



OPEN

Effects of the healthy lifestyle community program (cohort 1) on stress-eating and weight change after 8 weeks: a controlled study

Corinna Anand^{1,2✉}, Karin Hengst¹, Reinhold Gellner¹ & Heike Englert²

Stress-eating (eating more or more unhealthily in order to accommodate to stress), contributes to the development and maintenance of obesity. The effect of comprehensive weight loss interventions on changes in stress-eating as well as the contributing role of stress-eating on weight reduction has not been examined. The impact of the 8-week intensive phase of the Healthy Lifestyle Community Programme (HLCP, cohort 1) on emotional, external and restrained eating, as expressions of stress-eating was evaluated in a non-randomized controlled trial. Intervention: 14 seminars (twice per week, including practical units), complemented by stress-regulation and cooking workshops and coaching sessions empowering participants to change their behaviour towards a healthy plant-based diet (ad libitum), stress regulation, regular exercise and to focus on social support. Participants were recruited from the general population. In the intervention group, 91 participants (IG; age: 56 ± 10 , 77% female) and in the control group, 52 (CG; age: 62 ± 14 , 57% female) were enrolled. At baseline, participants of the IG reported higher levels of stress (9.7 ± 5.4 points [P] vs. 7.6 ± 6.2 ; $p < 0.011$), and of emotional eating (27.9 ± 9.4 vs. 20.0 ± 7.1 ; $p < 0.001$) and external eating (29.1 ± 4.9 vs. 25.5 ± 5.6 ; $p < 0.001$) than participants of the CG. Within 8 weeks, in the IG, scores of emotional eating (-3.5 ± 5.4 P) and external eating significantly decreased ($= -2.0 \pm 3.8$ P), while restrained eating increased (2.7 ± 5.0 P; p for all < 0.001). Weight change was negatively correlated with change of external eating ($R^2 = 0.045$; $CC = -0.285$; $p = 0.014$), indicating that a greater weight change was associated with a smaller change of external eating. This is the first study to prospectively investigate the role of stress-eating on the weight reduction effect of comprehensive lifestyle interventions. Our data confirm that overweight is associated with EE and external eating and suggest that the HLCP is capable to reduce both, weight and stress-eating.

Trial registration: German Clinical Trials Register (DRKS; reference: DRKS00018821; September 18th 2019; retrospectively registered).

Abbreviations

BGC	Between group differences
BMI	Body mass index
CC	Correlation coefficient
CG	Control group
corr.	Corrected
DEBQ	Dutch Eating Behaviour Questionnaire
EE	Emotional eating behaviour
ExE	External eating behaviour
HLCP	Healthy Lifestyle Community Programme
IG	Intervention group
MLR	Multiple linear regression modelling
NCDs	Non-communicable diseases

¹Faculty of Medicine, University of Muenster (WWU), Muenster, Germany. ²Department of Food, Nutrition, Facilities, University of Applied Sciences Muenster, Corrensstraße 25, 48149 Muenster, Germany. ✉email: corinna.anand@uni-muenster.de

NW	Normal weight
OW	Overweight
P	Points
PSL	Perceived stress level
PSS-10	Perceived stress scale-10
RE	Restrained eating behaviour
SD	Standard deviation
WC	Waist circumference
WHO	World Health Organisation

Chronic stress and overweight are of major public health relevance and there is a growing body of evidence that suggests that these two phenomena are connected^{1–4}.

On the one hand, being overweight is associated with higher psychological stress⁵. For instance, people with overweight are confronted with psychosocial stress through weight stigma⁶, including prejudice, discrimination, and negative attitudes⁷. This is even the case for those who self-identify as being overweight but have a normal body mass index (BMI)⁸.

On the other hand, psychological stress is associated with overweight^{9,10}. Stress contributes to the development and maintenance of obesity via multiple pathways, including physiological, psychological and behavioural mechanisms^{10,11}. For instance, stress triggers physiological changes in the hypothalamic–pituitary–adrenal axis (e. g. cortisol dysregulation¹²) and reward processing in the brain and may induce overeating, especially of foods high in fat, sugar and energy¹⁰. As chronic positive energy balance is required to gain excessive weight, it is of great interest to understand how stress may contribute to overeating, which eventually leads to a positive energy balance¹³. There are three stress-related eating styles that indicate why people tend to eat more or more unhealthily in order to deal with the effects of stress:

Firstly, the concept of *emotional eating*, which is rooted in the psychosomatic theory^{14,15}, describes eating in response to emotional stressors instead of internal signals of hunger or satiety^{13,16}. Emotional arousal and stress may increase food intake in people with emotional eating behaviour¹³.

Emotional eating tends to co-occur with a second stress-related eating style: *external eating*, i.e. eating in response to environmental food cues such as picture of a well-known restaurant or the smell of tasty food^{13,16}, again regardless of internal signals of hunger or satiety. People with emotional eating behaviour tend to shift their attention away from negative internal states by narrowing it to the immediate (food) environment, resulting in external eating¹⁶.

As a third relevant stress-related eating style, (3) *restrained eating*, i.e. eating less than desired to regulate body weight^{16,17}, is of special interest in the context of obesity research. It is usually treated as a desirable and necessary trait in order to overcome overweight¹⁸. Yet, dieting and restraint can cognitively suppress feelings of hunger and appetite and are discussed to be a trigger for overeating^{19,20}. Under stressful conditions, when cognitive control is disrupted by a stressor, people with restrained eating behaviour tend to eat more than non-dieters¹³. Thus, stress may lead to obesity by hindering the cognitive processes required for self-regulation and regulation of food intake in order to induce weight loss^{7,10}.

Complicating matters, it is especially unhealthy energy-dense, highly palatable foods, high in sugar and fat, which are often eaten in response to stress²¹. Current evidence indicates that comfort food is capable of decreasing stress arousal²¹ as well as psychological²² and physiological stress^{23,24}, and excessive intake typically leads to overweight²⁵. Moreover, individuals with an unhealthy diet, e.g. low intake of vitamins and minerals, might have an increased susceptibility to stress²⁶.

While comprehensive lifestyle intervention programs, including our own^{27,28}, are suitable to induce weight loss and meet the complexity of sustainable behaviour change^{29,30}, little is known about the effect of such programmes on stress-related eating behaviour and its influence on the effectiveness of the interventions in terms of improving body weight. Some, however, suggest that interventions which target emotional eating in a combined approach are effective for adults with overweight and/ or obesity who report elevated emotional eating³¹ and for individuals with diabetes³². Hence, weight loss interventions may improve eating behaviour³³.

To our knowledge, there are no studies that have prospectively examined the mediating role of stress-eating on weight change in behavioural interventions. Few however, have examined the role of stress eating on weight change and therefore indicate that there may be a mediating effect^{34–38}. For instance, studies suggest that mindfulness-based interventions support weight loss especially in participants who report higher levels of stress-related eating³⁴, and positively affect overall metabolic health, e.g. weight and fasting glucose^{35–38}. Moreover, a 6-month acceptance-based behavioural intervention contributed to significant weight reduction in adults with overweight, who had higher baseline levels of emotional eating (as one expression of stress-eating) in an uncontrolled pilot study³⁹. Here, greater decreases in emotional eating were associated with even greater weight loss.

Research gap. As described, a reduction of stress-eating is a promising target in the endeavours to combat obesity. To date, however, no studies have prospectively investigated the role of stress-related eating behaviour on the weight reduction effect of comprehensive healthy lifestyle intervention programs using standardized and validated instruments and assessing key variables of eating behaviour. Moreover, there are no evidence-based interventions to adequately consider the complexity of the interactions of stress, stress-eating and overweight. Holistic lifestyle approaches seem suitable to consider these interactions. As stress and obesity are highly prevalent in society today, innovative interventions should be conducted on a community-scale to improve the combined challenge of stress-related eating and obesity.

Methods

Study aim and hypotheses. We examined the effects of the holistic Healthy Lifestyle Community Programme (HLCP, cohort 1) on changes in stress-related eating behaviour, represented by emotional, external and restrained eating¹³, through the adoption of a healthy lifestyle, characterized by (1) good stress management^{10,40}, (2) a healthy diet^{41,42}, (3) regular physical activity⁴³ and (4) social support⁴⁴.

