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Patterns of eating behavior in people with severe obesity seeking weight loss treatment: An exploratory study

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ABSTRACT

Although subjects with severe obesity need specific interventions, knowledge about their eating behavior, physical and mental health profiles remains insufficient. This cross-sectional study aimed to identify profiles of individuals with severe obesity based on clinical, psychological and eating behavior characteristics. We included 126 participants (103 women; mean age: 47.2 ± 13.9 years; mean BMI: 41.0 ± 5.7 kg/m²). Cluster analyses were performed to identify profiles based on age, waist circumference, eating behavior, depressive symptoms, food-related quality of life and physical activity. Metabolic syndrome components and type 2 diabetes prevalence were compared between the clusters. Three clusters were identified. Cluster 1 labeled *struggling with food* (48% of the population) had high scores on both emotional eating and uncontrolled eating, low score on comfort with food and they had depressive symptoms. Cluster 2, *low loss of eating control* (29%), had low scores on emotional eating and uncontrolled eating, and high quality of life in the psychosocial dimension. Cluster 3, *pleasure from eating* (22%), had the greatest score on comfort with food, the highest physical activity level, and depressive symptoms. In cluster 2, prevalence of type 2 diabetes was higher, although not statistically significant. Otherwise, no differences were found between clusters. Conclusion: Subjects with severe obesity have different profiles, partly explained by their eating behavior, associated with clinical and behavioral patterns. Further studies should confirm this cluster structure and assess how these profiles impact the evolution of obesity and whether they can help to improve the personalization of care programs.

1. Introduction

Already at 13%, the prevalence of obesity is still increasing worldwide and projections indicate a continuous increase over the next years with a more marked increase among the most severe classes of obesity (Twells et al., 2014). Indeed, class II (body mass index, BMI **35.0–39.9** kg/m²) and class III (BMI ≥ 40.0 kg/m²) obesity showed a **30%** increase over the last decades leading to an important burden for the healthcare systems (Twells et al., 2014). Obesity, a multifactorial chronic disease, has many consequences on physical (e.g., physical multimorbidity, metabolic syndrome) (Kivimäki et al., 2017), psychosocial (e.g., health-related quality of life) (Fontaine and Barofsky, 2001) and mental health (e.g., depression) (Romain et al., 2018).

In individuals living with obesity, changes in health behavior are recommended to favor weight loss and improve health (Baillot et al., 2015). However, following the recommendations regarding diet and physical activity is difficult (Bastin et al., 2019). This may be due to the fact that obesity is a complex disease in which many factors interact including physiological, psychological, social and environmental factors (van Strien, 2018). Regarding eating behavior, different profiles can be observed in people with obesity. Uncontrolled eating (loss of control over food intake) is associated with higher energy intake and body mass index (BMI) (Pentikäinen et al., 2018). Cognitive restraint (ongoing regulation of food intake by conscious restriction instead of physiological cues) is associated with increased BMI, food intake and negative thoughts about eating (Brogan and Hevey, 2013). Emotional eating

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(eating in response to positive or negative emotions) is associated with increased BMI, snacking frequency, but also higher psychological distress, anxiety, and depressive symptoms (van Strien, 2018; Vittengl, 2018). Furthermore, in people with obesity, these eating patterns are associated with physical activity level (Dohle et al., 2014), body image (Carracca et al., 2011), fat mass reduction (Kontinen et al., 2010) and with successful weight loss after interventions (Andrade et al., 2010; Annesi et al., 2016). Therefore, considering behavioral phenotypes associated with different eating patterns could help clinicians to better guide and personalize interventions. So far, even though some studies are reporting different profiles of people with obesity (Ghachem et al., 2019), few assessed the relationship between different phenotypes of eating patterns with other health behaviours (e.g., physical activity) or with mental health markers such as depression (Bouhlal et al., 2017; Pentikäinen et al., 2018). Furthermore, none of these studies was performed in subjects with severe obesity. Also, few studies investigated eating behavior in people with type 2 diabetes (Laar et al., 2006). Therefore, the main aim of the present study was to identify clusters in a population of individuals living with severe obesity based on their potential differences in age, waist circumference, eating behavior, depressive symptoms, food-related quality of life and physical activity. The secondary objective was to determine whether these clusters differed in terms of prevalence of metabolic syndrome components and diabetes.

