

Analyzing the Sociodemographic Factors Impacting the Use of Virtual Reality for Controlling Obesity

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ABSTRACT

Obesity is one of the most pressing issues in society today. Virtual reality has been used in the design of tools that promote obesity control. However, the design of current VR tools lacks the involvement of prospective users and health practitioners. Such engagement is crucial in gathering semantic information that identifies stakeholders' needs and ensures that all aspects of health are considered. Therefore, this paper aims to study the sociodemographic factors and individual-level characteristics and preferences that make the design of any obesity-control VR tool effective and satisfactory for a wide range of users. The paper also aims to solicit opinions of health practitioners to identify best health aspects that should be available in the design of any VR tool for obesity control. Organizations, businesses, and people will be able to readily augment such VR technologies on the semantic web, as well as on personal and mobile devices.

KEYWORDS

Obesity Control, Psychological Factors, Semantic Web, Sociodemographic Factors, Statistical Analysis, Virtual Reality

INTRODUCTION

Obesity is a prominent global concern that is correlated with several chronic diseases and associated mortalities. Social determinants and environmental factors play an important role in the adoption of certain behaviors that cause obesity and related health issues. This makes obesity a complex public health issue dependent on several individual, socioeconomic, behavioral, and physiological factors (Dixon, 2010).

DOI: 10.4018/IJSWIS.300819

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National survey data show that the obesity epidemic began in the U.S. over 50 years ago (Finucane, et al., 2011). In 2017–2018, US obesity prevalence increased from 30.5% to 42.4%. During the same time, the prevalence of severe obesity increased from 4.7% to 9.2% (CDC, 2022).

The World Health Organization (WHO) formally recognized the obesity epidemic's global impact during a special obesity consultation in 1997 (James, 2008). Over the past 15 years, a large body of evidence has been accumulated documenting temporal increases in the prevalence of obesity worldwide. Obesity has roughly tripled globally since 1975. In the year 2020, 39 million children under the age of five were overweight or obese. In 2016, nearly 340 million children and adolescents aged 5 to 19 years old were overweight or obese. More than 1.9 billion individuals aged 18 and over were overweight in 2016. Over 650 million of them were fat. In 2016, 39 percent of adults aged 18 and above were overweight, with 13 percent being obese. Overweight and obesity kill more individuals than underweight in the majority of the world's population (WHO, 2022).

Smart cities are a critical arena for promoting physical activity and long-term health for their inhabitants (Galea & Tsay, 2021). Cities that are designed in a way that encourages more physical activity will have a big impact on the growth of any region. The Urban Development Network Program (URBACT) Healthy Cities Network suggests two important solutions for healthier smart cities: (i) active participation of city citizens in the decision-making process, and (ii) engagement of the health sector in the design of a healthy modern cities (Serrà, 2021).

Virtual reality (VR) has been utilized in the development of technologies to encourage physical activity and obesity control in the last decade. Existing VR technologies, on the other hand, lack the integration of potential users and the early involvement of healthcare practitioners in the design and development process. Involvement of potential users and health practitioners is critical in obtaining necessary semantic information that aids in recognizing stakeholders' requirements and ensuring that all elements of health are considered.

Therefore, the goal of this research is to investigate the sociodemographic aspects as well as individual-level traits and preferences that influence the effectiveness and satisfaction of any obesity-control VR tool for a wide variety of users. Furthermore, the paper seeks the input of health practitioners to determine the best health elements that should be included in the design of any VR product. The sociodemographic analysis help towards the development of the knowledge society by providing sufficient information about user trends and experts opinions. Our analysis aims to help in providing rich semantic information that is more domain-oriented which will make the design of VR applications and tools more intuitive. Such tools will be easily augmented on the semantic web and on personal and mobile devices for the use of organizations, business, and citizens.

BACKGROUND

VR and Obesity

The deployment of VR in rehabilitation and in response to numerous disorders is sound. Various studies in the past few years have promoted sound research related to methodological frameworks, services, and enhanced experiences. In the context of the use of VR to monitor, address, and prevent obesity, several complementary approaches can be used.

Riva (Riva G., 2011) provided a thorough study on the use of VR to treat obesity and eating disorders (EDs), summarizing various studies that identify unhealthy weight-control behaviors (fasting, vomiting, or laxative abuse) induced by negative body experiences as common antecedents of both obesity and EDs. The paper reviewed the "allocentric lock theory" of negative body image (BI) as the possible antecedent of both obesity and EDs. We will expand further on this paper's key contributions in our future research work by designing various VR-enhanced exercises to promote obesity prevention and treatment through well-being and fitness.

