used validated measures of weight discrimination. Out of the 11 studies, eight (72 %) utilized a validated measurement of weight discrimination. Two studies utilized and adapted the Everyday Discrimination Scale (EDS; [36,37]), a measure aimed to capture general perceptions of unfair treatment, adapted for one's weight status/body size. Three studies (N = 3) utilized the Stigmatizing Situations Inventory (SSI; [24,38]), a validated measure of assessing situations where individuals perceive stigma due to their weight status. Two studies (N = 2) utilized the weight-bias internalization scale (WBIS; [39]) aimed to measure internalized weight stigma (i.e., negative attitudes about weight-related stereotypes directed at the self. One study operationalized weight discrimination with the Fat Phobia Scale Short Form (FPS-SF; [40,41]), assessing attitudes and prejudice towards fatness [32], and one study measured weight discrimination using the Anti-Fat Attitudes Questionnaire-Revised (AFA-Q Revised; [42,43]). Indeed, two studies ([26]; Hackett et al., 2023) utilized non-validated weight discrimination measures. Overall, all studies utilized self-report (N = 11), focusing on weight stigma and internalization rather than discriminatory events.

3.5. Covariates and other factors considered

Researchers incorporated numerous covariates into their research. Four studies (N = 4) controlled for Socioeconomic Status (SES), age, BMI, and ethnicity/race. Five studies (N = 5) controlled for general discrimination and perceived stress. Notably, only one study out of these five (Incollingo et al., 2019) controlled for 'multiple attributions' of discrimination (i.e., discrimination from other marginalized identities). One study (Himmelstein et al., 2015) controlled for negative affect. Other contextual factors considered were education level (N = 1; [19]), depression (N = 1; [32]), and days since the last menstrual cycle (N = 1; [32]). One study that examined weight discrimination and cortisol in pregnant women also controlled for c-sections (Incollingo et al., 2019).

3.6. Summary of findings across studies

The relationship between cortisol output and weight discrimination was not consistently significant. Only 5 of the 11 (54.54 %) studies found a positive and significant association between cortisol output and weight discrimination, with five studies reporting multiple effect sizes. For example, Tomiyama et al. [19] reported a significant and positive relationship between weight stigma frequency in the morning and cortisol awakening response (i.e., two effect sizes). Jackson and colleagues [26] found that when controlling for age, sex, ethnicity, and SES, weight discrimination (retrospective) was related to greater cortisol output via hair. The evidence supporting a positive relationship was stronger than evidence identifying opposing results (N = 2; See Table 1). Even within the studies finding a negative relationship, the findings were not unilaterally supportive of this relationship. For instance, Jung et al. (2020) found that individuals with lower weight bias

Table 1
Summary of studies included in review.