2. Methods

2.1. Study design and setting

This cross-sectional analysis was an exploratory add-on study based on baseline data collected at the inclusion in a cohort study that aimed to investigate the effects of a behavioral intervention on emotional eating in people living with severe obesity. The study has been performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University Hospital of Montpellier where the study was performed. The complete study trial was registered at the number NCT01997697. All participants provided written informed consent. Participants were recruited over a 2 years period (2014–2016) at the Endocrinology – Diabetes - Nutrition Department of the University Hospital of Montpellier. The study was advertised by members from the multidisciplinary team.

2.2. Participants

This study included adults with severe obesity seeking non-surgical weight loss treatment. To be included in the cohort, participants had to be adults (18–65 years old) with class II or class III obesity ($BMI \geq 35 \text{ kg/m}^2$) – including those with diabetes, to be hospitalized for weight management in the Nutrition-Diabetes unit of the University Hospital of Montpellier, to be under healthcare coverage and to accept to participate in the study. Participants were excluded if they were unable to complete the different evaluations, had a medical contra-indication to physical activity, were engaged in a bariatric surgery program, or in case of known pregnancy.

2.3. Collected data

2.3.1. Socio-demographic information

Collected data included sex, date of birth, tobacco status (smoker, non-smoker, former smoker), marital status (single, divorced, married/cohabitation/couple, widowed) and socio-professional status, according to the five categories defined by the National Institute of Statistics and Economic Studies (1: manual worker; 2: intellectual professionals; 3: employees; 4: retirees; and 5: unemployed).

2.3.2. Metabolic syndrome components

Waist circumference was recorded to the nearest 0.1 cm midway between the last rib and the iliac crest using a non-stretch tape measure on lightly clad participants by a research nurse. Arterial blood pressure was measured, at the end of the physical examination with subject in sitting position, using a manual sphygmomanometer after a 5-min rest, using an appropriate cuff size. Blood was drawn in the morning after an 8-h overnight fast. Fasting plasma glucose was measured by routine biochemistry analysis. Type 2 diabetes was defined as fasting glucose $\geq 7.0 \text{ mmol/l}$ and/or the presence of any diabetes-related medication. Total and high-density lipoprotein (HDL) cholesterol were measured by routine enzymatic (KonePro; Konelab, Epoo, Finland).

2.3.3. Eating behavior

To evaluate eating behavior, the Three Factor Eating questionnaire R-21 (TFEQ) (de Lauzon et al., 2004) and Dutch Eating Behaviour Questionnaire (DEBQ) (Lluch et al., 1996) French versions were used. The TFEQ R-21 is a 21-item scale measuring three dimensions of eating behaviors being uncontrolled eating (tendency to eat more than usual due to a loss of control over intake accompanied by subjective feelings of hunger), cognitive restraint (conscious restriction of food intake in order to control body weight or to promote weight loss), and emotional eating (inability to resist emotional cues). The DEBQ is a 33-item scale questionnaire also measuring three dimensions including emotional eating, cognitive restraint and external eating (increase in food intake in response to external food cues such as sight or smell of food) (Lluch et al., 1996).

2.3.4. Physical activity and sedentary time

Physical activity and time spent in sedentary activities were evaluated using the Global Physical activity Questionnaire (GPAQ) (Bull et al., 2009). The GPAQ comprises 16 questions divided into 3 main activity categories including: work, transport and leisure. An additional part of the questionnaire also collects time spent in sedentary activities. Scores were expressed in METS minute per week for physical activity and minutes per day for sedentary activities.

2.3.5. Depressive symptoms and health-related quality of life

Depressive symptoms were screened and evaluated using the Center for Epidemiologic Scale – Depression (CESD) in its French validated form (Fahrer and Rouillon, 1989). This questionnaire includes 20 items and scores above 16 indicate the presence of depressive symptoms (Weissman et al., 1977).

