



The role of emotion regulation in childhood obesity: implications for prevention and treatment

E. Aparicio¹, J. Canals^{2,3}, V. Arijá^{1,4}, S. De Henauw^{5,6} and N. Michels^{5*}

¹Faculty of Medicine and Health Sciences, Nutrition and Mental Health Research Group (NUTRISAM), Institut de Investigació Sanitària Pere Virgili (IISPV), Universitat Rovira i Virgili (URV), Reus, Spain

²Faculty of Education Sciences and Psychology, Nutrition and Mental Health Research Group (NUTRISAM), Institut de Investigació Sanitària Pere Virgili (IISPV), Universitat Rovira i Virgili, Tarragona, Spain

³Research Center for Behavioral Assessment, CRAMC, Department of Psychology, URV, Tarragona, Spain

⁴Institut d'Investigació en Atenció Primària, IDIAP Jordi Gol i Gurina, Catalonia, Spain

⁵Department of Public Health, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

⁶Department of Health Sciences, Vesalius, University College Ghent, Ghent, Belgium

Abstract

Stress and negative emotions pose a major threat to public health, by increasing the risk of obesity. Since the management process for emotions (emotion regulation; ER) is developed in childhood, we present a novel conceptual framework model for the role of ER in the prevention and treatment of childhood obesity. A narrative review of the literature by electronic database search (MEDLINE, Web of Knowledge and Scopus) was conducted of observational and interventional/experimental literature on ER and obesity and the underlying concepts. We also present an overview of ER intervention techniques. Our model indicates that childhood ER is a link between stress and obesity. Stress along with ineffective ER leads to abnormal cortisol patterns, emotional eating, sedentary lifestyle, reduction of physical activity, and sleep problems. Simultaneously, a healthy lifestyle could show benefits on ER and in developing adaptive ER strategies. In the development of obesity and ER, parents also play a role. By contrast, effective ER skills decrease obesity-related unhealthy behaviour and enhance protective factors, which boost health. The literature contains some observational studies of children but very few intervention studies, most of which are pilot or on-going studies. In conclusion, encouraging effective ER could be a useful new approach for combating and treating childhood obesity. Future ER intervention studies are needed to confirm the validity of this model in children.

Key words: Emotion regulation: Obesity: Prevention: Treatment: Children

Introduction

The epidemic of overweight and obesity in children observed in recent years calls for a better understanding of the associated risk factors⁽¹⁾. It is generally accepted that the main lifestyle factors related to the rising prevalence of obesity derive from an imbalance in energy homeostasis caused by increased energy intake and/or sedentary behaviour. Despite lifestyle-based campaigns and interventions in children, adolescents and their parents, the prevalence of obesity has not decreased⁽²⁾. Therefore, new approaches are needed for prevention and treatment.

The potential role of psychological and emotional distress in obesity development has been less extensively researched⁽³⁾, but a generally positive relationship was found between negative affect or stress in children and weight gain (see Table 1)^(4–27). This is particularly relevant because mental disorders affect 10–20% of children and adolescents worldwide⁽²⁸⁾ and 47.7% of the children in a European study

presented psychosomatic or emotional symptoms⁽²⁹⁾. Being more vulnerable to develop mental disorders or being more susceptible to stress could be followed by a poor emotion regulation (ER)⁽³⁰⁾. As it has been suggested in adult populations, a poor ER may entail the use of maladaptive strategies to manage with emotions for example, by using food^(31–33). Since the manner how they deal with emotions might contribute to obesity, children should acquire efficient emotion management at an early age. Research into the relationship between ER and energy homeostasis could be extremely useful for designing preventive and treatment-based obesity programmes.

The present review discusses current literature on ER and obesity in childhood. Based on a non-systematic and narrative review, we present a novel conceptual framework for the role of ER in weight gain and obesity, discussing the potential underlying factors and their implications for prevention and treatment.

Abbreviation: ER, emotion regulation.

* **Corresponding author:** Nathalie Michels, email nathalie.michels@ugent.be



Table 1. Overview of studies about child and adolescent stress and negative affect as predictors of weight gain/overweight/obesity: prospective studies

