Subtyping youngsters with obesity: A theory-based cluster analysis

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ARTICLE INFO

ABSTRACT

Psychological mechanisms play a crucial role in explaining weight gain. Aim of the present study was to identify subtypes in youngsters with obesity in line with these mechanisms. Defining homogeneous clusters within this heterogeneous group provides relevant information for personalized treatments.

Data were collected in N = 572 participants (51% boys, aged 7–19) with extreme obesity (%BMI M = 187.8; SD = 30.9) recruited in an inpatient treatment centre. Based on psychological models of overweight/obesity, the Affect Regulation Model, the Reward Deficiency Model and The Dual Pathway Model, cluster variables were selected assessing emotional eating, reward reactivity and regulative capacities. Youngsters reported on emotional eating (DEBQ Emotional Eating) and reward sensitivity (BAS), while parents reported on children's regulative Executive Functions (BRIEF). Characteristics of the different clusters were examined concerning weight variables (pre and post treatment) and variables indexing problematic eating (DEBQ External Eating, Ch-EDE), affect regulation (FEEL-KJ) and depressive symptoms (CDI). Hierarchical cluster analyses supported the presence of three clusters, further evaluated by K-means cluster analyses. The cluster solutions differed according to age and sex (boys 7–13, boys 14–19, girls 7–13, girls 14–19). In all four age and gender subsamples, an "Emotional Eating" cluster displaying a vulnerable profile (high depression, maladaptive emotion regulation, problematic eating) and a "Reward Deficiency" cluster displaying a more resilient profile were detected. In girls 7–13, a "Weak Executive Functioning" indicative of insufficient self-regulative capacities, showed moderate to high emotional problems and problematic eating. In the other subgroups, the "Mean Level Functioning" cluster also showed elevated emotional problems and problematic eating. Given that different clusters can be identified, and given that these clusters have different profiles on emotional problems and problematic eating, subtyping youngsters with severe obesity is indicated, setting the stage for personalized treatments.

1. Introduction

The epidemic increase in obesity is often interpreted as inevitable, given the current western obesogenic environment characterized by an oversupply of energy-dense food, an absence of the need for being physically active and a strong inclination to a sedentary life style (O'Brien et al., 2007). Children and adolescents are considered more vulnerable in this context (Boswell, Byrne, & Davies, 2018; WHO, 2016). Several psychological determinants of eating behavior and weight are especially relevant in developing youth. Typical developmental maturation of affective and self-regulative processes (e.g., Cracco, Goossens, & Braet, 2017; Ernst, Pine, & Hardin, 2009) make children and youth highly vulnerable for unhealthy eating behaviors and weight gain (Russell & Russell, 2019).

Several models describe the role of psychological variables in determining the risk for developing weight problems, providing targets for interventions (Durks et al., 2017; Russell & Russell, 2019; Vervoort, Naets, De Guchtenaere, Tanghe, & Braet, 2020). Within the Affective Model of overweight, weight problems are assumed to result from overeating as a response to cope with negative feelings, and ignoring internal cues of satiety (Ganley, 1989). Emotional eating and problems with emotion regulation are considered determinants for overweight.

Emotional eating indeed is found to be related to overeating, higher weight and poorer weight loss outcomes (e.g., Braet & Van Strien, 1997; Goossens, Braet, Van Vlierberghe, & Mels, 2009; Gouveia, Canavarro, & Moreira, 2019; Jalo et al., 2019; Snoek, Engels, van Strien, & Otten, 2013). Innovative interventions might target emotion regulation to enhance treatment outcome (Aparicio, Canals, Arija, De Henauw, & Michels, 2016; Debeuf et al., 2020; van Strien, 2018). Within the Dual Pathway Model, eating behavior of children with overweight is conceptualized as a self-regulation failure reflecting two inadequate underlying mechanisms: a bottom-up automatic system and a top-down reflective system (Appelhans, 2009). The automatic system refers to a deficient stimulus-driven process affecting the eating behavior by an automatic positive appraisal of all observed rewarding stimuli (e.g., food) and by automatically eliciting a strong behavioural tendency to consume (De Decker et al., 2016; De Decker, Verbeken, Sioen, Van Lippevelde et al., 2017; Vandeweghe, Verbeken, Vervoort, Moens, & Braet, 2017; Vandeweghe, Vervoort, Verbeken, Moens, & Braet, 2016; Verbeken, Braet, Claus, Nederkoorn, & Oosterlaan, 2009). The reflective system regulates the influence of automatically triggered responses to rewarding stimuli to guide eating behaviour in line with normative standards or personal goals (Allom & Mullan, 2014; Laurent et al., 2020; Mamrot & Hanc, 2019; Naets, Vervoort, Tanghe, De Guchtenaere, & Braet, 2020; Russell & Russell, 2020). A successful reflective system draws on strong cognitive executive functions (e.g., working memory capacity, cognitive flexibility, planning) to maintain goal-relevant information, and inhibits the outcome of automatic reactive processes. A recent review, based on 135 studies, summarizes the evidence for both processes of the Dual Pathway Model in youngsters with weight problems (Kemps et al., 2020). Despite methodological variations and inconsistent findings across studies, convincing evidence was found that youngsters with overweight show reduced capacity for reflective processing as well as strong automatic reward processes. However, there is some evidence that individuals with obesity show blunted instead of increased automatic reward processes (Verbeken, Braet, Lammertyn, Goossens, & Moens, 2012) consistent with the idea that obesity is related to a Reward Deficiency Syndrome (Blum, Thanos, & Gold, 2014; Volkow et al., 2003). A reduced automatic approach motivation, indicative of deficient reward processing, combined with weak reflective capacities, is found to be associated with higher weight in children, while the combination with strong reflective capacities is found to be associated with lower weight (Mason, Do, & Dunton, early acces 2019).

So far it is often assumed that the underlying psychological mechanisms of weight problems are in disadvantage in *all* youngsters with overweight or obesity, neglecting heterogeneity or individual differences. Furthermore, most research on reactive and regulative processes has typically studied the two aspects of the Dual Pathway Model separately. The exact nature of the interaction between automatic and reflective processes in youngsters with severe weight problems is still unclear. It remains to be determined whether the assumption of joint processing, as proposed in the Dual Pathway Model (Appelhans, 2009) also holds in a population with severe weight problems, or rather that extreme levels of one of the processes overrule the other, as proposed by the Separable Subsystems Hypothesis (Corr, 2002; Vervoort et al., 2010). Cluster analyses provide a valuable tool to jointly examine the role of several underlying mechanisms in clarifying this heterogeneity.