Health-related quality of life was evaluated using the Quality of life, Obesity and Dietetics questionnaire (Ziegler et al., 2005). This French obesity scale has 36 items and 5 dimensions: (i) physical impact (eg. *Because of my weight, I have difficulty breathing on the slightest effort*), (ii) psychosocial impact (eg. *Because of my weight, I spend time alone or am introverted*), (iii) sex life (eg. *Because of my weight, I have little or no sexual desire*) (iv) comfort with food (eg. *I like to eat; Food offers me well-being and pleasure; I like thinking about food*), and (v) diet experience (eg. *A diet means deprivation and frustration to me; Diets make me aggressive*). In this questionnaire, higher scores refer to better health-related quality of life.

2.4. Statistical methods

The hypotheses and analytic plan were specified before the data were collected. Descriptive statistics were used to obtain an overview of participants' baseline characteristics.

To generate profiles, an exploratory cluster analysis using a two-step procedure was conducted. Firstly, to pre-determine the number of clusters that could naturally emerge, a hierarchical cluster analysis was performed using the Ward's method on squared Euclidian distances. This possible number was determined following the agglomeration schedule coefficient and the dendrogram. In a second step, K-mean

clustering was used to create the final cluster solution based on results from the first step. To prevent any distortion in the formation of clusters, data were checked for multicollinearity using the mahalanobis distance.

One-way ANOVAs were used to compare clusters according to the different continuous variables. When significant, the HSD post-hoc test was used to locate the differences. Chi² analyses were used to compare clusters on categorical variables (e.g., presence of type 2 diabetes). If significant, the column proportion test was used. The Holm procedure was used to adjust for multiple comparisons (Holm, 1979). Variables included in the cluster analysis: Variables entered to determine the clusters were emotional eating (DEBQ), cognitive restraint (TFEQ), uncontrolled eating (TFEQ), comfort with food, depressive symptoms, physical activity, waist circumference and age. Other eating behavior variables were not entered given the collinearity. Once clusters were created, all other variables were used to investigate between-cluster differences. All hypotheses were specified before the data collection as was the analytic plan.

We also calculated floor and ceiling effects for eating behavior variables in each cluster. For each dimension of DEBQ and TFEQ, floor and ceiling effect were determined by the percentage of participants who scoring at the minimum or maximum values, respectively. This percentage is considered as adequate when below 20%.

Among data included in the cluster analysis, missing values ranged between 0% (age, waist circumference) and 15% (depressive symptoms). To understand the pattern of missing data (missing completely at random, missing at random, missing not at random), and prevent the possibility of biased estimates, the Little's MCAR test was run. If significant, the assumption that data are missing completely at random should be rejected. In the present study, data were found to be missing completely at random ($p = 0.26$). Therefore, multiple imputations were used with the fully conditional specification method to replace missing values.

Alpha values were set to 0.05 after adjustment for the Holm procedure and only adjusted values are presented in the text.

3. Results

3.1. Population characteristics

One hundred and twenty-six participants (103 women, 23 men) were included in the present study (Table 1). Briefly, mean age was 47.2 ± 13.9 and mean BMI was 41.0 ± 5.7 kg/m². In total, 27% had type 2 diabetes ($n = 34$) and depressive symptoms were present in 55% ($n = 70$) of the participants.

3.2. Identification of clusters

Regarding the clusters' results, the dendrogram as the agglomeration coefficient suggested that a 3 or 4-class clustering was suitable.