We hypothesized that weight change in participants with a low level of perceived stress would be more pronounced than in those with a high level of perceived stress.

We further hypothesized, that levels of emotional and external eating behaviour would be reduced and levels of restrained eating behaviour would be increased in participants of the intervention group (IG) after 8 weeks compared to baseline and compared to participants of the control group (CG).

Moreover, we hypothesized that changes in stress-eating would be positively correlated with weight change. A primary report on the effect of the HLCP regarding weight reduction and the metabolic risk profile of non-communicable diseases (NCDs) in the long-term is reported elsewhere²⁷.

Study design. This report is based on a secondary analysis after 8 weeks, based on a non-randomized, controlled intervention trial with a duration of 24 months²⁷. The intervention in this study consisted of the HLCP (cohort 1). The control group received no intervention. In the main analysis²⁷, the long-term effects of the HLCP on weight and cardiometabolic risk markers were evaluated.

Study population. The sample size was calculated for the primary outcome of weight reduction²⁷ and eligible participants were included into the present secondary analyses, accordingly. We recruited participants from the general population, as the HLCP followed a real-world community-approach, which has been described before²⁷. Hence, we included not only participants with overweight and obesity but also persons who with normal-weight.

Participants of the intervention group and control group were recruited in two separate small municipalities ('intervention municipality' and 'control municipality') to keep the participants of the control group unaware of the lifestyle recommendations given to the intervention group. The complex real-world approach of our study, required involvement of local stakeholders within the 'intervention municipality'⁴⁵ in the planning stage and before recruitment was initiated, which is why randomization was not feasible (as described previously^{27,46}). Accordingly, participants from the 'control municipality' did not receive the intervention.

As with all lifestyle interventions, blinding of participants or instructors to group allocation was not possible (as described previously^{46,47}). The study was registered in the German Clinical Trials Register (DRKS; reference: DRKS00018821; www.drks.de, retrospectively registered).

Participants ≥ 18 years who were capable of understanding the study content were included. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the Westphalia-Lippe Medical Association and the Muenster University (Muenster, Germany; reference: 2017-105-f-S; approved 5 April 2017). All participants provided written informed consent.

Participants' flow diagram. A participants' flow diagram shows the study process from enrolment to analysis in Fig. 1. Before the onset of the study, 15 participants declined to participate. At baseline, 91 participants were included in intervention group and 52 in control group.

Data assessment. *Health check-ups.* Baseline data were collected in April and October 2017 in intervention group and control group, respectively (see²⁷), and equivalently in both groups after 8 weeks (i.e. the intensive phase of the HLCP in the intervention group). Unfavourably, it was not possible to recruit and start both study arms at the same time. This was due to the fact that funding was provided at relatively short notice, resulting in insufficient time and staff.

Anthropometric parameters. Body weight was determined by calibrated body scales, body height by self-report and BMI (kg/m^2) was calculated accordingly. Waist circumference was measured according to the WHO protocol⁴⁸.

Stress-related eating behaviour. Participants answered the German version of the Dutch Eating Behaviour Questionnaire (DEBQ)^{13,17}, which assesses three dimensions of stress-related eating behaviour (33 items): (1) *emotional eating* (e.g., "Do you have the desire to eat when you are irritated?"), (2) *external eating* (e.g., "Do you eat more than usual when you see others eating?"), and (3) *restrained eating* (e.g., "Do you deliberately eat less in order to not become heavier?"). The instrument has been shown to have good reliability (emotional eating: Cronbach's alpha [α] = 0.94, external eating: α = 0.89 restrained eating: α = 0.92) and construct validity, and to be suitable to reliably measure eating styles across age, gender, and BMI-status¹³. Responses were provided on a 5-point Likert scale ranging from 1 (seldom) to 5 (very often), resulting in maximal points of 65 for emotional, 50 for external, and 50 for restrained eating. Higher scores indicated a stronger expression of the respective eating behaviour.

Perceived stress level. In order to assess the psychosocial stress status, participants completed the German version of the Perceived Stress Scale-10 (PSS-10)⁴⁹. Each item (e.g. "In the last month, how often have you felt that you were unable to control the important things in your life?") was rated on a 5-point Likert scale ranging from 0 (never) to 4 (very often) resulting in maximal points of 40, with higher scores indicating higher levels

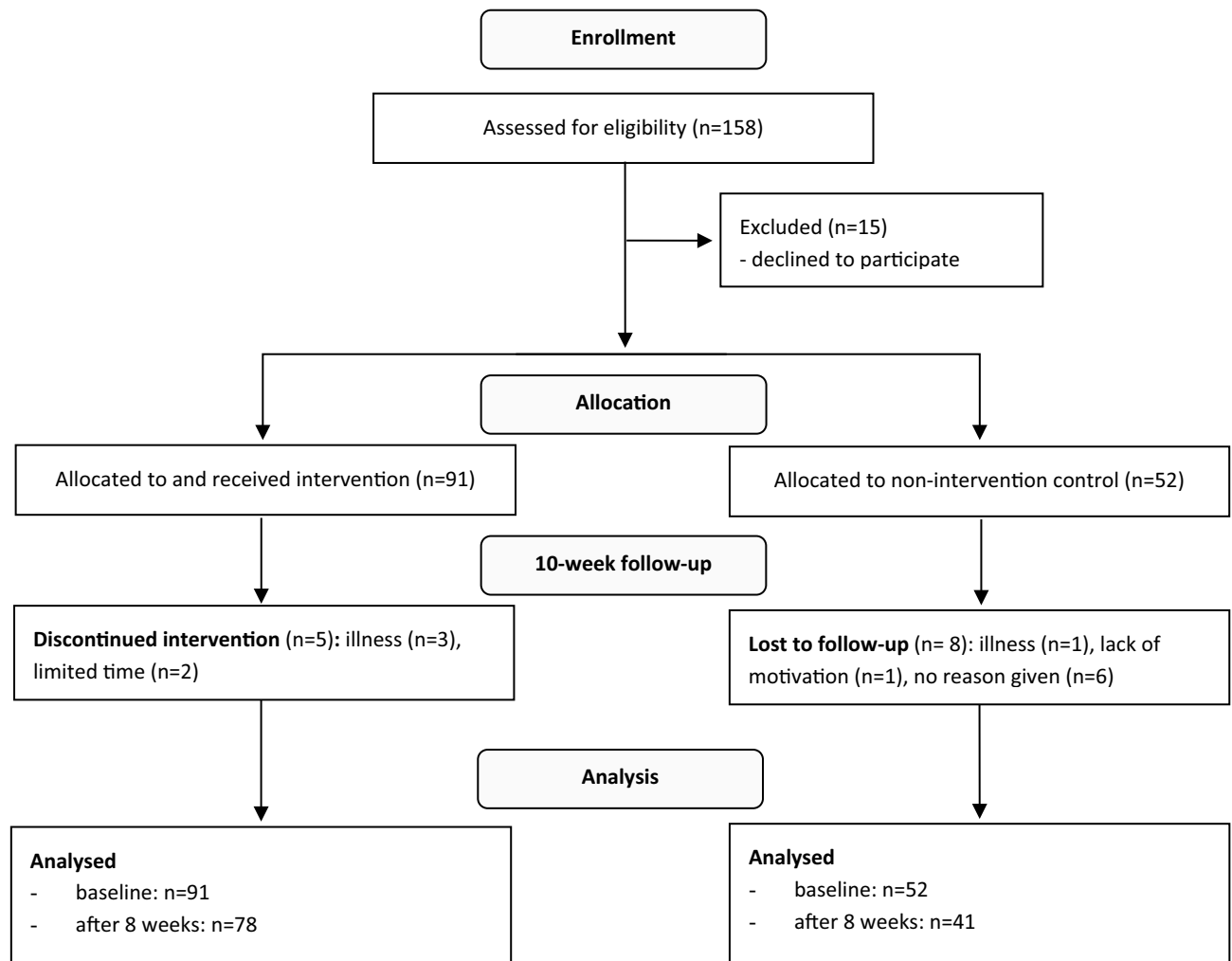


Figure 1. CONSORT structure participants' flow diagram; participants categorized as “lost to follow-up” withdraw from the study with the given reason. In the IG, information is given on how many participants discontinued the intervention (e.g. dropped out) and why.

of perceived stress. In order to compare high stress vs. low stress, participants who scored ≥ 14 on the PSS-10 at baseline were allocated to the high stress group⁵⁰.