Earlier cluster analyses evaluating the relevance of psychological mechanisms for overweight showed that differentiating between youngsters based on core psychological concepts of the Affect Regulation Model (Ganley, 1989) and the Dietary Restraint Model (Ruderman, 1986) is indeed relevant (Braet & Beyers, 2009; Braet, Beyers, Goossens, Verbeken, & Moens, 2012). In these studies, a large cluster emerged in 45% of the youngsters, characterized by high internalizing problems (e. g. depressive symptoms) and low dietary restraint. A second cluster (22%) was characterized by high internalizing problems and high dietary restraint. The third cluster (33%) was a non-symptomatic group, who did not show elevated levels on the mechanisms proposed by the

Affect Regulation or Dietary Restraint Models. This suggests that in a substantial proportion of youngsters, other mechanisms underlay weight problems, accounting for the heterogeneity in this population. These earlier studies (Braet & Beyers, 2009; Braet et al., 2012) did not test the assumed role of automatic reward processes nor the role of the dual pathway mechanisms. Moreover, although the presence of increased psychological problems was seen by the authors as evidence for the Affect Regulation Model, the causal mechanism suggesting emotional eating as underlying mechanism (Boswell et al., 2018), was not evaluated. An overarching study, integrating different inadequate psychological mechanisms for explaining problematic eating behavior and weight problems in youngsters with obesity is imperative. Because both the reflective and automatic aspects of the Dual Pathway model and the concepts of the Affect Regulation Model have proven to be relevant in several studies with youngsters with overweight and obesity, they might have complementary value in explaining the heterogeneity of this population. In the earlier cluster analyses by Braet and Beyers (2009,2012) different subtypes did not show weight differences, suggesting that the severity of the overweight problem is not indicative for a specific underlying psychological problem. A fine-grained subtyping of youngsters with obesity based on underlying mechanisms will be relevant both for science and practice, as it will be helpful in designing personalized treatment plans (Russell & Russell, 2019; Vervoort et al., 2020).

The current study therefor aims to further evaluate the usefulness of differentiating youngsters with obesity based on theoretically informed and evidence-based psychological processes (emotional, regulative and reactive processes) and has three aims.

Aim 1: We will test the relevance of a new clustering, based on three theory-driven and evidence-based psychological mechanisms explaining weight problems, being emotional eating, self-regulation capacities and reward processing. More specifically we aim to examine whether we can identify in youngsters with obesity a group (1) showing dominant emotional eating, reflecting the assumptions of the Affective Model (i.e., "Emotional Eating" cluster), (2) a group displaying the profile proposed by the Dual-Process Model, showing an unsuccessful self-regulative system, which is related to non-optimal executive functioning and altered automatic reward processing (i.e., "Weak executive functions/ strong reward processing" cluster) and (3) a group demonstrating dominantly low levels of reward processing, independent from levels of executive functioning (i.e., "Reward deficiency" cluster) as described by the Reward Deficiency Model. Given the diverging developmental trajectories and sex differences in bottom-up and top-down processes (Braet et al., 2008; Cracco et al., 2017; Ernst et al., 2009; Russell & Russell, 2019; Vervoort et al., 2015), and their differential impact on weight-related outcomes for boys and girls of different ages which was recently evidenced (De Decker, Verbeken, Sioen, Moens, et al., 2017; Naets et al., 2020; Russell & Russell, 2020), we decided to test this new clustering in four different groups: girls aged 7–13, boys aged 7–13, girls aged 14–19 and boys aged 14–19.[1]

Aim 2. Based on the theoretical models, we predict that clusters can also be validated by describing them on characteristics that are psychological comorbidities of obesity (i.e., emotional problems and emotion regulation, and problematic eating behaviors) (Aparicio et al., 2016; Boswell et al., 2018; Braet et al., 2008; Rao et al., 2020). First, youngsters belonging to the "Emotional Eating" cluster are predicted to show elevated emotional problems and maladaptive emotion regulation strategies. They turn to food when faced with difficult emotions, but rather than regulating these initial emotions, additional negative emotions (like guilt and ultimately depression) emerge. This pattern of emotional problems is reflected in the strong empirical evidence that individuals with obesity often suffer from comorbid depression (Braet,

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[1] Readers interested in the results of the full sample analyses can request those from the first author.

Mervielde, & Vandereycken, 1997; Quek, Tam, Zhang, & Ho, 2017). Second, youngster belonging to the "Weak executive functions/strong reward processing" cluster are predicted to show elevated external eating. Their regulative capacities are insufficient to inhibit their strong reactivity to tempting external cues from the environment. They are also expected to report high incidence rates of binge eating, because their deficient self-regulation cannot stop strong approach behavior (i.e., consumption) towards food (Van Malderen, Goossens, Verbeken, & Kemps, 2020; Voigt et al., 2009). Third, youngsters belonging to the "Reward Deficiency" cluster are predicted to show problems with emotion regulation (Tull, Gratz, Latzman, Kimbrel, & Lejuez, 2010) and high levels of depressive symptoms (Bijttebier, Beck, Claes, & Vander-eycken, 2009; Halahakoon et al., 2020). They are also expected to be often triggered by external stimuli to eat (high external eating) and to experience more binge eating episodes in an effort to satisfy their blunted reward system. Additionally, we will explore the clusters' profile on cognitive aspects of problematic eating (i.e., concerns on shape, weight and eating).

Aim 3. A final research question explores whether one of these subtypes displays more severe overweight/weight problems and poorer treatment outcome compared with the other groups. Although earlier work did not find significant weight differences between clusters (Braet & Beyers, 2009; Braet et al., 2012), they might react differently to weight loss interventions, resulting in differences in pre-post intervention weight changes.

2. Method

2.1. Participants

Participants were 572 children (7–13 years; N = 220; *M* = 11, *SD* = 1.5, 56% boys) and adolescents (14–19 years; N = 352; *M* = 16, *SD* = 1.3; 48% boys), who enrolled for an inpatient multidisciplinary obesity treatment at the Zeepreventorium De Haan during 2014–2018. To test sex and age differences, four subgroups were created, being girls aged 7–13 (n = 97), girls aged 14–19 (n = 183), boys aged 7–13 (n = 123), and boys aged 14–19 (n = 169). For all participants, age and sex adjusted Body Mass Index (%BMI) was calculated at intake by dividing measured BMI (weight in kg/squared length in cm) by norm BMI for age and sex, and multiplying this by 100. Norm BMI for age and sex was determined as the 50th percentiles of the BMI for age and sex based normative data. The resulting value describes the percentage distance from median BMI, which is considered a valuable alternative for BMI z-scores, especially for children and adolescents with severe weight problems (Freedman, Woo, Ogden, Xu, & Cole, 2020). An %BMI equal to or smaller than 85% is considered underweight, equal to or greater than 120% as overweight, equal to or greater than 140% as obese (Fredriks, van Buuren, Wit, & Verloove-Vanhorick, 2000; Rolland-Cachera, Akr-out, & Pénau, 2018). Mean %BMI in the present study was 187.82 (*SD* = 30.87). Post intervention weight and length was available for 538 participants. Prior to the start of data-collection, participants expressed their written assent/consent (depending on age) and one of their parents provided active written informed consent. The study was approved by the Ethical Committee of Ghent Universities Faculty of Psychology and Psychological Sciences (2015/88), and principles on ethical research and privacy were respected in accordance to national laws (Belgian implementation of the General Data Protection Regulation (GDPR) of May 25th, 2018) and the Declaration of Helsinki and its later amendments of 1964. The results of the present study represent secondary data-analyses of data collected by our research group to evaluate treatment outcome reported elsewhere (Naets, Vervoort, Ysebaert, et al., 2018; Verbeken, Boendermaker, et al., 2018; Verbeken, Braet, et al., 2018).