Authors	Study Design	N	Mean Age	BMI	Target Group	Ethnicity/Race of Participants (%)	Covariates	Cortisol Measurement	Time of Testing	WD Measurement	Type of Analysis	Significant (Directionality)
Tomiyama et al., [19]	Longitudinal	45	40.9	31.35	Adult Women with overweight/ obesity	White 61.70 %, Asian/Pacific Islander 19.10 %, and Hispanic/ Latino 14.90 %	SES, Education Level, Perceived Stress Scale	Saliva diurnal cortisol sampling	Samples collected across 4 days at awakening, 30 min post awakening, and across 3 days hourly between 1:00 and 4:00 p.m., and bedtime.	The Stigma Consciousness Scale (Pinel, 1999) and The Stigmatizing Situations Inventory [25]	Bivariate Correlation	Weight stigma frequency and morning serum cortisol levels (+ and significant) 2. Weight stigma frequency and cortisol awakening response (+ and significant)
Jackson et al., 2016 [26]	Longitudinal	563	67.7	34.1	Adults with overweight/ obesity	98 % White	Age, sex, ethnicity, and socioeconomic status (SES) were included as control variables.	Hair cortisol concentrations were determined from the scalp-nearest 2-cm hair seg	Not reported	MIDUS and the Health and Retirement Study-Perceived Discrimination Questionnaire*	ANCOVA result	The association between weight discrimination and hair cortisol was positive and significant (+ and significant)
Incollingo Rodriguez et al., 2016 [27]	Experimental	122	19.26	22.03	Adults with overweight/ obesity (Simulated)	34 % White, 19 % Asian, 1.9 % African American. 22.6 % Latino	SES	Saliva samples collected via passive drool at baseline and after the eating and drinking tasks.	Not reported	Revised Anti-Fat Attitudes Questionnaire [35,36]	ANCOVA and PROCESS Moderation	Cortisol at time 1 was significantly higher in the stigma condition compared with control (- and significant). Results indicated participants' perceptions of their own body weight (but not objective BMI) moderated the effect of weight stigma on cortisol reactivity
Himmelstein et al., 2015 [28]	Experimental	110	19.74	24.17	Undergraduate women	15.5 % White, 4.5 % Black, 20.9 % Hispanic, .9 % Native American, 1.8 % Middle Eastern, 37.3 % Asian, 18.2 % multiracial	Negative Affect, BMI, Age	Saliva samples collected via passive drool measured cortisol at baseline and 30 min post-manipulation	Not reported	Weight discrimination Condition	Mean Difference T-Test	Participants who reported an average self-perceived weight discrimination had lower cortisol before the manipulation in the control condition compared with the stigma condition (+, significant)
Incollingo Rodriguez et al., 2019 [29]	Longitudinal	214	25.24	"Pre-pregnancy: 30.34 6 months postpartum: 32.06"	Pregnant women with self-identified weight discrimination	50.5 % Black 23.4 % Latina 26.2 % White	race, age, education, c-section, multiple attributions (meaning that participants reported also experiencing	Diurnal saliva cortisol samples at both 6 months and 1 year postpartum	Not reported	Everyday Discrimination Scale [29]	Hierarchical regression	Not significant increase in 6-month total daily cortisol and 1-year total daily cortisol (+, non-significant)

(*continued on next page*)

Table 1 (*continued*)

Authors	Study Design	N	Mean Age	BMI	Target Group	Ethnicity/Race of Participants (%)	Covariates	Cortisol Measurement	Time of Testing	WD Measurement	Type of Analysis	Significant (Directionality)
							discrimination based on other identities in addition to weight/height)					
Nicolau et al., 2023 [30]	Cross-sectional	79	45.5	35.9	Adults with overweight/ obesity	100 % White	None	Plasma cortisol levels measured at 8 a.m. after overnight fast of at least 8 h	8:00 a.m.	Weight bias internalization scale (WBIS; [32]) and the Stigmatizing Situations Inventory (SSI; [31])	Bivariate Correlation	Positive, significant relationship between cortisol and weight stigma (+, significant)
Huynh et al., 2016 [31]	Longitudinal	292	16.39	measured but did not report	Adolescents from schools with large Asian, European, and Latin American backgrounds	42 % Latin American, 29 % European, 23 % Asian, 6 % other ethnic backgrounds	age, sex, ethnicity, household income, and BMI	5 saliva samples over 3 consecutive days (when they wake up, 15 min after wake, 30 min after wake, before dinner, and at bedtime).	Not reported	Expanded Version of the Everyday Discrimination Scale [30]	Bivariate Correlation	Weight/height-specific discrimination was not significantly related to AUC cortisol output, controlling for Wake time, age, and discrimination (-, non-significant)
Schvey et al., 2014 [32]	Experimental	123	26.98	27.05	18–50 year old women who were lean (BMI = 18.5–24.9) or overweight (BMI great than or equal to 25); 7 participants had "underweight" BMI	51.2 % White, 19.4 % Black, 12.4 % Asian, 7.8 % Hispanic, 3.9 % Native American, and 5.4 % "other"	age, race, BMI, stress, depression, time since waking, days since last menstrual cycle	Saliva sample measured both before and after experimental video	Not reported	The Fat Phobia Scale (shortened form; [34])	ANCOVA	A significant time by condition interaction on cortisol reactivity, such that when in the stigmatizing condition, regardless of body weight, women experienced a significantly smaller decline in cortisol level from pre-video to post-video as compared with those in the neutral condition (+, significant) sustained cortisol elevation, whereas those in the neutral condition experienced a greater decline from pre-video to post-video.
Jung et al., 2020 [33]	Experimental	79	32.4	35.5	Adults with BMI greater than 30 kg/m2	Did not report	Did not report	Saliva collected at baseline, after the first stage of experiment, and	Not reported	Modified Weight Bias Internalization Scale (WBIS-M)	ANOVA	Individuals with lower levels of internalized stigmatization have

