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MASTER’S THESIS

Effect of meal patterns on weight loss after Sleeve Gastrectomy in patients undergoing surgery at Padova University Hospital

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Contents:

Abstract

Introduction: In the modern era, obesity and being overweight are a major global concern due to their rising prevalence and numerous adverse effects on both individuals and society. Despite ongoing development and testing of prevention and treatment methods for obesity, the condition continues to grow. The choice of treatment varies according to the individual and the cause of obesity. There are various methods in order to prevent and treatment of obesity. Among these, bariatric surgery is a well-known and effective treatment option for obesity, particularly for those who have not responded satisfactorily to other approaches, as it has been shown to reduce weight and improve health outcomes in such patients, however, the long-term effects of bariatric surgery are still not clear and more studies in this field are needed. As obesity is a multi-caused disease, in its treatment also, different methods are usually used together and affect each other. As a result, studying in the field of understanding these interactions can also be very useful.

Goal and scope of this study: Evaluation the effect of meal patterns of patients undergoing bariatric surgery on weight loss after surgery in three follow-ups, three months, six months and one year after surgery. The results of this study can be useful in more accurate prediction of the results of bariatric surgery and giving a better perspective of the result of weight loss after surgery based on the patient's meal pattern.

Material and methods: In this observational study, 124 obese patients of patients who were enrolled in the Center for the Study and the Integrated Treatment of Obesity (Ce.S.T.I.O), in the Azienda Ospedale University of Padova underwent bariatric surgery of Sleeve Gastrectomy from 2019 to 2021 and were followed up with available data up to 1 year after surgery. All pre-operation evaluations have been done and data have been recorded in the electronic data system of Padova hospital (E-health) as well as patients' clusters regarding meal pattern and comorbidities. Patients were followed up for one year after surgery and their body weight recorded as follows; pre-operation weight, minimum and maximum weight, 1^{st}follow-up one month after surgery, 2^{nd}follow-up six months after surgery and 3^{rd} follow-up one year after surgery. Then descriptive statistics parameters were calculated for all variables (numerical and nominal) using the SPSS statistics program version 24.0. Results were expressed as the mean ± standard deviation or percentage of total**.** The comparison between all body weight in whole period and among follow-ups for whole population and also each cluster separately has been done with a t-test for paired two sample for continues variables how statistically significant a difference of less than 5% in the study population and for each cluster separately (expressed as kilogram and percentage). The rate of stop weight loss and also number of people with comorbidities and their improvement after surgery were also evaluated and expressed as the percentage.

Results: After Sleeve Gastrectomy, our 124 patients, all of whom were severely obese and also had obesity-related comorbidities, experienced favorable weight loss so that the mean body weight in all study population from 119.8± 22.58 kg pre-operation body weight decreased to 82.2±18.65 kg (p-value <0.00001) one year after surgery. Although the amount of weight loss was more significant in the first months after surgery and decreased over time, overall patients experienced a 31% weight loss in this period. Regarding the meal pattern, although the results of weight loss were approximately close to each other for all meal pattern clusters, and the rate of stopping weight loss was somewhat inconsistent with the results of weight loss, but it can be said that clusters I and III, which were characterized by respectively eating three main meals daily, breakfast, lunch and dinner, and eating two snacks in addition to the three main meals, were in the best conditions of weight loss and experienced the greatest change (approximately 33% weight loss), while cluster V, which was characterized by overeating during the day and night, experienced the least amount of weight loss (27% weight loss and the maximum rate of stopping weight loss). In addition to the positive effect of bariatric surgery on weight loss in study population, the comorbidity status of patients also improved on average by 70% after surgery.

Conclusion: Our study confirmed the positive effect of bariatric surgery on weight loss and improving obesity-related comorbidities in patients with various levels of severe obesity. The effect of bariatric surgery on short-term weight loss is very significant and evident, but there may not any certainty in its durability in the long term. Although in our study, a decisive result of the effect of meal pattern on weight loss after surgery was not adopted, but the observations weakly supported this consequence that probably patients who are in cluster I and III will probably get a better result from bariatric surgery than people who are in cluster V. On the other hand, our study strongly confirmed that having a special wrong eating habits such as overeating at night, or it can be called night eating disorder (NES), which is a distinctive feature of Cluster V, is more relevant than other meal patterns on weight loss after bariatric surgery. Overall, examining the

effect of a behavioral pattern (meal pattern) on the result of a clinical practice is not simple. So, further multidisciplinary studies needed to clarify the possible relationships between meal patterns and weight loss after bariatric surgery.

1 Introduction

1.1 Obesity

1.1.1 Definition and classification

Overweight and obesity are medical conditions characterized by excessive accumulation of body fat that poses a risk to an individual's health. The World Health Organization (WHO) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health. It is important to note, however, that the threshold for body weight and fat distribution leading to co-morbid diseases may differ among populations. For example, certain ethnic groups may have a higher risk of developing obesity-related conditions such as diabetes or cardiovascular diseases, even at lower body mass indexes (BMI) than those of other populations. Therefore, it is necessary to consider the individual's overall health, including genetic and environmental factors, when assessing the health risks associated with overweight and obesity.

Regarding the classification of obesity, first of all, it should be mentioned that, an ideal obesity classification system would also be easy to use, understandable for patients and healthcare providers, and able to reflect the diversity of body types and shapes across different cultures and populations. It should also take into account other factors that can affect health outcomes, such as age, gender, and underlying medical conditions. Finally, it would be important for such a system to be regularly updated and refined as new research findings become available, to ensure that it remains relevant and effective over time. BMI and waist circumference are two easily accessible measures that can provide important information about a person's body fat level and associated health risks, although they do have limitations. It's important to note that other factors, such as muscle mass, can also affect BMI and waist circumference measurements. As such, these measures should always be interpreted in conjunction with other clinical information and should not be used as the only criteria for diagnosis or treatment. (1).

The BMI number and classifications are listed below (table 1.1). The National Institute of Health (NIH) and the World Health Organization (WHO) use of this classification for BMI for White, Hispanic, and Black individuals. Because these cutoffs underestimate the risk of obesity in Asian and South Asian populations, slight alterations are considered for their classification (2, 3).

Table 1.1: The BMI classifications and cut-off points (2, 3).

definition	**BMI (Kg/m2)**		**class**
Severely underweight	less than 16.5kg/m^2		-
Underweight	BMI under 18.5 kg/m^2		-
Normal weight	greater than or equal to 18.5 to 24.9 kg/m^2		-
Overweight	greater than or equal to 25 to 29.9 kg/m^2 (Asian and South Asian population: between 23 and 24.9 kg/m^2)		-
Obesity	greater than or equal to 30 kg/m^2 (Asian and South Asian population: greater than 25 kg/m^2)	30 to 34.9 kg/m^2	I
		35 to 39.9 kg/m^2	II
		greater than or equal to 40 kg/m^2	III

The BMI classification alone is not enough, especially in obese people and the risk of obesity-related diseases. There is another factor called body fat distribution which is an important risk factor for obesity-related disease. Increased visceral adipose tissue (also called central or abdominal fat) is associated with increased risk for cardio-metabolic diseases. Waist circumstance (WC) is used as a surrogate marker of abdominal fat mass. WC correlates with subcutaneous and visceral fat mass and is related to increased cardio-metabolic risk. A WC >40 inches (102 cm) in men and >35 inches (88 cm) in women is considered to confer an increased cardio-metabolic risk (4).

1.1.2 Epidemiology of obesity

Considering that obesity is firstly a chronic and multifactorial disease in itself, and secondly, it is an important risk factor for many other diseases, which puts a significant pressure on people and health systems worldwide. Overweight and obesity rates have been on the rise globally over the past few decades.

Although several factors have an effect on obesity such as age groups, gender, geographical and socioeconomic status, for instance, obesity is more prevalent in women and old age rather than others, the prevalence of obesity has increased globally regardless of all the factors involved in it. Obesity is a complex medical condition that is defined by an excess amount of body fat that can negatively affect an individual's overall health. Obesity is associated with an increased risk of developing numerous chronic diseases, including diabetes mellitus, cardiovascular disease, several types of cancers, musculoskeletal disorders, and poor mental health. Obesity and all negative effects of it can disrupt people's social life and impose huge costs on the healthcare system (5).

1.1.2.1 Obesity as a worldwide concern

As mentioned earlier, the prevalence of obesity has been increasing for years. A study concerning the epidemiology of obesity conducted on six different regions of the world estimated overweight and obesity to be 39% of the world's population (a total of 1.9 billion overweight adults and 609 million obese adults) in 2015. This study also showed that in young adulthood (ages 20-44), women may have a lower prevalence of overweight compared to men. However, as women approach menopause (around age 45-49), this trend may reverse, and women may have a higher prevalence of overweight compared to men (5). According to data from the World Health Organization (WHO), in 2022, more than 1 billion people were obese which 650 million of them were adults, 340 million were adolescents and 39 million were children worldwide (6).

Fanny Janssen et al concluded that “the prevalence of obesity is expected to reach maximum levels between 2030 and 2052 among men, and between 2026 and 2054 among women” (7).

1.1.2.2 Obesity in Europe

The World Health Organization (WHO) has reported that overweight and obesity are major public health concerns in the European Region, affecting a significant proportion of the population, including children. Overweight and obesity are known to increase the risk of various non-communicable diseases (NCDs), including heart disease, stroke, diabetes, and certain cancers.

Recent estimates suggest that overweight and obesity are the fourth most common risk factors for NCDs in the European Region, after high blood pressure, dietary risks, and tobacco. Furthermore, overweight and obesity are the leading risk factor for disability, causing 7% of total years lived with disability (8).

Over half of all men and women in Europe are overweight, and roughly one-third are obese. The economic cost of obesity is also significant, with EU countries spending an average of 7% of their public health budgets on obesity and diseases linked to obesity.

To combat this issue, the European Union invests in research with a multidisciplinary approach that focuses on understanding the complex interactions between food, nutrition, genetics, age, and health (9).

1.1.2.3 Obesity in Italy

The *Osservasalute 2016* report (it refers to the *Istat* multi-purpose survey*, "Aspetti della vita quotidiana"*) proved the high prevalence of overweight and obesity in Italy with more than 45% of adults overweight and 10% obese in 2015. The North-South gap in obesity prevalence also highlights the need for targeted interventions in certain regions. The fact that being overweight will reduce Italian GDP by 2.8% and lead to a decrease in production equivalent to 571,000 full-time workers per year is alarming. Additionally, the fact that overweight will represent 9% of health costs, higher than the average of other countries, underscores the need for effective public health policies to address this issue.

Furthermore, the finding that being overweight will lead to Italians living on average 2.7 years less highlights the serious health consequences of excess weight. It is essential to educate the public on the importance of maintaining a healthy weight and encourage healthy lifestyle habits, including regular exercise and a balanced diet.

It is also worth noting that the cost of being overweight will be borne by all Italians, as each person will need to pay an additional 289 € in taxes per year to cover these costs. Therefore, addressing this issue is not only crucial for individual health but also has important economic implications for the country as a whole (10, 11).

1.1.3 Etiology of obesity

Even though weight gain and obesity can occur in individuals of any age or gender, there are distinct patterns that may differ between genders. Additionally, certain critical periods, as well as specific nutritional and environmental factors, can contribute to a higher likelihood of obesity, such as pregnancy.

Human development stages and life-time

Obesity in adolescence has a strong link to early childhood, as a considerable proportion of cases develop before the age of five. Additionally, childhood obesity tends to persist into adulthood, and those who were obese during adolescence are more likely to experience severe obesity in later life. Additionally, prospective cohort study showed that the likelihood of an individual developing obesity or overweight over the course of their lifetime is significant.

Gender (obesity in females and males)

Most women tend to gain weight after they hit puberty. The timing of puberty and the onset of overweight in adulthood are linked, with an earlier onset of puberty often associated with a higher BMI. However, several factors such as pregnancy, menopause, and the use of oral contraceptives may trigger this weight gain. While, males typically experience an upsurge in body weight until their sixth decade, after which it begins to diminish. This weight gain may be attributed to a shift from a more active lifestyle during their youth to a more sedentary one in later years. Moreover, a decline in serum testosterone levels in older men is linked to a reduction in muscle mass and a surge in fat mass.

Behavioral determinants

Diet and eating habits are crucial behavioral factors that can impact the risk of obesity. Consuming food with high amounts of fat, refined carbohydrates, fast foods, and sugar-sweetened beverages, while not consuming enough weight-regulating foods like yogurt, fruits, nuts, whole grains, and vegetables, and overeating or consuming large portions, can increase the risk of obesity. Studies have shown that eating patterns play a significant role in the development of obesity. For instance, consuming several meals throughout the day, while considering daily caloric intake, has been linked to a reduced risk of obesity. On the other hand, a lack of control over eating patterns and night-eating syndrome, characterized by consuming at least 25% of daily energy intake at night, can increase the risk of obesity (12).

Sedentary life-style and low physical activity because of the low energy expenditure, poor sleep or sleep deprivation because of the negative on metabolism, excess alcohol consumption are also common behavioral determinants of obesity (12, 13).

Environmental, socioeconomic, ethnicity and cultural determinants

According to numerous studies, any environmental factor that limits the ability of individuals to walk and engage in physical activity and increase access to food especially pre-made and take-away food can escalate the likelihood of obesity. This includes factors such as the expansion of urban areas, reliance on transportation, and inadequate facilities for walking. Typically, individuals from lower socioeconomic backgrounds exhibit a greater incidence of obesity. This could be attributed to factors such as their economic circumstances, food accessibility and availability, physical surroundings, overall education, and nutritional knowledge. There also seems to be a relationship between obesity and ethnic background. In general, black people are more likely to be obese than white people (12).

Beliefs and cultural characteristics of individuals can play a crucial role in the escalation of obesity rates. For instance, societies that consider being overweight as a symbol of beauty, well-being, and prosperity may be a fundamental reason behind the high occurrence of obesity in affluent nations. Eating customs like sharing plates and traditional clothing styles such as abayas or wide gowns worn by many women in the area are also significant contributors to the surge in obesity prevalence. Furthermore, the impact of men on women's perceptions of body size is a crucial concern in some countries. As an illustration, in Qatar, almost 43% of Arab women who participated in a survey believed that men favored plump women (14, 15).

Health and medications

In adults with mental health, sensory, or physical disabilities, there is a higher prevalence of obesity. Many medical conditions because of the physiological alterations and changes in metabolism can lead to obesity by altering the body weight. Some of the typical examples are polycystic ovary syndrome, Cushing’s syndrome, hypothyroidism, and growth hormone deficiency. For instance in hypothyroidism, there is a decrease in metabolism that causes a modest weight gain.

In addition to physical health, mental health and psychological aspects play a very important role in increasing the risk of obesity. On the one hand, it affects behavioral determinants and changes in wrong habits related to obesity, and weight gain alone can be one of the symptoms of mental illnesses such as depression, on the other hand, various medications that treat psychiatric disorders and antidepressants can also lead to weight gain.

Regarding medications, in general, many prescription medications can cause weight gain. The exact effect of the weight gain varies depending on the medication, but overall the mechanism can be through different approaches such as slowed metabolism, fluid retention, increased appetite, increased fat storage, and/or impaired exercise tolerance. Antidiabetic medications such as sulfonylureas, rosiglitazone, thiazolidinediones, and pioglitazone and also insulin therapy in diabetic patients lead to weight gain (12).

Genetic and epigenetic

Vidhu V. Thaker, in 2017, in a review study regarding genetic and epigenetic cause of obesity concluded that Obesity is a multifaceted trait that arises from the interplay of genetics, epigenetics, metagenomics, and environmental factors. To explain the genetic causes of obesity, he divided them into three categories.