2.2. Instruments

Emotional Eating (EE) was measured with the Emotional Eating subscales of the child version (DEBQ-child, Braet et al., 2008) of the Dutch Eating Behavior Questionnaire (DEBQ, Van Strien, Frijters, Bergers, & Defares, 1986). Thirteen items make up the Emotional Eating Scale and this scale includes statements referring to eating in response to negative emotions. All items have to be answered on a 5-point Likert scale, ranging from 1 = never to 5 = very often. Higher scores indicate more problematic eating behavior (i.e., emotional eating). Raw scale scores are converted to T-scores based on age and sex specific norm data for obese individuals (Braet et al., 2008). The DEBQ-child has shown satisfactory reliability and validity in youngsters between 7 and 18 years old (Braet et al., 2008). In the present sample, internal consistency is excellent (Cronbach's α = 0.95).

Reward Sensitivity (RS) was indexed by the Behavioral Activation Scale (BAS) of the age-downward adaptation of Carver and White's Behavioral Inhibition/Behavioral Activation scales, Dutch version (Muris, Meesters, De Kanter, & Timmerman, 2005). Thirteen items are scored on a 4-point scale (1 = not at all true, 2 = somewhat not true, 3 = somewhat true, 4 = all true) and include statements as "I often do things for no other reason than that they might be fun". Raw BAS-scores are converted to T-scores based on age and sex appropriate norm data. The BAS-scale gives valid self-report indices of reward sensitivity in children and adolescents aged 2–18, as shown by the meaningful relations with instruments assessing related personality traits and psychopathological symptoms (Muris et al., 2005; Vervoort et al., 2010). In the present sample, internal consistency of the total BAS scale is good (Cronbach's α = 0.84).

Executive Functioning (EF) was assessed by the Dutch parent version (Smidts & Huizinga, 2009) of the Behavior Rating Inventory of Executive Functioning (BRIEF, Gioia, Isquith, Guy, Kenworthy, & Baron, 2000), containing 75 items. All items are scored on a 3-point scale ranging from 1 = never to 3 = often, and summed to obtain a total score. Higher scores indicate more problems with EF. Raw scale scores are converted to T-scores based on sex- and age-specific norm data. Reli-ability and validity of the instrument was evidenced for youth aged 5 to 18 (Smidts & Huizinga, 2009). In the present sample, internal consis-tency is excellent (Cronbach's α = 0.97).

Depressive symptoms were measured with the Dutch version (Tim-bremont & Braet, 2002) of the Child Depression Inventory (CDI, Kovacs, 1992). The CDI is a 27-item self-report measure for youth aged 7–17 years to assess cognitive, affective, and behavioral symptoms of depression. Each item comprises three response options, which vary in severity, and are rated on a 3-point scale; children and adolescents select the one that characterized them best during the past 2 weeks. Raw CDI-scores are converted to percentile scores based on age and sex appropriate norm data. The CDI shows good psychometric qualities in terms of internal consistency and test-retest reliability in non-clinical youth (Timbremont & Braet, 2002). The internal consistency of the CDI in the current sample was good (Cronbach's α = 0.86).

Emotion regulation (ER) was assessed using the maladaptive emotion regulation scales of the Dutch version (Braet, Cracco, & Theuwis, 2013) of the Fragebogen zur Erhebung der Emotionsregulation bei Kindern und Jugendlichen (Feel-KJ, Grob & Smolenski, 2005). The FEEL-KJ is a 90-item self-report measure assessing various ER strategies in response to anger, fear, and sadness in youth aged 8 to 18. Participants rate each item on a 5-point Likert scale from 1 = almost never to 5 = almost al-ways. Higher scores on the maladaptive ER scales indicate more frequent use of maladaptive emotion regulation strategies. Raw Feel-KJ-scores are converted to T-scores based on age and sex appro-priate norm data. Good psychometric qualities are reported (Braet et al., 2013; Cracco, Van Durme, & Braet, 2015). Internal consistency for the maladaptive scale in the current study was excellent (Cronbach's α = 0.92).

Problematic eating behaviors were measured with the External

Eating subscale of the child version (DEBQ-child, Braet et al., 2008) and the Children's Eating Disorder Examination Questionnaire (Ch-EDE-Q, Decaluwe & Braet, 2004).

The DEBQ-child is a Dutch age-downward adaptation of the Dutch Eating Behavior Questionnaire (DEBQ, Van Strien et al., 1986). The External Eating scale contains 10 items that have to be answered on a 5-point Likert scale, ranging from 1 = never to 5 = very often. Higher scores indicate more problematic eating behavior. Raw DEBQ-scores are converted to T-scores based on age and sex appropriate norm data. The DEBQ-child has shown satisfactory validity and reliability in child and adolescent samples (Banos et al., 2011; Braet et al., 2008). In the present sample, the internal consistency is good (Cronbach's α = 0.87).

The Ch-EDE-Q is a Dutch age-downward adaptation of the Eating Disorder Examination Questionnaire (Fairburn & Cooper, 1993). The ChEDE-Q was designed for use in youngsters from 8 to 18 years old. The current study includes the subscales assessing the frequency and severity of cognitive aspects of problematic eating behaviors (i.e., eating, weight and shape concerns). All items concern the last 4 weeks and are to be answered on a seven point scale, with minimum score 0 and maximum score 6. The higher the score, the more frequent and the more intense the eating problem. Raw ChEDE-Q-scores are converted to T-scores based on age and sex appropriate norm data. Further, the diagnostic items (to be answered with yes or no) measuring episodes of objective binge eating (OBE), and subjective binge eating (SBE) were registered. OBE can be defined as eating an objectively/unambiguously large amount of food (an amount that is also considered large by other people) within a distinct period of time, accompanied by loss of control while eating. SBE can be defined as eating a subjectively large amount of food (an amount that is considered large by the individual but not by other people), accompanied by loss of control while eating (Fairburn & Cooper, 1993). Research demonstrated the reliability and validity of the ChEDE-Q for examining eating pathology in youngsters from the general population (Goossens & Braet, 2010; Van Durme, Craeynest, Braet, & Goossens, 2015) and in clinical samples of treatment seeking obese youngsters (Decaluwe & Braet, 2003; Decaluwe & Braet, 2003). Seventeen children under 13 did not fill out the Ch-EDE-Q, resulting in a sample of n = 557 for this variable. In the current sample internal consistency was acceptable for Eating (Cronbach's α = 0.77) and Weight Concerns (Cronbach's alpha = .72) and good for Shape Concerns (Cronbach's α = 0.89).