First author and year	Country	Follow-up duration (years)	Sample (n)/sex (% girls)	Age or grades at baseline	Psychological predictor: measurement tool	Adiposity measures	Results
Goodman (2002) ⁽⁴⁾	USA	1	9374 (48.6 %)	Grades 7–12 (12–18 years)	Depressive symptoms: CES-D	Measured and self-reported: BMI	Depressive symptoms increased risk of obesity in obese and non-obese subjects
Anderson (2011) ⁽⁵⁾	USA	2	918 (100 %)	Grade 6 (11 years)	Depressive symptoms: CES-D	Measured: BMI	Depressive symptoms associated with greater likelihood of obesity in white females
Bradley (2008) ⁽⁶⁾	USA	11	1254 (48 %)	2 years to grade 6	Externalising and internalising problems: CBCL	Measured: BMI	Positive association between externalising or internalising problems and BMI
van Jaarsveld (2009) ⁽⁷⁾	UK	5	4065 (42 %)	11–12 years	Perceived stress at a single time point and mean perceived stress over 5 years: PSS short form	Measured: waist, BMI	Perceived stress associated with Δ BMI z-scores, Δ waist High mean of stress associated with 5-year BMI z-score trajectory and 5-year waist z-score trajectory
Midei (2009) ⁽⁸⁾	USA	3	160 (48.7 %)	14 years	Trait anxiety symptoms: STAIC Anger and anxiety: Cook–Medley Hostility Scale	Measured: waist:hip ratio	Higher anger associated with increased waist:hip ratio
Tanofsky-Kraff (2006) ⁽⁹⁾	USA	4.2	146 (52 %)	6–12 years	Depressive symptoms: CDI Child Symptom Inventory	Measured: body fat mass	No association
Rofey (2009) ⁽¹⁰⁾	USA	3	285 (49 %)	8–18 years	Depression and anxiety: K-SADS-E, K-SADS-P, K-SADS-PL (DSM-III and DMS-IV criteria)	Measured: BMI	Females: depression and anxiety associated with high BMI Males: anxiety associated with high BMI No association with depression
Aparicio (2013) ⁽¹¹⁾	Spain	3	229 (62 %)	10 years	Depression and anxiety: SCARED, CDI MINI-KID (DSM-IV criteria)	Measured: BMI, waist, body fat mass	Females: anxiety symptoms associated with Δ BMI and body fat mass; depression disorder associated with Δ waist Males: anxiety and depression associated with Δ BMI and waist Inverse relationship observed between major depression disorder and BMI
Larsen (2014) ⁽¹²⁾	Netherlands	3	1465 (49.4 %)	11.4–16.9 years	Depressive symptoms: CES-D	Measured: BMI	Females: depressive symptoms associated with higher BMI z-score Males: no association
Rhew (2008) ⁽¹³⁾	USA	1	466 (46.2 %); 165 subsample BMI measures	12 years mean	Depressive symptoms: MFQ	Measured and self-reported: BMI	BMI self-reported: females: depressive symptoms associated with lower BMI than non-depressive symptoms; females: depressive symptoms associated with higher BMI than non-depressive symptoms BMI measures: no association
Michels (2015) ⁽¹⁴⁾	Belgium	2	316 (50 %)	5–12 years	Negative events: Coddington Life Events Scale for Children Negative emotions: anger, anxiety, sadness Behavioural problems: SDQ	Measured: BMI, waist:height ratio, fat percentage	Stress positively or negatively associated with adiposity depending on cortisol and lifestyle, which had a moderating effect
Stice (2005) ⁽¹⁵⁾	USA	4	496 (100 %)	11–15 years	Depressive symptoms: SADS for School-Age Children	Measured: BMI	No association
Jansen (2008) ⁽¹⁶⁾	Netherlands	3	787 (49 %)	9–10 years	Depressive symptoms and social anxiety: Rotterdam Youth Health Monitor RYM questionnaire, Short Depression Inventory for Children, Dutch social anxiety scale for children	Measured: BMI	No association
Chen (2009) ⁽¹⁷⁾	USA	4	543 (100 %)	10 years	Depressive symptoms: CSI (reported by parents) (DSM-IV criteria)	Measured: BMI	No association
Hammerton (2014) ⁽¹⁸⁾	UK	1–2	289 (57.1 %)	9–17 years	Depressive disorder: CAPA (DSM-IV criteria)	Measured: BMI	No association
Child or adolescent emotional problems and adult overweight/obesity							
Pine (1997) ⁽¹⁹⁾	USA	8–10	644 (52 %)	9–18 years	Depressive symptoms: CES-D (DSM-III criteria)	Self-reported: BMI	Depressive symptoms associated with higher BMI
Pine (2001) ⁽²⁰⁾	USA	10	177 (50.2 %)	6–17 years	Depressive symptoms: SADS for School-Age Children and SADS Lifetime Disorders version	Self-reported: BMI	Depressive symptoms associated with high BMI in adulthood
Franko (2005) ⁽²¹⁾	USA	2–5	1554 (100 %)	16 years	Depressive symptoms: CES-D	Measured and self-reported: BMI	Depressive symptoms associated with high BMI and with obesity
Anderson (2006) ⁽²²⁾	USA	22	661 (53 %)	15 years mean (9–18 years)	Depression and anxiety: DISC (DSM-IV criteria)	Self-reported: BMI	Females: positive relationship Males: no association
Richardson (2003) ⁽²³⁾	USA	10	881 (48 %)	11–15 years	Depression disorder: DISC (DSM-III criteria)	Measured: BMI	Females: depression in later adolescence increases risk of obesity in adulthood; no association in early adolescence Males: no association
Ternouth (2009) ⁽²⁴⁾	UK	20	7588 (51.1 %)	10 years	Emotional problems: Rutter B scale	Self-reported: BMI	Females: childhood emotional problems predicted weight gain in women Males: no association
Hasler (2005) ⁽²⁵⁾	Germany	21	591 (50.5 %)	19 years	Child depressive symptoms: SPIKE	Self-reported: BMI	Females and males: depressive symptoms before age 17 years associated with increased weight gain
Duarte (2010) ⁽²⁶⁾	Finland	18–23	2209 (0 %)	8 years	Depressive symptoms: depression, CDI Emotion problems (Rutter questionnaire)	Measured: BMI	No association
Wickrama (2009) ⁽²⁷⁾	USA	6	11 404 (52 %)	12–19 years	Depressive symptoms: CES-D	Self-reported: BMI	No association

CES-D, Center for Epidemiologic Studies Depression Scale; CBCL, Child Behaviour Checklist; PSS, Perceived Stress Scales; STAIC, State-Trait Anxiety Inventory for Children; CDI, Children's Depression Inventory; SADS, Shedule for Affective Disorders and Schizophrenia, K-SADS-E, Kiddie-Schedule for Affective Disorders and Schizophrenia Epidemiologic version; K-SADS-P, Kiddie-Schedule for Affective Disorders and Schizophrenia Present Episode version; K-SADS-PL, Kiddie-Schedule for Affective Disorders and Schizophrenia Present and Lifetime version; DSM, Diagnostic and Statistical Manual of Mental Disorders; SCARED, Screen for Child Anxiety Related Emotional Disorders; MINI-KID, MINI-International Neuropsychiatric Interview for Children and Adolescents; MFQ, Mood and Feeling Questionnaire; SDQ, Strengths and Difficulties Questionnaire; RYM, Rotterdam Youth Monitor; CSI, Child Symptom Inventory; CAPA, Child and Adolescent Psychiatric Assessment; DISC, Diagnostic Interview Schedule for Children; SPIKE, Structured Psychopathological Interview and Rating of the Social Consequences for Epidemiology.