Table 1
Population characteristics.

| Description | Population (n = 126) |
|----------------------------------|-------------------------------|
| Demographics | |
| Age (years) | 47.2 ± 13.9 |
| Women, n (%) | 103 (82) |
| Tobacco consumption, n (%) | 58 (46) |
| BMI (kg/m ²) | 41.0 ± 5.7 |
| Metabolic syndrome components | |
| Waist circumference (cm) | 115.9 ± 13.4 |
| Triglycerides (mmol/L) | 1.5 ± 0.7 |
| HDL cholesterol (mmol/L) | 1.2 ± 0.3 |
| Fasting glucose (mmol/L) | 6.3 ± 3.7 |
| Systolic blood pressure (mmHg) | 123.8 ± 13.6 |
| Diastolic blood pressure (mmHg) | 70.2 ± 10.7 |
| Diagnosed type 2 diabetes, n (%) | 34 (Goldschmidt et al., 2014) |

Data are mean ± standard deviation (unless otherwise stated).

However, in the 4-class solution, one of the clusters had a small sample size (<1%), therefore this solution was considered as not appropriate, and the 3-class solution was retained.

The three clusters, labeled *struggling with food*, *low loss of eating control* and *pleasure from eating* included respectively 48% ($n = 61$), 29% ($n = 37$) and 22% ($n = 28$) of the population (Table 2). A radar chart comparing z-standardized scores of all variables that differ significantly between the clusters is displayed in Fig. 1. The radar plot including all studied variables is available in supplementary data (Fig. SI).

3.3. Cluster differences in eating behavior

The three groups differed from each other in emotional eating evaluated either with DEBQ [$F(2, 125) = 38.09$, $p < 0.0001$] or with TFEQ [$F(2, 125) = 23.31$, $p < 0.0001$], external eating evaluated by DEBQ [$F(2, 125) = 21.74$, $p < 0.0001$], uncontrolled eating [$F(2, 123) = 36.43$, $p < 0.0001$], but not regarding cognitive restraint as evaluated by DEBQ [$F(2, 123) = 7.17$, $p = 0.11$] or TFEQ [$F(2, 125) = 4.25$, $p = 0.80$].

Results also indicated no ceiling or floor effects in the different clusters regarding eating behavior variables as described by both, DEBQ, and TFEQ. For the floor effects, regarding the *struggling with food*, *low loss of eating control* and *pleasure from eating* clusters, it was as follows: cognitive restraint – DEBQ: 0%, 0% and 3%; emotional eating – DEBQ: 0%, 0%; and 2%, external eating – DEBQ: 0% for all three groups; cognitive restraint – TFEQ: 0%, 0.7%, 1.5%; uncontrolled eating: 0%, 0%, 0.7%; emotional eating – TFEQ: 0.7%, 4.4%, 1.5%. For the ceiling effects, it was as follows: cognitive restraint – DEBQ: 1%, 0% and 0%; emotional eating – DEBQ: 9%, 0%, and 3%; external eating – DEBQ: 1.3%, 0%, 0; cognitive restraint – TFEQ: 0% for all three groups; uncontrolled eating: 0% for all three groups; emotional eating – TFEQ: 8%, 0%, and 1.5%.

Participants of cluster 1 can be described as “*struggling with food*”. As compared with participants of the two other clusters, they had higher scores on emotional eating, measured by both DEBQ and TFEQ ($p < 0.001$ in both cases), on external eating, evaluated by DEBQ ($p < 0.001$ for all tests), and on uncontrolled eating as evaluated by TFEQ ($p < 0.001$).

Participants of cluster 2 were labeled “*low loss of eating control*” and had the lowest score on uncontrolled eating and the difference was significant compared with the *struggling with food* cluster ($p < 0.001$).

Cluster 3 was labeled “*pleasure from eating*” and was characterized by its high score on the comfort with food scale being significantly different from the two other groups [$F(2, 125) = 24.22$, $p < 0.0001$]. Furthermore, it did not differ from the two other clusters on the different eating behavior scores.