3. Data analyses

Based on a recent study of Naets et al. (2020) showing the differential impact of someone's sex and age on psychological mechanisms for obesity, subtype analyses were conducted separately in adolescent boys and girls, as well as in childhood boys and girls, leading to four different cluster analyses. These analyses were performed using IBM® SPSS® Statistics 24 (Aim 1), using standardized Z-scores of the Emotional Eating Scale of the DEBQ (EE), the total scale of the BRIEF for assessing Executive Functioning (EF) and the total BAS-scale of the BIS/BAS scale for assessing Reward Sensitivity (RS). Cluster analyses were performed in two steps. (1) To evaluate whether our hypothesized three cluster solution would be probable, we inspected the agglomeration schedule coefficients and the dendrogram outputs of Hierarchical Clustering analyses, using Ward's method on squared Euclidian distances among cluster variables (Sebastiani & Perls, 2016; Yim & Ramdeen, 2015). Both techniques provided support for a three cluster solution. (2) The principle cluster technique to identify the final clusters was the k-means cluster technique in an iterative procedure with 100 iterations. To check whether the clustering procedure had indeed resulted in different subtypes of youngsters with obesity, scores on clustering variables were compared between the clusters by means of one-way ANOVAs for continuous variables and Chi-squared (χ^2) test for dichotomous variables. Differences between clusters were further evaluated, using eta square (η^2) for significant F(2,df)-tests and Cramer's V (ϕ_c) for

significant χ^2(2)-tests, as small (if η^2 is between 0.01 and 0.06 or ϕ_c between 0.07 and 0.21), medium (if η^2 is between 0.06 and 0.14 or ϕ_c between 0.21 and 0.35) or large (if η^2 is at least 0.14 or ϕ_c is at least 0.35) (Kim, 2017; Lakens, 2013). Standardized T-scores (T = 10*z+50) based on norm data or published data were used to interpret whether the clusters were indicative of 'high problematic functioning' (T-score > 60), 'moderate functioning' (T-score between 40 and 60) or 'low problematic functioning' (T-score < 40) on the clustering variables[2] vis-à-vis functioning in the given age and sex group.

External validity of the subtypes was evaluated by comparing the scores of the different clusters on variables related to emotion regulation, depressive symptoms, problematic eating behaviors and cognitions (Aim 2), and finally on two weight related variables, being %BMI before treatment and pre-post treatment change in %BMI (Aim 3) in all four sex and age subsamples using one-way ANOVAs.

4. Results

Table 1 displays the final cluster centers (based on standardized clustering variables) for the three-cluster solution in the four subsamples, showing that the interpretation of the three clusters differs between groups.

4.1. Identifying and labeling the clusters (Aim 1, Table 2, Fig. 1)

In boys, a first cluster was interpreted as "Mean Level Functioning" given the moderate scores on all three clustering variables and included 41% of the boys aged 7–13 and 46% of the boys aged 14–19. A second cluster was interpreted as "Emotional Eating" cluster given the high levels of EE and included 30% of the boys aged 7–13 and 40% of the boys aged 14–19. A third cluster was interpreted as a "Reward Deficiency" cluster, given the low RS scores and included 29% of the boys aged 7–13 and 14% of the boys aged 14–19.

In girls, cluster labeling was different between age groups for one cluster. In girls aged 7–13, a first cluster was labelled "Problematic Reflective Functioning" (31% of girls aged 7–13), given the low levels of EF. In girls aged 14–19, a first cluster was comparable to the "Mean Level Functioning" cluster in boys (19% of girls aged 14–19). The "Emotional Eating" cluster was also found in girls, in both age groups (21% of the girls aged 7–13 and 36% of the girls aged 14–19). The third cluster in girls was similar in both age groups and comparable to the "Reward Deficiency" cluster in boys. This cluster included 49% of the girls aged 7–13 and 45% of the girls aged 14–19.

4.2. Differences between clusters on validating variables (Aim 2, Table 3)

4.2.1. Emotional regulation and depressive symptoms

The use of maladaptive emotion regulation strategies differed significantly between clusters in the adolescent subsamples (boys and girls aged 14–19). In these subsamples, the "Emotional Eating" cluster showed the highest scores on the FEEL-KJ maladaptive scales compared with the other two clusters.

Depressive symptoms differed significantly between clusters. In all subsamples, the "Emotional Eating" cluster showed high scores on the CDI-depressive symptoms (>Perc 65) with significantly higher scores compared with the "Reward Deficiency" cluster, for 3 subsamples (not for girls aged 7–13). The "Emotional Eating" cluster also reported significantly more depressive symptoms compared with the "Mean Level Functioning" cluster in boys aged 14–19, but not in boys aged 7–13 and not in girls aged 14–19. In girls aged 7–13, the "Weak Executive Functioning" cluster showed the highest CDI-scores.

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[2] For Reward Sensitivity, T-scores < 40 are indicative of low levels of automatic reactivity to rewarding stimuli, signaling deficient reward processing.

Table 1
Final cluster centers (Z-scores).

	Cluster 1				Cluster 2				Cluster 3			
	Boys		Girls		Boys		Girls		Boys		Girls	
	7–13	14–19	7–13	14–19	7–13	14–19	7–13	14–19	7–13	14–19	7–13	14–19
Z(Emotional Eating)	−0.67	−0.52	0.23	−0.84	1.21	0.83	−0.61	−0.47	−0.31	−0.69	1.10	1.05
Z(Executive Functioning)	0.41	−0.34	1.18	0.64	0.52	0.69	−0.54	−0.62	−1.11	−0.86	−0.50	0.44
Z(Reward Sensitivity)	0.46	0.13	0.49	0.82	0.10	0.48	−0.50	−0.57	−0.73	−1.79	0.43	0.29

Note. Higher Z-scores on EF indicate more problems with executive functioning, higher Z-scores on RS stronger reward sensitivity, higher Z-scores on EE more emotional eating.

Table 2
Means (standard deviations) of standardized clustering variables (T-scores) for boys and girls.