Emotion regulation

Definition of emotion regulation

ER is a growing field within psychology and holds a central role in all the psychological areas including health, development, clinical, social and personality as well as in a variety of other disciplines⁽³⁴⁾. ER can be broadly defined as the set of strategies used to maintain a positive affective status or improve or suppress a negative affective status in stressful and non-stressful circumstances^(35,36). Nevertheless, there is no single, unified approach of ER. One of the first definitions was given by Thompson⁽³⁷⁾, who defined ER as 'the extrinsic and intrinsic process by which individuals are able to monitor, evaluate and modify their emotions to accomplish their goal'⁽³⁷⁾. This concept has been amplified to describe a process for modifying and maintaining feelings, behaviours and psychological features of emotions. In other words, ER refers to attempts to influence which emotions one has and how one experiences or expresses these emotions^(34,38). Also, the Adaptive Coping with Emotions (ACE) model has explained how emotion dysregulation can occur and provided tools to enhance effective ER⁽³⁹⁾. This new model is based on the acquisition of skills which help to maintain or restore mental health and to address aversive emotions. To summarise, ER is a common process that depends on certain skills and is frequently used in daily life to ensure personal well-being.

Psychological factors related to emotion regulation

ER is related to and interacts with other psychological factors. According to Gross⁽³⁴⁾, ER along with coping and mood regulation concepts shape the affective regulation term. Coping is understood as responses to alleviate stress, whereas ER is conceptualised as an ongoing process that occurs under both stressful and non-stressful circumstances and is organised around specific emotions (i.e. sadness, fear, anger) and includes efforts to up- or down-regulate both positive and negative emotions^(35,36). In contrast, mood refers to less specific and longer-lasting experiences and seems to be influenced by cognition more than by behaviour processes. Mood regulation may be distinguished from ER by its predominant focus on altering subjective feeling states⁽³⁴⁾. Therefore, it is suggested that there is a considerable overlap among these regulatory processes⁽³⁴⁾.

Other factors are executive functions, which are important in the management of cognitive and behavioural processes including working memory, reasoning, task flexibility, inhibition capacity and impulsivity, problem solving, planning and execution⁽⁴⁰⁾. Some studies have reported a direct link between executive function abilities and specific ER capacities⁽⁴¹⁾. Interestingly, impairments of executive function have been reported in overweight adults⁽⁴²⁾ and also in children^(43,44) since it might contribute to eating styles⁽⁴⁵⁾. Indeed, childhood disorders characterised by impaired executive function, such as attention-deficit/hyperactivity disorder, are associated with overeating and obesity^(46,47).

Self-regulation is a key factor related to ER and executive function that can be understood to include effortful control

and impulsivity control. The concept of effortful control encompasses the abilities to inhibit or activate behaviours for the benefit of long-term goals; impulsivity is characterised by high reward sensitivity and a high deficit of response inhibition. These factors have a direct relationship with dietary restraint, in which efforts are made to suppress reward-based impulses to eat in pursuing long-term weight goals⁽⁴⁸⁾. Several studies in children have found that an increase in impulsivity, a decrease in inhibitory control and a higher reward sensitivity are associated with unhealthier food choices and overweight^(49–53).

Emotion regulation in children

Childhood and adolescence are two critical periods in the development of executive function, behaviour-regulation skills and consequently ER strategies. However, newborns and infants are capable of regulating their emotions. From the first days of life, using a neonatal self-regulation assessment, individual differences have been found in controlling negative emotions in a stressful environment⁽⁵⁴⁾. At preschool age, children acquire a large range of strategies to manage their own mood and this ability is established in adolescence⁽⁵⁵⁾.

Parental influence is essential in the process of ER development, where parents serve as role models and influence the family atmosphere⁽⁵⁶⁾. Children learn ER skills early through interactions with their parents or caregivers, as well as through family factors like family expressivity or communication⁽⁵⁷⁾. Also, a negative parental response to children's emotions teaches children to avoid rather than understand emotions and has been linked to inappropriate ER strategies⁽⁵⁸⁾. Parenting styles characterised by 'high warmth and high control' have an influence on children's effective ER leading to greater self-efficacy, self-discipline and successful dealing with challenges^(56,59).

ER is essential to healthy psychological functioning. In children, it is an important predictor of risk behaviours^(60,61) and mental problems⁽⁶⁰⁾, particularly those related to emotional problems⁽⁶²⁾. Children who do not develop adequate ER strategies will be less able to survive in new environments where they face conflicts. The use of maladaptive ER can generate a vicious circle, since it may increase negative emotions which are involved in developing maladaptive strategies⁽³⁹⁾.

Emotion regulation skills

According to the theory of adaptive coping cited above⁽³⁹⁾, adaptive ER is conceptualised as a situation-dependent interaction between ER skills. The regulatory skills in this model are: awareness of emotions (i.e. the ability to identify and label emotions), understanding emotions (i.e. the ability to identify the causes and maintaining factors of emotions); acceptance and tolerance (i.e. the ability to accept and tolerate negative emotions when necessary); self-support and self-compassion (i.e. the ability to provide effective self-support and self-compassion in distressing situations by self-soothing, self-encouragement and active self-coaching); modifying emotions (i.e. the ability to modify emotions in an adaptive way, which includes self-efficacy) and

readiness to confront (i.e. the ability to address situations likely to cause negative emotions). Enhancing or acquiring these skills helps in maintaining or restoring mental health and in approaching aversive emotions⁽⁶³⁾.

A new model for the role of emotion regulation in obesity development

A discussion of findings in the field of ER and obesity is synthesised to provide evidence for the proposed model of the role of ER in obesity prevention and treatment. A schematic illustration of this model is given in Fig. 1.