Further parameters. In the main analysis of the study²⁷, additional parameters were assessed, including sociodemographic characteristics (e.g. age and sex), blood parameters (e.g. fasting glucose, insulin, lipids), vital parameters (e.g. blood pressure) as well as hormonal stress status (i.e. cortisol awakening response⁴⁷) amongst others⁵¹.

Lifestyle intervention. The intervention was led by the study team and cooperating health care providers (e.g. local practitioners) and has been described in detail previously²⁷. In short, the 8-week intensive phase of the comprehensive HLCP started and ended with an individual health check-up, including the above-mentioned parameter assessment, and a personal coaching session for every participant. Here, health check-up results, personal goals and options for lifestyle and eating behaviour change were discussed.

After the coaching sessions, the intensive phase continued with 14 consecutive seminars (twice per week for 2 h each) with a strong emphasis on the potential of behaviour change, perception of internal signals (e.g. appetite, hunger, frustration, stress or eating with pleasure) and community support as well as improvement of self-efficacy and relapse prevention. The four main topics of lifestyle change included a healthy, predominantly plant-based diet, stress regulation, physical activity, and social health²⁷. One of the 14 seminars was exclusively about stress as a health factor, including information about stress-eating. Exercises on stress regulation and mindful eating (e.g. ‘eating meditation’) were integrated into all seminar sessions. Moreover, participants were guided to reflect their own eating behaviour and to change towards healthy, more plant-based dietary patterns using vivid study material (e.g. recipe book, training manual, pleasure exercises). Crucially, participants were empowered to improve their practical cooking and food preparation skills (e.g. presentation of healthy food and live-preparation of healthy plant-based recipes within the seminars), Additionally, cooking workshops (goal:

try out and learn new healthy recipes with like-minded people) and *stress-and-eating-workshops* (goal: reflect persona eating behaviour in the context of stress in an environment of trust) were offered in smaller groups (~20 participants; ~2-h duration) to allow for more room for individual self-reflection and change strategies as well as to strengthen group support.

After the intensive phase of 8 weeks, a subsequent 22-months-alumni-phase with a less intensive intervention followed. Here, participants joined monthly meetings (2 h each) in which contents of the intensive phase were refreshed and group support was strengthened. Notably, results of this follow-up phase are not part of this sub-study.

Control group (CG). Participants of the control group did not receive any intervention. For ethical reasons, they were informed about their health check-up results and were offered to participate in a subsequent HLCP after completion of the study.

Statistics. Continuous variables are presented as mean \pm standard deviation (SD), categorical variables as frequencies and valid percent. Normality was tested using the Shapiro–Wilk test and judged by histograms. All data were analysed in accordance with the predefined study plan. All available data were analysed. Missing data were not imputed.

To compare intervention group and control group, independent t-test was used for normally distributed continuous variables (e.g. changes of eating behaviour scores) and Mann–Whitney *U* test as its nonparametric alternative. For dichotomous variables, Fisher’s exact test was used. Within-group comparisons were performed by one sample *t*-test for normally distributed variables. Otherwise the nonparametric Wilcoxon signed-rank test was performed. All tests were two-sided. Relations between two continuous variables (e.g. weight change and change of emotional eating) were assessed with Spearman correlation coefficient (two-sided).

Subgroups were formed to separately analyse the weight reduction effects of the intervention in participants who were overweight and normal-weight and in participants with high and low stress levels.

Multiple linear regression modeling (MLR) was used to explore the effect of the intervention on the change of stress eating dimensions, adjusting for sex and the baseline value of the respective variable. Variables found to be associated with change of DEBQ and PSS-10 parameters were also added as covariates (in addition to the group variable) to the multiple regression model using a forward–backward selection approach. Regression models that were statistically relevant ($p \leq 0.05$), with the highest corrected R^2 , and the lowest number of covariates were selected. In all models, residuals have been checked for normality.

p -values < 0.05 are considered significant, and are to be understood as exploratory⁵² because all presented data are secondary outcome parameters. All available cases were used.

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp.

Ethics approval and consent to participate. The study was conducted in accordance with the Declaration of Helsinki and the study protocol was reviewed and approved by the ethics committee of the Westphalia-Lippe Medical Association and the Muenster University (Muenster, Germany; approval number 2017-105-f-S; approved April 5th 2017). All participants provided written informed consent.

Results

Baseline characteristics of the intervention and control group. Participants of the intervention group attended 9 out of 14 seminars (63%), on average. Baseline characteristics of intervention group and control group are shown in Table 1. The groups showed statistically relevant differences: participants of the intervention group were younger ($p < 0.001$), more often female ($p = 0.024$), had a higher BMI ($p = 0.020$) and were more often overweight ($p = 0.015$). They also reported higher levels of emotional ($p < 0.001$) and external eating behaviour ($p < 0.001$) as well as a higher average perceived level of stress ($p = 0.011$).

Association of stress, stress-eating and weight status (both groups combined). Spearman correlation analyses revealed no significant correlation of the BMI and perceived stress level ($p = 0.065$; see Table 2). But highly stressed participants (PSS-10 ≥ 14 points) of both groups combined ($n = 32$) had a higher BMI (31 ± 8 kg/m²) than those with a low stress level (27 ± 6 kg/m²; $p = 0.006$).

Due to sex-specific reference values, men and women were analysed separately regarding the connection of stress level and waist circumference ([WC] high-risk WC for men ≥ 102 cm and for women ≥ 88 cm, respectively). Women with a high level of perceived stress more often had a high-risk waist circumference (86% [$n = 24$]) than those with a low stress level (61% [$n = 43$]; $p = 0.029$). In men, we detected no statistically relevant connection ($p = 0.122$). However, only 4 men had a high-risk waist circumference and all of them reported a high stress level at baseline.

Accordingly, male and female participants with a high perceived stress level had a higher WC than those with a low stress level (men: 134 ± 20 vs. 104 ± 11 ; $p = 0.008$; women: 99 ± 13 vs. 93 ± 14 ; $p = 0.049$). In men, a higher waist circumference was associated with external eating (correlation coefficient [CC] = 0.346; $p = 0.029$), whereas in women higher waist circumference was associated with a higher emotional eating score (CC = 0.265; $p = 0.010$).

A higher perceived stress level was also associated with higher scores of emotional and external eating behaviour, but not of restrained eating behaviour (see Table 2).

Participants who were overweight ($n = 91$) scored higher than participants with normal weight ($n = 45$) in emotional eating behaviour (27 ± 10 points [P] vs. 21 ± 8 P; $p = 0.002$) and external eating behaviour (29 ± 5 P vs. 26 ± 5 P; $p = 0.010$). The positive association between the BMI, emotional and external eating behaviour was

	Intervention	Control	p-value
	n = 91	n = 52	
Sociodemographics			
Age, mean \pm SD	56 \pm 10	62 \pm 14	< 0.001^a
Female, n (%)	70 (77)	31 (57)	0.024^b
Anthropometrics			
Weight (kg), mean \pm SD	85 \pm 19	80 \pm 18	0.113 ^a
BMI (kg/m ²), mean \pm SD	29 \pm 5	27 \pm 7	0.020^a
Participants with overweight/obesity ^c , n (%)	67 (74)	28 (55)	0.015^b
WC (cm), mean \pm SD	98 \pm 14	98 \pm 17	0.770 ^a
Participants with elevated WC ^d , n (%)	60 (67)	31 (61)	0.465 ^b
Psychosocial stress parameters			
Stress-related eating scores ^e , mean \pm SD	n = 88	n = 48	
Emotional eating behaviour	27.9 \pm 9.4	20.0 \pm 7.1	< 0.001
External eating behaviour	29.1 \pm 4.9	25.5 \pm 5.6	< 0.001
Restrained eating behaviour	28.7 \pm 6.5	28.9 \pm 7.6	0.547
Perceived stress score ^f , mean \pm SD	9.7 \pm 5.4	7.6 \pm 6.2	0.011^a
High stress level ^g , n (%)	23 (25)	11 (21)	0.684 ²

Table 1. Baseline characteristics by study group (n = 143). Significant values are in bold. *BMI* Body Mass Index, *WC* Waist circumference, ^aMann–Whitney-*U* test, ^bFisher's exact test, ^cBMI \geq 25 kg/m², ^d \geq 102 cm and \geq 88 cm for men and women, respectively, ^eDutch Eating Behavior Questionnaire¹³, ^fPerceived Stress Scale (PSS)-10 score⁴⁹, ^gPSS-10 score \geq 14.

	n =	BMI		perceived stress level	
		CC	p =	CC	p =
Perceived stress level	138	0.158	0.065	–	–
Stress-related eating					
Emotional eating	117	0.326	< 0.001	0.520	< 0.001
External eating	117	0.264	0.002	0.344	< 0.001
Restrained eating	135	0.013	0.885	– 0.005	0.952

Table 2. Association between Body Mass Index (BMI), perceived stress (PSS-10) and stress-related eating behaviour in the intervention and control group (combined). Significant values are in bold. *BMI* Body Mass Index (kg/m²), *CC* Pearson correlation coefficient, *p* p-value.

also confirmed by Spearman correlation, but higher restrained eating behaviour was not linked to lower BMI (Table 2).