(*continued on next page*)

Table 1 (*continued*)

Authors	Study Design	N	Mean Age	BMI	Target Group	Ethnicity/Race of Participants (%)	Covariates	Cortisol Measurement	Time of Testing	WD Measurement	Type of Analysis	Significant (Directionality)
								then two more samples were taken at end of experiment.		(Durso, Latner, & Hayashi, 2012).		higher cortisol levels at the beginning of Time 1; however, this difference was not significant Significant differences can be found directly after the test phase Participants with low internalization have higher cortisol responses than participants with moderate or high internalization (-, significant).
Wu et al., 2019 [34]	Cross-sectional	166	45.7	26.6	Asian Americans with overweight/obesity (between age 21–65)	94 % first-generation Asian Americans	age, BMI, years lived in Asia, years lived in U.S., frequency of swimming, frequency of hair wash, level of acculturation, level of perceived racism, level of perceived stress	50-mg hair cortisol sample	Not reported	Stigmatizing Situations Inventory (SSI; [25])	Regression	Weight stigma negatively and not significantly predicted cortisol output (-, non-significant).
Hackett et al., 2023 [35]	Longitudinal	4341	66.62	30.37	Adults over 50 with overweight/obesity	97.9 % White, 2.1 % other	age, sex, ethnicity, SES, BMI	hair cortisol (at least 10 mg)	Not reported	MIDUS and the Health and Retirement Study-Perceived Discrimination Questionnaire*	Regression	Those with higher hair cortisol concentration were more likely to have experienced perceived weight discrimination (+, significant).

Note. *Not a validated measure of weight discrimination; WD Measurement = Weight Discrimination Measurement.

internalization had higher cortisol levels at one time. However, these findings were not significantly different in the test phase. Interestingly, in this study, cortisol responses among participants with lower internalization were not significantly different from the cortisol responses among those with higher internalization. Three studies were identified as having non-significant findings, and two trending toward negative relationships. One of these studies found a negative, non-significant relationship between weight discrimination, such that a non-significant negative relationship between weight stigma and cortisol output was detected (Wu et al., 2019). A second study found that weight/height-specific discrimination did not significantly relate to cortisol output, where a negative, non-significant association was reported.

4. Discussion

The current systematic review had three aims: The first was to describe the relationship between measured cortisol levels and perceived discrimination against weight-minoritized populations. The second aim was to describe the nature of moderators and covariates in relation to salivary cortisol levels and perceived discrimination across studies. Overall, there was inconsistent evidence to conclude a significant relationship between cortisol activity and weight discrimination. Significant findings were identified in six of the eleven reported studies. Despite this somewhat limited finding, only two studies identified a negative relationship between weight stigma and cortisol levels, with the remaining studies making no significant conclusions. The lack of a scientific consensus but skew towards a positive relationship between weight stigma and cortisol suggests the possibility of other variables, such as measurement strategies impacting outcomes.