ER strategies have been classified as ineffective/maladaptive *v.* effective/adaptative, based on their immediate effects on affect, behaviour and cognition^(30,64). Presence of stress or negative life events could cause emotional dysregulation and therefore increase the vulnerability to develop maladaptive ER strategies in modulating the negative emotion. Thus, it is not only the fact that individuals experience negative emotions but also the way in which they cope with them that may determine the emotional impact on weight gain.

Only very few observational studies have assessed the relationship between ER and obesity in children. Therefore, related factors such as executive function and self-control, which include similar aspects of ER, have also been included in the overview shown in Table 2^(51,52,65–71). Although the evidence is modest, better ER-related skills were associated with a healthier diet (more fruit/vegetables and less snack food, although not all

studies reported significant findings), higher physical activity and, in some cases, a healthier weight status.

Physiological mechanisms leading to obesity

Studies have shown that stress can increase overweight and the related adverse metabolic consequences through neuroendocrine changes⁽⁷²⁾. Repeated activation of the hypothalamic–pituitary–adrenal (HPA) axis mediates stress responses and increases cortisol secretion. This chronic cortisol hypersecretion may cause fat to accumulate in the visceral adipose tissues⁽⁷³⁾ through interaction with lipid homeostasis at several levels: lipolysis, adipogenesis, lipogenesis, and the regulation of circulating fatty acids⁽⁷⁴⁾. However, intense acute or chronic stress might also lead to hypo-activation of the HPA axis, or hypocortisolism⁽⁷²⁾. The cortisol response to stress is complex, but both hypo- and hypercortisolism may be harmful. According to a meta-analysis, HPA activity depends on the personal response to stress, since cortisol output increases with distress and decreases in individuals with post-traumatic acute stress⁽⁷⁵⁾. Recent research in schoolchildren indicates that stress is associated with hypercortisolism⁽⁷⁶⁾. Additionally, other findings point out that maladaptive ER induces cortisol reactivity⁽⁷⁷⁾.

Therefore, stress in combination with maladaptive coping strategies could lead to dysregulated cortisol secretion and obesity. Since cortisol is appetite-stimulating, it also increases appetite and the attraction to sweet and fatty foods, mainly by stimulating reward pathways or by influencing other hormones^(76,78).

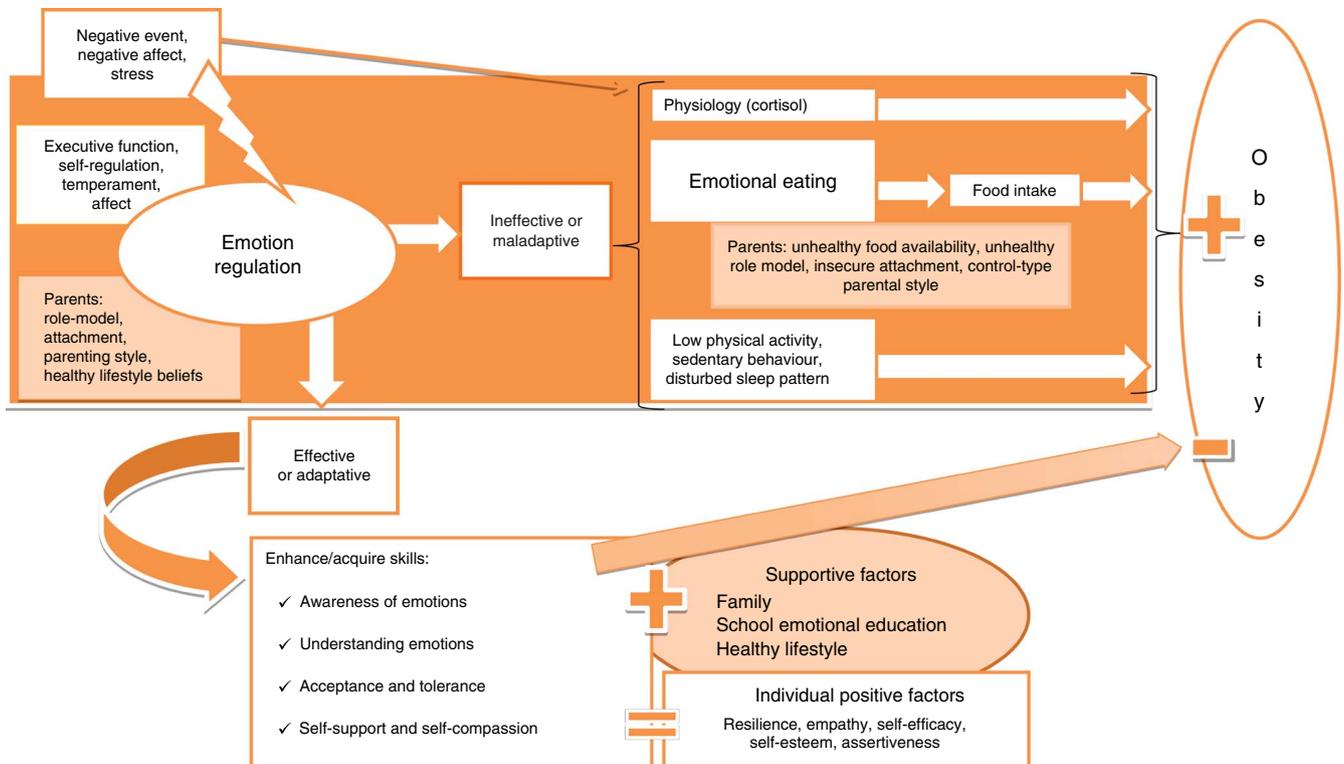


Fig. 1. Conceptual framework for the role of emotion regulation in the prevention and treatment of childhood obesity. For a colour figure, see the online version.