Changes of weight, stress level and stress-eating after 8 weeks. As described before⁵³, in the intervention group, weight decreased significantly after 8 weeks (-1.5 ± 1.9 kg) compared to baseline ($p < 0.001$), significantly more than in control group (-0.3 ± 1.7 kg; $p < 0.001$), and more distinctly in participants with overweight (-1.8 ± 2.0 kg)⁵³. Average perceived stress levels decreased after 8 weeks in the intervention group and the control group, resulting in no differences between the groups (Table 3).

In the intervention group, but not in the control group ($p > 0.158$), participants with a low stress level and who were overweight ($n = 45$) lost more weight (-2.0 ± 2.1 kg) than those with a low stress level who were of normal-weight ($n = 18$; -0.9 ± 1.1 kg; $p = 0.016$). There was no difference in weight reduction within the intervention group between participants with high and low stress levels ($p > 0.202$). Notably, the change of weight was neither associated with a change of perceived stress in all participants (IG: correlation coefficient [CC] = -0.034 ; $p = 0.765$; CG: CC = -0.178 ; $p = 0.307$) nor in subgroups of participants with overweight (IG: CC = 0.044 ; $p = 0.742$; CG: CC = -1.112 ; $p = 0.657$) or normal-weight (IG: -0.044 ; $p = 0.853$; CG: CC = -0.207 ; $p = 0.425$).

We did, however, observe a significant change of all scores of stress-related eating behaviour, i.e. a decrease of emotional and external eating and an increase of restrained eating in the intervention group (for all $p < 0.001$), but not in the control group, resulting in relevant between-group differences ($p < 0.05$; Fig. 2). Restrained eating behaviour in the intervention group changed significantly only in participants with overweight, but not in participants who were normal-weight (see Table 3).

As correlation analyses revealed, the weight reduction in the intervention group was not associated with a change of emotional ($p = 0.537$) or restrained eating ($p = 0.335$). However, weight change was negatively correlated

	Intervention group			Control group			BGC
	Baseline	Change	p [#] =	Baseline	Change	p [#] =	p ^{\$} =
Normal weight	n = 23	n = 20		n = 23	n = 20		
Perceived stress level	9 ± 4	- 3 ± 4	0.002	7 ± 5	- 2 ± 4	0.024	0.376
Emotional eating	23 ± 8	- 4 ± 5	0.002	20 ± 7	+ 2 ± 3	0.189	<0.001
External eating	28 ± 5	- 2 ± 3	0.027	25 ± 5	- 1 ± 3	0.550	0.246
Restrained eating	28 ± 7	+ 2 ± 6	0.121	29 ± 9	+ 2 ± 5	0.282	0.661
Overweight	n = 66	n = 58		n = 26	n = 21		
Perceived stress level	10 ± 6	- 3 ± 5	<0.001	8 ± 7	- 2 ± 4	0.039	0.841
Emotional eating	30 ± 9	- 3 ± 6	<0.001	20 ± 8	- 1 ± 3	0.165	0.110
External eating	29 ± 5	- 2 ± 4	<0.001	26 ± 6	- 1 ± 2	0.165	0.142
Restrained eating	29 ± 7	+ 3 ± 5	<0.001	29 ± 6	0 ± 4	0.223	0.025

Table 3. Change of perceived stress and stress-related eating behaviour after 8 weeks in participants with normal weight and overweight of the intervention and control group. Significant values are in bold. Normal weight (BMI < 25 kg/m²); Overweight (≥ 25 kg/m²); w = week; p[#] = within group p-value; p^{\$} = between group p-value; BGC between group comparison.

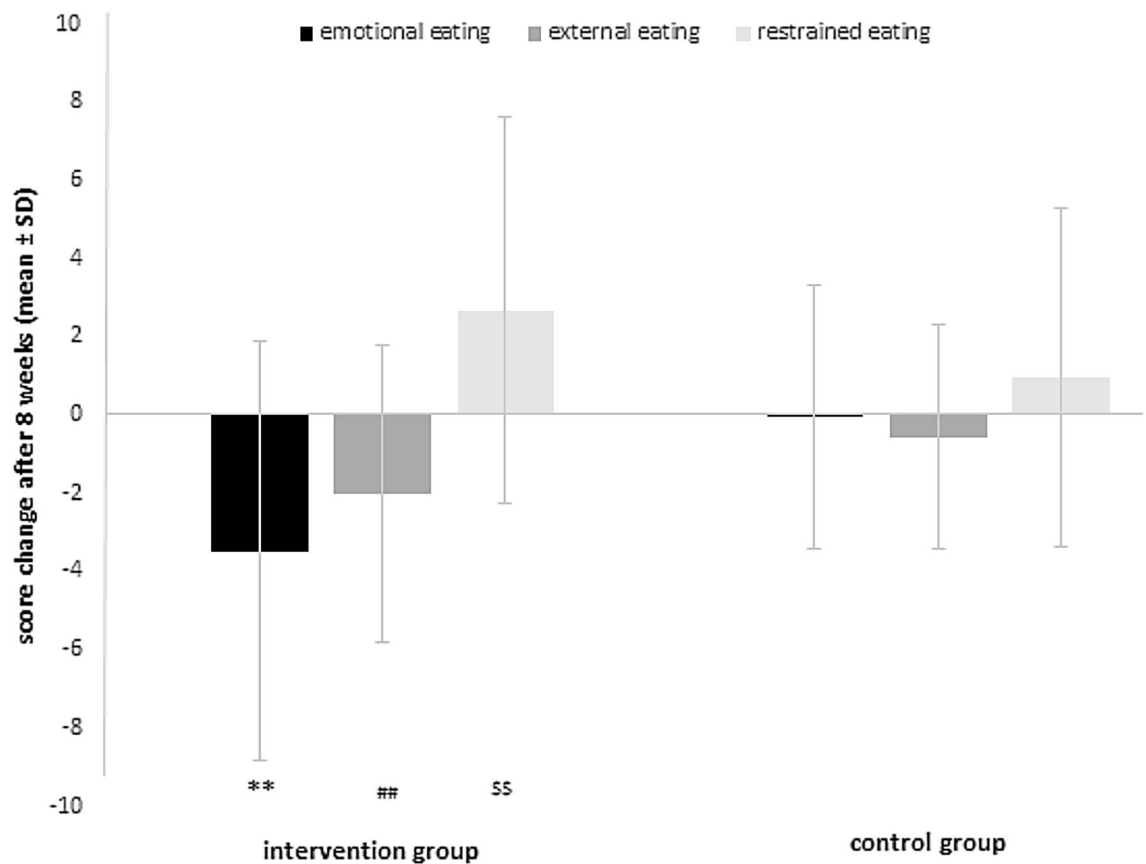


Figure 2. Change of stress-related eating behaviour in the intervention group (IG) and control group (CG); Changes of stress-eating scores: emotional eating: IG = - 3.5 ± 5.4 points (P); CG = - 0.05 ± 3.4 P; external eating: IG = - 2.0 ± 3.8 P; CG = - 0.6 ± 2.9 P; restrained eating: IG = 2.7 ± 5.0 P; CG = 1.0 ± 4.3 P. legend: **,##,\$\$p < 0.001. compared to baseline; **p < 0.001, ##p = 0.042, \$\$p = 0.024 compared to CG.

with external eating ($R^2 = 0.045$; $CC = -0.285$; $p = 0.014$; see Fig. 3) and this was even more pronounced in the overweight subgroup ($R^2 = 0.089$; $CC = -0.535$; $p < 0.001$). These results indicate that a greater weight change was associated with a smaller change of external eating behaviour. In further analyses, we found participants with lower baseline values of external eating tended to have a smaller decrease or even increase of external eating after 8 weeks ($R^2 = 0.173$; $CC = -0.442$; $p < 0.001$). Against this background, we tested if participants with a higher weight reduction, i.e. less change of external eating, had lower baseline values of the external eating score, but this was not the case ($R^2 = 0.005$; $CC = 0.049$; $p = 0.673$).