3.4. Cluster differences in clinical characteristics

The three clusters differed only according to age [$F(2, 125) = 16.0$, $p < 0.001$]. Otherwise, no other differences were noted regarding sex distribution [$\chi^2(2) = 0.29$; $p = 1$], tobacco consumption [$\chi^2(2) = 1.89$; $p = 1$], BMI [$F(2, 125) = 1.93$, $p = 0.15$], waist circumference [$F(2, 125) = 2.68$, $p = 0.63$], systolic [$F(2, 125) = 3.36$, $p = 0.30$] and diastolic blood pressure [$F(2, 125) = 1.39$, $p = 0.80$] prevalence of diagnosed type 2 diabetes [$\chi^2(2) = 9.85$; $p = 0.08$], fasting plasma glucose [$F(2, 125) = 2.12$; $p = 0.77$], triglycerides levels [$F(2, 125) = 0.64$, $p = 0.5$], HDL cholesterol levels [$F(2, 125) = 2.65$, $p = 0.07$], and marital status [$\chi^2(6) = 7.08$; $p = 0.31$].

Participants from the *low loss of eating control* cluster were significantly older and tended to have a higher prevalence of type 2 diabetes (46% vs 22% in cluster 1 and 14% in cluster 3), although not reaching statistical significance.

Table 2
Comparison between the three clusters.

| Description | Cluster 1 | Cluster 2 | Cluster 3 | P-value | Norm values ^a | |
|----------------------------------|--------------------------------|-----------------------|--------------------------|-----------------------------|--------------------------|-----------|
| | Struggling with eating | Low control on eating | Pleasure from eating | | | |
| Size (n, %) | 61 (55%) | 37 (22%) | 28 (23%) | | | |
| Demographics | | | | | | |
| Age (years) | 41.5 ± 13.8 | 56.3 ± 10.0 | 47.3 ± 12.2 | <0.001 ^{2>1,3} | | |
| Women (%) | 48% | 30% | 22% | 1 | | |
| Tobacco consumption (%) | 48% | 31% | 21% | 1 | | |
| BMI (kg/m ²) | 40.1 ± 5.6 | 41.4 ± 5.8 | 42.5 ± 7.8 | 1 | | |
| Metabolic syndrome components | | | | | | |
| Waist circumference (cm) | 113.1 ± 13.6 | 119.0 ± 11.5 | 113.1 ± 13.6 | 0.63 | | |
| Triglycerides (mmol/L) | 1.66 ± 0.7 | 1.8 ± 0.9 | 1.7 ± 0.7 | 0.5 | | |
| HDL cholesterol (mmol/L) | 1.2 ± 0.3 | 1.3 ± 0.4 | 1.2 ± 0.2 | 0.07 | | |
| Fasting glucose (mmol/L) | 5.9 ± 3.3 | 7.4 ± 5.0 | 5.4 ± 1.2 | 0.77 | | |
| Diagnosed type 2 diabetes, n (%) | 13 (Führer and Rouillon, 1989) | 17 (46) | 4 (Andrade et al., 2010) | 0.08 | | |
| Systolic blood pressure (mmHg) | 122 ± 14 | 128 ± 14 | 120 ± 8 | 0.30 | | |
| Diastolic blood pressure (mmHg) | 70 ± 12 | 71 ± 9 | 67 ± 8 | 0.80 | | |
| Eating behaviours | | | | | Men | Women |
| DEBQ | | | | | N=517 | N=653 |
| Cognitive restraint (DEBQ) | 2.6 ± 0.7 | 2.9 ± 0.6 | 3.2 ± 1.0 | 0.11 | 1.8 ± 0.8 | 2.5 ± 0.9 |
| Emotional eating (DEBQ) | 3.8 ± 0.8 | 2.2 ± 0.8 | 2.7 ± 1.3 | <0.0001 ^{1>2,3} | 1.7 ± 0.6 | 2.1 ± 0.7 |
| External eating (DEBQ) | 3.4 ± 0.6 | 2.6 ± 0.5 | 2.6 ± 0.8 | 0.0001 ^{1>2,3} | 2.6 ± 0.3 | 2.7 ± 0.5 |
| TFEQ | | | | | N=236 | N = 284 |
| Uncontrolled eating (TFEQ) | 60.8 ± 17.6 | 29.7 ± 17.5 | 34.2 ± 24.6 | <0.0001 ^{1>2,3} | 26 ± 18 | 27 ± 19 |
| Cognitive restraint (TFEQ) | 36.0 ± 17.1 | 44.5 ± 19.2 | 48.4 ± 29.0 | 0.80 | 22 ± 18 | 39 ± 21 |
| Emotional eating (TFEQ) | 76.6 ± 20.7 | 43.4 ± 26.3 | 47.5 ± 31.5 | <0.0001 ^{1>2,3} | 22 ± 25 | 43 ± 31 |
| Depression (CESD) | 21 ± 11 | 10 ± 6 | 24 ± 12 | <0.0001 ^{2<1,3} | | |
| Health-related Quality of life | | | | | N=47 | N=163 |
| Physical impact | 49 ± 20 | 57 ± 19 | 50 ± 21 | 0.80 | 62 ± 23 | 56 ± 22 |
| Psychosocial impact | 46 ± 20 | 67 ± 19 | 44 ± 25 | <0.0001 ^{2>1,3} | 73 ± 23 | 53 ± 22 |
| Sex life | 67 ± 26 | 65 ± 25 | 55 ± 26 | 1 | 80 ± 23 | 65 ± 29 |
| Comfort with food (EQVOD) | 37 ± 24 | 35 ± 14 | 68 ± 22 | <0.0001 ^{3>1,2} | 56 ± 25 | 56 ± 22 |
| Diet experience | 37 ± 23 | 56 ± 24 | 52 ± 32 | 0.001 ^{1<2,3} | 60 ± 21 | 49 ± 23 |
| Physical activity behaviour | | | | | | |
| PA MET/wk (GPAQ) | 2238 ± 2632 | 1521 ± 1957 | 8525 ± 7031 | <0.0001 ^{3>1,2} | | |
| Sedentary time (min/day) | 524 ± 243 | 405 ± 228 | 331 ± 236 | 0.02 ^{1>2,3} | | |