Table 2. Emotion regulation or related terms as predictors of childhood weight gain/overweight/obesity: observational studies

First author and year	Country	Type of study	Sample (n)/sex (% girls)	Age or grade at baseline	Emotion regulation predictor: measurement tool	Outcome: adiposity-related measures or obesity-related behaviour measures	Results
Isasi (2013) ⁽⁶⁵⁾	USA	Cross-sectional	612 (58 %)	12 years	Emotion regulation: soothability, sadness management, anger management, assessed by three scales: Self-efficacy for healthy eating Self-efficacy for physical activity Depressive symptoms	Food intake: YAQ Physical activity: Youth Risk Behaviour Survey Time spent in sedentary behaviours Anthropometry: measured BMI	Stronger emotion regulation associated with higher intake of fruit/vegetables and physical activity; association mediated by self-efficacy. No association with BMI
Graziano (2010) ⁽⁵¹⁾	USA	Longitudinal 3-5-year follow-up	57 (43.8 %)	2 years	Emotion regulation: laboratory task: videotapes of frustration tasks (Prize in the Box and High Chair) Inhibitory control/reward sensitivity: delay of gratification task, assessment of the overall total time touching gift Sustained attention: children were instructed to watch a 5-min segment of the videotape 'Spot', overall duration of attention was measured	Measured: BMI	Maladaptive emotion regulation and inhibitory control/reward sensitivity predicted more extreme weight problems at 5-5 years
Graziano (2013) ⁽⁵²⁾	USA	Longitudinal 7-year follow-up	195 (58.4 %)	2 years	Child behaviour problems: CBCL Laboratory task: as above, except that CBCL was replaced by the Toddler Behaviour Assessment Questionnaire	Measured: BMI	Toddlers with better self-regulation skills at age 2 years had lower BMI z-scores at 10 years old and were less likely to show an increase in BMI z-scores from 4 to 10 years
Isasi (2011) ⁽⁶⁶⁾	USA	Cross-sectional	1771 (51 %)	12 years	Statistical method to reduce data: Factor 1, self-regulation (including emotion regulation) Factor 2, temperament; pleasure Self-regulation measures: Multiple indicators of effortful: planfulness, problem solving, soothability, self-reinforcement Multiple indicators of dysregulation: impulsivity, impatience, immediate gratification, anger ability, distractibility, self-criticism Self-efficacy for healthy eating Self-efficacy for physical activity	Dietary intake: short FFQ Physical activity and sedentary behaviour: Youth Risk Behaviour Survey Anthropometry: measured BMI	Effortful control had a positive indirect effect on fruit and vegetable intake, mediated by self-efficacy Effortful control had a positive indirect effect on physical activity, mediated by self-efficacy Dysregulation had direct effects on higher intake of junk food/snacks and time spent in sedentary behaviours
Wills (2007) ⁽⁶⁷⁾	USA	Cross-sectional	539 (48 %)	14.6 years (mean)	Self-control measures: Good self-control: soothability, planfulness, problem solving, cognitive effort, future time perspective, self-reinforcement Poor self-control: distractibility, impulsiveness, anger ability, tension maintenance, impatience, present time orientation, negative self-management	Dietary intake: FFQ Physical activity and sedentary behaviour: Youth Risk Behaviour Survey	Good self-control was related to more fruit and vegetable intake, more participation in sports, and less sedentary behaviour Poor self-control was related to more saturated fat intake and less vigorous exercise
Riggs (2010) ⁽⁶⁸⁾	USA	Longitudinal 4-month follow-up	184 (52 %)	9.3 years (mean)	Executive cognitive function: BRIEF-SR (including a subscale of emotion control; inhibitory control; working memory; organisation of materials)	Dietary intake: FFQ Physical activity: Physical Activity Questionnaire for Older Children	Baseline executive cognitive function was associated with more fruit/vegetable intake and physical activity 4 months later; no association with snack food intake
Riggs (2012) ⁽⁶⁹⁾	USA	Cross-sectional	1587 (49 %)	9.3 years	Executive cognitive function: BRIEF-SR (including a subscale of emotion control; inhibitory control; working memory; organisation of materials)	Dietary intake: FFQ Physical activity: Physical Activity Questionnaire for Older Children	Executive cognitive function was negatively associated with high-energy snack food intake and sedentary behaviour Executive cognitive function was positively associated with fruit and vegetable intake and physical activity
Riggs (2010) ⁽⁷⁰⁾	USA	Cross-sectional	107 (54 %)	9.4 years	Executive cognitive function: BRIEF-SR (including a subscale of emotional control; inhibitory control; working memory; organisation of materials)	Dietary intake: FFQ Physical activity: Physical Activity Questionnaire for Older Children	Executive cognitive function was negatively related to snack food intake, but not significantly related to fruit and vegetable intake
Hughes (2015) ⁽⁷¹⁾	USA	Cross-sectional	187 (47.6 %)	4.7 years	Eating self-regulation: Laboratory task: eating in the absence of hunger Questionnaire: CEBQ (satiety responsiveness and food responsiveness) Non-eating self-regulation (self-regulation, executive function, emotion regulation): Laboratory task: tapping task, flexible item selection task, delay of gratification Gift delay task Questionnaire: CBQ (effortful control)	Anthropometry: measured BMI	Eating self-regulation was associated with BMI, but not other types of self-regulation

YAQ, Youth Adolescent Questionnaire; CBCL, Child Behavior Checklist; BRIEF-SR, Behavioural Rating Inventory of Executive Function – Self-Report Version; CEBQ, Child Eating Behaviour Questionnaire; CBQ, Children's Behavior Questionnaire.