1-monogenic obesity which is caused by a single gene mutation in the Leptin-Melanocortin pathway, such as mutations in the genes that encode Leptin.

2-syndromic obesity refers to severe obesity that is associated with other phenotypes, such as neurodevelopmental abnormalities or other organ/system malformations. For example, Prader-Willi Syndrome (PWS) is a condition characterized by severe neonatal hypotonia and eating disorders that evolve in several phases.

3-polygenic obesity which is caused by the cumulative contribution of a large number of genes whose effect is amplified in an environment that promotes weight gain (16).

Epigenetics is the field of biology that investigates the causal connections between genes and their products which produce phenotype (17). Epigenetic mechanisms that are currently understood involve DNA methylation, modifications of histones, and regulation through microRNAs. These mechanisms can be transmitted either mitotically, through cell division, or meiotically, resulting in trans-generational inheritance (16). That each of these mechanisms can be effective on the occurrence of obesity. An illustration can be seen in a genome-wide methylation study on obesity with extending the recent discovery on methylation variability in cancer research to obesity. In this study, it has been demonstrated that differential variability is a crucial aspect of obesity-related methylation changes when considering genome-wide DNA methylation profiling. The study additionally verified the involvement of epigenetics and DNA methylation in the origin and development of obesity, and their potential application in predicting the condition of obesity (18).

1.1.4 Complications of obesity

Obesity is a complex medical condition that raises the likelihood of contracting the prevalent non-communicable chronic illnesses of the modern era. Unfortunately, people are now experiencing obesity at an earlier age, and this could result in extended periods of poor health. For healthcare professionals, this poses a significant obstacle because if left unaddressed, the associated symptoms and organ dysfunction could become permanent and difficult to manage. Timely intervention is therefore critical to prevent irreversible health consequences (19). Although the complications of obesity are not limited to physical injuries, comorbidities and diseases, it can be said that the most significant complications of obesity are non-communicable diseases.

1.1.4.1 Non communicable diseases and obesity

WHO defines non-communicable diseases (NCDs), also called chronic diseases, as conditions that usually persist for a long period of time and are caused by a combination of genetic, physiological, environmental and behavioral factors. These diseases are responsible for the death of about 41 million people per year, which is 74% of all global deaths. The main categories of non-communicable diseases include cardiovascular diseases (such as heart attacks and strokes), cancer, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma), and diabetes (20).

Obesity with a rising Body Mass Index (BMI) affecting nearly all bodily systems and contributing to the development of non-communicable diseases. The slow but persistent progress of non-infectious bodily dysfunction leads to the emergence of non-communicable disorders. Obesity-related non-communicable diseases (NCDs) are responsible for millions of deaths worldwide and have become a significant economic burden. The negative effects on health resulting from obesity are due to its pathophysiology and severity. Inflammation of low intensity and an imbalance in antioxidants are critical factors in the development of NCDs associated with obesity (21). The role of adipose tissue accumulation in obesity is also significant so that metabolic disorders, including insulin resistance, dyslipidemia, and hyperuricemia, are rooted in the chronic low-grade inflammation caused by the accumulation of adipose tissue, particularly in central fat, in individuals with obesity. Finally, metabolic disorders resulting from obesity play a role in the occurrence of non-communicable and chronic diseases such as cardiovascular diseases, cancers and type 2 diabetes (22).

1.1.4.2 Cardiovascular diseases

CVD is responsible for the highest number of fatalities globally, encompassing a diverse range of conditions such as cardiac muscle and vascular system disorders that affect essential organs like the heart and brain. The most important cardiovascular diseases (CVDs) comprise;

1- Ischemic heart disease (IHD); IHD is a condition with two most important indications include angina and acute myocardial infarction (AMI). Angina is caused by atherosclerosis, which leads to the partial blockage or stenosis of one or more coronary arteries. While, acute myocardial infarction (AMI) occurs when a major coronary artery is completely blocked, causing the cardiac muscle to die due to a lack of oxygen and nutrients.

2- Stroke; Stroke occurs when there is an interruption in the blood supply to part of the brain, which can be due to a blocked blood vessel (known as ischemic stroke) or a burst blood vessel (known as hemorrhagic stroke).

3- Congestive heart failure (CHF); The condition, which is known as the final stage of many heart diseases, is marked by irregularities in both the functioning of the heart muscle and the regulation of neurohormones, which can lead to symptoms such as tiredness, retention of fluids, and a shortened lifespan.

4- Rheumatic heart disease (RHD); RHD is a consequence of acute rheumatic fever (ARF), which results from a weak autoimmune response to certain microbes, that impacts connective tissue, primarily joints and heart valves.

The likelihood of developing CVDs is significantly influenced by the presence of multiple risk factors, which primarily consist of tobacco use, high blood pressure, high blood sugar, abnormal lipid levels, obesity, and lack of physical activity (23).

As mentioned earlier and also Carl J. Lavie et al, in a review study, in 2018, concluded that obesity is not only a risk factor for cardiovascular disease, most of the risk factors for cardiovascular disease are negatively impacted by obesity, and it is also a significant predictor of coronary heart disease. Due to the negative impact of obesity on the structure and functioning of the heart, the occurrence of nearly all types of cardiovascular diseases is heightened in the presence of obesity (24).

Obesity is connected to premature atherosclerosis, higher chances of myocardial infarction and heart failure, and reduced survival rates which are the main reasons for cardiovascular deaths, especially in individuals with extreme weight categories. The factors that contribute to cardiovascular disease in obesity are diverse and include metabolic dysregulation, leading to an increase in atherogenic risk factors such as insulin resistance, hypertension, and dyslipidemia. Adverse cardiac remodeling is also a significant issue characterized by hypertrophy, chamber enlargement, and impaired ventricular systolic and diastolic function. Moreover, obesity is related to vascular endothelial dysfunction, premature coronary artery disease, increased sympathetic tone, pulmonary hypertension with right-sided heart strain, and arrhythmias. Chronic inflammation is also connected to obesity, manifested by increased levels of pro-inflammatory cytokines circulating in the body, primarily derived from hepatic and adipose sources. These cytokines may play significant roles in the mechanisms of insulin resistance, plaque activation, myocardial hypertrophy, and the progression of cardiovascular disease (25).

1.1.4.3 Cancers

With approximately 14.1 million new cases and 8.2 million deaths occurring each year, cancer ranks as the second most common cause of mortality globally. In addition to known cancer risk factors like genetic pre-disposition, ionizing radiation, tobacco use, infections, unhealthy diet, alcohol consumption, sedentary lifestyle, and other environmental exposures, obesity has been established as a risk factor for several types of cancer.

As summarized in Table 1.2, based on the International Agency for Research on Cancer (IARC) Working Group, compelling proof exists indicating that elevated body weight is linked with a higher likelihood of developing cancer in no fewer than 13 bodily locations, such as endometrial, esophageal, renal, and pancreatic adenocarcinomas, as well as hepatocellular carcinoma, gastric cardia cancer, meningioma, multiple myeloma, and colorectal, post-menopausal breast, ovarian, gallbladder, and thyroid cancers (26).

Table 1.2: Epidemiologic evidence associating overweight/obesity and cancer risk by level of evidence and strength of Relative Risk increase for overweight/obesity in comparison to normal-range body mass index (18.5–24.9 kg/m2) defined by the WHO as synopsized by the IARC Working group in 2017 (26).

Evidence level	Strength of Relative Risk Increase for Obesity and Cancer Risk		
	High (RR Increase ≥ 3)	Modest (RR Increase: 1.50-2.99)	Little (RR Increase: 1.00-1.49)
Convincing/ sufficient	Endometrial Adenocarcinoma Esophageal Adenocarcinoma	Renal Adenocarcinoma Hepatocellular cancer Pancreatic Adenocarcinoma Gastric cardia cancer Multiple myeloma Meningioma	Colorectal cancer Post-menopausal breast cancer Gall bladder cancer Ovarian cancer Thyroid cancer
Limited		Advanced stage prostate cancer Male breast cancer Diffuse large B-cell lymphoma	

1.1.4.4 Type 2 Diabetes

Type 2 diabetes, also known as diabetes, is characterized by the body's inability to effectively use insulin that is produced, leading to insulin resistance. Over time, the level of insulin production by the pancreatic β-cell may decrease, causing insulin deficiency to occur. This results in increased blood glucose levels due to the combined effects of insulin resistance and deficiency. Despite efforts to improve the situation and decrease its prevalence, the global prevalence of type 2 diabetes remains high and is continuing to rise. Type 2 diabetes can be influenced by various factors, but three significant risk factors that contribute to its development are obesity, inadequate physical activity, and unhealthy eating habits (27, 28). Moreover, Sydney

A in a study showed that; “Obesity-related changes in adipocyte function are associated with abnormalities in FFA levels and adipokine expression, which in turn are important promoters of insulin resistance (cause of diabetes)” (29).

1.2 Prevention of obesity

Preventing obesity is equally significant as managing and treating it, considering its adverse clinical complications, association with 50 medical conditions, psychosocial impact, economic impact, potential impact on future generations, as previously mentioned (30). On the other hand, Given that preventing obesity is significantly simpler than treating it, it should be considered a key priority for the national healthcare system (31).

Being obese can impact an individual's quality of life and their ability to participate in society. Often, those who are obese are subjected to prejudice, discrimination, and social stigma, leading to reduced employment opportunities and difficulty competing with non-obese individuals (32, 33). It is noteworthy that even in a study by Klea D. Bertakis and colleagues with the purpose of investigation the influence of patient obesity on primary care physician practice style, physician’s, on primary visit, spend less time educating and providing health information to obese patients compared to non-obese patients (34).

In a study conducted in 2021 with the aim of investigating the economic impact of obesity and overweight and estimating it for the future through analyzing all costs of obesity (fig 1.1) in eight different countries, it was shown that obesity has a very powerful effect on the economy in different ways, which will increase in the future. But the control and reduction of obesity prevalence can change this trend of increasing economic costs in the future (35).

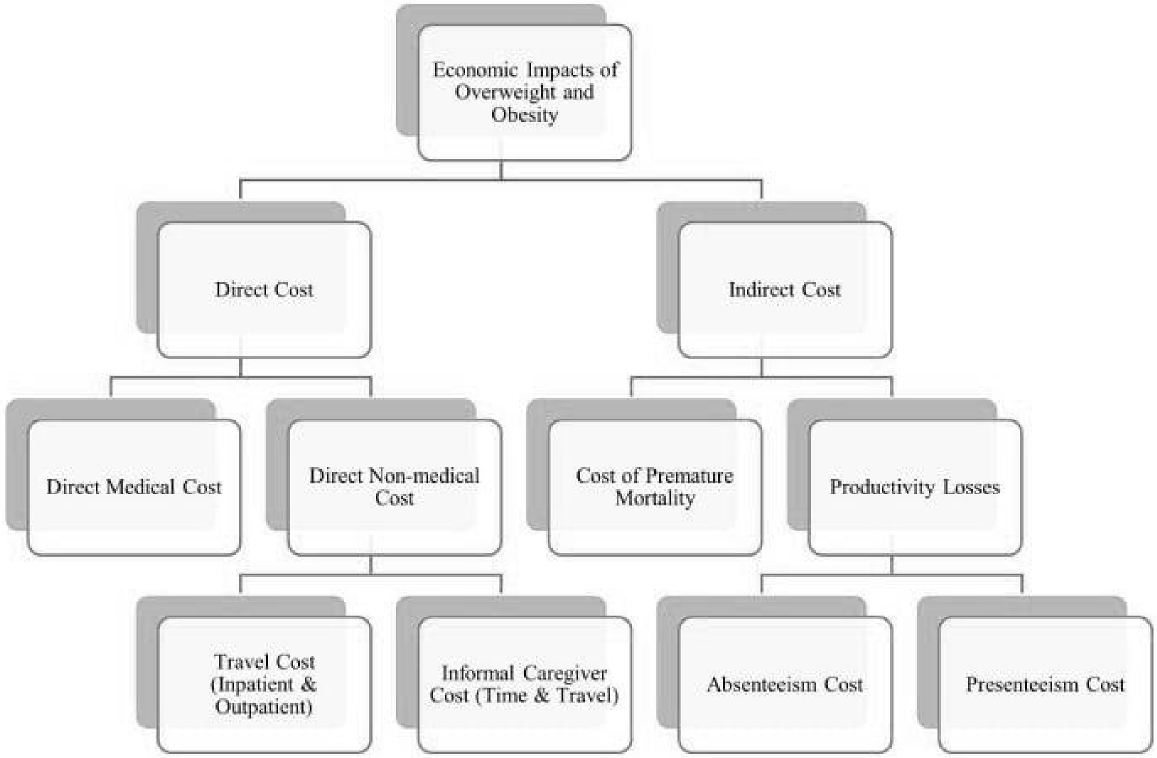


Figure 1.1: cost components framework of obesity (35).

Regarding the impact of obesity on pregnancy, all pregnancy complications like gestational hypertension, gestational diabetes, preterm labor and the risk of delivering by caesarean section are more likely to occur in obese women. For instance, the probability of gestational diabetes in women who are morbidly obese is 4 times higher than women with normal BMI (36, 37). Moreover, Nicola Heslehurst proved that; "there is 264% increase in the odds of child obesity when mothers have obesity before conception" (38).

1.2.1 Life style role in obesity

There are multiple lifestyle factors that can contribute to the development of obesity. These factors include not only unhealthy eating habits and a poor diet, but also a sedentary lifestyle and lack of physical activity, as well as harmful habits such as excessive alcohol consumption and smoking (39, 40, 41). Prevention and management of these factors play a very effective role in preventing obesity.

1.2.2 Eating habit

Although obesity is usually not a single cause and many factors play a role in its occurrence, the positive effect of wrong dietary habits in increasing the risk of overweight and obesity (42). Eating behavior is shaped by a combination of factors such as the types of food consumed, cooking techniques utilized, meal pattern followed, and eating habits developed under the influence of cultural and social factors. These factors collectively impact the likelihood of obesity (43, 44).

Incorrect dietary behaviors such as frequent fast food consumption, infrequent meal intake, consuming meals while watching TV, skipping breakfast, consuming sugar-sweetened drinks, dining at restaurants, and eating when not hungry have been linked to a higher likelihood of developing obesity (43, 44, 45). For instance, skipping breakfast is associated with 4.5 times increase the risk of obesity among people who usually do not consume breakfast compared to people who regularly eat breakfast (46). Research studies have examined the correlation between eating habits and obesity, with one such example being the consumption of fast food. The findings suggest that there is a direct association between the intake of fast food and higher BMI and body fat percentage, consequently increasing the likelihood of obesity (44). In Bangladesh, a cross-sectional study carried out in 2020 revealed that individuals who consume fast food have a 3.3 times higher likelihood of being obese compared to those who do not consume fast food. In addition, the first group has approximately 1.5 times less normal weight individuals than the second group (figure 1.2) (47).