	Boys 7-13		Boys 14-19		Boys 7-13		Boys 14-19		Boys 7-13		Boys 14-19	
	"Mean Level Functioning"				"Emotional Eating"				"Reward Deficiency"			
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
T(EE)	41.02	(7.11)	49.28	(9.08)	69.09	(9.17)	57.83	(10.89)	46.44	(10.40)	49.94	(11.26)
T(EF)	54.10	(7.04)	45.44	(9.64)	55.35	(10.59)	57.47	(9.41)	36.83	(5.92)	39.46	(8.16)
T(RS)	48.67	(7.82)	43.23	(7.20)	44.96	(9.76)	47.31	(8.11)	36.45	(9.73)	20.87	(8.40)
	Girls 7-13		Girls 14-19		Girls 7-13		Girls 14-19		Girls 7-13		Girls 14-19	
	"Weak Executive Functions"		"Mean Level Functioning"		"Emotional Eating"				"Reward Deficiency"			
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
T(EE)	56.10	(12.68)	45.04	(6.11)	68.56	(12.71)	71.00	(8.30)	44.14	(7.98)	50.20	(9.09)
T(EF)	64.17	(6.51)	55.91	(8.97)	46.45	(6.48)	53.95	(8.85)	46.02	(6.37)	43.46	(7.28)
T(RS)	44.51	(6.87)	48.30	(7.64)	43.92	(7.91)	43.11	(8.90)	35.82	(8.28)	34.86	(7.50)

Note. Higher Z-scores on EF indicate more problems with executive functioning, higher Z-scores on RS stronger reward sensitivity, higher Z-scores on EE more emotional eating.

4.2.2. Problematic eating behavior and cognitions

External Eating differed significantly between clusters in all four subsamples. The "Emotional Eating" cluster scored significantly higher than the two other clusters in boys and girls of both age groups. The "Reward Deficiency" cluster scored significantly lower than the two other clusters in boys aged 14–19 and in girls aged 7–13.

With respect to the presence of objective and subjective binge eating episodes, significant differences between clusters emerged in boys aged 14–19, not in the other subsamples. More individuals in the "Emotional Eating" cluster reported objective (38%) and subjective (28%) binge eating episodes, while in the "Reward Deficiency" cluster, only a small portion reported objective (1%) and subjective (1%) binge eating episodes.

Shape, Eating and Weight Concerns differed significantly between clusters for three subsamples, but not for girls aged 7–13. The "Emotional Eating" cluster scored significantly higher compared with the two other clusters on Shape and Weight Concerns in boys aged 7–13, significantly higher on Eating Concerns in boys aged 14–19, and significantly higher on all three Concerns in girls aged 14–19. Only in boys aged 14–19, the "Reward Deficiency" cluster scored significantly lower compared with the two other clusters on all three Concerns.

4.3. Differences between clusters on weight related variables (Aim 3, Table 4)

Significant differences between clusters on weight related variables emerged in boys aged 14–19, where the "Reward deficiency" cluster showed significantly smaller weight loss (defined as less change in the % BMI after treatment) compared to the other clusters. There were no other significant differences between clusters neither on pre-treatment %BMI, nor on %BMI change.

5. Discussion

Different psychological mechanisms are assumed to play a crucial

role in explaining someones weight. Given the large hetereogeneity between youngsters with weight problems, it is questionable that these different psychological mechanisms would be equally meaningful in all individuals with obesity. The aim of the present study was to find sub-types of youngsters with obesity, clustering them on three strongly evidenced psychological mechanisms explaining their eating behavior and overweight: (1) emotional eating, (2) altered reward processing and (3) deficient self-regulating executive functions. Because a recent study by Naets et al. (2020) showed that psychological mechanisms have a differential impact according someone's sex and age, analyses were conducted separately four different subsamples: childhood boys, child-hood girls, adolescent boys, and adolescent girls. After establishing subtypes through the cluster analyses, we validated the cluster by comparing them on variables relating to emotional processing, prob-lematic eating and weight parameters.

In line with the hypothesis for Aim 1, three subtypes of youngsters with obesity could be identified in all four age and gender subsamples. A first cluster appeared in all four subsamples, characterized by elevated levels of emotional eating and mean/moderate levels of executive functioning and reward processing. This cluster, further referred to as the "Emotional eating" subtype, represented 30% of the childhood boys, 40% of adolescent boys, 21% of childhood girls and 36% of adolescent girls. A second cluster type in boys of both age groups was characterized by moderate levels of functioning on all three psychological processes (emotional eating, reflective executive functioning and automatic reward processing). This cluster, further referred to as the "Mean Level Functioning" subtype, represented 41% of the childhood boys, 46% of adolescent boys, and 19% of adolescent girls. Interestingly, in childhood girls, this particular cluster was not found. Alternatively, in 31% of girls aged 9–13, another cluster was found characterized by difficulties in self-regulation. This cluster was labelled the "Weak Executive Func-tions" subtype. A third cluster, characterized by low levels of automatic reactivity to rewarding stimuli, appeared in all age and sex subsamples. This cluster was labelled the "Reward Deficiency" subtype and repre-sented 29% of childhood boys, 14% of adolescent boys, 48% of

Table 3

Means (standard deviations) of standardized variables related to emotion regulation (T-scores), depressive symptoms (percentile-scores) and eating disorder symptoms for boys and girls.

Boys 7-13	"Mean Level Functioning"		"Emotional Eating"		"Reward Deficiency"					
	M	(SD)	M	(SD)	M	(SD)	F(2,df)	p-value	E.S.	Interpretation E.S.
T(FEEL-KJ maladaptive)	52.94	(12.75)	56.89	(12.74)	50.44	(13.60)	2.30	.11	–	–
P(CDI)	74.38[a]	(22.86)	74.59[a]	(25.19)	59.81[b]	(30.58)	4.05	.02	.06	Medium
T(DEBQ-Ch External Eating)	50.70[a]	(12.43)	60.80[b]	(9.44)	48.12[a]	(15.52)	12.11	<.001	.17	Large
T(Ch-EDE-Q Shape Concerns)	48.69[a]	(9.37)	54.02[b]	(9.51)	47.56[a]	(10.34)	4.60	.01	.08	Medium
T(Ch-EDE-Q Eating Concerns)	49.41[a,b]	(9.94)	53.32[a]	(9.70)	47.30[b]	(9.70)	3.44	.04	.06	Medium
T(Ch-EDE-Q Weight Concerns)	49.40[a]	(9.85)	54.33[b]	(8.76)	46.24[a]	(9.96)	6.41	.002	.10	Medium to large
	No	Yes	No	Yes	No	Yes	Chi²(2)	p-value		
Ch-EDE-Q Objective Binge Eating	36	10	27	8	30	4	1.71	.40	–	–
Ch-EDE-Q Subjective Binge Eating	39	6	30	6	27	7	0.74	.69	–	–