Significant variability existed in the measurement of stigma across published studies. Across the eleven studies, fifteen metrics of weight stigma were collected. Of those fifteen metrics, the same measure was rarely utilized more than once. The Stigmatizing Situations Inventory was used in three of the eleven studies, and the MIDUS and Health and Retirement Study-Perceived Discrimination Questionnaire were each used twice. Similar measures were reported twice, with one study using the Everyday Discrimination Scale and one Using the expanded version of the same measure. Similarly, one study utilized the Weight Bias Internationalization Scale, and a second used the Modified Weight Bias Internationalization Scale. While not appropriate for statistical analysis given the number of studies identified, there is some preliminary evidence that the choice of measure may have impacted outcomes. Both studies that utilized a version of the Everyday Discrimination Scale reported non-significant findings. Studies that measured stigma using the MIDUS and Health and Retirement Study-Perceived Discrimination Questionnaire reported significant positive relationships. Other measures were indicative of variability in outcomes. Two studies utilizing the Stigmatizing Situations Inventory reported a significant positive relationship, whereas the third identified a non-significant negative one. Studies utilizing the Modified Weight Bias Internalization Scale reported contradictory findings, with one reporting a significant positive relationship and the other reporting a significant negative one. Each of these measures assessed slightly different facets of a latent construct—consequently, each measure captured elements of the construct associated with cortisol in different ways.

Like the measurement of weight stigma, cortisol was assessed using various techniques. Seven of the eleven studies utilized a saliva sample in some capacity, with meaningful variability between studies related to the technique used to collect the sample. Four studies that utilized a saliva sample reported significant positive relationships between the experience of discrimination and cortisol levels, two reported significant negative relationships, and the remaining two identified no significant relationship. Three studies measured hair cortisol concentrations; two reported significant positive relationships between cortisol and stigma. The third study that utilized a hair cortisol measurement strategy reported no significant findings. The final study measured cortisol levels in a plasma sample. This study identified a significant positive association between the experience of weight stigma and cortisol levels. Given the limited number of studies utilizing each technique, it is challenging to draw compelling conclusions about the impact of cortisol measurement strategy on outcomes. However, small variability in techniques can have significant ramifications for outcomes, even when using the same medium of cortisol [44]. Consequently, it is possible that some of the inconsistencies in the findings may result from inconsistencies in measurement. This may be reflected in the current review of salivary cortisol measurement. Researchers interested in addressing this measurement variability may consider utilizing a multimodal assessment technique of cortisol to better understand the ramifications of each measurement strategy.

In addition to measurement strategies, context influences the relationship between weight discrimination and cortisol activity. Most studies controlled for BMI in examining weight discrimination and cortisol activity. This covariate is well-aligned with the literature, which suggests that adiposity is correlated with cortisol activity [45]. A complex relation between adiposity, weight discrimination, neuroendocrine activity, and disordered eating behaviors has also been identified. For example, Muenning and colleagues [46] found a positive relation between hypercortisolism and binge eating behaviors, as cortisol is known to be an appetite-activating hormone in the body's HPA system. While BMI was considered, no study to date has examined these factors in relation to disordered eating behaviors, which may be influenced by cortisol. Additionally, disordered eating is identified as a risk factor for cardiovascular disease and obesity [2]. Other covariates, such as socioeconomic status and neighborhood disadvantage, were considered in relation to weight discrimination and cortisol. Hackman and colleagues (2005) found that lower socioeconomic status is associated with higher levels of global life stress, which is related to adverse physiology (such as cortisol dysfunction). Neighborhood stress, social support, and citizen participation are potential risk factors for high cortisol reactivity [47]. However, measuring cortisol longitudinally with neighborhood stress found a hypercortisolistic (lower than average) profile. It is possible that chronic discrimination at the institutional level over a life span (i.e., living in a neighborhood for 20+ years) may influence the HPA system to lower its reaction to more minute, implicit discrimination in comparison to more direct, chronic discrimination at the interpersonal level. It also may be possible that these constructs, such as neighborhood-related stress and citizen participation, are seen as more "controllable" occurrences of chronic discrimination and may not be psychologically harmful as perceived discrimination that is coded as "uncontrollable" [2].

4.1. Limitations of the review and future directions

Despite notable strengths, such as racial and ethnic diversity and a wide range of study designs, there are notable limitations across the reviewed studies. Many reviewed studies utilized saliva measurements of cortisol, which have documented low reliability [48]. Additionally, several studies utilized a cross-sectional approach, therefore needed to establish temporal precedence on the relation between cortisol activity and weight discrimination limiting the causal attributions the current review aimed to clarify. Few studies provided information about the effects of perceived discrimination on cortisol over time.