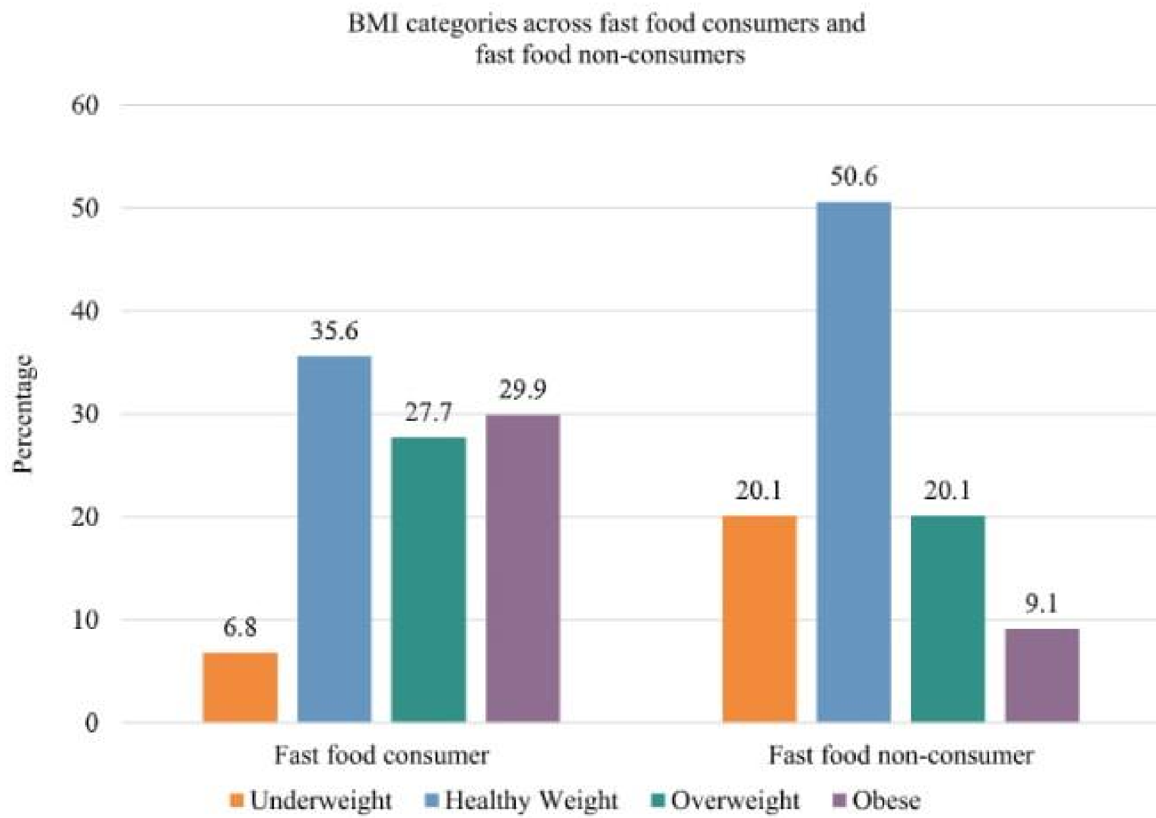


Figure 1.2: Distribution of BMI categories according to fast-food consumption (47)

1.2.3 Physical activity

As mentioned also earlier, physical inactivity and sedentary behavior increases the risk of obesity (48). While it is commonly recommended to engage in physical activity as well as maintain a healthy diet in order to prevent and manage obesity, research shows that improving physical activity levels and reducing sedentary behavior in combination with a healthier diet can result in a 46% decrease in obesity rates. On the other hand, even if a person's diet remains unchanged or worsens, improving physical activity levels alone can still lead to a reduction in obesity rates of more than 30% (49).

1.3 Treatment of obesity

Given the widespread occurrence of obesity and its associated comorbidities and complications, it is understandable that treatment for this condition is of paramount importance. However, the objectives of managing obesity and overweight extend beyond simply shedding pounds; they also involve enhancing factors linked to obesity, mitigating associated illnesses, reducing mortality rates, enhancing overall quality of life, and alleviating psychosocial issues. Numerous approaches can be employed to address obesity, such as dietary therapy, increased physical activity, behavioral modifications, pharmaceutical interventions, and surgical procedures (with pharmacotherapy and bariatric surgery typically reserved for instances when other methods prove inadequate). The targets of obesity treatment must be practical, and the most appropriate strategies must be selected on a patient-by-patient basis. In other words, treatments must be tailored to obese individuals and consider their attitudes and motivations. It is essential to recognize that managing obesity is a multifaceted process that necessitates patient behavioral changes and collaboration, as well as the involvement of an effective healthcare team, for the best possible outcome (50, 51, 52).

1.3.1 Behavioral and life-style modification

The most predominant obesity-related lifestyle behaviors, which are known as unhealthy life-style, are unhealthy diet, unhealthy smoking, heavy alcohol consumption and physical inactivity (39). Making modifications to any of these key behaviors, with the assistance of a proficient dietician who provides tailored counseling to the patient, or in collaboration with psychotherapy specialists, could lead to a considerable enhancement and control of obesity (51).

Another thing that can be mentioned in the field of behavioral intervention and life style change is regulation of the circadian system. P. Gómez-Abellán in a review article in 2012 demonstrated that, Since the disruption of the circadian system (chronodisruption) is one of the reasons for increasing the risk of developing obesity and pathological conditions related to it, in some patients, behavioral interventions include regular exposure to the light, regulation of time and quality of sleep and also eating meals which help to the regulation of the circadian system can help in the treatment of obesity (53).

1.3.2 Diet therapy

Diet therapy, which is called medical nutrition therapy (MNT) today and as an important part of health care system, is the treatment of diseases through nutritional therapy by registered dietitians (RDs) who are well-qualified health care professionals in the field of nutrition and how the body uses food, as well as the states of diseases and the relationship between nutrition and them (54).

There are many interventions in the field of weight loss and obesity treatment through diet therapy, which usually focus on balanced energy intake and calorie restriction (according to obesity guidelines recommendations; for men consumption of 1500-1800 kcal per day and for women consumption of 1200-1500 kcal per day or reduction of 500-750 kcal of daily energy intake). Although it is noteworthy that there is no any ideal diet at all, the most approved diet in the field of obesity treatment is restriction of food with high amount of carbohydrate and fat and low in fiber and high calorie beverages like sugar-sweetened drinks and on the other hand increase consumption of food with high in fiber and water like fruits, legumes, vegetables, and soups which leads long-lasting satiety while being low in calories. (52) Conventional therapies such as lifestyle modification (diet and exercise) and pharmacotherapy remain important but are limited by their results in terms of weight loss (55).

1.3.3 Pharmaceutical treatment

The use of medications or pharmacotherapy in the treatment of obesity is actually a step after changing the lifestyle, diet therapy and increasing physical activity, as well as a step before surgical treatment. That is, usually, if the diet therapy and physical activity are not useful or the amount of weight loss is small, medications are used. Another point is that medications alone have a very small effect in the treatment of obesity (5-10% weight loss) and all types of them should be prescribed along with changing the diet and increasing physical activity and generally life style and behavioral intervention. Medicines that are commonly used for weight loss include; Orlistat, Liraglutide, Lorcaserin, Topiramate/phentermine, Phentermine and Bupropion/naltrexone. Obesity treatment medications are categorized based on their specific functions, compositions, and conditions of use, and should only be prescribed to obese patients according to their individual conditions, and under the guidance of a physician and a dietitian (52).

Recently, due to the fact that the use of old medicines in the treatment of obesity has not met with sufficient satisfaction and usually there is imbalance between their efficacy and safety, peptide therapy that is therapy with a new class of multi-agonist medications for example Semaglutide (a glucagon-like peptide-1 receptor agonist) has emerged that each of these medications usually can carry out the functions of several independent hormones in the body, which this aspect increases their effectiveness in metabolic system. Accordingly they can be more effective than conventional ones in treatment of obesity (56, 57, 58).

1.3.4New and emerging noninvasive treatments

Nanotechnology-based strategies

Nanotechnology is the application of nanoparticles in the size range from 1 to 100 nm (59). Although at present, no nano-drugs are approved or clinically tested for obesity (60). Numerous researches have been carried out to explore the potential impacts of utilizing nanotechnology in addressing various illnesses and conditions such as metabolic syndrome and obesity. Nanotechnology and the use of nanoparticles despite its challenges, including particle size, cost, and stability, it has unique features that make them highly effective in the treatment of diseases, including the unique size of the particles to reach the target tissue and adjustable properties (61). A review in 2019 showed that with the aim of obesity treatment, it is possible to use of nano-particles target the diseased WAT (white adipocyte tissue) and reduced its off-target toxic effects (62).

Gene therapy

It has been proven that obesity is the result of a strong interaction between genetic, epigenetic and environmental factors and genetic factors have a strong influence on determining body mass index (BMI) (63). Furthermore, in a review study in U.S in 2014, Mingming Gao proved that one of the most urgent issues in the United States is obesity, which has been found to have a strong genetic component through family studies. By examining rare mutations in both humans and model organisms, researchers have gained a better understanding of the various pathways that can contribute to obesity. Specifically, investigations into candidate genes have revealed that certain genes involved in regulating energy expenditure and food intake can significantly impact an individual's likelihood of developing obesity. When a genetic defect causing obesity is clearly identified, introducing functional copies of the gene to affected cells could provide a cure akin to monogenic diseases that are treatable through gene therapy. Several gene therapy targets for treating obesity are linked to clock machinery genes, which control circadian rhythms, β3-AR genes that play a role in thermogenesis and lipolysis, PPAR genes responsible for regulating adipocyte differentiation, the FTO gene, which is involved in food intake and fatty acid metabolism, low-density lipoprotein receptor genes, and genes associated with glucocorticoids and their receptors that contribute to visceral adipose tissue expansion (64). Gene therapy can be carried out using different techniques, including the use of viral vectors for delivery, non-viral gene carriers like proteins and lipids, and genome-editing technologies such as zinc finger nucleases, CRISPR systems, and transcription activator-like effector nucleases (65). Although several studies have been conducted in connection with the use of gene therapy for the treatment of obesity, but the use of this method for the treatment of obesity has not yet reached the clinical stage.

Application of contouring devices

According to the International Society for Aesthetic Plastic Surgery's report in 2021, liposuction has emerged as a popular cosmetic surgical procedure worldwide, with 1,903,063 procedures performed globally. It ranks first in popularity among cosmetic procedures, followed by breast augmentation (66). Despite liposuction being the most widely used and efficient technique for body contouring, there have been recent endeavors to create minimally invasive fat removal technologies that are both safe and effective. Currently available non-invasive techniques comprise of focused ultrasound, high-intensity focused ultrasound, monopolar radiofrequency, bipolar radiofrequency, laser/light sources, and cryolipolysis. Ultrasound-based methods, which mainly aim to destroy fat tissue without damaging the adjacent tissues, although their effectiveness and safety have been confirmed in some studies, they have not yet received FDA approval. While regarding the efficacy and safety of radiofrequency-based methods such as monopolar radiofrequency and bipolar radiofrequency and laser/light sources, the data are limited. Cryolipolysis is a new and innovative method of non-invasive fat reduction that involves controlled exposure to cold temperatures to gradually and selectively eliminate adipocytes, offering a solution for excess body fat (67, 68).

There are various Body-Contouring Devices including Endermologie, TriActive, SmoothShapes, VelaShape, VelaSmooth, Thermage, Accent, TiteFX, Vanquish, Exilis, Ultrashape, Liposonix, VASERShape, Coolsculpting, Zerona, each of which has specific technology (69).

1.3.5Surgical treatments (Bariatric surgery)

Bariatric surgery modifies either the stomach, intestine, or both, leading to a reduction in body weight. With the advent of safer laparoscopic techniques, the popularity of bariatric surgery has increased significantly, with approximately 160,000 operations performed annually in the United States. Generally, the majority of these procedures are aimed at treating moderate to severe cases of obesity, specifically targeting those classified as class II (BMI of 35–39.9) and III (BMI of 40 or more) (52).

Patients' eligibility for bariatric surgery:

Before considering surgery, individuals must have attempted all reasonable non-surgical approaches for weight loss and managing any associated issues without success. Additionally, they must have an acceptable level of risk for undergoing the procedure. Candidates must have a body mass index (BMI) exceeding 40 kg/m2 or have a BMI greater than 35 kg/m2 along with serious complications like diabetes, hypertension, obstructive sleep apnea, and a high-risk lipid profile. Bariatric surgery cannot be performed in certain cases due to contraindications such as the presence of any life-threatening disorder, uncontrolled psychiatric disorders, current drug or alcohol abuse, inability to follow nutritional requirements and the presence of cancer which is not in remission.

Roux-en-Y Gastric Bypass (RYGB), Sleeve Gastrectomy (SG), Adjustable Gastric Banding (AGB), Biliopancreatic Diversion (BPD) and Vertical Banded Gastroplasty (VBG) are the procedures of bariatric surgery that among them, RYGB, SG and AGB are the most common methods (52).

1.3.5.1 Roux-en-Y Gastric Bypass (RYGB)

RYGB, which is mainly performed laparoscopically, involves separating a small portion of the upper stomach from the rest of it, resulting in the creation of a stomach pouch that is less than 30 mL in size (figure 1.3). As a result, food bypasses a section of the stomach and small intestine where it would usually be absorbed, decreasing the amount of food and calories that can be absorbed. The pouch is linked to the upper part of the jejunum via a narrow opening, which slows down the emptying of the stomach. The part of the small intestine that is connected to the bypassed stomach is joined to the lower part of the small intestine, allowing bile acids and pancreatic enzymes to mix with the contents of the gastrointestinal tract, thus minimizing malabsorption and nutritional deficiencies. Another type of RYGB, called the very long limb RYGB, involves a modified distal gastric bypass that creates a 100-cm common channel for digestion and absorption, along with an exceptionally lengthy Roux limb spanning 400 to 500 cm (52).

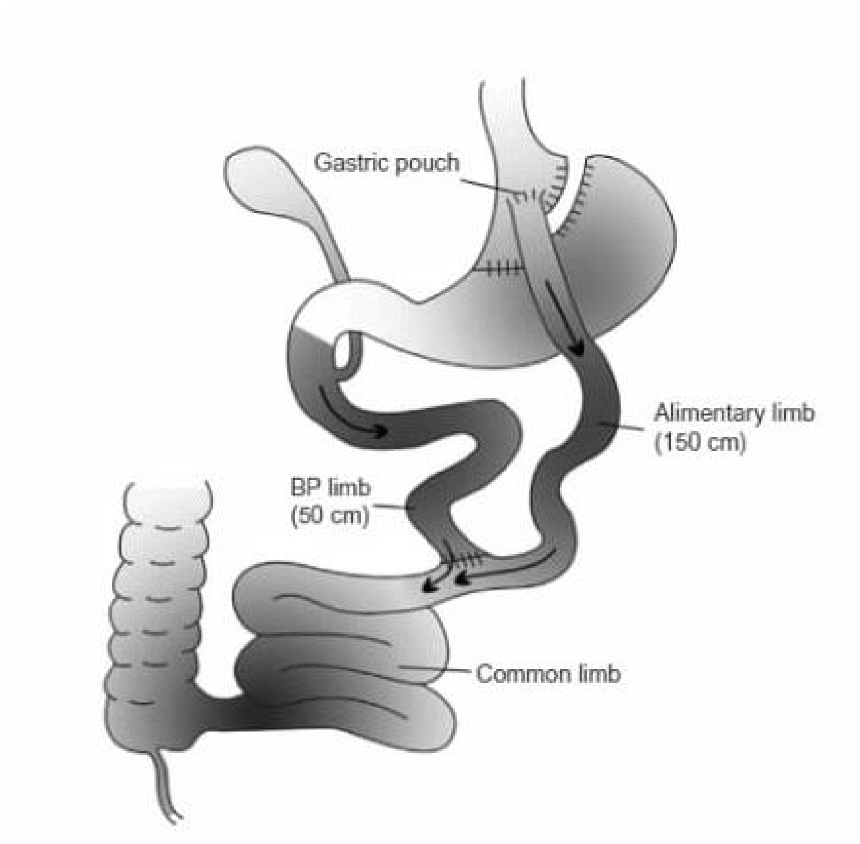


Figure 1.3: Roux-en-Y Gastric Bypass (RYGB) (52)

1.3.5.2 Biliopancreatic Diversion

Biliopancreatic Diversion with duodenal switch, an infrequent approach in bariatric surgery, involves removing a section of the stomach to limit its capacity. The residual portion of the stomach then discharges into the duodenum, which is separated and linked to the ileum (figure 1.4). As a result, a significant portion of the small intestine, including the sphincter of Oddi where bile acids and pancreatic enzymes enter, is bypassed, leading to a reduction in food absorption (52).