Data are mean ± standard deviation (unless otherwise stated). P-values are obtained with the Holm procedure. METs: metabolic equivalents of the task.

^a Norm values: Norm values may vary depending on the study sample. Here we reported values from the validation articles. DEBQ norm values were calculated in adults from the general Dutch population (van Strien et al., 1986). TFEQ norm values were calculated in adults (age 30-67y) from the general French population (de Lauzon et al., 2004). As the QOLOD questionnaire is an obesity-specific questionnaire, Health-related Quality of life norm values have been calculated in adults (age 18-65y) with a BMI above 25 kg/m² (mean BMI: 35.8 ± 7.5) (Ziegler et al., 2005).

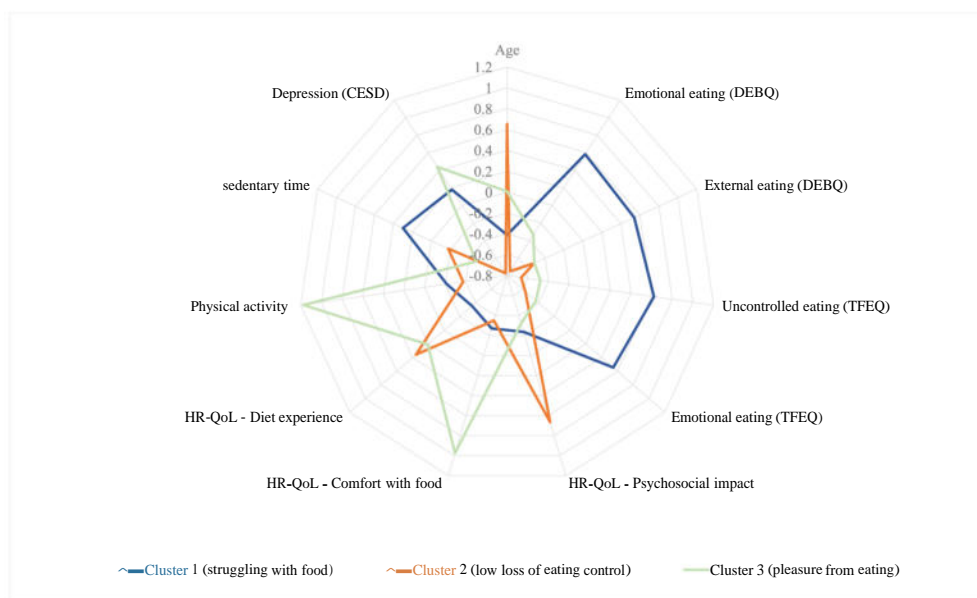


Fig. 1. Radar chart representing z-standardized scores of all variables that differ significantly between the clusters.