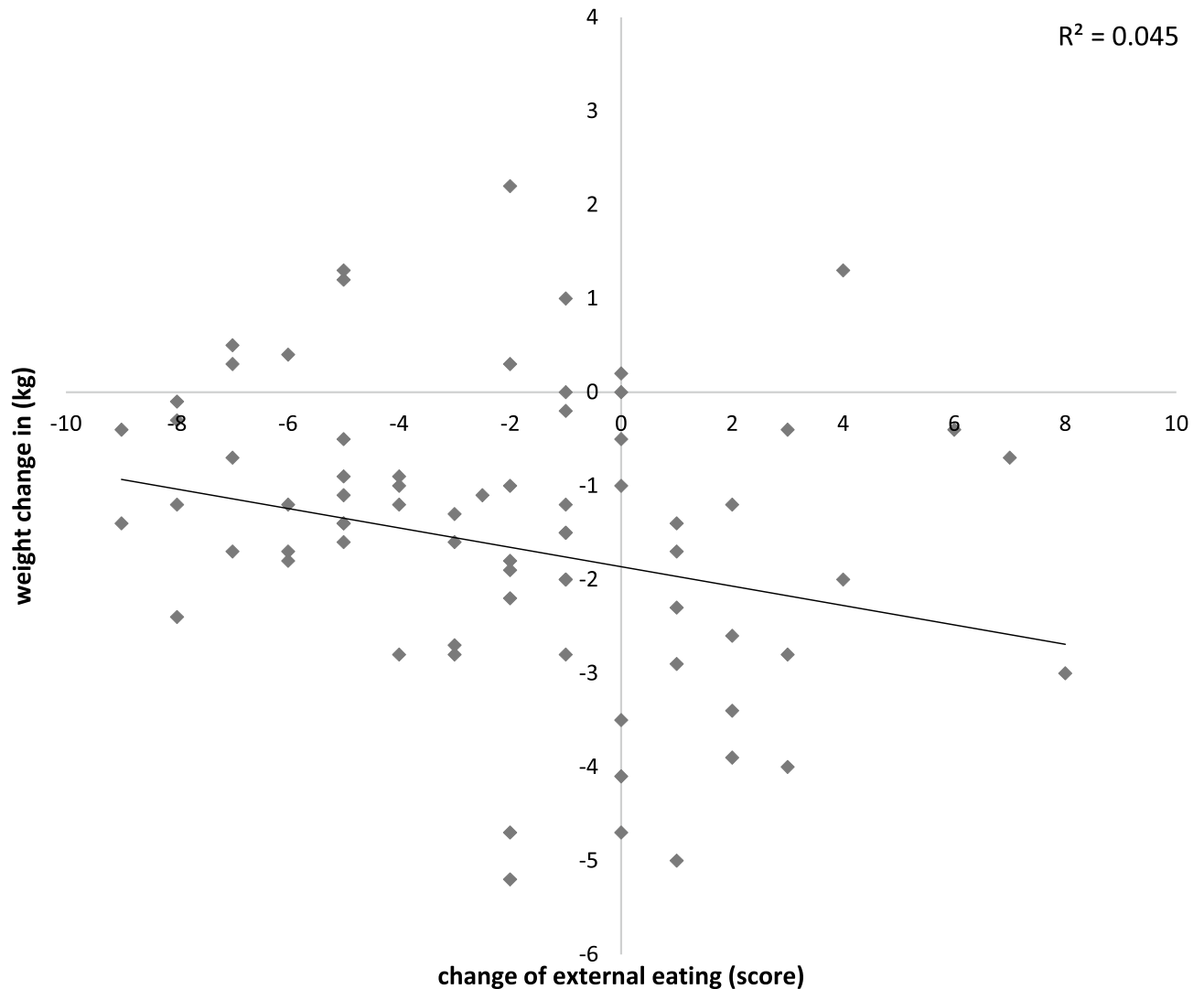


Figure 3. Correlation of the change of external eating and weight change in participants of the intervention group ($n = 78$) after 8 weeks; Spearman correlation coefficient (CC) = 0.285; $p = 0.014$.

Multiple linear regression modelling (MLR). When adjusting for the baseline value of the respective variables, MLR revealed no significant impact of the HLCP on emotional (corrected [corr.] $R^2 = 0.274$; $\beta = -1.438$; $p = 0.121$) or external eating behaviour (corr. $R^2 = 0.123$; $\beta = -0.603$; $p = 0.386$), but indicated an effect on restrained eating behaviour (corr. $R^2 = 0.203$; $\beta = 1.609$; $p = 0.049$).

However, the changes of the three stress-related eating styles were not predictive for weight loss in the intervention group (emotional eating: $p = 0.500$; external eating: $p = 0.071$; restrained eating: $p = 0.101$). In the control group, weight gain was predicted by an increase of emotional eating (corr. $R^2 = 0.219$; $\beta = -0.252$; $p = 0.004$).

The change of perceived stress did not qualify as a predictor for weight change ($p > 0.754$).

Discussion

The Healthy Lifestyle Community Program (HLCP, cohort 1) resulted in a change of stress-related eating behaviour after 8 weeks, which was measured by emotional and external eating, which decreased, and restraint eating, which increased. This is in line with our hypotheses before the onset of the study. Although, multiple linear regression modelling did not confirm a significant impact of the HLCP on emotional and external eating behaviour, its impact on restrained eating was significant. Moreover, we found that a greater weight reduction was associated with a smaller change of external eating scores in the intervention group, especially in participants who were overweight.

In the control group, an increase of emotional eating was predictive for weight gain.

In our sample, a higher BMI was linked to higher levels of emotional and external eating behaviour. Scores of emotional and external eating decreased significantly in the intervention group compared to baseline and more than in the control group. As these two eating styles are related to overeating in stressful situations and to overweight^{16,54}, the reduction is considered to support weight loss efforts⁵⁵. Moreover, a reduction of external

eating is desirable, because ubiquitously available energy-dense and highly palatable comfort foods challenge people with external eating behaviour²⁵.

Here, a more intuitive and mindful eating behaviour may contribute to the reduction of stress-eating^{56,57}. In accordance with our results, other interventions, combining mindfulness and cognitive behavioural approaches also resulted in reduced external^{35,58–60} and emotional eating^{55,56}. As O'Reilly and colleagues⁵⁷ summarized, interventions that reduced external eating typically included mindful eating components, which was also the case in the HLCP, i.e. exercises on these topics were incorporated in the HLCP seminars and workshops. However, in our multiple regression analyses, the group variable was not predictive for the change of stress-eating. A stronger emphasis on mindful eating might have led to clearer results here.

And yet, although we observed a reduction of emotional and external eating as well as weight⁵³ in the intervention group, correlation and regression analyses did not reveal that the changes of eating behaviour favoured weight loss. To the contrary, we found a negative association of the changes of external eating and weight, indicating that those participants who lost more weight changed external eating to a smaller extent than those who lost less or gained weight. These results are not consistent with the literature in this field. Existing evidence clearly suggests, that an increase of external eating is associated rather with weight gain than with weight loss^{17,35,57}. Compared to others, the change of external eating was relatively modest in our study. For instance, an eight-week healing meditation resulted in -7.9 points in women with overweight and obesity⁶¹. Assuming that participants with greater weight change may have started with low levels of external eating and therefore may have had smaller scope for change, was also not backed up by our analyses.