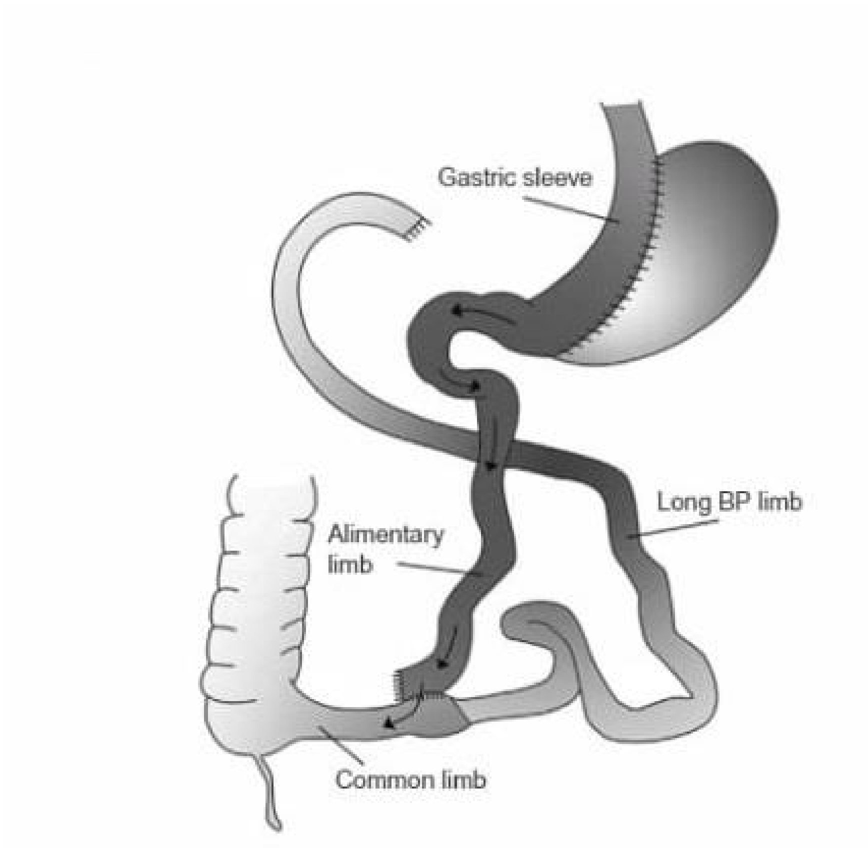


Figure 1.4: Biliopancreatic Diversion (BPD) (52)

1.3.5.3 Sleeve Gastrectomy (SG)

Sleeve Gastrectomy (SG) involves the removal of a portion of the stomach to create a tubular stomach passage, but it does not involve any alterations to the small intestine's anatomy (figure 1.5). In the past, this particular method was done for patients who were deemed too risky for RYGB or biliopancreatic diversion, especially those with a BMI exceeding 60. Nowadays, due to the significant and lasting weight loss that SG achieves, it is utilized as a permanent solution for extreme obesity in the United States (52).

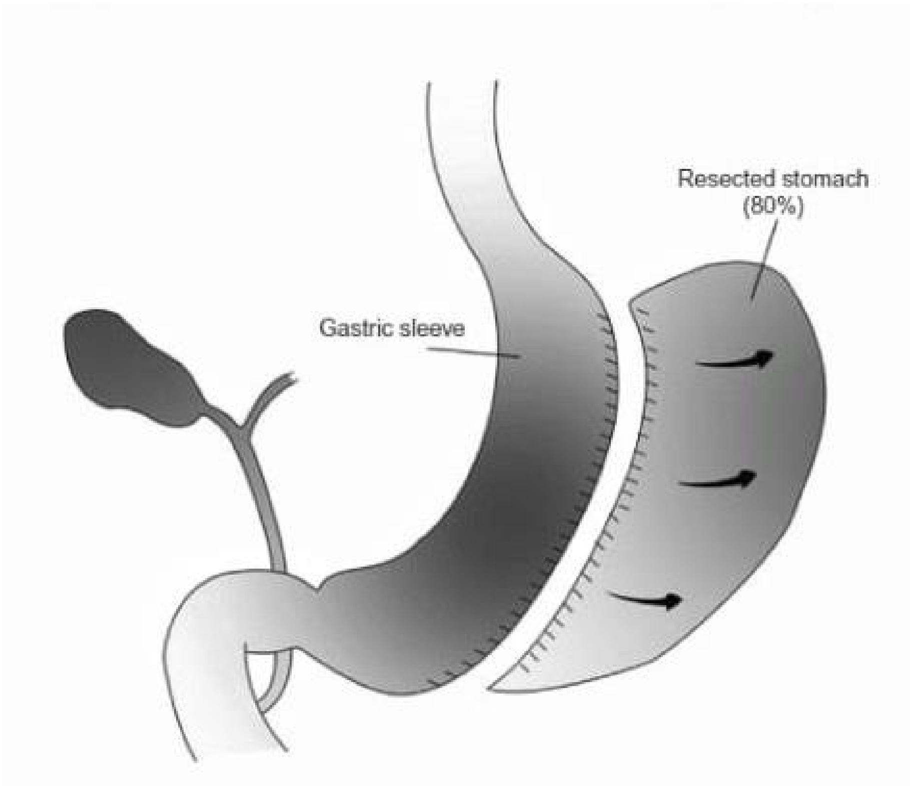


Figure 1.5: Sleeve Gastrectomy (SG) (52)

1.3.5.4 Adjustable Gastric Banding (AGB)

AGB is a laparoscopic procedure that involves the placement of a band around the upper stomach to create a small upper pouch and a larger lower pouch (figure 1.6). The band is typically adjusted four to six times by injecting saline into a subcutaneously placed port. This causes the band to expand and restrict the upper stomach pouch, leading to slower eating and earlier satiety, thereby reducing the amount of food that can be consumed (52).

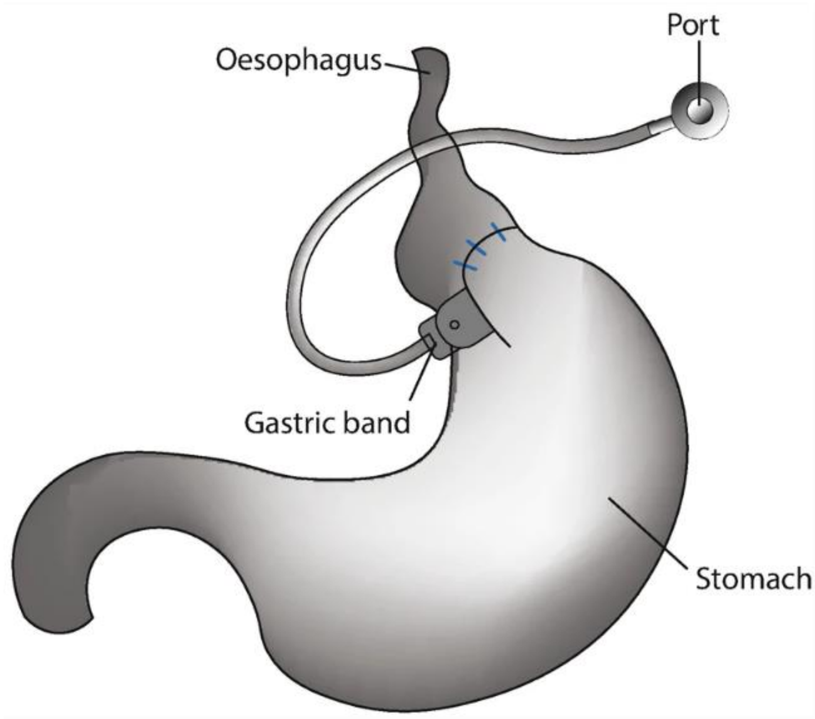


Figure 1.6: Adjustable Gastric Band (AGB) (70)

1.3.5.5 Vertical Banded Gastroplasty (VBG)

In this method, stomach is separated into a small upper pouch and a larger lower pouch using a stapling device. An inelastic plastic band is wrapped around the opening where the upper pouch connects to the lower pouch (figure 1.7). Due to high complication rates and less extensive weight loss compared to other procedures, the use of this technique is infrequent nowadays (52).

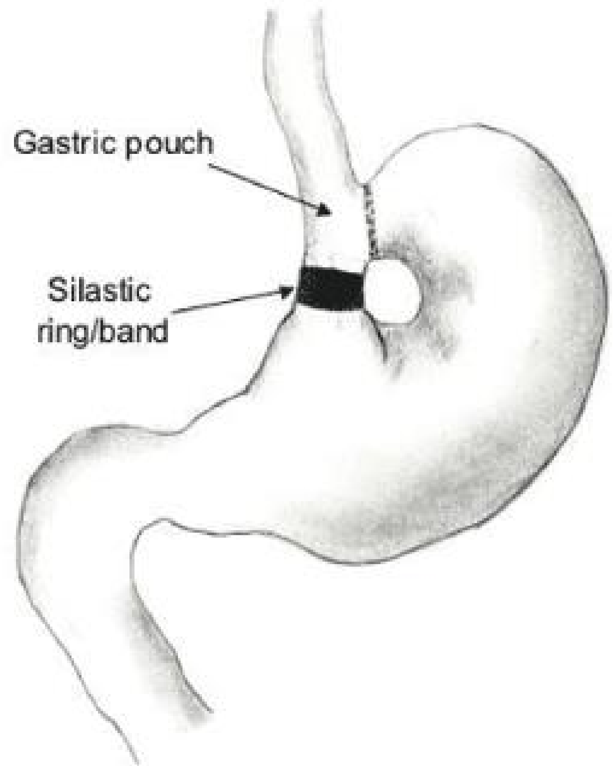


Figure 1.7: Vertical Banded Gastroplasty (VBG) (71)

1.3.5.6 The complications of bariatric surgery

Bariatric surgery can lead to various complications, including gastric or anastomotic leaks in 1%-3% of patients who display tachycardia as an early sign. Pulmonary issues like pneumonia, pulmonary embolism, and ventilator dependency can also arise, as can other complications such as incisional hernia, GI bleeding, deep venous thrombosis, and ventral hernia. These complications can cause significant morbidity, lengthen hospital stays, and increase costs. Nutritional deficiencies like vitamin B12, iron, and protein-energy undernutrition can occur due to inadequate intake or malabsorption.

After malabsorptive procedures, patients may experience malodorous flatulence and diarrhea. Calcium and vitamin D absorption can be impaired, leading to deficiencies and hypocalcemia and secondary hyperparathyroidism in rare cases. Prolonged vomiting can cause thiamin deficiency, and reflux may occur, especially after SG. Rapid weight loss can result in cholelithiasis, gout, and nephrolithiasis. Psychological disorders like depression are common before bariatric surgery but usually resolve post-surgery. Patients who undergo bariatric surgery may have a slightly higher risk of suicide and an increased incidence of alcohol use. Adjusting to new eating habits can be challenging and may require supportive therapies (52).

1.4 Meal patterns

Rebecca M. Leech et al, in 2015, in a review article regarding understanding meal patterns, represented definitions and different approaches about meal patterns and their classification and showed that the concept of "meal patterns" is a broad term frequently employed to refer to how individuals eat at the meal level, including larger meals like breakfast, lunch, and dinner, as well as smaller ones such as snacks or suppers.

This review article also demonstrated that three constructs have been used to describe meals: (1) patterning, which encompasses aspects such as frequency, spacing, regularity, skipping, and timing; (2) format, which includes considerations such as the types of food combinations, sequencing of foods, and nutrient profile or content; and (3) context, which refers to the social or environmental setting in which the meal is consumed, such as eating with others or with family, eating in front of the television, or eating outside the home. There are four different approaches to define eating occasions (EO) or in other words, meals and snacks which include;

1-time-of-day: This method categorizes meals based on the time of day when they are consumed, with larger meals eaten during specific time periods (06.00-10.00, 12.00-15.00, and 18.00-21.00 hours) defined as "meals" and smaller ones eaten outside these periods considered "snacks." While this approach is straightforward, it has limitations, such as vague time parameters, a maximum of three meals per day, and a failure to account for irregular eating schedules, like those of shift workers. Additionally, this approach is prone to bias as researchers may base their categorization of meals and snacks on their personal understanding of eating patterns, which could be influenced by cultural and regional factors. Ultimately, a time-of-day definition depends on the researcher's perception of the timing of eating and requires a specific measure of time.

2-participant identified: The definition depends on the participant to recognize an eating occasion as either a meal or a snack, usually by selecting from a predetermined list of meal labels such as breakfast, lunch, dinner/supper or snack. Although this approach avoids imposing a complicated criterion for classifying eating occasions, it lacks standardization as it is subjective and dependent on the participant's perception of whether an eating event constitutes a meal or snack.

3-food-based classification (FBC): The FBC of EO is designed to encompass both qualitative and quantitative aspects of eating habits. At first, foods were categorized into seven groups based on their nutritional characteristics, such as source (plant/animal) and nutrient/energy density. Then, depending on the combination of these categories, eating occasions were classified into one of six types of EO, ranging from a well-balanced meal to an unhealthy snack. Another version of the FBC system, which distinguishes between "core" and "non-core" foods, has also been developed. However, the FBC of EO has not been widely adopted, likely due to the complexity of its criteria.

4-neutral: The variations in eating habits across cultures have resulted in the adoption of the neutral term, eating event, for any instance involving food consumption. Subsequently, standardized criteria such as the timing of the event and the number of hot or cold dishes were employed to describe meal patterns based on empirical data. The advantage of a neutral definition is that it enables standardization and facilitates comparisons across diverse cultural and population groups (72).

1.4.1 Meal pattern and obesity

Although the complete understanding of how meal pattern relates to obesity is still not clear, studies have been conducted in this area and have various results. A study on the relationship between meal patterns and obesity in Swedish women showed that obese women reported consuming food more frequently throughout a typical day and tended to eat later in the day compared to the control group. These results are important to consider when addressing the treatment of obesity (73). Additionally another study showed that A primary finding in our meal pattern analysis is that participants with the highest energetic intake around midnight had the highest overall daily energy intake (10 669 kcal/d), corresponding to more frequent eating. These findings are partly consistent with previous studies suggesting that, in adults with BMI within the normal range, consuming a high proportion of daily energy intake at night or late evening is associated with higher total energy intake On the other hand, these studies found that a higher intake in the morning or afternoon was associated with a lower total energy intake (74).

In another study on behavioral determinants of obesity, dietary patterns (such as skipping meals) were identified as determinants of obesity in children, along with other factors such as high energy density diets, high consumption of sugar-sweetened beverages, large portion sizes of foods and low physical activity (75).

These diverse findings demonstrate that surely there are associations between meal patterns and weight gain, indicating that recognizing and comprehending these relationships could aid in the development of effective obesity treatments and provide more accurate advice to patients.

2 Goal and scope of study

Many weight loss strategies are applicable in the management of obesity, including life-style and behavioral change treatment, pharmacotherapy and bariatric surgery (76). Bariatric surgery, regardless of the type of the procedure, is the most clinically effective and cost effective intervention for patients with moderate and severe obesity. Firstly, in comparison with non-surgical interventions, bariatric surgery leads to more significant weight reduction. Secondly, weight loss is maintained for years after surgery, whereas in other treatments patients regain weight after a while. Lastly, the incidence of comorbidities is much lower in patients who have undergone surgery (77, 78, 79).