3.5. Cluster differences in quality of life, depressive symptoms and physical activity

Concerning quality of life, the three clusters differed on psychosocial impact [$F(2, 125) = 13.49, p < 0.0001$], diet experience [$F(2, 125) = 7.15, p = 0.001$] and comfort with food [$F(2, 125) = 24.22, <0.0001$]. No differences were noted regarding physical impact [$F(2, 125) = 2.32, p = 0.8$] or sex life [$F(2, 125) = 2.36, p = 1$]. Significant differences between the three groups were also noted for depression [$F(2, 125) = 18.00, p < 0.0001$] and 66%, 75%, and 24% of the struggling with food, comfort with food and low loss of eating control were found to have significant depressive symptoms ($p < 0.0001$). Finally, regarding physical activity, differences were noted between the three clusters for physical activity [$F(2, 125) = 28.03, p < 0.0001$] and for sedentary time [$F(2, 125) = 6.53, p = 0.02$].

Participants of the *struggling with food* cluster had lower diet experience compared to participants from both *pleasure from eating* ($p = 0.02$) and *low loss of eating control* ($p < 0.001$) clusters.

Members of *low loss of eating control* had better health-related quality of life on the psychosocial dimension and lower depression scores than the ones in the two other clusters ($p < 0.001$ for all tests).

Regarding other specificities, participants from the *pleasure from eating* cluster had a greater physical activity level ($p < 0.001$) and the lowest sedentary time ($p = 0.002$).

4. Discussion

The present study, which took place in individuals consulting in a single hospital department specialized for the treatment of obesity allowed us to identify three clusters of people with severe obesity and seeking non-surgical weight loss treatment. The results from this study may help in the development of non-pharmacological personalized interventions and help clinicians to appropriately stratify patients according to different biological, and behavioral criteria. In the present study, Cluster 1 (*struggling with food*) was characterized by individuals with high scores on both emotional eating and uncontrolled eating, low score on comfort with food and the presence of depressive symptoms. Cluster 2 (*low loss of eating control*) was characterized by individuals with low scores on emotional eating and uncontrolled eating scales, better quality of life in the psychosocial dimension, no depressive symptoms and the lowest physical activity level. Cluster 3 (*pleasure from eating*) was characterized by the greatest score on comfort with food and the highest physical activity level. These clusters represented 48%, 29% and 22% of our population, respectively.

Most of the participants belonged to cluster 1 (*struggling with food*). The national weight control registry study showed that people struggling with eating were more likely to use professionals' resources (Ogden et al., 2012). It may thus not be surprising that this cluster is the most represented in our population that has specifically come to seek help from health professionals. Ogden et al. also pointed out that people struggling with food were more likely to be depressed (Ogden et al., 2012), which is in agreement with our results showing that the *struggling with food* cluster and the *pleasure from eating* cluster had more depressive symptoms compared to the *low loss of eating control* cluster. This is also consistent with the fact that individuals in the *struggling with food* cluster scored high on emotional eating and on uncontrolled eating that are known to be associated with depression and with binge eating episodes (Goldschmidt et al., 2014; van Strien, 2018).

Cluster 2 (*low loss of eating control*) was associated with a higher prevalence of type 2 diabetes (46% vs below 22% in other clusters, albeit not significantly different) and a higher age. Although altered eating behaviors are common among people with diabetes (Laar et al., 2006), our results show that when they consult for weight loss, they eventually have less stress on their diet than those who do not have diabetes. Moreover, this lower tendency to have stress on diet is also associated with food intake in people with diabetes (van Strien et al., 2007).