Another key issue in the provision of VR systems, as well as applications related to obesity, is related to BI and representation. Alcaniz et al. (Alcañiz, et al., 2000) presented a new method for accurate 3D deformation of a human body model that uses a reduced number of parameters. The original goal was to reform different parts of a 3D human body through geometry. The chosen algorithm is based on a series of boxes around the geometric parts to be changed. Any change in the position of a box vertex is converted to geometry deformation and eventually to opportune displacement of the neighbor boxes. In our approach, the development of VR-enhanced learning exercises investigates novel combinations of VR tools for the representation and association of body imaging to prevent obesity.

Perpina et al. (Perpiña, et al., 1999) provided evidence of VR interventions' efficiency in dealing with obesity disorders. Their study's purpose was to probe one specific component's effectiveness level in the assessment and treatment of BI in ED by means of VR. Two treatment conditions were applied: (a) The Standard Body Image Treatment Condition (SBIT) and (b) the VR Condition. Thirteen patients with EDs were assigned randomly to one of these conditions. No differences between the conditions were found in general EDs measures, but patients treated in the VR condition showed greater significant improvement in specific BI measures. These results suggest that BI treatment with VR could be more targeted to its disturbances than traditional techniques. In our proposed project, we intend to move beyond this finding and justify an integrated management model to prevent, address, and treat obesity based on the design, delivery, and implementation of VR solutions for obesity.

Cesa et al. (Cesa, et al., 2013) elaborated further on VR's contribution to obesity treatment. Despite the study's limitations, the findings support the hypothesis that the integration of a VR-based treatment, aimed at both unlocking the body's negative memory and modifying its behavioral and emotional correlates, may improve the long-term outcome of a treatment for obese Binge-Eating Disorder (BED) patients. As expected, the VR-based treatment, compared with the standard Cognitive Behavioral Therapy (CBT) approach, prevented weight regain more effectively, but did not manage binge-eating episodes more effectively. In our research proposal, we use this study's findings to personalize learning exercises.

Several other studies (Fairburn & Wilson, 1993), (Ricca, Mannucci, Zucchi, Rotella, & Faravelli, 2000), (Riva, Bacchetta, Cesa, Conti, & Molinari, 2001)), have emphasized similar findings on the use of VR in the delivery of sound responses to obesity and EDs.

Rizzo et al. (Rizzo, Lange, Suma, & Bolas, 2011) elaborated on interactive games and VR's capacity to support obesity patients. Interactive digital games and new forms of natural movement-based interface devices also are discussed in the context of the emerging area of exergaming, along with some of the early results from studies on energy expenditure during the use of these systems. While these results suggest that playing currently available, active exergames uses significantly more energy than sedentary activities and is equivalent to a brisk walk, these activities do not reach the intensity level that would match playing the actual sport, nor do they deliver the recommended daily amount of exercise for children. However, these results provide some support for the use of digital exergames using the current state of technology as a complement to, rather than a replacement for, regular exercise. This project's main aim is to deliver interactive exercises and games for obesity management.

We are going to evaluate one of the key findings from Rizzo's work: "This may change in the future as new advances in novel full-body interaction systems for providing vigorous interaction with digital games are expected to drive the creation of engaging, low-cost, interactive, game-based applications designed to increase exercise participation in persons at risk for obesity." (Rizzo, Lange, Suma, & Bolas, 2011).

Moreover, VR in the treatment of obesity is getting more and more attention. Recent studies focused on either improving previous research or innovating new methods. In (Thomas, et al., 2021), the authors investigated five experimental intervention components in try to uncover intervention techniques that could help in improving the outcomes of an online behavioral lifestyle intervention

(BLI). The authors will test the finalized treatment package in a future randomized trial. Authors in (Phelan, Peruvemba, David Levinson, Aidan Lacy, & Werner, 2021) discussed weight regain problem. The study emphasized that VR has the potential to improve on standard BWLT by giving patients more opportunities to practice behavioral modification skills on a more frequent basis, as well as greater positive reinforcement and encouragement from an interventionist in realistic scenarios.

In (Belghali, Statsenko, & Al-Za'abi, 2021), the authors suggested the use of serious games as a validated intervention in therapeutic practice. The proposed concept entails VR serious game based on education, movement, enjoyment, and executive functioning (EF) training. Another recent paper also focused on using VR in childhood obesity treatment (Persky, et al., 2021). The authors looked into the effectiveness of communication with parents focusing on two key causes of childhood obesity: genes and environment. Parents' feeding responses were compared to messages that focused on genetics alone; family environment alone; genetics family environment interaction; and no causal message. Parents chose foods for their children using the VR buffet after receiving one of the four types of messages.