Boys 14-19	"Mean Level Functioning"		"Emotional Eating"		"Reward Deficiency"					
	M	(SD)	M	(SD)	M	(SD)	F(2,df)	p-value	E.S.	Interpretation E.S
T(FEEL-KJ maladaptive)	49.84[a]	(14.07)	59.12[b]	(12.03)	39.92[c]	(15.72)	19.93	<.001	.19	Large
P(CDI)	67.06[a]	(26.61)	79.72[b]	(21.42)	60.08[a]	(33.39)	6.95	<.001	.08	Medium
T(DEBQ-Ch External Eating)	48.55[a]	(11.40)	57.61[b]	(9.64)	42.04[c]	(9.29)	24.56	<.001	.23	Large
T(Ch-EDE-Q Shape Concerns)	50.06[a]	(9.96)	51.87[a]	(9.32)	44.51[b]	(10.40)	5.40	.008	.06	Medium
T(Ch-EDE-Q Eating Concerns)	49.42[a]	(8.73)	52.76[b]	(11.14)	44.06[c]	(7.52)	7.48	.001	.08	Medium
T(Ch-EDE-Q Weight Concerns)	50.33[a]	(9.74)	51.09[a]	(9.30)	43.55[b]	(10.52)	6.60	.002	.08	Medium
	No	Yes	No	Yes	No	Yes	Chi²(2)	p-value		
Ch-EDE-Q Objective Binge Eating	62	19	39	24	22	2	11.54	.003	.26	Medium
Ch-EDE-Q Subjective Binge Eating	66	11	46	18	22	2	6.40	.04	.20	Medium

GIRLS 7-13	"Weak Executive Functions"		"Emotional Eating"		"Reward deficiency"					
	M	(SD)	M	(SD)	M	(SD)	F(2,df)	p-value	E.S.	Interpretation E.S
T(FEEL-KJ maladaptive)	49.03	(12.44)	48.80	(12.90)	44.87	(1.88)	1.34	.27	–	
P(CDI)	82.27[a]	(14.50)	69.45[b]	(22.31)	60.81[b]	(29.97)	6.96	<.001	.13	Medium to large
T(DEBQ-Ch External Eating)	55.14[a]	(11.81)	64.33[c]	(11.85)	46.60[b]	(9.70)	19.72	<.001	.30	Large
T(Ch-EDE-Q Shape Concerns)	49.51	(9.65)	51.53	(10.42)	49.62	(10.18)	0.28	.76	–	–
T(Ch-EDE-Q Eating Concerns)	50.27	(9.05)	51.27	(10.31)	49.80	(10.53)	0.27	.77	–	–
T(Ch-EDE-Q Weight Concerns)	50.77	(10.28)	49.61	(10.32)	49.73	(9.91)	0.10	.90	–	–
	No	Yes	No	yes	No	Yes	Chi²(2)	p-value		
Ch-EDE-Q Objective Binge Eating	19	4	11	8	31	7	4.64	.10	–	–
Ch-EDE-Q Subjective Binge Eating	17	5	13	5	28	7	0.41	.82	–	–

GIRLS 14-19	"Mean Level Functioning"		"Emotional Eating"		"Reward deficiency"					
	M	(SD)	M	(SD)	M	(SD)	F(2,df)	p-value	E.S	Interpretation E.S
T(FEEL-KJ maladaptive)	50.74[a]	(12.83)	54.72[b]	(12.39)	48.13[a]	(10.00)	6.04	.03	.06	Medium
P(CDI)	71.09[a,b]	(21.76)	80.09[a]	(20.30)	61.82[b]	(28.20)	10.21	<.001	.10	Medium to large
T(DEBQ-Ch External Eating)	48.57[a]	(10.46)	59.39[b]	(9.71)	48.26[a]	(9.29)	27.34	<.001	.23	Large
T(Ch-EDE-Q Shape Concerns)	49.05[a]	(9.15)	54.46[b]	(9.07)	46.91[a]	(9.86)	11.84	<.001	.12	Medium to large
T(Ch-EDE-Q Eating Concerns)	49.40[a]	(7.21)	55.53[b]	(11.19)	45.92[a]	(7.84)	20.54	<.001	.19	Large
T(Ch-EDE-Q Weight Concerns)	49.63[a]	(8.78)	53.91[b]	(9.72)	47.10[a]	(9.78)	9.26	<.001	.09	Medium to large
	No	Yes	No	Yes	No	Yes	Chi²(2)	p-value		
Ch-EDE-Q Objective Binge Eating	28	7	40	21	65	16	4.56	.10	–	–
Ch-EDE-Q Subjective Binge Eating	31	4	46	16	67	12	3.97	.14	–	–

Note. Means sharing the same superscript are not significantly different from each other. E.S. = effect-size for the overall difference between clusters: η^2 for one-way ANOVA, ϕv for χ^2. F(2,df): df = 120, 166, 94, 180 for FEEL-KJ, CDI, DEBQ-Ch and 114, 166, 85, 180 for EDE-Ch for boys 7–13, boys 14–19, girls 7–13 and girls 14–19 respectively.

childhood girls and 45% of adolescent girls.

In all four subsamples, the expected clusters involving emotional eating and deficient reward processes could be identified, consistent with the assumptions from the Affective Model and the Reward Deficiency Model respectively. However, on the cluster involving self-regulation, interpretation of the cluster solutions differed from our hypothesis. Following the Dual Pathway Model, a cluster with weak reflective capacities and strong automatic reflective processing was expected. Yet, the data of the present study show evidence for a subtype with weak reflective capacities only in childhood girls (i.e., the "Weak Executive Functions" subtype). However, inconsistent with the assumptions of the Dual Pathway Model, there are no indications for deficient reward processing in this particular cluster. Although interactive effects of reflective and reactive processes were not tested, this pattern of results might point to the suggestion that in girls aged 9–13 with obesity, both processes reflect the activity of separable rather than joint subsystems, since weak reflective processes seem to overrule

reactivity. In boys of both age groups and in adolescent girls, a cluster with moderate levels of functioning on all three psychological processes was identified (i.e., the "Mean Level Functioning" subtype). It must be noted, however, that by using T-scores based on age and sex specific norm data, information on adaptiveness in terms of 'fully developed' might be lacking. There is evidence that self-regulation is not fully developed before young adulthood (Jurado & Rosselli, 2007; Zelazo & Carlson, 2012). Moderate levels of functioning in children and adolescents might not be equally strong than moderate levels of functioning in adults, since the average functioning in younger age groups is still underdeveloped compared to fully matured self-regulation in adulthood. Analogously, Reward Sensitivity peaks through adolescence (Galvan, 2013). Moderate levels of Reward Sensitivity in this age group might therefore be indicative of a relatively stronger reactive system than moderate levels in adults. Furthermore, the development of reflective and reactive processes diverges in adolescence: reactivity is increased while reflective capacities mature at a slower pace, putting strains on

Table 4
Means (standard deviations) of adjusted BMI for boys and girls.