Since weight loss is the basic goal of bariatric surgery, many studies have been conducted regarding the evaluation of weight loss after surgery both in short-term and long-term, as well as the comparison among different types of procedure (80, 81, 82). Moreover, some studies focused on the relationship among nutrition and eating habits with bariatric surgery. For instance the significance of nutritional management before and after surgery, eating disorders and problematic eating behaviors (PEBs) before and after surgery and their impact on outcomes (83, 84, 85). But instead, there are few studies with the purpose of evaluating the direct impact of patients' eating habits before surgery on weight loss after surgery.

The scope of our study, therefore, is evaluation the effect of meal patterns of 125 patients before bariatric surgery on weight loss after surgery, considering weight loss trend in the short-time (1 month), medium time (6 months) and long-time (1 year) after surgery. We tried to find a meaningful relationship among patient's meal patterns and weight loss trend. On the one hand, this finding would be useful for physicians to have a more explicit prospective of surgery outcomes and a prediction of them. In this way, clinicians can more confidently inform the patients about the results they are going to get from the surgery, identifying the patients that could require more strict follow-up and tailored intervention because their unfavorable eating habits before surgery. On the other hand, these results are very beneficial for patients who are candidates for bariatric surgery because they can choose bariatric surgery as a treatment for obesity with a more realistic expectation of its outcomes and they can achieve a better outcomes by receiving more detailed recommendations from the physician or by making small changes in their meal pattern before surgery.

3 Materials and methods

3.1 Patients selection and description

In this observational study 193 patients with obesity were enrolled in the Center for the Study and the Integrated Treatment of Obesity (Ce.S.T.I.O), in the Azienda Ospedale University of Padova in the period from 2019 to 2021. Among these patients only those having all medical history, psychological evaluation with psychometer tests and dietetic visit were finally recruited (173 patients). All patients presented indication to bariatric surgery according recent guide line. Among these patients, 136 patients underwent bariatric surgery in that period of time. 37 patients did not undergo bariatric surgery and among the operated patients, 12 subjects were not followed up or their recorded information was insufficient, so these patients were excluded from the study. So, the current study was conducted on exactly 124 patients who underwent bariatric surgery and were followed up with available data up to 1 year after surgery.

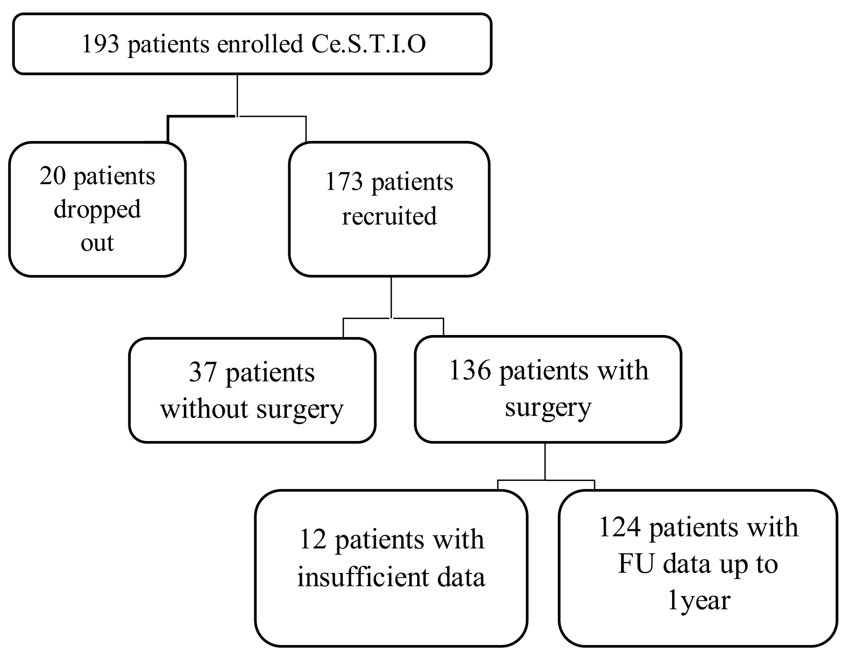


Figure 3.1: description of the study population

3.2 Data collection and review

Pre-operation evaluations included; Anthropometric Measurements, biochemical assessment, and psychometric parameters were performed. Additionally, patients' status regarding heavy alcohol consumption, smoking, having or not having physical activity and information about obesity-related comorbidities were recorded. Then, according to international guidelines, bariatric surgery of sleeve Gastrectomy (SG) was prescribed to patients with severe obesity for whom other obesity treatment methods have failed or they were not satisfactory.

Since the aim of the present study was to investigate the relationship between the patients' meal patterns and the results they get from bariatric surgery, before the surgery, the patients were clustered into five separate clusters according to their different eating habits and meal patterns.

After surgery, up to 1 year, the patients visited the centre during three different follow-ups to check-up and record their current body weight. Patients' data have been recorded in the electronic data system of Padova hospital (E-health). Patients' body weights were recorded as follows;

1. Pre-operation weight
2. Maximum and minimum weight
3. 1st follow-up : 1 month post-operation
4. 2nd follow-up: 6 months post-operation
5. 3rd follow-up : 12 months post-operation

Furthermore, the status of blood indicators, complications, medicines and the improvement in obesity-related comorbidities of patients after surgery were also analysed and recorded. Then data collection was done through abovementioned electronic data system (E-health).

3.2.1 Anthropometric measurements

All anthropometric measurements were taken with subjects wearing only light clothes without shoes. Height was measured to the nearest 0.01 m using a stadiometer. Body weight was determined to the nearest 0.1 kg using a calibrated balance beam scale. BMI was calculated as weight (kg) divided by height squared (m^2).

3.2.2 Biochemical assessment

Patients underwent blood tests to evaluate the following: fasting plasma glucose (FPG), insulin, lipid profile [total cholesterol (TC), High-Density Lipoprotein-cholesterol (HDL) and Low-Density Lipoprotein-cholesterol ((LDL), triglycerides (TG)]. All patients were in a fasted state (8-hour fast) when being tested. Blood test samples were stored at −20 °C until analysis. All biochemical blood analyses were performed with standard diagnostic kits according to the WHO First International Reference Standard. LDL cholesterol was calculated according to Friedewald. Patients without diagnosed diabetes underwent a 3-h oral glucose tolerance test (OGTT) which monitored blood glucose and insulin plasma levels after a glucose load (75 g). Insulin resistance was evaluated by calculating the homeostasis model assessment of insulin-resistance index (HOMA): [fasting serum insulin (μU/ml) × FPG (mmol/l)]/22.5. However, HOMA was not calculated for patients that were being treated with insulin at that point in time.

3.2.3 Psychometric parameters

The role of psychological issues in the development of obesity is poorly understood but its great impact has been reported, thus making mental health evaluations critical in individuals with obesity.

Psychometric data was collected via the following psychological tests: Short Form Health Survey (SF-36), Symptom Checklist-90-R_gsi (SCL-90-R_gsi), Eating Attitude Test (EAT26), Binge Eating Scale (BES), Yale Food Addiction Scale (YFAS) and Barratt Impulsiveness Scale-11 (BIS-11).

SF-36 evaluates the individual's perception on their physical and mental health as well as quality of life. SCL-90 assesses internalised and externalised symptoms, as well as appetite and sleep disorders. EAT-26 aids in eating disorder screening, while BES screens for the presence of binge-eating behaviour. YFAS evaluates food addiction and BIS-11 attempts to assess impulsive behaviour.

3.2.4 Obesity-related comorbidities

Four obesity-related comorbidities were examined in this study including; hypertension, dyslipidemia, diabetes mellitus and OSAS (Obstructive Sleep Apnea Syndrome). Before the surgery, it was determined whether the patients have these comorbidities or no through blood tests observation the symptoms and other specific required diagnostic methods, and it was recorded in the E-Health system. In addition, the medicines that the patients received in this regard were also recorded. Then, after the surgery, these patients were re-examined to determine how effective the bariatric surgery of sleeve Gastrectomy was in improving comorbidities, and again these post-operation information was recorded in E-Health system. In association with hypertension, dyslipidemia and OSAS, only the presence or absence of diseases was recorded. But regarding diabetes mellitus, patients were placed in one of these three conditions, which include; no diabetes (FPG = 70-99 mg/dL and OGTT< 140 mg/dL), pre-diabetes (FPG =100-125 mg/dL and OGTT= 140-199 mg/dL), and diabetes (FPG > 125 mg/dL and OGTT> 199 mg/dL).

3.2.5 Meal pattern clustering

Regarding the clustering of patients in terms of meal pattern. There were five different clusters, each of which corresponded to a specific meal patterns, including; cluster I: consumption of three main meals of breakfast, lunch and dinner, cluster II: varied meal patterns and not following a particular pattern, cluster III: eating three main meals of breakfast, lunch and dinner and two snacks in the morning and evening, cluster IV: overeating during the day hours and cluster V overeating during the day and night hours. Based on the questions that were asked to the patients during consultation, their meal patterns were diagnosed and then they were assigned to the appropriate cluster.

3.3 Intervention

Before the surgery, the patients were on the waiting list for eight months. During this time, all of them received nutrition and diet counseling in order to lose weight, and some of them received medicines if needed. In the last four weeks before the surgery, they all received a very low-calorie diet in order to achieve maximum weight loss. Then all patients underwent the bariatric surgery of Sleeve Gastrectomy (SG) in the same method.

3.4 Statistic analysis

Descriptive statistics parameters were calculated for all variables (numerical and nominal) using the SPSS statistics program version 24.0. Results were expressed as the mean ± standard deviation or percentage of total. The comparison between baseline pre-operation evaluations of body weight and all post-operation evaluations of it in different follow-ups and also between pre-operation body weight and next one year post-operation body weight has been done with a t-test for paired two sample for continues variables through data analysis in Excel 2013 considering how statistically significant a difference of less than 5% in the study population and for each cluster separately (expressed as kilogram and percentage). For each cluster the changes in body weight expressed as percentage of mean weight change from pre-operation by last follow-up and also in the whole period and compared. The variation of body weight in each cluster is also calculated to show the variation in the recorded mean body weights of the patients from pre-operation to the last follow-up for each cluster. The number of patients who stopped weight loss after surgery was expressed as a percentage of the total for the entire study population and also for each cluster separately. Regarding obesity-related comorbidities, the number of patients who had comorbidities was expressed as a percentage of the total before and after surgery, and then a comparison was made between them.

4 Results

4.1Population description

In this study, out of 173 recruited patients, 124 patients were considered, of which 89 patients were female (72%) and 35 patients were male (28%) (figure 4.1). Mean age of the patients in this study was 45 years (with a wide range from 19 to 71 years old) (figure 4.2).

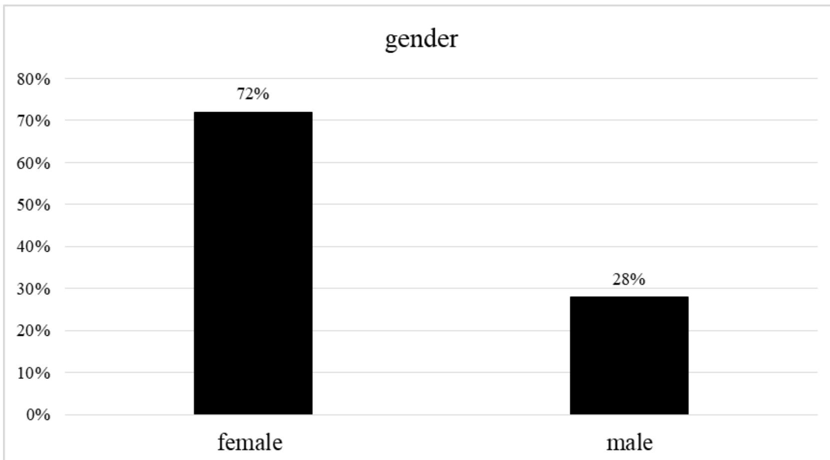


Figure 4.1: proportion of males and females in the study population.

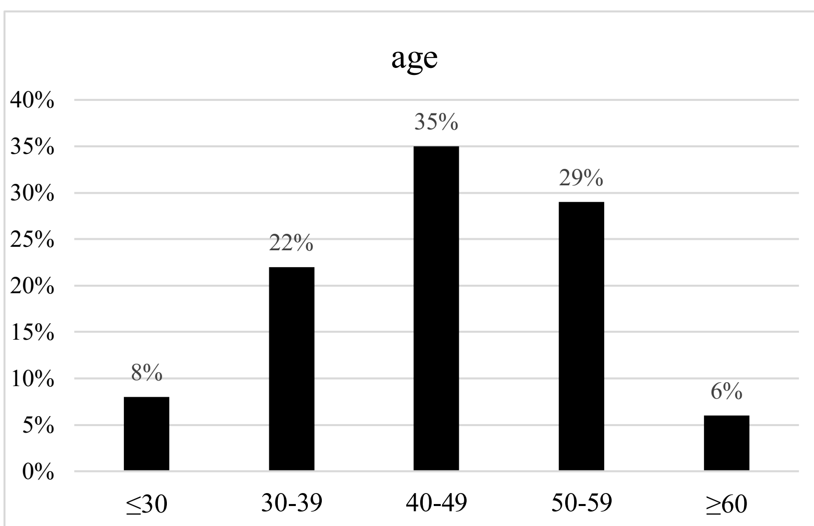


Figure 4.2: age range of patients in the study population

As regards to the anthropometric parameters, mean value for BMI of patients at first visit was 44.05± 6.32 kg/m^2 (with the range of 33.3 to 66.4 kg/m^2). In particular, based on BMI classification, 5 patients had class I obesity (4%) with a mean BMI value of 34.11± 0.59 kg/m^2, 35 patients had class II obesity (28%) with a mean BMI value of 38.16 ± 1.28 kg/m^2, and 84 patients had class III obesity (68%) with a mean BMI value of 47.09± 5.36 kg/m^2 (3) (figure 4.3)

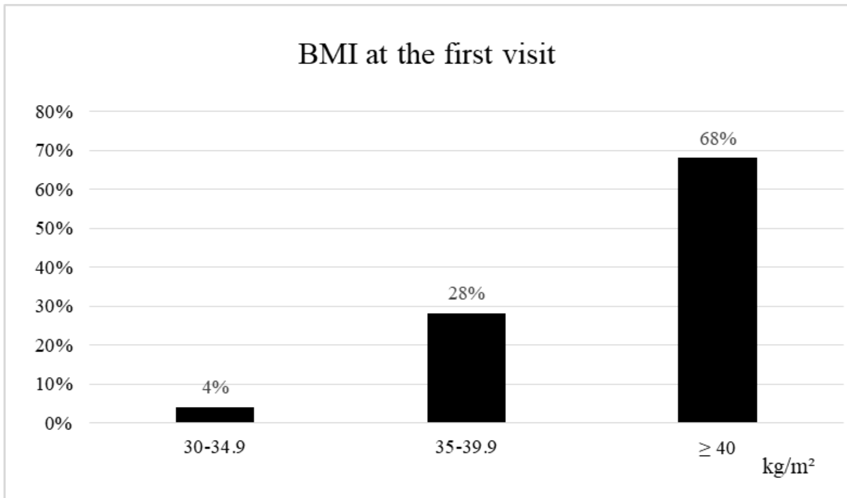


Figure 4.3: the percentages of population distribution by BMI range

As regard to heavy consumption of alcohol and smoking, 13% of patients had only heavy alcohol consumption and 23% of patients smoked. Only 5% of all patients were both smokers and heavy alcohol consumers. And it is noteworthy that 69% of patients did not have any of these two factors. (figure 4.4)