VR can help individuals establish and internalize certain automatic and desired behavioral patterns experienced in VR space. This process draws extensively on the classic Pavlov's dog experiment. A VR-enabled experience with a reward will be repeated, whereas a VR-enabled experience with a penalty will make an individual reconsider a certain action already taken.

Semantic Web and VR

The Web is one of the most powerful and promising tools for creating immersive VR environments. It provides ideal circumstances for collaborative VR environment development and use, including indexing, searching, and processing of interactive 3D content. The improvement of web-based VR has been made possible by a variety of 3D formats (e.g., VRML and X3D), game engines (e.g., Unreal and Unity), and programming libraries (e.g., WebGL and WebXR) (Flotyński, et al., 2019). These opportunities have growth even further with the introduction of the Semantic Web (Berners-Lee, 2001), which is now a key trend in the evolution of the Web. It converts the Web into a network that connects structured content to formal and expressive semantic descriptions. Semantic descriptions are made possible by structured data representation standards, and by ontologies, which are clear conceptualization specifications (Gruber, 2009).

In the literature, there are some studies in using ontologies and semantic information to model how the virtual environments interact, for instance NiMMiT (Notation for Multimodal interaction Techniques), which is a notation based on diagram that describes multimodal interaction (De Boeck, Raymaekers, & Coninx, 2006). Another study suggested using ontologies to create multi-user virtual environments and avatars. It focused on the representation of 3D content geometry, space, animation, and behavior. The entities covered are semantic equivalents of entities included in widely employed 3D formats, such as VRML and X3D (Chu & Li., 2012). In (Rumiński & Walczak, 2014), a contextual augmented reality environment was suggested, which comprises three components: the trackable, interface, and content objects. In (Flotyński & Walczak, Conceptual semantic representation of 3d content, 2013), environments were represented at multiple levels of abstraction: conceptual level, concrete level and platform using the model of SCM (Semantic Content Model) which was intended for semantic representation of interactive 3D contents.

Semantic Web and Obesity

Semantic web was used to understand the complex relationships among all obesity contributing factors. In [1] a combination of Semantic Web technologies and Deep Learning were used a Semantic Deep Learning approach to transform information about prognoses, therapies, diagnoses, and other clinical concepts into reusable and reliable One. semantic metadata was used to create intelligible abstraction to predict any health risk to generate individualized recommendation [3]. This study has used unintuitive, massive, raw, health unstructured observations data as interviews, sensors, questionnaires) and to

annotate them with semantic metadata to create a compact, intelligible abstraction for health risk predictions for individualized recommendation generation. This is done to model semantic meta data to be used for the prediction.

The ontology of fast-food facts was developed to standardize knowledge of fast food as a high calorie intake which make it a major contributor to diseases that threatening life [4]. Then link the nutritional data that could be aggregated and analyzed for the information needs of experts and consumers. The ontology is built on metadata from about 21 fast food institution nutritional resources. In childhood obesity, frequent monitoring of the patients by health specialists is required to deliver efficient obesity treatment and management [5]. Thus, the patients are regularly examined then compare the measurements with the predefined percentile values. The ontology and semantic rules are used as a decision support system on the obesity consultation and management during childhood and youth.

RESEARCH GOAL AND CONTRIBUTION

The key assumption upon which this research builds is that, apart from physical causes of obesity related to genetic and other risk factors, obesity is related to certain lifestyles that, if prevented, effectively can pre-empt the emergence of obesity.

Our research builds on extant literature and connects lifestyles – over-consumption, unhealthy diet, lack of alternative protein sources, cultural issues, etc. – with the obesity management problem. To recognize the most appropriate VR exercises for a wide segment of society, we need to examine the factors with the greatest effect on the targeted audience’s lifestyle and weight gain. This paper seeks to examine in what ways VR can make a good fit with the risk factors driving obesity, and suggest ways to pre-empt and address it, as well as monitor the of outcomes.

Several research attempts have designed VR technologies for obesity control; however, current literature – to the best of our knowledge – lacks designs that are based on opinions solicited from potential users. Furthermore, integration of health practitioners’ feedback is absent from the design process of current obesity-control VR tools.

Therefore, the aim of this paper is to study the sociodemographic factors and individual-level characteristics and preferences that make the design of any obesity-control VR tool effective and satisfactory for a wide range of users. In addition, the paper aims to solicit opinions of health practitioners to identify best health aspects that should be available in the design of any VR tool.

The sociodemographic study will aid the development of the knowledge society by giving sufficient information on user patterns and expert viewpoints. Our research intends to aid in the provision of rich semantic information that is more domain-oriented, resulting in more intuitive VR app and tool design. Organizations, businesses, and people will be able to readily augment such technologies on the semantic web as well as on personal and mobile devices.