Emotional eating: a mediator between emotional dysregulation and obesity

Emotional eating and stress/emotions. In a stressful situation, some individuals will use maladaptive coping strategies such as eating mainly highly palatable and high-energy food to suppress negative emotions and stress⁽³³⁾. According to the theory of emotional eating, the eating behaviour to deal with emotions is defined as emotional eating⁽⁷⁹⁾. A poor emotional regulation leads to emotional eating in adults^(31,32,80). Studies consistently report that emotional eating is often followed by negative emotions, also in children^(81–85). Consequently, emotional eating is the result of self-inability to regulate emotions, and this maladaptive strategy might underlie the relationship between emotional dysregulation and obesity by modifying dietary intake^(50,51,65). Studies in children and adolescents have revealed an association between maladaptive ER strategies and emotional eating^(83,86–88). However, different maladaptive strategies of ER have been assessed in these studies and this may lead to bias in the results. Harrist *et al.*⁽⁸⁶⁾ conducted a longitudinal study in 782 children and found that reactivity to anger and worry was consistently related to emotional eating. In this vein, maladaptive ER such as ruminative thinking increased the desire to eat in adolescents⁽⁸⁸⁾.

Emotional eating and food intake. Emotional eating leads to an unhealthier diet since it is suggested that food with high energy density can ameliorate negative affect or stress⁽⁸⁹⁾. As a result, emotional eating increases the intake of sweet and fatty foods, or 'comfort food'^(90–92). In experimental studies, emotional eaters have been found to consume more sweet and fatty foods^(93–95) in response to stress. Although there are fewer studies of child populations, the conclusions are often similar: emotional eating was associated with high intake of sweet and/or fatty food in both observational^(85,96–98) and laboratory studies^(95,99–101). Although these observational studies were cross-sectional, several were conducted on large samples and showed strong association^(96–99). Moreover, sex appeared to play a role in the effect of emotional eating on food choices since females often tend to eat more sweet and fatty food. However, the possible interaction of sex and age remains unclear.

Emotional eating and obesity. Since emotional eating is related to less healthy dietary intake, it has been longitudinally linked to weight gain and obesity, especially in females^(102,103). Although no significant relationship was observed in a small number of studies⁽¹⁰⁴⁾, other studies identified a significant percentage of emotional eating in overweight children^(81,85,105,106). Braet *et al.*⁽¹⁰⁵⁾ showed that in a large sample of children and adolescents 10.5 % of overweight children reported high scores of emotional eating. Especially in adolescence, the relationship becomes stronger in overweight females⁽¹⁰⁵⁾ with loss of control^(81,106). Interestingly, obese individuals are also more vulnerable to emotional eating since, according to psychosomatic theory, they are unable to distinguish between hunger and negative emotions as a cause of their desire for food⁽¹⁰⁷⁾. In addition, the cognitive load of coping

with a negative emotion may overcome the self-regulation process so that obese individuals no longer maintain their self-control. Therefore, emotional eating may have an important role in the development and maintaining of overweight and obesity.

Emotional eating and parental influence. Parents and family members influence children's food choices not only through food availability, eating patterns at home, and role modelling⁽¹⁰⁸⁾, but also through other processes. Parental feeding practices could lead to unhealthy eating behaviours and childhood obesity^(109,110), since parents can pressure children to eat or restrict their diet or can use sweets as rewards or to change their temperament. Children also learn from their parents' behaviour, for example by using food to calm negative emotion. A laboratory study conducted on twenty-five preschool children and their mothers showed that children of mothers who use food for ER consume more sweet palatable foods in the absence of hunger⁽¹¹¹⁾. Similarly, a cross-sectional study in 497 children and mothers found that maternal feeding behaviours affect emotional eating in children⁽¹¹²⁾. These practices may have a negative impact on the development of self-regulation of eating, since children learn to use food as a strategy to cope with emotions and are likely to use the same maladaptive emotional eating later in their lives^(111,113). Finally, it is strongly supported that certain parenting styles, such as the authority and permissive parenting style, increase the risk of overweight^(59,114), especially those children who fail to delay gratification or have poor self-regulation⁽¹¹⁵⁾. Indeed, it has been suggested that ER mediates the relationship of parental attachment with emotional eating or unhealthy food consumption and sedentary activities in children^(87,112).

Lifestyle: a mediator between emotional dysregulation and obesity

Stress and negative affect are linked to other aspects of obesity-related lifestyle like sedentary behaviour and low physical activity. Children and adolescents with stress or negative affect may perform less physical activity due to decreased motivation and are likely to spend more time on sedentary activities like video games, Internet and television^(98,116,117). A recent review suggests that cognitive abilities and self-regulation may enhance active or inactive physical activity behaviours⁽¹¹⁸⁾. Indeed, a failure in ER or self-regulation might predispose to sedentary behaviour whereas successful self-regulation has been associated with more physical activity^(65,66). Simultaneously, an individual could perform physical activity to deal with stressful states or negative emotions. In a representative Canadian sample (aged 15 years or over), 40 % reported using exercise for stress coping and these individuals were more likely to use positive coping strategies and less likely to use alcohol or drugs for coping⁽¹¹⁹⁾. Physical activity could play a role as an adaptive coping strategy and also increase well-being and efficient ER skills in adults⁽¹²⁰⁾ and adolescents⁽¹²¹⁾. This effect could be possible through neuro-hormonal mechanisms but also psychological and sociological aspects^(122,123).

Concurrently, stress and disturbed affective states may influence sleep patterns, causing difficulties in falling asleep or sleep disruption^(124,125). Indeed, a comprehensive review described the bidirectional relationship between stress and sleep problems and their underlying pathways⁽¹²⁶⁾. Ineffective ER strategies appear to be related to sleep disturbances, which reduce sleep quantity and quality. Since sleep problems may be associated with diminished self-regulation of appetite, they can increase the risk of overeating and obesity^(126,127). In the other direction, sleep also plays a role in regulating cognitive and emotional processes. Poor sleep may negatively affect the ability of perception, processing and understanding emotional stimuli^(126,128). A recent laboratory study showed that sleep loss affects adequate attention resources during an emotional task⁽¹²⁸⁾. As a consequence, adequate sleep patterns could ameliorate negative emotions and be helpful in ER.