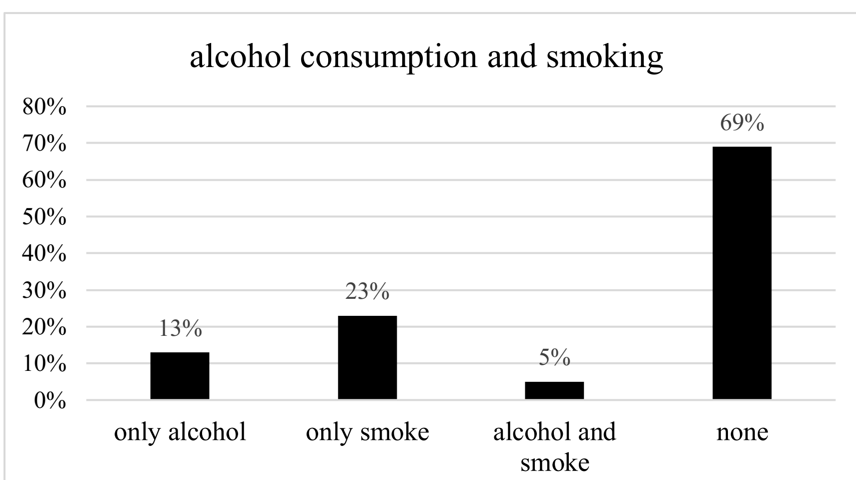


Figure 4.4: Alcohol and smoke consumption in the study population

Among all patients, only 17% had physical activity (PA), while 83% of them did not have any physical activity. (figure 4.5)

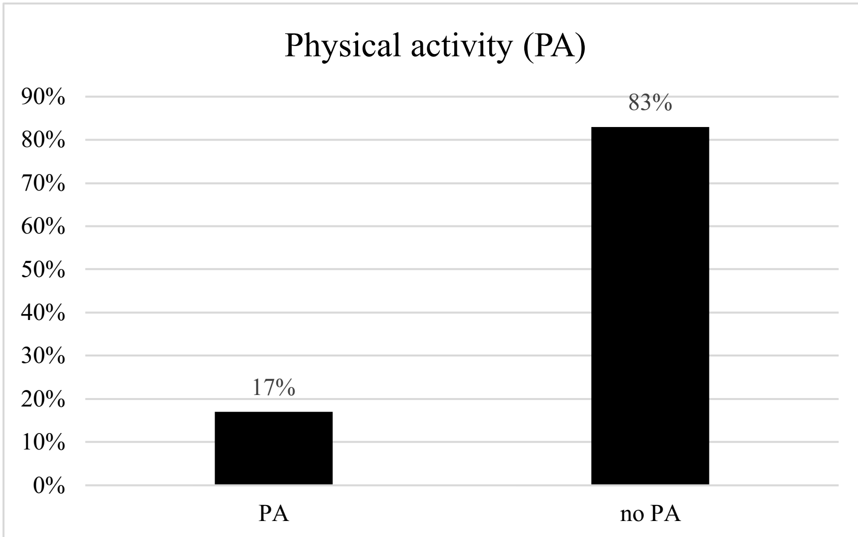


Figure 4.5: Physical activity status in the studied population

Comorbidities:

The comorbidities recorded during the first visit are illustrated in figure 6; the state of hypertension, dyslipidemia, obstructive sleep apnea syndrome (OSAS) and diabetes of the patients were examined, and the results showed that 44.3% of the patients were suffering from hypertension, 47.6% of them examined with dyslipidemia and 20% of them had OSAS. Regarding diabetes mellitus (type II diabetes), 17% of patients had diabetes mellitus (DM) and 38% of them were pre-diabetes. (figure 4.6)

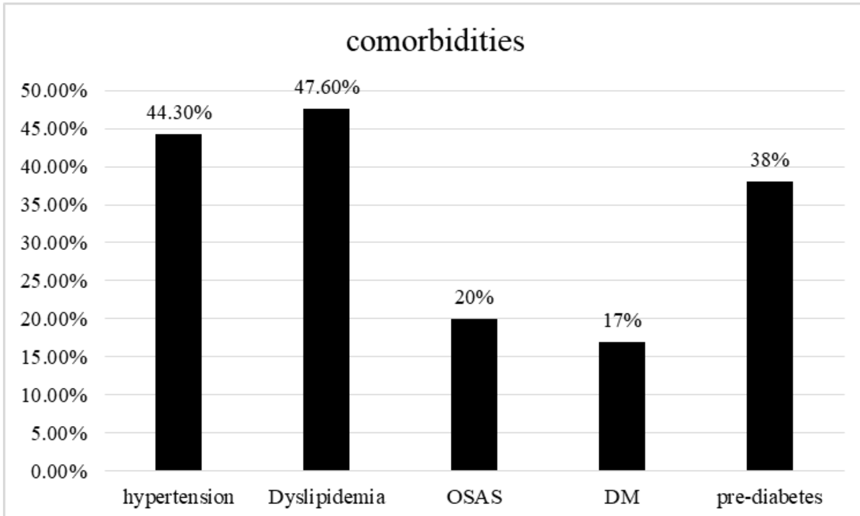


Figure 4.6: comorbidities in the studied population

4.2 change in body weight of patients from pre-operation to 1st, 6th and 12th months (1st, 2nd,3rd follow-up) in whole population

The mean body weight before surgery (pre-operation) was 119.8± 22.58 kg. At the first follow-up visit or one month after surgery, the mean body weight of the patients reached 104.73±19.43 kg (p-value <0.00001), corresponding to a mean weight loss of 12% of the baseline body weight during this period. At the 2nd follow-up visit 6 months after surgery, weight loss trend showed an approximately 16% decrease compared to the previous follow-up and mean body weight decreased from 104.73±19.43 kg to 88.18±18.57 kg (p-value <0.00001). Finally, in the last follow-up and 1 year after surgery, mean weight reached to 82.2±18.65 kg (p-value <0.00001) and in comparison with previous follow-up it decreased by about 7%. (figure 4.7). Overall, patients experienced a mean 31% weight loss one year after surgery compared to before surgery approximately (result is significant at $p< 0.05$).

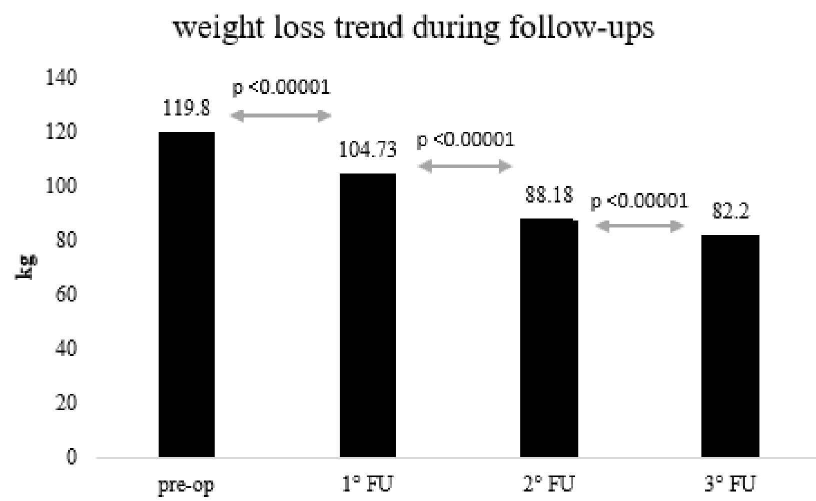


Figure 4.7: weight loss trend in the whole study population

4.3 change of body weight from pre-operation to 1st, 6th and 12th months (1st, 2nd, 3rd follow-up) in each cluster separately

As already mentioned, in this study and in order to find the relationship among meal pattern and weight loss after surgery, patients were categorised in 5 different clusters regarding their meal pattern. In study population, more than 50% of patients were in clusters 2 and 4. While the patients had relatively the same distribution in the other three clusters (1, 3, 5). The distribution of patients in clusters is shown in table 4.1.

Table 4.1: the distribution of study population in different clusters

cluster	Number of patients	%
1	21	17%
2	27	22%
3	19	15%
4	37	30%
5	20	16%
total	124	100%

Cluster I

This cluster is characterized by eating only three main meals (breakfast, lunch and dinner) daily. Seventeen% of patients (33% male and 67% females) were in cluster I. The mean age in this cluster is 45±11.30 years. At the first visit, the mean BMI was 45±8.41 kg/m² (with a wide range of 33.49 to 66.49 kg/m²). Based on BMI classification 57% of patients in this cluster had obesity class III, 38% of them with class II and 5% of them with obesity class I.

Figure 4.8 demonstrates the weight loss trend of patients in this cluster. The mean pre-operation weight was 122.65±26.95 kg, then it reached 103.59±21.82 kg in the 1st follow-up (mean 15.5% weight loss with the p-value < 0.00001). In the 2nd follow-up, the mean body weight was 89.92±20.96 kg (mean 13% weight loss compared to the 1st follow-up with the p-value < 0.00001). The mean body weight in 3rd follow-up was 82.15±18.9 kg (mean 9% weight loss compared with the 2nd follow-up with the p-value= 0.004543) (figure 8). In the entire one-year period after surgery, cluster I patients experienced a mean weight loss of 33% compared to their pre-surgery weight.

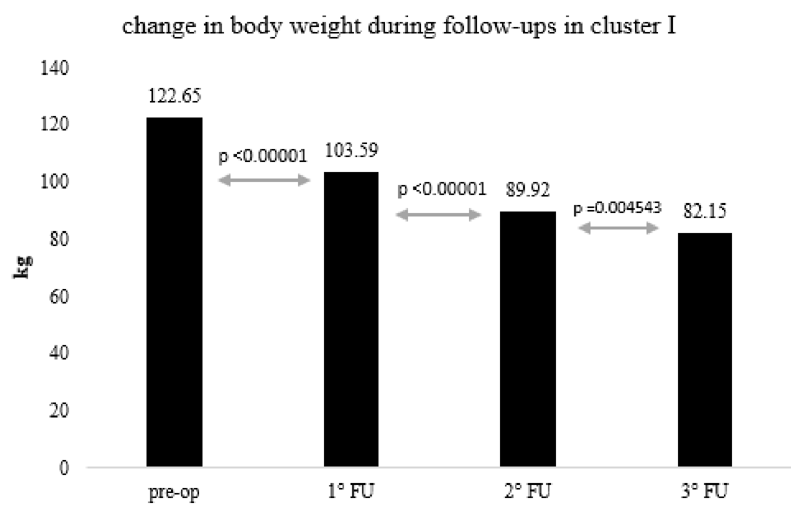


Figure 4.8: weight loss trend in cluster I

Cluster II

Cluster II, which included patients who did not have a constant daily meal pattern, is the second most populated cluster in this study, with 22% of the total population included (30% male and 70% females). The mean age in this cluster is 45±7.41 years. The mean BMI was 44±6.78 kg/m² (with a wide range of 33.39 to 57.94 kg/m²) at the first visit. Based on BMI classification 70.3% of patients in this cluster had obesity class III, 22.2% of them with class II and 7.5% of them with obesity class I were visited.

Figure 4.9 shows the change in body weight of patients in this cluster, mean pre-operation weight was 119.26 ±23 kg then it reached 106.22±20.59 kg in the 1st follow-up (mean 11% weight loss with the p-value < 0.00001). In the 2nd follow-up, the mean weight loss was 87.43±19.82 kg (mean 18% weight loss compared to the 1st follow-up with the p-value < 0.00001). The mean body weight in 3rd follow-up was 81.95 ±19.76 kg (mean 6% weight loss compared with the 2nd follow-up with the p-value < 0.00001 and) (figure 9). One year after surgery, the mean body weight of these patients decreased by 31% compared to the mean pre-operation weight.

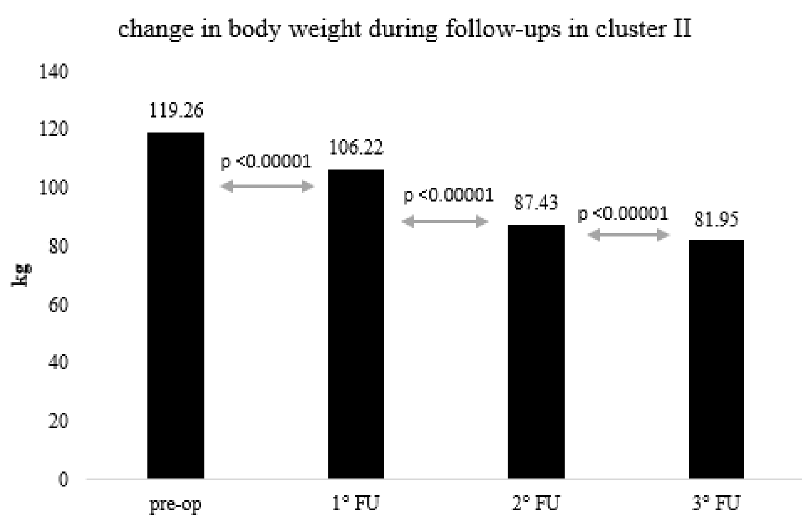


Figure 4.9: weight loss trend in cluster II

Cluster III

Cluster III is characterized by eating breakfast, morning snack, lunch, afternoon snack and dinner as meal pattern. Fifteen % of the total population were in cluster III (16% male and 84% females). The mean age in this cluster is 42±9.8 years. The mean BMI, at the first visit, was 43.22 ±5.58 kg/m² (with a wide range of 34.6 to 52.79 kg/m²). Based on BMI classification 63% of patients in this cluster had obesity class III, 32% of them with class II and 5% of them with obesity class I were visited.

Figure 4.10 shows the change in body weight of patients in this cluster, the mean pre-operation weight was 116 ±22.32 kg. While this value in the 1st follow-up reached 100.2±18.2 kg. (mean 14% weight loss with the p-value < 0.00001). In the 2nd follow-up, the mean body weight was 81.13±15.11 kg (mean 19% weight loss compared to the 1°follow-up with the p-value < 0.00001). The mean body weight in 3rd follow-up was 77.92±16.53 kg (mean 4% weight loss compared with the 2nd follow-up with the p-value = 0.022809) (figure 10). On average, the body weight of patients in this cluster decreased by mean 33% after one year, compared to the mean weight before surgery.

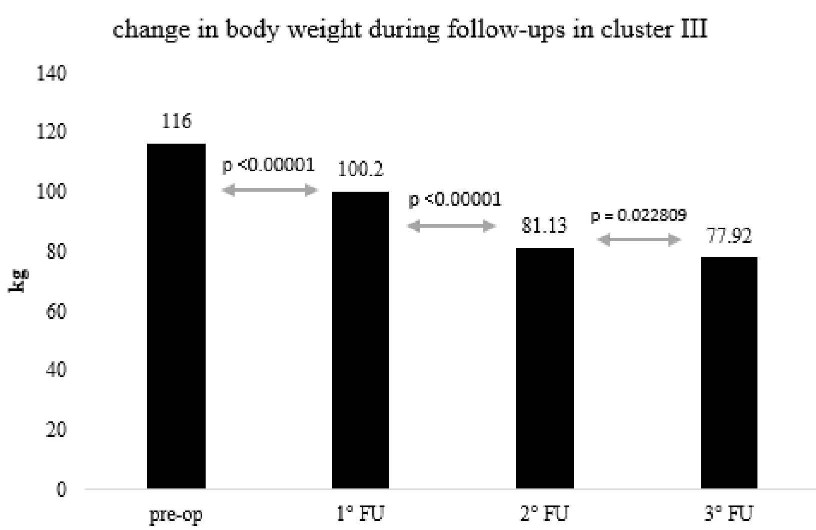


Figure 4.10: weight loss trend in cluster III

Cluster IV

Cluster IV, which included patients who tedn to overeat continuously during the day hours, is the most populated cluster in this study with 30% of total population (73% female, 27% male). The mean age in this cluster is 44±11.9 years. The mean BMI, at the first visit, was 44.47 ±5.29 kg/m² (with a wide range of 34.13to 55.77 kg/m²). Based on BMI classification 81% of patients in this cluster had obesity class III, 16% of them with class II and 3% of them with obesity class I were visited.