RESEARCH APPROACH

In April 2020, a cross-sectional observational study was piloted in Saudi Arabia. Two questionnaires were conducted in our study: the first one was for users, while the second was for health professionals. The purpose of the user survey was to find out how social, economic, and psychological factors influenced participants’ physical activity and weight gain. The purpose of the expert survey was to assist us better understand the uses and benefits of VR in hospitals, fitness centers, and other health institutions. It also aimed to use physicians’ knowledge to define VR strategies for obesity management. Participants of the user survey were divided into two groups: those who engaged in physical activities and those who did not.

Our research found that obesity is connected to several sociodemographic and psychological variables such as age, gender, socioeconomic status (SES) and self-image. Males in one age range, 40-49 years old, who practice physical activities are more likely to be overweight. On the other hand,

males in the non-practicing group are more obese. Obesity is more prevalent in children under the age of 19 and people aged 40 and up among non-practicing participants. We found that obesity is greatest in divorced practicing participants, as well as married, divorced, or widowed non-practicing participants. The findings also show that obesity and SES are linked in both practicing and non-practicing participants. Both the practicing and non-practicing participants had important p-values for their thoughts towards their bodies. When it comes to fitness habits, 91.5% of people favor aerobic workouts. In terms of workout venue, 63% of participants choose to exercise indoors.

Experts who took part in the study via an expert questionnaire identified demographic groups that would benefit the most from utilizing VR to help them lose weight with 37.5 percent of responses indicating that those age groups are 5-16 and 38-50. Furthermore, the health professionals underlined the need of utilizing VR to encourage and follow healthy practices such as calorie counting and boosting awareness by teaching users about healthy habits, changing users' diets, and leveraging media to reduce obesity.

RELATED WORK

Several studies have investigated different sociodemographic factors that affect obesity and, therefore, impact the design of suitable VR tools to control obesity. Such factors include age, gender, marital status, average income, and education level. In this section, we discuss the findings from some existing studies in the literature.

Individual Characteristics

Obesity's prevalence varies according to key individual characteristics, such as age and gender, increasing cross-sectionally across the lifespan: 13.9% in early childhood (2-5 years old); 18.4% in childhood (6-11 years old); 20.6% in adolescence (12-19 years old); 35.7% in young adulthood (20-39 years old); 42.8% in adulthood (40-59 years old); and 41.0% in older adulthood (≥ 60 years old) (Hales, Fryar, Carroll, Freedman, & Ogden., 2018). During the 2007-2008 and 2015-2016 periods, obesity significantly increased only in women (Hales, Fryar, Carroll, Freedman, & Ogden., 2018), suggesting a gender-specific vulnerability to expression of this disease. According to the data in (Finucane, et al., 2011), the gender-specific prevalence of obesity was highest in North America (men: 29.2%) and in southern Africa (women: 36.5%). Obesity prevalence $>30\%$ also was observed in women living in North America, Latin America, North Africa, and the Middle East.

Marital Status

In the literature, many studies examined the relationship between marital status and body mass index (BMI) (Sobal, Rauschenbach, & Frongillo, 1992) (Tzotzas, et al., 2010) (Lipowicz, Gronkiewicz, & Malina, 2002), and the prevalence of overweight and obesity in many countries. The evidence presented in these studies suggests that an association exists between weight and marital status. Regardless of education level, married women and men have higher BMIs and are more likely to be overweight and/or obese than their never-married age and gender peers (Lipowicz, Gronkiewicz, & Malina, 2002).

Socioeconomic Position (SEP)

Like most diseases, obesity (a BMI ≥ 30 kg/m²) and its risk factors are distributed unequally within the population (Avendano M & Banks J, 2009). In developed countries, people with a low socioeconomic position (SEP) are more likely to be obese than peers with a high SEP (McLaren, 2007). Compared with obesity, SEP inequities in overweight (a BMI of 25 to 29.9 kg/m²) are much smaller. From a health economic perspective, overweight inequality is worth considering because overweight is a risk factor for obesity and, thus, offers prevention potential (Roskam, 2009). SEP is measured by

education, income, and/or occupation (Roskam, 2009). These indicators not only can influence a person's body weight, but obese individuals also have less of a chance of attaining higher education, achieving a better occupational position, or earning a high income (McLaren, 2007). How strongly these indicators contribute to excess weight (a BMI ≥ 25 kg/m²) differs significantly between countries. In the U.K., low SES (in women) and low income (in men) were related more strongly with obesity than low education levels (Wardle, Waller, & Jarvis, 2002). For women in the U.S., higher BMI is associated with lower education, but not lower income (Flegal, Harlan, & Landis, Secular trends in body mass index and skinfold thickness with socioeconomic factors in young adult women, 1988). In an urban Swiss working population, education and occupation were associated independently with BMI, and obesity was related inversely with education levels in both genders (Galobardes, Morabia, & Bernstein, 2000). Generally, people in wealthy segments have a lower risk of obesity than those in low-income segments, possibly owing to access to a high level of health education, sufficient income to purchase healthy foods, adequate time for leisure and physical-fitness activities, and access to quality health care (Caballero, 2005).