Moreover, the mediating effect of changes in stress-eating on weight change should be clarified in mediation models to give insights in the complex interaction of stress-related eating behaviour and weight reduction in the context of comprehensive lifestyle interventions.

Notably, the intervention group started with significantly higher levels of emotional and external eating behaviour than the control group. This might have influenced the results, as adjusting for baseline values did not identify the HLCP to be a significant predictor of stress-eating changes. Further research with more comparable groups may give valuable insights into the effect of the HLCP on emotional and external eating behaviour and their impact on weight change.

Importantly, the role of restrained eating behaviour as a dimension of stress-eating needs to be further explored. It is generally agreed, that cognitive control of food intake is necessary to successfully reduce weight, and results from the German Weight Control Registry underline, that weight-loss maintenance is associated with higher dietary restraint⁶². In line with this, our results indicate that the increase of restrained eating contributed to the weight loss effect of the HLCP. But, individuals with restrained eating behaviour are more likely to overeat when it comes to stressful events. For instance, a Malaysian study with nurses ($n = 1022$) documented that participants who were overweight tried to achieve an ideal weight by reducing their food intake, which, however, led to weight gain instead²⁰. Additionally, dietary restraint may leave individuals vulnerable to emotional eating in stressful situations¹⁹. As the three discussed dimensions of stress-related eating behaviour may reinforce each other, the individual may end up stuck in a vicious cycle⁶². Tomiyama concluded, that stress-induced eating may be difficult to eliminate because highly palatable foods are easily accessible, and eating is pleasurable and may therefore serve as a tempting coping mechanism to escape stressful situations¹⁰. Hence, holistic approaches for lifestyle change, providing comprehensive behavioural measures to reduce weight and stress-related eating behaviour are a great challenge and of great importance.

Moreover, rigid restraint may lead to the above-mentioned vicious cycle, but flexible restraint was shown to not promote weight gain⁶³ and to predict better long-term weight loss⁶⁴. Hence, encouraging flexible restraint may be important in preventing and treating obesity⁶⁵. However, we did not differentiate between rigid and flexible restraint in this study. In further research, measuring different types of restrained eating may give insight on whether the increase in restrictive eating behaviour was a healthy or unhealthy effect of the HLCP.

In accordance with other studies^{66–70}, our analyses indicate that a high perceived stress level is associated with overweight, higher waist circumference and higher levels of emotional and external eating behaviour. Underlining this, we observed that higher levels of emotional and external eating were associated with higher BMI and were more often reported by participants who were overweight, as it was described before⁷¹. Yet, we did not find the change of perceived stress to be associated to greater reduction of weight parameters. Significant interactions between changes in chronic stress and group condition, may indicate that a greater decrease of chronic stress may be related to greater decreases in weight parameters, as Daubermier et al. (2011) suggested for abdominal fat³⁵. Yet, we also did not find, that the intervention reduced perceived stress levels noteworthy compared to the control group⁵¹, allowing no such conclusion.

Some limitations of the study have to be mentioned. First, recruiting from the general population with regard to participation in the Healthy Lifestyle Community Program (HLCP, cohort 1) may have contributed to the considerable higher baseline levels of emotional and external eating, BMI and perceived stress in the intervention group (IG). Despite efforts to enrol comparable participants in both groups, it seems possible that recruitment of participants in the intervention group was influenced by the fact that they had a greater need for interventions to improve weight, eating behaviour, and their general chronic disease risk profile. Second, the mostly female sample might limit the generalizability of these findings. Third, in statistical analysis, subgroups (i.e. normal and overweight as well as high and low stress level) were built retrospectively and were not considered in the calculation of the sample size. Future studies examining the effect of the HLCP on stress-related eating should aim for a replication in a larger sample.

Conclusions

Our study is the first one to prospectively investigate the role of stress-related eating behaviour on the weight reduction effect of comprehensive healthy lifestyle intervention programs using standardized and validated instruments and assessing key variables of eating behaviour. Our data confirm the assumption that overweight is associated with higher levels of perceived stress as well as emotional and external eating and suggest that the Healthy Lifestyle Community Program (HLCP, cohort 1) may reduce the same, and increases dietary restraint. The impact of these changes on weight loss have to be further explored. Our findings underline the need to consider stress-associated eating behaviour in holistic weight loss interventions to account for the complex association of chronic stress, overweight, and obesity.

Data availability

The data are available from the corresponding author (CA) upon reasonable request.

Received: 9 March 2022; Accepted: 23 December 2022

Published online: 01 March 2023

References

- Williams, E. P., Mesidor, M., Winters, K., Dubbert, P. M. & Wyatt, S. B. Overweight and obesity: Prevalence, consequences, and causes of a growing public health problem. *Curr. Obes. Rep.* **4**, 363–370. <https://doi.org/10.1007/s13679-015-0169-4> (2015).
- O'Connor, D. B., Thayer, J. F. & Vedhara, K. Stress and health: A review of psychological processes. *Annu. Rev. Psychol.* **72**, 663–688. <https://doi.org/10.1146/annurev-psych-062520-122331> (2021).
- Suliman, S. *et al.* Posttraumatic stress disorder, overweight, and obesity: A systematic review and meta-analysis. *Harv. Rev. Psychiatry*. **24**, 271–293. <https://doi.org/10.1097/HRP.000000000000106> (2016).
- Wiss, D. A. & Brewerton, T. D. Adverse childhood experiences and adult obesity: A Systematic review of plausible mechanisms and meta-analysis of cross-sectional studies. *Physiol. Behav.* **223**, 112964. <https://doi.org/10.1016/j.physbeh.2020.112964> (2020).
- Sinha, R. & Jastreboff, A. M. Stress as a common risk factor for obesity and addiction. *Biol. Psychiat.* **73**, 827–835. <https://doi.org/10.1016/j.biopsych.2013.01.032> (2013).
- Brewis, A. A., Wutich, A., Falletta-Cowden, A. & Rodriguez-Soto, I. Body norms and fat stigma in global perspective. *Curr. Anthropol.* **52**, 269–276. <https://doi.org/10.1086/659309> (2011).
- Tomiyaama, A. J. Weight stigma is stressful: A review of evidence for the cyclic obesity/weight-based stigma model. *Appetite* **82**, 8–15. <https://doi.org/10.1016/j.appet.2014.06.108> (2014).
- Himmelstein, M. S., Incollingo Belsky, A. C. & Tomiyama, A. J. The weight of stigma: Cortisol reactivity to manipulated weight stigma. *Obesity* **23**, 368–374. <https://doi.org/10.1002/oby.20959> (2015).
- Wardle, J., Chida, Y., Gibson, E. L., Whitaker, K. L. & Steptoe, A. Stress and adiposity: A meta-analysis of longitudinal studies. *Obesity* **19**, 771–778. <https://doi.org/10.1038/oby.2010.241> (2011).
- Tomiyaama, A. J. Stress and obesity. *Annu. Rev. Psychol.* **70**, 703–718. <https://doi.org/10.1146/annurev-psych-010418-102936> (2019).
- Tsenkova, V., Boylan, J. M. & Ryff, C. Stress eating and health: Findings from MIDUS, a national study of US adults. *Appetite* **69**, 151–155. <https://doi.org/10.1016/j.appet.2013.05.020> (2013).
- Joseph, J. J. & Golden, S. H. Cortisol dysregulation: The bidirectional link between stress, depression, and type 2 diabetes mellitus. *Ann. N. Y. Acad. Sci.* **1391**, 20–34. <https://doi.org/10.1111/nyas.13217> (2017).
- Nagl, M., Hilbert, A., de Zwaan, M., Braehler, E. & Kersting, A. The German version of the Dutch eating behavior questionnaire: Psychometric properties, measurement invariance, and population-based norms. *PLoS ONE* <https://doi.org/10.1371/journal.pone.0162510> (2016).
- Kaplan, H. I. & Kaplan, H. S. The psychosomatic concept of obesity. *J. Nerv. Ment. Dis.* **125**, 181–201. <https://doi.org/10.1097/00005053-195704000-00004> (1957).
- Canetti, L., Bachar, E. & Berry, E. M. Food and emotion. *Behav. Proc.* **60**, 157–164. [https://doi.org/10.1016/S0376-6357\(02\)00082-7](https://doi.org/10.1016/S0376-6357(02)00082-7) (2002).
- van Strien, T. Causes of emotional eating and matched treatment of obesity. *Curr. Diab. Rep.* **18**, 35. <https://doi.org/10.1007/s11892-018-1000-x> (2018).
- van Strien, T., Bergers, J. F. G. & Defares, P. The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *Int. J. Eat. Disord.* **5**, 295–315 (1986).
- Peckmezian, T. & Hay, P. A systematic review and narrative synthesis of interventions for uncomplicated obesity: Weight loss, well-being and impact on eating disorders. *J. Eat. Disord.* **5**, 15. <https://doi.org/10.1186/s40337-017-0143-5> (2017).
- Polivy, J. & Herman, C. P. Dieting and binging: A causal analysis. *Am. Psychol.* **40**, 193–201. <https://doi.org/10.1037/0003-066X.40.2.193> (1985).
- Siew, H. H. Eating behaviour and its associations with overweight among nurses on shift duty in teaching hospital. *MH* **14**, 68–77. <https://doi.org/10.17576/MH.2019.1401.06> (2019).
- Adam, T. C. & Epel, E. S. Stress, eating and the reward system. *Physiol. Behav.* **91**, 449–458. <https://doi.org/10.1016/j.physbeh.2007.04.011> (2007).
- Finch, L. E. & Tomiyama, A. J. Comfort eating, psychological stress, and depressive symptoms in young adult women. *Appetite* **95**, 239–244. <https://doi.org/10.1016/j.appet.2015.07.017> (2015).
- Tomiyaama, A. J., Dallman, M. F. & Epel, E. S. Comfort food is comforting to those most stressed: Evidence of the chronic stress response network in high stress women. *Psychoneuroendocrinology* **36**, 1513–1519. <https://doi.org/10.1016/j.psyneuen.2011.04.005> (2011).
- van Strien, T., Roelofs, K. & de Weerth, C. Cortisol reactivity and distress-induced emotional eating. *Psychoneuroendocrinology* **38**, 677–684. <https://doi.org/10.1016/j.psyneuen.2012.08.008> (2013).
- Morris, M. J., Beilharz, J. E., Maniam, J., Reichelt, A. C. & Westbrook, R. F. Why is obesity such a problem in the 21st century? The intersection of palatable food, cues and reward pathways, stress, and cognition. *Neurosci. Biobehav. Rev.* **58**, 36–45. <https://doi.org/10.1016/j.neubiorev.2014.12.002> (2015).
- Geiker, N. R. W. *et al.* Does stress influence sleep patterns, food intake, weight gain, abdominal obesity and weight loss interventions and vice versa?. *Obes. Rev.* **19**, 81–97. <https://doi.org/10.1111/obr.12603> (2018).
- Anand, C. *et al.* Bridging the gap between science and society: Long-term effects of the healthy lifestyle community program (HLCP) on weight and the metabolic risk profile: A controlled study. *BMJ Nutr. Prev. Health* <https://doi.org/10.1136/bmjnp-2021-000340> (2022).
- Koeder, C. *et al.* Effect of a 1-year controlled lifestyle intervention on body weight and other risk markers (the healthy lifestyle community programme, cohort 2). *Obes. Facts.* **15**, 228–239. <https://doi.org/10.1159/000521164> (2022).