Boys 7-13	"Mean Level Functioning"		"Emotional Eating"		"Reward deficiency"				
	M	(SD)	M	(SD)	M	(SD)	F(2,df)	p-value	E.S.
adjBMI	184.57	(30.43)	191.69	(30.56)	183.22	(36.85)	0.74	.48	–
adjBMI change	27.46	(11.81)	30.59	(6.92)	26.43	(8.95)	1.71	.19	–
	"Mean Level Functioning"		"Emotional Eating"		"Reward deficiency"				
Boys 14-19	M	(SD)	M	(SD)	M	(SD)			
adjBMI	188.86	(35.37)	194.09	(27.13)	186.37	(48.28)	0.62	.54	–
adjBMI change	28.99[a]	(11.31)	27.73[a]	(8.54)	21.93 [b]	(13.43)	3.75	.03	.05
	"Weak Executive Functions"		"Emotional Eating"		"Reward deficiency"				
Girls 7-13	M	(SD)	M	(SD)	M	(SD)			
adjBMI	178.13	(26.35)	187.08	(21.73)	187.83	(26.33)	1.44	.24	–
adjBMI change	27.86	(7.43)	25.96	(12.25)	25.74	(12.18)	0.34	.71	–
	"Mean Level Functioning"		"Emotional Eating"		"Reward deficiency"				
Girls 14-17	M	(SD)	M	(SD)	M	(SD)			
adjBMI	192.39	(26.36)	186.67	(28.73)	187.03	(30.16)	0.52	.60	–
adjBMI change	247.87	(6.52)	21.83	(11.34)	22.23	(7.96)	1.35	.26	

Note. E.S. = effect-size for the overall difference between clusters: partial eta^2 F(2,df): df = 120, 164, 94, 180 for adjBMI and 112, 153, 88, 173 for adjBMI change for boys 7–13, boys 14–19, girls 7–13 and girls 14–19 respectively.
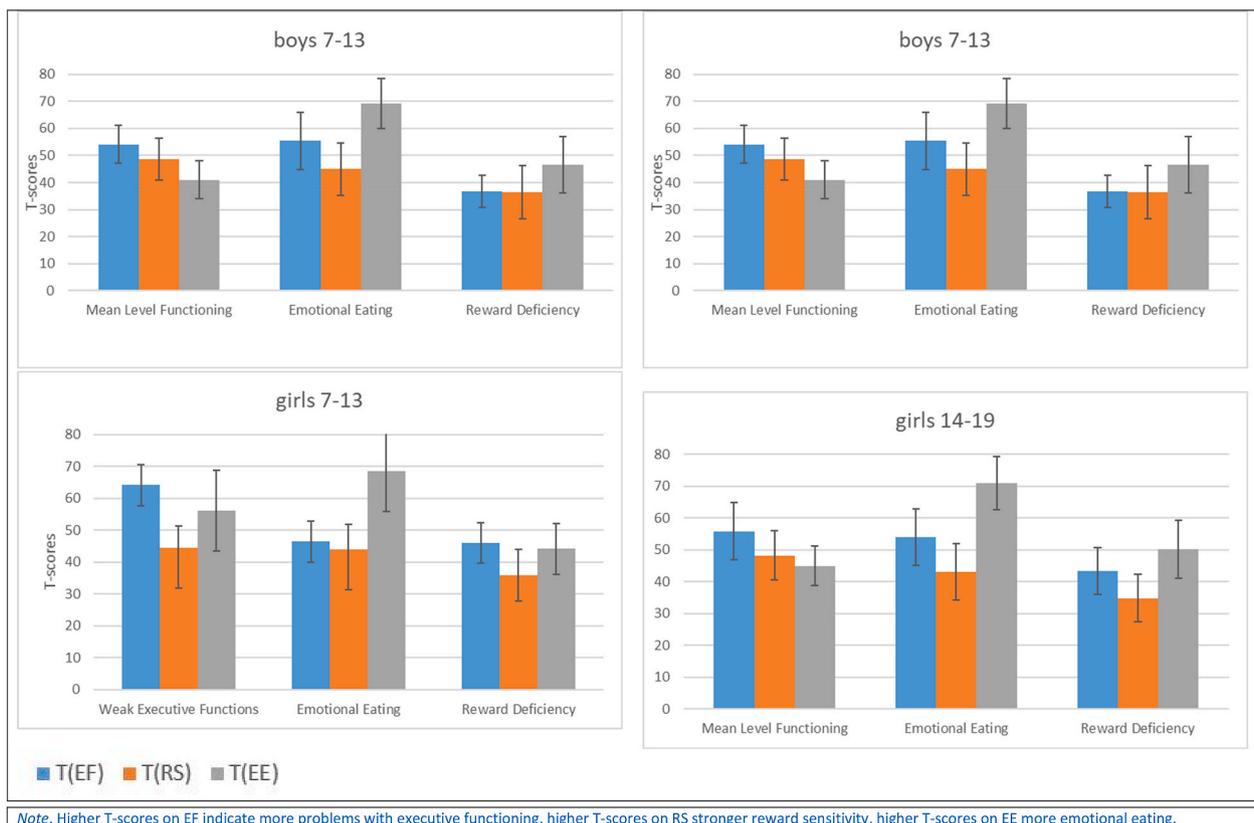
Fig. 1. Means and standard deviations of standardized clustering variables (T-scores) for boys and girls
Note. Higher T-scores on EF indicate more problems with executive functioning, higher T-scores on RS stronger reward sensitivity, higher T-scores on EE more emotional eating.

self-regulation (Ernst, 2014; Ernst et al., 2009; Hardin & Ernst, 2009). Therefore, although the data suggest that participants in the present study have rather moderate self-regulative capacities typical for their age, this level of functioning might still be insufficient to deal with the both the challenges and temptations presented in the environment and the strong reward sensitivity that is typical for adolescence. The imbalance between top-down control and bottom-up automatic processes (Ernst, 2014) puts youngsters at risk for developing eating and weight problems (Russell & Russell, 2020). The cluster identified here as the "Mean Level Functioning" subtype, can therefore tentatively be seen as support for the assumption that, in an obesogenic environment, the joint operation of moderate executive functioning and moderate reward sensitivity might contributes to weight problems.

In order to gain more insight on the characteristics of the identified

subtypes, the clusters were validated using indices of psychological functioning (i.e., emotion regulation, depressive symptoms and problematic eating behaviors) (Aim 2). Inspection of the results show that the different clusters indeed show different patterns of psychological comorbidities of obesity. In adolescents, the "Emotional Eating" subtype displayed higher use of maladaptive ER strategies than both other subtypes. In children, differences between subtypes on emotion regulation did not yet emerge.

Depressive symptoms were elevated in all subtypes, in all four age and gender subsamples, with all scores above the median, even (almost) reaching the upper quartile for the "Mean Level Functioning", the 'Emotional Eating' and the "Weak Executive Functioning" subtypes. Unexpectedly, depression scores were moderately high (percentile around 60) in the "Reward Deficiency" subtype, so this subtype reported significantly less symptoms of depression compared to other obesity subtypes. Interesting, also other 'signs' of resilience emerge: e.g. adolescent boys of the "Reward Deficiency" subtype used significantly less maladaptive ER strategies, while the use of maladaptive ER strategies in adolescent girls of this type was moderate.