Based on the current review's findings and the reviewed articles' limitations, there are multiple indicated directions to advance our understanding of the relationship between cortisol and stigma. Future studies should incorporate more real-time measurements of perceived discrimination, such as utilizing an Ecological Momentary Assessment and regular cortisol measurements. Such efforts would facilitate understanding the immediate and long-term effects of discrimination. Additionally, while most studies measured BMI, this was not universally practiced. Given the strong relation between adiposity and cortisol [2],

future studies should utilize an adiposity-independent approach to examine the relation between these constructs. Most studies utilized a global discrimination scale instead of a measurement that examined discrimination in relation to target identity (e.g., weight, race). Given the importance and complexity of identity across an intersectional framework, there is a need for a well-validated specific measurement tool for weight-related discrimination in conjunction with measuring other marginalized identities. To that end, future research should assess intersectional discrimination (i.e., being in a larger body, being a person of color) as not additive but comprehensively a distinct form of discrimination aside from weight discrimination alone. Finally, only one study examined negative affect as a potential moderator. Negative affect may indirectly impact the relation between discrimination and cortisol, such that high levels of negative affect may be attributed to elevated scores of perceived discrimination independent of actual discriminatory events (Yuri et al., 2009). While there are pragmatic limitations to the number of covariates that can be controlled, researchers should be cautious about uncontrolled predictors of cortisol. Researchers are encouraged to assess other contextual variables that may impact the relation between perceived discrimination and physiological health outcomes, such as foreign-born status and acculturative stress [2].

This systematic review has several important limitations. First, systematic reviews are ideally pre-registered on a repository (e.g., PROSPERO; [49]) to enhance transparency and reproducibility. However, the present systematic review did not utilize pre-registration. While the authors followed PRISMA guidelines, the lack of pre-registration could lead to potential biases min the inclusion and exclusion of studies. Secondly, given the focus of this review on a topic of investigation that can still be viewed as being in its infancy, a limited number of studies met the inclusion criteria. Consequently, the review has seemingly introduced more questions than it has answered. Our review focused exclusively on weight discrimination as the central form of discrimination; however, other forms of discrimination, such as sexual minority-related discrimination and foreign-born discrimination, may have similar impacts on cortisol. By focusing on the broader construct of general discrimination, it is possible that a consensus would have emerged in measurement strategies. Additionally, given that this is a systematic review, no overall effect size across studies was reported. As such, the strength of the relation between perceived discrimination and cortisol activity cannot be interpreted from this review. As more work is published on these constructs, a meta-analysis should examine the effects of varying forms of discrimination on cortisol output to suffice a comprehensive effect size.

5. Conclusion

This study aimed to examine the nature of the relationship between measured cortisol levels and weight related perceived discrimination, as well as examine moderators and covariates on the relation between cortisol levels and perceived discrimination across studies. A review of the extant literature indicated a trend toward a significant positive relationship between cortisol and perceived stigma, but there is no clear scientific consensus. Similarly, the review indicated the broad range of moderators and covariates that may influence the outcomes of future studies on this topic. The studies included in the review had significant variability in their measurement strategies in terms of measuring stigma and cortisol measurement. As such, it is unclear if the inconsistency in findings indicates the relationship between cortisol and perceived discrimination or reflects difficulty in consistently capturing the same constructs.

CRediT authorship contribution statement

Maria A. Kalantzis: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Formal analysis, Conceptualization. **Daniel M. Maitland:** Writing – review & editing, Resources, Investigation, Data curation. **Miranda Yannon:** Writing – original draft, Visualization, Resources, Formal analysis. **Christina Gaggiano:** Writing – original draft, Methodology, Formal analysis. **Jinbo He:** Writing – review & editing, Writing – original draft, Resources. **Aldo Barrita:** Writing – review & editing, Writing – original draft, Investigation. **Lorelai Symmes:** Writing – review & editing, Writing – original draft. **William H. O'Brien:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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