Enhancing emotion-regulation skills for prevention and treatment of obesity

Interventions in adults

Several intervention studies and randomised controlled trials have recently been conducted in adults to test the effectiveness of ER strategies in regulating obesity and food intake⁽¹²⁹⁾. The most frequent strategies are based on the regulatory skills and correspond to new approaches within the cognitive-behavioural psychological therapies. So, mindfulness therapy, acceptance and commitment therapy, self-compassion therapy (loving-kindness therapy), emotionally focused therapy and dialectical behaviour therapy lead to less psychological distress^(130–134), fewer binge eating episodes^(130,131,135), less emotional eating⁽¹³⁶⁾, fewer food cravings^(136–138), healthier eating patterns^(131,139), weight loss^(131,132,134,138), fewer personal barriers to physical activity⁽¹⁴⁰⁾, and improved self-efficacy to weight loss⁽¹⁴¹⁾. Despite a few non-significant findings⁽¹⁴²⁾, these strategies are a promising approach for obesity treatment and prevention.

Mechanisms of intervention

Mindfulness therapy encourages individuals to be non-judgmentally aware of and to understand their emotions so that they can avoid maladaptive ER such as emotional eating⁽¹³⁷⁾. Acceptance therapy could reduce frustration and food preoccupation because it increases the ability to tolerate aversive internal experiences (i.e. anger or sadness)⁽¹³²⁾. Similarly to these therapies, dialectical behaviour therapy and emotionally focused therapy enhance identification, enabling individuals to accept and modify emotions adaptively. Self-compassion therapy is related to self-support and can help to reduce the sense of threat and stimulate a self-soothing system⁽¹⁴³⁾.

The skills used in the several types of therapies are inter-related, and other individual positive factors should be encouraged simultaneously, such as self-empathy, self-esteem, assertiveness, self-efficacy and resilience. For example, self-compassion and mindfulness are related to lower self-criticism since they enhance self-kindness, self-acceptance, self-empathy

and self-esteem⁽³⁹⁾. Through self-empathy, we develop a concern for our well-being, learn to be sensitive and tolerant of our distress, and develop a deep understanding of its roots and causes. Self-empathy is negatively associated with negative affect and stress and could help us to deal with weight and food stress in a non-judgemental/critical way and to develop self-warmth⁽¹⁴³⁾. Self-esteem also could be a mediator between emotional disorders and obesity⁽¹⁴⁴⁾, since low self-esteem in childhood predicts weight gain⁽²⁴⁾. So, good self-esteem could help to enhance self-encouragement and self-coaching, which enables individuals to modify their emotions and to confront negative situations. Along with these skills, assertiveness could be developed and be useful as a strategy of social relation, self-confidence and coping. The ability to analyse and actively modify emotions improves emotional self-efficacy, which reduces stress and avoidance of aversive events. In addition, resilience, which is the capacity to deal successfully with disturbances, is related to awareness, acceptance and tolerance; it decreases vulnerability to negative emotion and boosts self-regulation abilities (i.e. impulse control). This emotional resilience and self-efficacy facilitates a disposition to experience emotionally challenging situations with additional opportunities to strengthen ER skills⁽³⁹⁾. Later, Forman & Butyn⁽¹⁴⁵⁾ considered the acceptance-based intervention efficacious for weight control in individuals who are more susceptible to eating in response to internal and external cues (for instance, availability of unhealthy food). These skills included an ability to tolerate uncomfortable internal responses and a reduction of pleasure, behavioural commitment to clearly defined values, and conscience of decision-making process⁽¹⁴⁵⁾.

Interventions in children

Systematic reviews of interventions show that successful childhood obesity interventions should be multidimensional, combining traditional strategies with behavioural and psychological approaches⁽²⁾. Nevertheless, few interventional studies have focused on emotional factors. One recent review of behavioural interventions reported that only a small number of intervention studies focused on stress management and emotional control training but that these studies were generally effective⁽¹⁴⁶⁾. The latter-mentioned ER techniques have been applied in children and adolescents in the field of mental disorders but not in child obesity. Nevertheless, we have highlighted some intervention studies which could use methods with similar features of ER techniques such as calm down and awareness about feelings and deal with emotion in a healthy way.

In the field of childhood obesity prevention focusing on ER, to our knowledge there is only one pilot study and two ongoing studies^(147–149). A school-based pilot intervention translated specific components of a violence and substance abuse programme into a lifestyle intervention. This pilot programme included seven lessons focusing on teaching tools for controlling impulsiveness, recognising and adaptively dealing with stress, and analysing the effectiveness of possible solutions⁽¹⁴⁷⁾. Although it was a short-term and non-randomised controlled study, the result was a significant change in positive attitudes



toward self-regulation of appetite and positive changes in food and lifestyle⁽¹⁴⁷⁾. A randomised clinical trial and prospective study conducted in 779 adolescents and their parents applied a cognitive-behavioural skills intervention combined with nutrition education and physical activity. The programme included four of fifteen sessions on cognitive reappraisal, emotional and behavioural regulation, stress, coping, goal-setting and overcoming barriers to a healthy lifestyle⁽¹⁴⁹⁾. This intervention indicated a positive impact on physical activity, BMI and psychological outcomes and also after 6 months, the participants had lower BMI⁽¹⁵⁰⁾. Another school-based intervention study is currently being carried out in toddlers, combining a traditional obesity prevention programme with a programme to enhance self-regulation. The study teaches children tools for behavioural self-regulation and includes a parental intervention⁽¹⁴⁸⁾.