Participants from the *low loss of eating control* cluster also had a better health-related quality of life on the psychosocial component than participants from the two other clusters. This might be related to their lower level of depression as compared with the two other clusters. Indeed, a previous study showed that impairment in health-related quality of life is more likely to be due to depression than to body mass index (Fabricatore et al., 2005).

Cluster 3 (*pleasure from eating*) was characterized by the highest level on the comfort with food component of quality of life, meaning that they eat with pleasure. Furthermore, *pleasure from eating* participants had a greater physical activity level compared with the two other clusters. The present finding is of interest as despite being the more active group, there did not seem to be any repercussion of this activity on the physical dimension of health-related quality of life by contrast to what could have been expected (Jepsen et al., 2013, 2020). This finding is supported by a meta-analysis suggesting no overall benefits of physical activity alone on quality of life in people with severe obesity (Baillot et al., 2018). Another option could be a discrepancy in self-reporting or social desirability with participants over-reporting physical activity and under-reporting their eating behaviours. However, without any objective measures, it is difficult to conclude on this point. Otherwise, another hypothesis is the fact that this cluster mainly reflect subjects with mood disorders as 71% of participants reported depressive symptoms. This particularly high level of participants with depressive symptoms was also found in the *struggling with food* cluster and it may be due to the fact that participants seeking weight loss treatment are more likely to present depressive symptoms (Goldschmidt et al., 2014; Gruszka et al., 2018; Ogden et al., 2012).

Regarding the cluster's formation, the present study is of interest as it replicates certain clusters from previous studies. For example, in the Ghachem et al. (2018) (Ghachem et al., 2019) study, the most discriminant variables between the clusters were physical activity, depression, physical health and chronic diseases, as it is the case in our study. Moreover, they also identified a cluster of participants with a poor physical health as is the low loss of eating control cluster which was characterized by a larger waist circumference, elevated blood pressure, impaired fasting glucose, and the higher prevalence of type 2 diabetes. Interestingly, they also highlighted the facts that profiles should be considered as dynamic because 13–20% of participants transitioned towards a worsened health profile while 17% improved their health profile. Another example can be drawn from Ogden et al. who also identified a "struggling" cluster, as in our study, which was characterized by its difficulty to control their eating behavior and to have high prevalence of depression. Overall, these studies showed that clusters from previous studies could be replicated in part.

In terms of clinical practice, the present study is of interest to better personalize interventions. For example, a previous study (Acosta et al., 2021) showed that when weight-management medications were selected according to patients' phenotypes (including energy expenditure and eating behavior), participants were more likely to lose weight.

Several study limitations should be highlighted. First, the study design was cross-sectional, hence we cannot infer any causality between the three clusters and the factors studied. Further, we included participants seeking treatment for weight loss in a single department who are therefore not representative of the population of people living with obesity. Moreover, our data are the baseline from a larger project, so the sample size was not calculated for the present study which should be considered as exploratory. Despite this limitation, our study replicated in parts several clusters identified in other studies even though the structure identified should be validated in larger populations. In fact, it is possible that some statistical analyses were underpowered and failed to detect some associations. Nevertheless, we used a conservative approach to avoid spurious findings due to the sample size using the Holm procedure. In addition, the number of patients with diabetes did not allow to assess the association between diabetes-related medications and eating behavior. Finally, the subjective nature of our results should

be pointed out, as they are based on self-administered questionnaires. No structured interview allowed to diagnose eating disorders such as binge eating disorders.

In conclusion, this study identified three distinct clusters in people with obesity seeking weight loss treatment. These findings are of importance as they highlight the need to consider these specificities to improve individualized interventions as they might have some implications on treatment efficacy. Future studies should confirm our results and assess the physical and psychosocial consequences over time of these clusters among people with obesity.

Declarations of competing interest

None.

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Author contributions

All authors have read and approved the final version of the manuscript.

Clinical registration

This study is a subsidiary study from a registered study at the number NCT01997697.

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Ethical statement

The study has been performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University Hospital of Montpellier where the study was performed. The complete study trial was registered at the number NCT01997697. All participants provided written informed consent.

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