29. Wennehorst, K. *et al.* A comprehensive lifestyle intervention to prevent type 2 diabetes and cardiovascular diseases: The German CHIP trial. *Prev. Sci.* **17**, 386–397. <https://doi.org/10.1007/s11121-015-0623-2> (2016).
30. Wilson, K. Obesity: Lifestyle modification and behavior interventions. *FP Essent.* **492**, 19–24 (2020).
31. Braden, A. *et al.* An open trial examining dialectical behavior therapy skills and behavioral weight loss for adults with emotional eating and overweight/obesity. *Behav. Ther.* **53**, 614–627. <https://doi.org/10.1016/j.beth.2022.01.008> (2022).
32. Braden, A. *et al.* Emotional eating is associated with weight loss success among adults enrolled in a weight loss program. *J. Behav. Med.* **39**, 727–732. <https://doi.org/10.1007/s10865-016-9728-8> (2016).
33. Mason, C. *et al.* Eating behaviors and weight loss outcomes in a 12-month randomized trial of diet and/or exercise intervention in postmenopausal women. *Int. J. Behav. Nutr. Phys. Act.* **16**, 113. <https://doi.org/10.1186/s12966-019-0887-1> (2019).
34. Radin, R. M. *et al.* Do stress eating or compulsive eating influence metabolic health in a mindfulness-based weight loss intervention?. *Health Psychol.* **39**, 147–158. <https://doi.org/10.1037/hea0000807> (2020).
35. Daubenmier, J. *et al.* Mindfulness intervention for stress eating to reduce cortisol and abdominal fat among overweight and obese women: An exploratory randomized controlled study. *J. Obes.* **2011**, 651936. <https://doi.org/10.1155/2011/651936> (2011).
36. Daubenmier, J. *et al.* *Effects of a Mindfulness-Based Weight Loss Intervention in Adults with Obesity: A Randomized Clinical Trial* (Himmelfarb Health Sciences Library Immunology and Tropical Medicine, 2016). <https://doi.org/10.1002/oby.21396>.
37. Mason, A. E. *et al.* Reduced reward-driven eating accounts for the impact of a mindfulness-based diet and exercise intervention on weight loss: Data from the SHINE randomized controlled trial. *Appetite* **100**, 86–93. <https://doi.org/10.1016/j.appet.2016.02.009> (2016).
38. Mason, A. E. *et al.* Effects of a mindfulness-based intervention on mindful eating, sweets consumption, and fasting glucose levels in obese adults: Data from the SHINE randomized controlled trial. *J. Behav. Med.* **39**, 201–213. <https://doi.org/10.1007/s10865-015-9692-8> (2016).
39. Niemeier, H. M., Leahey, T., Palm Reed, K., Brown, R. A. & Wing, R. R. An acceptance-based behavioral intervention for weight loss: A pilot study. *Behav. Ther.* **43**, 427–435. <https://doi.org/10.1016/j.beth.2011.10.005> (2012).
40. Schneiderman, N., Ironson, G. & Siegel, S. D. Stress and health: Psychological, behavioral, and biological determinants. *Annu. Rev. Clin. Psychol.* **1**, 607–628. <https://doi.org/10.1146/annurev.clinpsy.1.102803.144141> (2005).
41. Jayedi, A., Soltani, S., Abdolshahi, A. & Shab-Bidar, S. Healthy and unhealthy dietary patterns and the risk of chronic disease: An umbrella review of meta-analyses of prospective cohort studies. *Br. J. Nutr.* **124**, 1133–1144. <https://doi.org/10.1017/S0007114520002330> (2020).
42. Morze, J., Danielewicz, A., Hoffmann, G. & Schwingshackl, L. Diet quality as assessed by the healthy eating index, alternate healthy eating index, dietary approaches to stop hypertension score, and health outcomes: A second update of a systematic review and meta-analysis of cohort studies. *J. Acad. Nutr. Diet.* **120**, 1998–2031.e15. <https://doi.org/10.1016/j.jand.2020.08.076> (2020).
43. Posadzki, P. *et al.* Exercise/physical activity and health outcomes: An overview of Cochrane systematic reviews. *BMC Public Health* **20**, 1724. <https://doi.org/10.1186/s12889-020-09855-3> (2020).
44. Gariépy, G., Honkaniemi, H. & Quesnel-Vallée, A. Social support and protection from depression: Systematic review of current findings in Western countries. *Br. J. Psychiatry.* **209**, 284–293. <https://doi.org/10.1192/bjpp.bp.115.169094> (2016).
45. Renn, O. Real-world laboratories: The road to transdisciplinary research?. *GAIA Ecol. Perspect. Sci. Soc.* **27**, 1. <https://doi.org/10.14512/gaia.27.S1.1> (2018).
46. Koeder, C., Hahn, A. & Englert, H. Effect of a 6-month controlled lifestyle intervention on common carotid intima-media thickness. *J. Nutr. Health Aging* <https://doi.org/10.1007/s12603-021-1628-0> (2021).
47. Anand, C., Hengst, K., Gellner, R. & Englert, H. Effects of the Healthy Lifestyle Community Program (cohort 1) on stress-related eating behaviour and weight change after 8 weeks: results of a controlled study. *Sci. Rep.* (2022).
48. World Health Organisation (WHO). *Physical Status: The Use and Interpretation of Anthropometry: Report of a WHO Expert Committee* (WHO, 1995).
49. Klein, E. M. *et al.* The German version of the perceived stress scale: Psychometric characteristics in a representative German community sample. *BMC Psychiatry* **16**, 159. <https://doi.org/10.1186/s12888-016-0875-9> (2016).
50. O'Connor, D. B. *et al.* Cortisol awakening rise in middle-aged women in relation to psychological stress. *Psychoneuroendocrinology* **34**, 1486–1494. <https://doi.org/10.1016/j.psyneuen.2009.05.002> (2009).
51. Anand, C., Hengst, K., Gellner, R. & Englert, H. Eight weeks into lifestyle change: What are the effects of the Healthy Lifestyle Community Program (cohort 1) on cortisol and psychosocial stress? (2022). <https://doi.org/10.1093/gao/9781884446054.article.T085278>.
52. Gaus, W. Interpretation of statistical significance: Exploratory versus confirmative testing in clinical trials, epidemiological studies, meta-analyses and toxicological screening (using ginkgo biloba as an example). *Clin. Exp. Pharmacol.* <https://doi.org/10.4172/2161-1459.1000182> (2015).
53. Anand, C. & Ragna-Marie, K. Bridging the gap between science and society: Long-term effects of the Healthy Lifestyle Community Program (HLCP, cohort 1) on weight and the metabolic risk profile: a controlled study. *BMJ Nutr. Prev. Health* <https://doi.org/10.1093/gao/9781884446054.article.T085278> (2003).
54. van Strien, T., Donker, M. H. & Ouwens, M. Is desire to eat in response to positive emotions an “obese” eating style: Is Kummerspeck for some people a misnomer?. *Appetite* **100**, 225–235. <https://doi.org/10.1016/j.appet.2016.02.035> (2016).
55. Lattimore, P. Mindfulness-based emotional eating awareness training: Taking the emotional out of eating. *Eat Weight Disord.* **25**, 649–657. <https://doi.org/10.1007/s40519-019-00667-y> (2020).
56. Schnepfer, R., Richard, A., Wilhelm, F. H. & Blechert, J. A combined mindfulness-prolonged chewing intervention reduces body weight, food craving, and emotional eating. *J. Consult. Clin. Psychol.* **87**, 106–111. <https://doi.org/10.1037/ccp0000361> (2019).
57. O'Reilly, G. A., Cook, L., Spruijt-Metz, D. & Black, D. S. Mindfulness-based interventions for obesity-related eating behaviours: A literature review. *Obes. Rev.* **15**, 453–461. <https://doi.org/10.1111/obr.12156> (2014).
58. Alberts, H. J. E. M., Thewissen, R. & Raes, L. Dealing with problematic eating behaviour: The effects of a mindfulness-based intervention on eating behaviour, food cravings, dichotomous thinking and body image concern. *Appetite* **58**, 847–851. <https://doi.org/10.1016/j.appet.2012.01.009> (2012).
59. Woolhouse, H., Knowles, A. & Crafti, N. Adding mindfulness to CBT programs for binge eating: A mixed-methods evaluation. *Eat Disord.* **20**, 321–339. <https://doi.org/10.1080/10640266.2012.691791> (2012).
60. Warren, J. M., Smith, N. & Ashwell, M. A structured literature review on the role of mindfulness, mindful eating and intuitive eating in changing eating behaviours: Effectiveness and associated potential mechanisms. *Nutr. Res. Rev.* **30**, 272–283. <https://doi.org/10.1017/S0954422417000154> (2017).
61. Sampaio, C. V. S., Magnavita, G. & Ladeia, A. M. Effect of Healing Meditation on stress and eating behavior in overweight and obese women: A randomized clinical trial. *Complement. Ther. Clin. Pract.* **45**, 101468. <https://doi.org/10.1016/j.ctcp.2021.101468> (2021).
62. Neumann, M. *et al.* Features and trajectories of eating behavior in weight-loss maintenance: Results from the German weight control registry. *Obesity* **26**, 1501–1508. <https://doi.org/10.1002/oby.22270> (2018).
63. Wellman, J. D., Araiza, A. M., Newell, E. E. & McCoy, S. K. Weight stigma facilitates unhealthy eating and weight gain via fear of fat. *Stigma Health.* **3**, 186–194. <https://doi.org/10.1037/sah0000088> (2018).
64. Westenhoefer, J. *et al.* Cognitive and weight-related correlates of flexible and rigid restrained eating behaviour. *Eat. Behav.* **14**, 69–72. <https://doi.org/10.1016/j.eatbeh.2012.10.015> (2013).