Figure 4.11 demonstrates the change in body weight of patients in this cluster, the mean pre-operation weight was 122.28 ±19.77 kg then it reached 108.36±17.58 kg in the 1st follow-up (mean 11% weight loss with the p-value < 0.00001). In the 2nd follow-up, the mean body weight was 91.74±16.42 kg (mean 15% weight loss compared to the 1st follow-up with the p-value < 0.00001). The mean body weight, in 3rd follow-up, was 83.09±17.62 kg (mean 9.5% weight loss compared with the 2nd follow-up with the p-value < 0.00001) (figure 11). The mean weight change in the entire period for cluster IV was a 32% decrease.

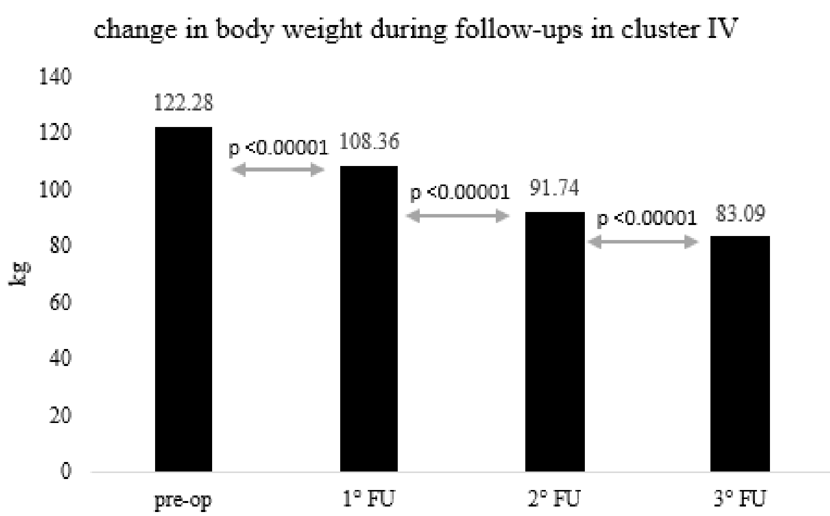


Figure 4.11: weight loss trend in cluster IV

Cluster V

The meal pattern of cluster V is overeating during day and night hours. Sixteen % of the total population were in this cluster (65% female, 35% male). The mean age, in this cluster, is 51±10.67 years. The mean BMI, at the first visit, was 43.05 ±5.22 kg/m² (with a wide range of 36.19 to 56.61 kg/m²). Based on BMI classification 55% of patients in this cluster had obesity class III, 45% of them with class II and none of them with obesity class I were visited.
Figure 4.12 shows the change in body weight of patients in this cluster, the mean pre-operation weight was 116.52 ±20.95 kg then it reached 101.5±17.98 kg in the 1st follow-up (mean 13% weight loss with the p-value < 0.00001). In the 2nd follow-up, the mean body weight was 87.46±18.85 kg (mean 14% weight loss compared to the 1st follow-up with the p-value < 0.00001). The mean body weight, in 3rd follow-up, was 85±19.81 kg (mean 3% weight loss compared with the 2nd follow-up with the p-value= 0.043638) (figure 12). On average, the body weight of patients, in cluster V, decreased by mean 27% after one year compared to the weight before surgery. Patients in this cluster generally experienced less weight loss than other clusters.

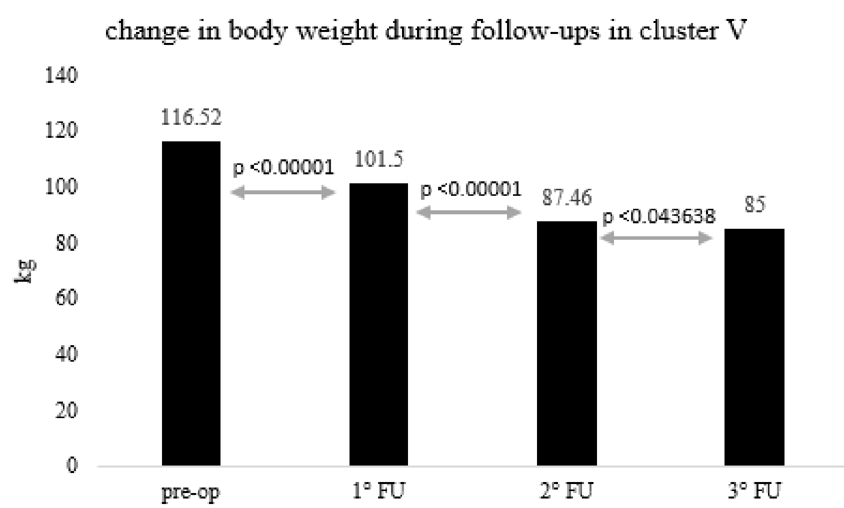
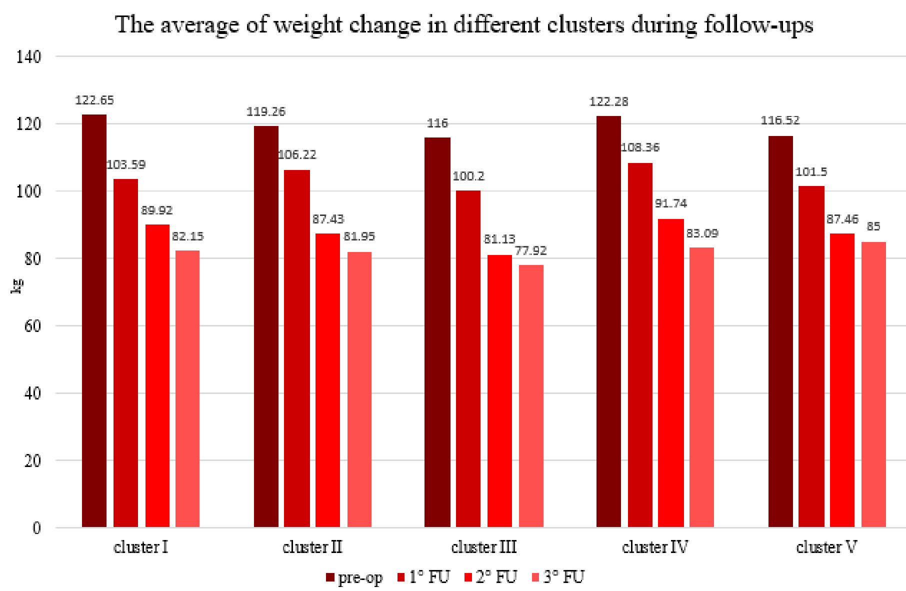


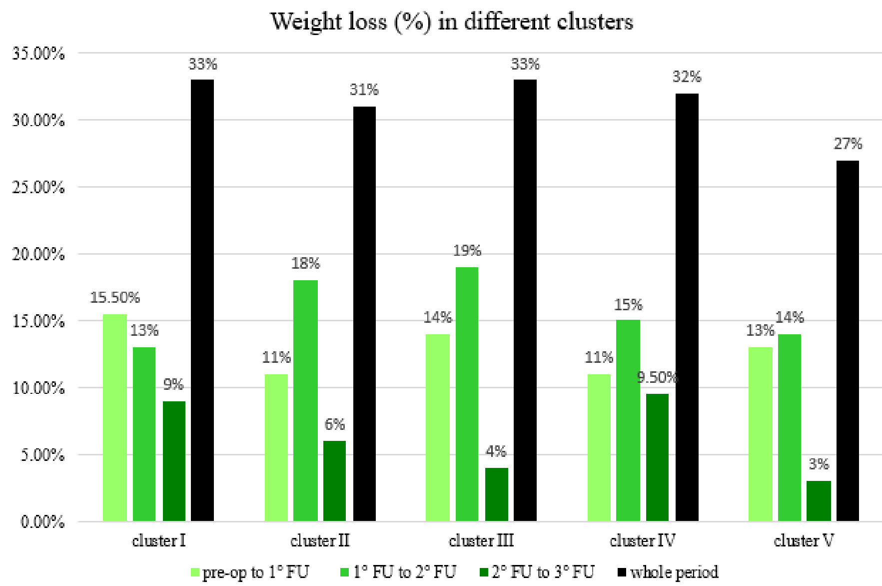
Figure 4.12: weight loss trend in cluster V

Since the goal of this study is to investigate the effect of meal patterns on the weight change of patients after surgery, figures 4.13 and 4.14 compare the mean body weight of patients in different follow-ups in each cluster and the percentage of mean weight loss of patients from before surgery to the third follow-up respectively.

As can be understood from the results, the difference between weight loss in different clusters, especially in weight changes between the mean weight before surgery to the 1st follow-up and from the 1st follow-up to the 2nd follow-up, is very small. From the 2nd follow-up to the 3rd follow-up, the rate of weight loss has decreased, and this decrease was much higher in cluster III and cluster V. The mean weight loss during the whole period was not much different among different clusters, but in general, the weight loss in cluster V, patients who overeat during day and night hours, was less than the rest of the clusters.



Figures 4.13: Comparison of different clusters based on the mean body weight from before surgery to 3rd follow-up



Figures 4.14: Comparison of different clusters based on % of weight loss from 1st follow-up to 3rd follow-up and during whole period

Figure 4.15 shows the variation of mean body weights in clusters. For each cluster, the variation among the mean body weights in measured body weights of pre-operation, follow-up 1st, 2nd and 3rd post-operation were calculated in order to demonstrate the amount of variability and dispersion of the mean body weight in this one-year period in each cluster. Variation of body weights in cluster I and III were similar to each other, while this index in cluster V was less than other clusters. It means that the cluster V experienced less changes and variability in their mean body weight during this period.

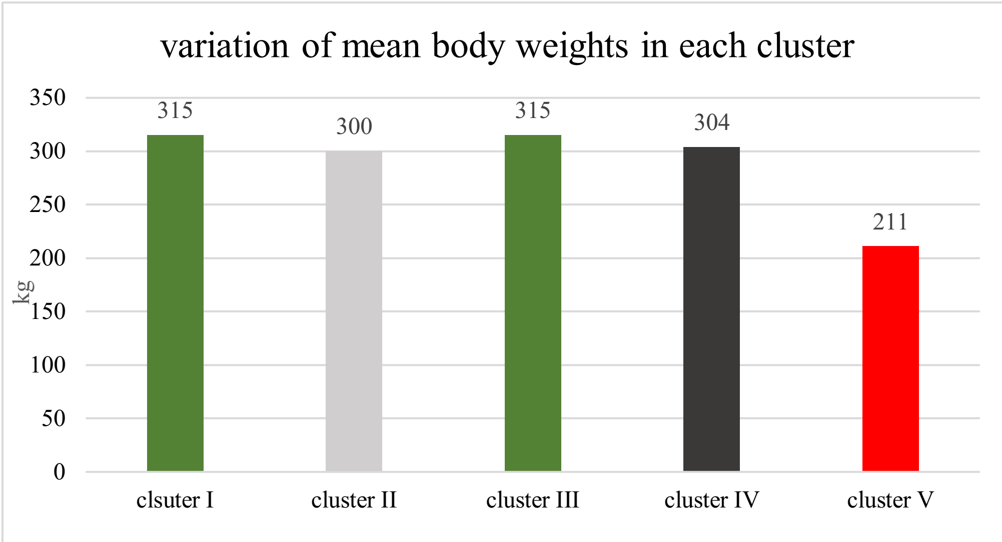


Figure 4.15: variation of mean body weights from pre-operation to 1st, 2nd and 3rd follow-up post-operation

From surgery to the 2nd follow-up, all patients maintained their weight loss process, but from the 2nd follow-up to the 3rd follow-up, 21% of patients stopped weight loss or gained weight, of which 35% were in cluster V, 28.5% in cluster I, 22% in cluster II, 21% in cluster III, and 8% in cluster IV. (figure 4.16).

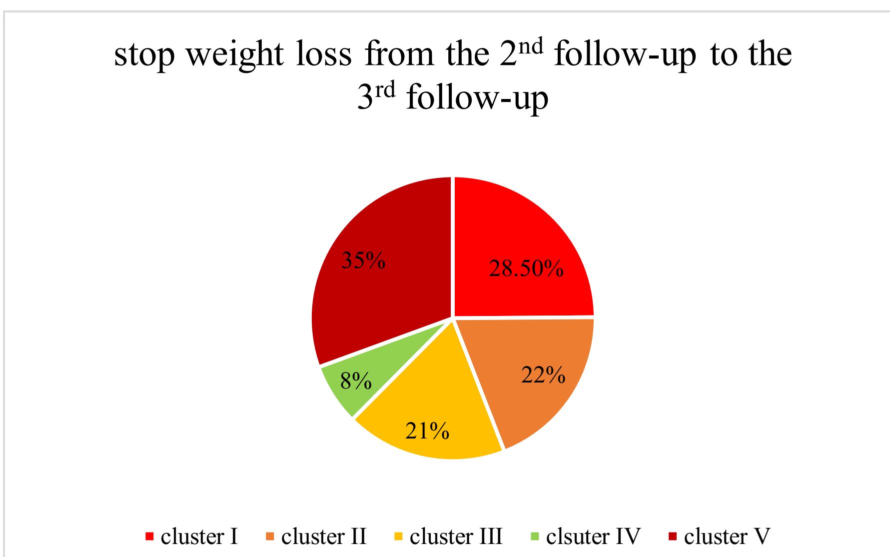


Figure 4.16: % of patients with stop weight loss from the 2nd to the 3rd follow-up

As can be seen in the figure 4.16 and as expected, the patients in cluster five who are characterized by overeating during the day and night hours had the highest rate of stop weight loss. On the other hand, it is very interesting to note that the patients in cluster IV, who had a meal pattern similar to cluster V (overeating during day hours), showed the lowest rate of stop weight loss. Patients in other clusters also experienced relatively similar statistics in terms of stop weight loss. (figure 4.16)

4.4 Trend of comorbidities from pre-operation and intervention to one year after bariatric surgery

The state of improvement of comorbidities after surgery and other pharmacotherapies as an intervention is significant (On average, they have decreased by 70%), and Figures 4.17, 4.18, 4.19, 4.20 show these differences for the different disorders.