Problematic eating behaviors were most prominent in the "Emotional Eating" subtype with highest scores on External Eating in all subgroups and most reports of objective and subjective binges in adolescent boys. Unexpectedly, External Eating was moderate in the subtypes involving low regulative capacities, i.e., the "Mean Level Functioning" and the "Weak Executive Functioning" subtypes, and for adolescent boys and childhood girls also in the "Reward Deficiency" subtypes. Adolescent boys of the "Reward Deficiency" subtype also reported the least objective and subjective binges. Cognitive aspects of problematic eating (i.e. Shape, Eating and Weight Concerns) were moderate in all subtypes, but mostly significantly higher in the "Emotional Eating" subtypes for child and adolescent boys and in adolescent girls, and significantly lower in the "Reward Deficiency" subtypes for adolescent boys. Summarizing, data suggest that, concerning psychological outcomes of obesity, children and adolescents of the "Emotional Eating subtype" seem the most vulnerable, while those of the "Reward Deficiency" subtype seem the most resilient.

Consistent with the results of earlier cluster analyses (Braet & Beyers, 2009; Braet et al., 2012), there were no significant differences on pre-treatment weight between subtypes (Aim 3). Even more, post-treatment weight change only differed significantly between subtypes in adolescent boys, where the "Reward Deficiency" subtype lost significantly less weight compared to the other groups. It may seem remarkable that the cluster that appeared most protected against eating pathology and emotional suffering, lost the least weight over time. This might be related to the extreme low scores on Reward Sensitivity in this particular subtype of adolescent boys ($M = 20.87$, $SD = 8.40$). This extreme low score might indicate not only weak automatic reactivity towards rewarding stimuli, but also a more general lack of motivation and drive towards goad directed behavior (Gray, 1982). This motivational deficit might explain difficulties in adhering to healthy lifestyle behaviors in order to establish and maintain weight loss.

The results of this study have to be interpreted in line with its specific characteristics, strengths and weaknesses. The present study included a large sample (n = 572) of children and adolescents with extreme obesity (mean %BMI = 187.82). The sample was recruited over several years in a specialized inpatient centre for multidisciplinary obesity treatment, which makes it a very particular and highly selected group. This approach only allows to draw conclusions for this particular weight range, and therefore results do not necessarily generalize to girls, boys, children and adolescents with overweight or modest obesity. Two clustering variables (EE and RS) and all validating variables were assessed using only self-report, which is known to be biased (Braet et al., 2014) and lacking input from other informants (e.g. parents, care givers, treatment center staff) which might have brought in additional information on relevant characteristics. Yet, parents did report on their offspring's executive functioning and participant's weight and length were

measured by staff members. The present study only focused on weight loss immediately after inpatient treatment. It is possible that the treatment outcome for the different subtypes might diverge at follow-up, when children and adolescents leave the highly controlled inpatient setting with limited food temptation and return back home, into what is probably an obesogenic environment (WHO, 2016). The different environmental characteristics might have differential impact on the different subtypes. The present study described different subtypes of youngsters with severe obesity, based on theory-driven and empirically-supported psychological variables. However, obesity is not only determined by individual, psychological factors (Bohnert, Loren, & Miller, 2020; Harrist et al., 2012; Russell & Russell, 2019). For example, individual biological factors, like low grade inflammation (Mac Giollabhui et al., 2020; Montero, Walther, Perez-Martin, Roche, & Vinet, 2012), or the obesogenic environment (Birch & Anzman, 2010; Swinburn, Egger, & Raza, 1999) are evidence-based determinants of this multifactorial problem.

Irrespective of its limitations, this study is of great clinical relevance. Childhood obesity is still a major health problem with long-lasting consequences that needs urgent effort both from science and clinicians (WHO, 2016). Behavioural lifestyle interventions might lead to clinically meaningful weight loss, however not all children and adolescents succeed in obtaining or sustaining this (Al-Khudairy et al., 2017; Mead et al., 2017). The limited success of the present obesity intervention might be the result of an 'one-size-fits-all' approach that neglects the hetereogeneity of children and adolescents with obesity. A personal approach, tailored to relevant individual characteristics might have beneficial effects on treatment outcome (Hamel & Robbins, 2013; Vervoort et al., 2020). Identifying subtypes of patients prior to the start of treatment, could make it easier to tailor treatments to relevant determinants of a patient's weight problem. Furthermore, scrutinizing the differences between subtypes on psychological comorbidities of obesity, brings valid information for personalizing treatment, not only aiming sustainable weight change, but also at fostering mental well-being. For example, children and adolescents of the "Emotional Eating" subtype seem to have multiple problems threatening their well-being. For them, additional training in emotion regulation should be highly recommended. Children and adolescents with insufficient self-regulation capacities, i.e., those in the "Weak Executive Functioning" and the "Mean levels functioning" might benefit from intensive inhibition training (Kemps et al., 2020; Naets, Vervoort, Verbeken, & Braet, 2018; Verbeken, Braet, Goossens, & van der Oord, 2013; Verbeken, Braet, et al., 2018). Additional environmental changes aimed at limiting access to unhealthy food might further increase their chances of attaining and maintaining a more healthy lifestyle. The"Reward Deficiency" seemed to be the most resilient in relation to emotional difficulties and problematic eating behavior. However, the adolescent boys in this subtype lost the least weight during treatment. To increase their chances of a healthy life, further research on their specificities is imperative.

To conclude, the present study confirms there is great heterogeneity in children and obesity with diverging psychological profiles. In order to maximize potential treatment outcome for all these youngsters, not only related to weight but also to mental well-being, requires a theory-driven and evidence-based approach. Given the multifactorial nature of obesity, multidisciplinary collaborations are required to find a solution for this problem.

Author contributions

working on this manuscript. LV, TN and AT share Project Administration. LV was in charge of Conceptualization, Methodology, Software, Validation, Formal Analysis, Writing (original draft) and Visualization. CB and LG were additionally involved in Conceptualization, LC in Conceptualization, Methodology and Formal Analysis. The other authors reviewed and edited the first draft.TN, SV, and AT participated in Investigation. TN and LV did Data Curation. Resources were provided by CB.

Originality and plagiarism

We state that we have written entirely original works, and that all work of others that is mentioned has been appropriately cited.

Multiple, redundant or concurrent publication

The research described in this manuscript is not published, submitted or presented elsewhere.

Reporting standards

Our report presents an accurate account of the work performed as well as an objective discussion of its significance. If we would ever discover a significant error or inaccuracy in this work, we will promptly notify the journal editor or publisher and cooperate with the editor to retract or correct the paper.

Data access and retention

We keep the raw data available for editorial review, and we are prepared to provide public access to such data.

Declaration of competing interest

The authors have no conflict of interest to declare.

Acknowledgement

The authors like to thank all children and adolescents and their parents for participating in the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105723.

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