65. Meule, A., Westenhöfer, J. & Kübler, A. Food cravings mediate the relationship between rigid, but not flexible control of eating behavior and dieting success. *Appetite* 57, 582–584. <https://doi.org/10.1016/j.appet.2011.07.013> (2011).
66. Barrington, W. E., Ceballos, R. M., Bishop, S. K., McGregor, B. & Beresford, S. Perceived stress, behavior, and body mass index among adults participating in a worksite obesity prevention program, Seattle, 2005–2007. *Prev. Chronic Dis.* 9, E152–E152. <https://doi.org/10.5888/pcd9.120001> (2012).
67. Ibrahim, M., Thearle, M. S., Krakoff, J. & Gluck, M. E. Perceived stress and anhedonia predict short- and long-term weight change, respectively, in healthy adults. *Eat. Behav.* 21, 214–219. <https://doi.org/10.1016/j.eatbeh.2016.03.009> (2016).
68. Järvelin-Reijonen, E. *et al.* High perceived stress is associated with unfavorable eating behavior in overweight and obese Finns of working age. *Appetite* 103, 249–258. <https://doi.org/10.1016/j.appet.2016.04.023> (2016).
69. Richardson, A. S. *et al.* Perceived stress, unhealthy eating behaviors, and severe obesity in low-income women. *Nutr. J.* 14, 122. <https://doi.org/10.1186/s12937-015-0110-4> (2015).
70. Sims, R. *et al.* Perceived stress and eating behaviors in a community-based sample of African Americans. *Eat. Behav.* 9, 137–142. <https://doi.org/10.1016/j.eatbeh.2007.06.006> (2008).
71. Cebolla, A., Barrada, J. R., van Strien, T., Oliver, E. & Baños, R. Validation of the Dutch Eating Behavior Questionnaire (DEBQ) in a sample of Spanish women. *Appetite* 73, 58–64. <https://doi.org/10.1016/j.appet.2013.10.014> (2014).

Acknowledgements

We would like to thank the study participants, the local stakeholders involved, e.g. city administration, medical practitioners, clubs and volunteers, Matthias Borowski for his statistical advice, our student helpers and the entire research group, especially Sarah Husain, Christian Koeder, Alwine Kraatz, Ragna-Marie Kranz and Nora Schoch, who took part in the investigation.

Author contributions

C.A.: conceptualization, methodology, validation, formal analysis, investigation, participant management, data assessment and curation, writing: original draft review and editing of the manuscript, visualization, project administration, funding acquisition. K.H.: methodology, medical advice, writing: review and editing, supervision. R.G.: methodology, medical advice, writing: review and editing, supervision. H.E.: conceptualization, methodology, investigation, writing: review and editing, project administration, supervision, funding acquisition. All authors read and approved the final manuscript.

Funding

Open Access funding enabled and organized by Projekt DEAL. This work was conducted as part of the project “KRAKE” and was funded by EUREGIO within the INTERREG V A programme Deutschland-Niederland (ANBest INTERREG DE-NL) with the following grant number: 203018. Additionally, the German Diabetes Foundation (DDS) funded the analysis of cortisol with the following Grant Number: 400/04/17. We acknowledge support from the Open Access Publication Fund of the University of Muenster.

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to C.A.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2023