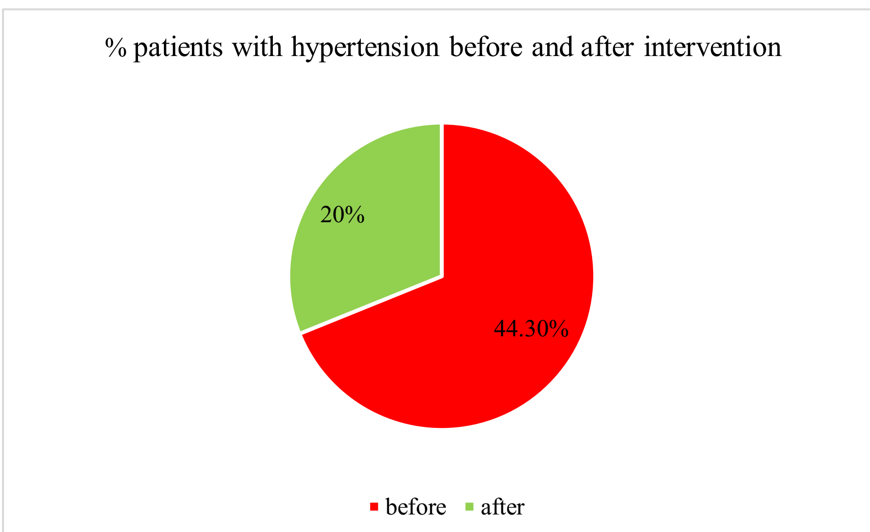


Figure 4.17: % of study population with hypertension before and after intervention

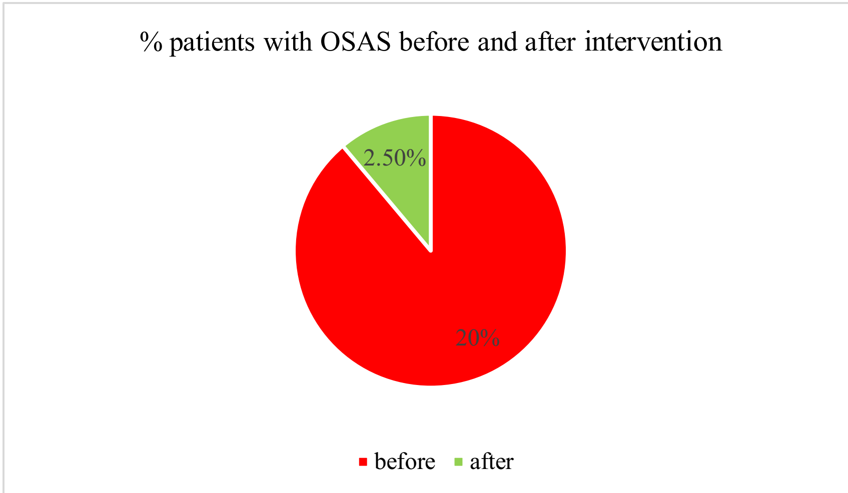


Figure 4.18: % of study population with OSAS before and after intervention

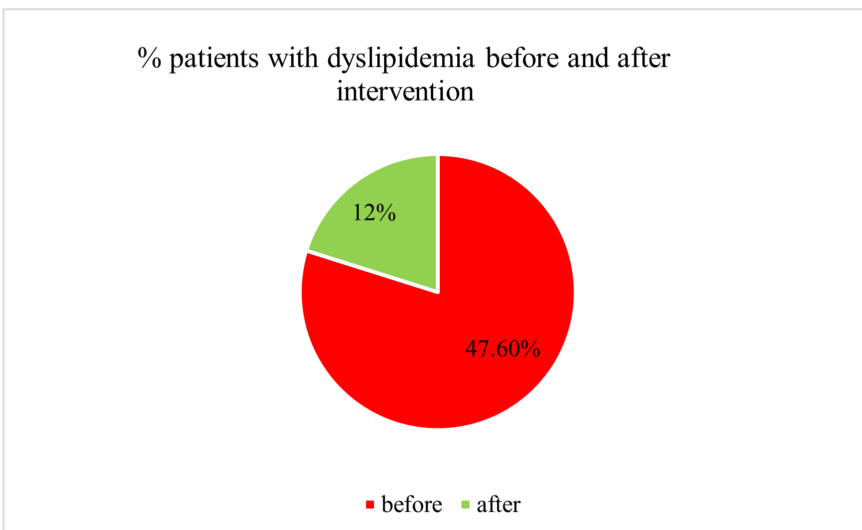


Figure 4.19: % of study population with dyslipidemia before and after intervention

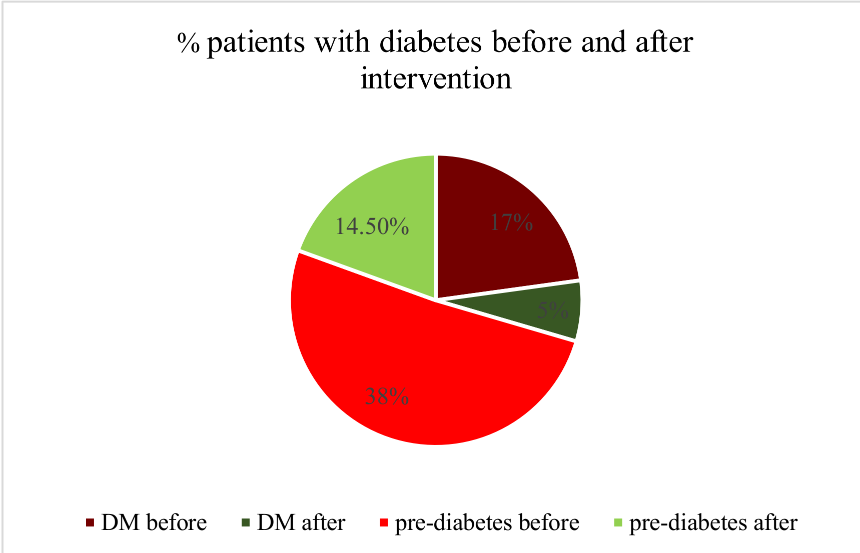


Figure 4.20: % of study population with diabetes before and after intervention

The effect of bariatric surgery in improving comorbidities is highly evident so that, as it can be concluded from the results the comorbidity status of patients decreased and improved by on average seventy percent after surgery.

5 Discussion

5.1 Main findings

In this study, a population including 124 patients with severe obesity and obesity-related comorbidities underwent sleeve Gastrectomy surgery and then were followed up for one year in 3 separate follow-ups (one month, six months, and one year after surgery). Then, their weight loss status and the improvement of their comorbidities were examined. Regarding weight loss, during the entire period or after the 3rd follow-up, the patients experienced weight loss of mean 31% compared to the pre-surgery body weight. Additionally, Patients were divided into five separate clusters based on their meal patterns (Cluster I: eating three main meals; breakfast, lunch, dinner, cluster II: varied meal pattern, Cluster III: eating three main meals and two snacks in the morning and afternoon hours, cluster IV: overeating during the day hours and cluster V: overeating during the day and night hours) and their weight loss after surgery was analyzed according to the cluster they belong to. Cluster I experienced mean 33% weight loss (mean 15.5% in 1st follow-p, 13% in 2nd follow-up and 9% in 3rd follow-up), cluster II experienced mean 31% weight loss (mean 11% in 1st follow-p, 18% in 2nd follow-up and 6% in 3rd follow-up), cluster III experienced mean 33% weight loss (14% in 1st follow-p, 19% in 2nd follow-up and 4% in 3rd follow-up), cluster IV experienced mean 32% weight loss (11% in 1st follow-p, 15% in 2nd follow-up and 9.5% in 3rd follow-up), cluster V experienced mean 27% weight loss (13% in 1st follow-p, 14% in 2nd follow-up and 3% in 3rd follow-up). The patients continued to lose weight until the 2nd follow-up, but about 21% of them stopped weight loss from the 2nd follow-up to the 3rd follow-up, and the majority of these patients were in cluster V (35%) and the least of them belonged to cluster IV (8%). While this index for clusters I, II and III were very close to each other and respectively 28.5%, 22% and 21% (figure 4.16). Since comparing the results related to obesity-related comorbidities including hypertension, OSAS, dyslipidemia and diabetes mellitus, a mean 70% improvement in patients' condition after surgery was found.

5.2 Considerations regarding the analysis of the results

First of all, as it is clear from Figure 4.7, bariatric surgery has an obvious effect on body weight of patients in whole population that 100% of them were obese and 68% of them suffered from class III obesity (figure 4.3) especially up to six months after surgery. On average, six months after surgery, approximately 26% weight loss has been observed in the population. From the 6th post-operative month to the 12th month, the patients experienced less weight loss (a mean 7% weight loss). Anyway, in our study like in other published observations, a significant weight loss after surgery was also observed (86, 87, 88). These results also show that the short-term effect of bariatric surgery on weight loss is significant (in the first months after the surgery), while its effect decreases over time and there may not any guarantee for the long-term durability of weight loss.

Afterwards, the weight loss of the patients was investigated according to their meal pattern which categorised them into five distinct clusters. Although the weight changes were very similar when comparing the clusters, more precisely, some differences can be founded.

Firstly, it can be said that the weight changes during the whole period in cluster I and III were completely similar (mean 33% weight loss), although there were small differences in the weight changes between different follow-ups. In addition, according to Figure 4.15, the variation of weight changes in the entire period was completely the same in these two clusters. These two cluster were also similar to each other regarding meal pattern so that patients had three main regular meals; breakfast, lunch, dinner in cluster I and in cluster III, they had daily two snacks in the morning and evening hours in addition to these three main regular meals. And since these people got a more reasonable result with a very small difference from other clusters, it can be said that it is possible that bariatric surgery candidates who have such a meal pattern will probably get a better weight loss result from the bariatric surgery.

Regarding the cluster II, due to the fact that the patients did not follow a constant meal pattern, for example, on weekdays, they ate three main meals while on weekends, they overate, so, the obtained results cannot show the relationship of a specific meal pattern with weight loss after surgery. But since the results of this cluster, both in terms of weight loss and in terms of stopping weight loss (figure 4.13, 4.14 and 4.16), are very close to other clusters, it can be said that, These results can only support the conclusion that there is probably no significant relationship between meal pattern and weight loss after bariatric surgery.

Conversely, the status of weight change of the patients in Caster IV was very interesting. Despite the fact that the meal pattern of these patients was overeating during the day hours, they experienced a good weight loss (a mean 32% decrease in body weight) (figure 4.11). In addition, the patients in this cluster, as shown in figure 4.16, have the lowest percentage of stop weight loss and regaining weight loss from the 2nd follow-up to the 3rd follow-up after surgery. The results obtained from this cluster support the conclusion that overeating, which is considered a bad habit in the meal pattern, does not have a negative effect on weight loss after bariatric surgery, and subsequently, there is not probably a meaningful relationship among this meal pattern and weight loss.

Patients in cluster V, who are characterized by overeating during day and night hours, experienced the least mean weight loss during the whole period (mean 27% weight loss) so that from the 2nd follow-up to the 3rd follow-up, their weight was almost unchanged (figure 4.13 and 4.14). The variation in body weights during the entire period, as can be seen from figure 4.15, was less than the rest of the clusters. Additionally, they had the highest percentage of stopping weight loss and regaining weight after surgery compared to other clusters (figure 4.16). According to the condition of the patients in cluster IV and V, it can also be concluded that overeating at night hours is much more important than overeating during the day hours on not achieving the desired weight loss from bariatric surgery. Our results are in agreement with a systematic review study entitled daily timing of meals and weight loss after bariatric surgery published in 2021 by Marine Cossec et al, in which the authors concluded that, although no precise definition can be found for late eating, eating at the end of the day could leads to poor weight loss results from bariatric surgery (90).

Regardless of bariatric surgery, here are other literatures that pointed out the positive effect of late eating and night-eating syndrome on increasing the risk of overweight and obesity and. Christina Berg, in a study on “Eating patterns and portion size associated with obesity in a Swedish population” concluded that skipping breakfast, lunch, and eating at night was found to have a significant association with obesity. Also individuals who are obese tend to consume food later in the day compared to those who are not obese. (89). Eating multiple meals during the day considering daily calorie intake has been associated with a lower likelihood of developing obesity. While, a lack of regulation over eating habits and the presence of night-eating syndrome, which involves consuming at least a quarter of daily energy intake during nighttime hours, may heighten the risk of obesity. (12). These results partially align with prior research indicating that adults with a normal BMI who consume a large percentage of their daily energy intake dur ing nighttime or late evening tend to have a higher overall energy intake. Additionally, a higher energy intake during the morning or afternoon is linked to a lower total energy intake (74).

The status of the study population was also investigated in terms of people who stopped losing weight after surgery. Overall, by 2^{nd} follow-p, the patients in all clusters lost weight but from 2^{nd} follow-up to 3^{rd} follow-up, 21% of patients stopped weight loss or gained weight that most of them were in cluster V and the least in cluster IV. The results showed that the mean weight loss in different clusters is almost similar but when we merge the result of weight loss in each cluster, it can be concluded that the patients in cluster V had least weight loss and highest rate of stopping weight loss. While cluster I and III were in better condition. Therefore, it can be said that, the meal pattern, along with other factors, may be an effective factor on the result of weight loss after bariatric surgery.

In association with obesity-related comorbidities, condition of patients before and after surgery for hypertension, dyslipidemia, OSAS and type 2 diabetes were investigated and compared, and as it is also found in other literatures, a significant improvement in the patients' condition regarding obesity-related comorbidities was observed after surgery. (91, 92)

5.3 Study limitations

Our study had significant limitations in terms of methodology and data. Firstly, our study population cannot be representative of the general population because, as shown in Figure 4.1, 72% of our population were female, so there was no gender balance in our study population. The gender imbalance observed in our study is in anyway very typical for bariatric series, in which most part of the patients are usually women.

The duration of the study period and also the interval between follow-ups were very short, and there is the possibility than a more extended duration of follow-up could produce more decisive results. The first year after surgery is usually characterized by an important weight loss in the majority of the patients, the so called “surgical honeymoon”, with weight regain coming out in the second and third years after surgery. On the other hand, our finding of a difference in weight loss between different meal patterns even in this generally positive period increases the clinical significance and strength of our results.

Examining the meal pattern of patients and identifying clusters in this short period of time is very difficult and could not be accurate because the meal patterns is a behavioral phenomenon and therefore very complex. In other words, patient's meal pattern cannot be determined simply by asking the patient, for example, do you overeat? And receiving a yes or no answer from the patient without knowing what was the patient's analysis of overeating, consumption of how much food in his view is overeating or whether he is completely honest in his answer or not (which is what we did in the study). Hence, psychological tests and multidimensional studies are probably needed to be able to accurately identify the cluster of meal pattern for each person.

Regarding data collection, the most important issue was the presence of some missing data. For example, the weights of some patients were not recorded in some follow-up visits, due to the lack of standard protocols for data collection in each follow-up or the lack of regular and timely patient visits in each follow-up. In data analysis, we decide to estimate the weight for missing visits according to the weight change of other people in the cluster and the mean weight change of other patients. This statistical adjustment could introduce some bias in our results. BMI of the patients was available only for the first visit and before surgery, and on the other hand, the information about the height of the patients was not available to calculate the BMI for each follow-up, despite significant variations in height should not occur in this short period of time. Moreover, although some factors affecting weight were taken into account in our study, not all factors were investigated and separated, such as genetics and socio-economic conditions of people, which can definitely have a significant effect on body weight. Finally, another limitation regarding the lack of data, which can be said to be important for the scope of our study and it could have affected our results, is the fact that the patients' information about whether they followed the pre-intervention meal pattern after the surgery or whether they changed it was not available.

5.4 Conclusion

Our small short-term study confirm that bariatric surgery is a suitable and effective option in terms of weight loss and decreasing obesity-related comorbidities in patients with various levels of severe obesity. The effect of bariatric surgery on short-term weight loss is very significant and evident, but there may not any certainty in its durability in the long term, and probably other factors affect it. Although a concrete and strong relationship between the meal patterns and weight loss after surgery was not observed in this study, the differences observed in our patients belonging to the clusters I, III and V and the status of the entire study population in terms of stopping weight loss, suggest the possibility that the meal pattern of patients who undergo bariatric surgery could have a weak effect on weight loss after surgery. People who eat the three regular main meals of breakfast, lunch, and dinner (cluster I) or two other snacks in the morning and evening hours in addition to main meals (cluster III), probably get better results regarding weight loss from bariatric surgery than others. People who overeat during the day and night hours (cluster V) are likely to get weaker results and stop weight loss more than others. It seems that having a special wrong eating habits such as overeating at night, or it can be called night eating disorder (NES), which is a distinctive feature of Cluster V, is more relevant than other meal patterns on weight loss after bariatric surgery. This is also suggested by the fact that the meal pattern of cluster IV, despite being somehow similar to cluster V (overeating only during day hours at not at night), is associated to a favorable weight loss after surgery and the lowest rate of stop weight loss. Overall, examining the effect of a behavioral pattern (meal pattern) on the result of a clinical practice is not simple. So, further multidisciplinary studies on a more well-organized study population with a more completed and detailed range of data are needed to clarify the possible relationships between meal patterns and weight loss after bariatric surgery.

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