In childhood obesity treatment, successful intervention studies have applied cognitive-behavioural therapy to encourage the development of effective ER^(151–157). One pilot interventional study applied a cognitive-behavioural skills-building programme in primary care services. The programme was carried out through seven telephone and clinical sessions, which included evaluation of emotional responses and behaviour. Although their results did not show an effect on BMI, they observed an increase in physical activity, healthy lifestyle behaviours and nutrition knowledge. Long-term results were mainly attained in children with supportive families^(153,154). Another interventional study conducted in thirty-one children aged 6–12 years and their parents showed positive persistent results since anthropometric parameters and energy intake were reduced and family habits and emotional and social problems were improved at 5 years follow-up⁽¹⁵²⁾. Although these studies did not include a control group, their results are promising. Indeed, Sacher *et al.*⁽¹⁵⁶⁾ developed a randomised controlled trial through a multicomponent community-based childhood obesity intervention based on nutritional and behavioural change in 160 obese children and their parents. The intervention showed a reduction in waist circumference and BMI at 6 and 12 months post-intervention. Therefore, both clinical and community settings now support the development of childhood obesity programmes using ER-related skills.

Implications for prevention and treatment

Our model highlighted the role of ineffective ER in weight gain. Effective ER skills development could reduce vulnerability during emotional problems and distress, and avoid developing maladaptive ER strategies such as unhealthy eating behaviour related to obesity (i.e. emotional eating, sedentary behaviour). Therefore, future studies should urgently explore the impact of ER on obesity prevention and treatment by applying interdisciplinary interventions.

Implications for prevention

Given that the acquisition of healthy ER and dietary habits starts in infancy, prevention strategies should be implemented early in life and target the promotion of mental health, effective ER

techniques and healthy lifestyle habits such as eating behaviour. Learning effective ER skills from an early age (i.e. as awareness and understanding emotions, acceptance of emotional distress and to learn to have a tolerance under frustration and negative feelings) could avoid children acquiring and developing maladaptive ER such as emotional eating when they feel overwhelmed by intense emotions or stressful events. These intervention approaches should be applied along with nutritional interventions through family-based community programmes, in primary care or in schools. Since parenting style and parental modelling influence children's ER and lifestyle, community obesity prevention programmes should provide support to parents for teaching conflict and negative emotion management techniques and also seek to actively involve parents and family members in changing their own behaviour. To integrate this approach into the school setting, teachers can act as health agents and ER, along with healthy eating habits and lifestyle, can be incorporated into the school curriculum. This type of curricular programme should focus on learning and encouraging awareness and understanding of feelings, identifying internal strengths and learning effective ER skills. Of course, ER programmes should be adapted to the children's age and should include working groups for parents, to reinforce the concepts and techniques that children learn in class and to help the parents face difficult situations they may encounter with their children. One such novel ER approach has been proposed for a school-based obesity prevention programme^(158,159).

Implications for treatment

In obesity treatment, public health agents and paediatricians are encouraged to consider traditional weight-loss methods and nutritional recommendations along with ER intervention. Through ER-based intervention, barriers in the treatment progress such as shame and preoccupation with food can be targeted by fostering greater self-soothing, self-esteem, resilience and body acceptance. Additionally, families need to be aware of the emotional distress that overweight children suffer from. Consequently, the family should also be involved in the intervention to learn effective ER and how to resolve potential conflicts with the child.

Limitations in the interpretation of the model

Since the model presented in this study is intended to illustrate the potential role of ER in the development of obesity, other risk factors in the stress-obesity pathway have not been mentioned. First, it has been assumed that the associations between stress and obesity share genetic factors like polymorphism on the serotonin 5-HT_{2C} receptor gene, monoamine oxidase A, serotonin transporter gene or the fat mass and obesity associated gene (*FTO* gene)^(160–162). In addition, a recent review suggested that socio-economic disadvantages and family disharmony are a common starting point for weight gain and psychological distress in children⁽³⁾. At the same time, several prenatal, perinatal and postnatal factors (for example, toxics exposure, maternal nutrition, maternal stress, maternal

psychopathology and negative events during early life) have been identified as obesity and/or neurodevelopmental risk factors^(161,163,164).

Additionally, due to the multifaceted nature of the concept, ER has been discussed in the literature under other terms such as self-regulation, self-efficacy, effortful control, impulsivity and emotional eating. This lack of consistent terminology has hindered the literature search strategy and interpretation of studies.

Conclusion

Stress and negative emotions during childhood pose a major threat to public health, since they have been related not only to psychological disease but also to physiological disturbances such as obesity. Our model posits that ER – the process used to cope with negative emotions – is a fundamental link between childhood stress and obesity. The present review enhances knowledge of the mechanistic pathways between ER and eating behaviour and obesity by condensing existing studies to a visual research framework. Stress, combined with ineffective ER, could already be present in childhood and could cause abnormal cortisol patterns, emotional eating, decreased physical activity, increased sedentary behaviour and the onset of sleep problems. A healthy lifestyle, such as physical activity and adequate sleep, could show benefits on ER and in developing adaptive ER strategies. Parents also influence the development of ER and obesity in children, as role models and through their parenting style and parental feeding practice. Effective ER skills could decrease obesity-related unhealthy behaviour and enhance protective factors, which boost mental and physical health. As a result, effective ER could contribute to the prevention and treatment of childhood obesity. Although the literature is limited in child populations, some observational studies but few interventional studies on this relationship have been published whose findings are modest but promising. We proposed that psycho-educative intervention in ER training could increase the efficacy of prevention and treatment programmes of obesity. Therefore, encouraging adaptive ER could be an effective new approach, along with nutritional and physical activity intervention, in the fight against and the treatment of childhood obesity. Also, developing an effective ER could have effects on other health issues such as better well-being and preventing psychological problems in children. Based on the literature addressing the adult population, possible successful therapies include mindfulness-based stress reduction therapy, acceptance and commitment therapy or self-compassion therapy. Furthermore, protective factors could be stimulated, such as resilience, assertiveness, empathy, self-efficacy and self-esteem. Future ER interventions are needed to confirm the validity of this model in children. Scientists in the nutritional area should be encouraged to conduct more interdisciplinary studies on this nutrition- and obesity-related topic.

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