Another study (Pei, Cheng, Kangx, Yuan, & Yan, 2015) examined the assessment of the association between SES and obesity. The study aimed to examine the effect of SES on overweight/obesity and abdominal obesity by gender and age in rural Northwest China. The study concluded that in men, likelihood of overweight/obesity and abdominal obesity was higher in high SES groups compared with low SES groups. However, women with an elevated level of education were less likely to be overweight/obese than their counterparts with a low level of education. A strong positive association between age and obesity in the population was proved after the inclusion of multiple lifestyle factors.

According to (Cutler & Lleras-Muny, 2006), individuals with higher education levels are less likely to smoke, drink often, be overweight or obese, or use illegal drugs. Similarly, people with more education are more likely to exercise and obtain preventive care. Authors also found that the relationship between education and health appears to be non-linear for obesity, with increasing effects with higher education levels. A review by Grossman and Kaestner (Kaestner, Grossman, & Yarnoff, 2011) concluded that education level is the most important correlate of good health. Cross-sectional estimates from a study of twins conducted by (Webbink, Martin, & Visscher, 2008) also confirms the negative relationship between education and the probability of being overweight. By looking at differences between genders within a study of socioeconomic factors and obesity, (Yoon & Park, 2006) found that income, rather than education, exerted a greater effect on BMI and waist circumference (WC) in men, whereas higher education levels in women resulted in lower BMI and WC.

Physical Activity

Several benefits from physical activity on weight have been demonstrated in the literature, but physical activity levels related to work, transportation, and household chores have declined dramatically, and sedentary behaviors such as TV viewing and screen time (Internet and computer use) have increased leading to an overall reduction in total physical activity.

A more general study (Chamieh, Moore, Summerbell, & Tamim, 2015), with the objective to assess age and gender differentials in the prevalence of obesity in Lebanon, examined correlates of obesity, with an emphasis on physical activity and socioeconomic disparities. The prevalence of obesity among Lebanese adults was 26.1%. Gender differences in obesity estimates were observed across age groups and the three obesity classes, with men showing higher prevalence rates in younger age groups (20-49 years), and women showing higher prevalence rates in older age groups (50 years and older). Obesity showed significant associations with SES in women, decreasing with higher education attainment, greater household assets, and lower crowding index, a net of the effect from other co-variates. There was a significant positive association between obesity and energy intake in both genders and a negative association between obesity and physical activity, particularly among women.

Gender

A recent study (Bernardi, Goldani, & Pinheiro, 2017) aims to evaluate obesity according to gender, low birth weight (LBW), and lifelong social mobility as an explanation of obesity's etiology. The study was conducted within the context of the epidemiological transition in middle-income countries. The study used data from a birth cohort study conducted in Ribeirão Preto, São Paulo, Brazil. Data regarding anthropometric measurements, schooling, and smoking status were collected on those ages 23-25. Social mobility was determined based on maternal and adult offspring schooling and categorized as low-low, low-high, and high-high. Analysis of covariance was performed to assess the association between social mobility and BMI or WC in adulthood, stratified by LBW and gender. The experiment concluded that women born with LBW belonging to the group with less education in early adulthood had high BMI and WC compared with the low-high social mobility group.

Psychological Factors

Psychological factors usually are the main causes of EDs and obesity. Individuals who suffer from psychological disorders (e.g., depression, anxiety) may have more difficulty controlling food consumption, exercising an adequate amount, and maintaining a healthy weight. Food often is used as a coping mechanism by those with weight problems, particularly when they are sad, anxious, stressed, lonely, and frustrated. With many obese individuals, there appears to be a perpetual cycle of mood disturbance, overeating, and weight gain. The resulted weight gain may cause a dysphoric mood due to their inability to control their stress. The resulting guilt may reactivate the cycle, leading to a continuous pattern of using food to cope with emotions (Collins & Bentz, 2009).

Another study (Simon & Evette, 2008) evaluates the association between obesity and depression among middle-aged women. The experiment examined 4,641 females ages 40-65 who completed a structured phone interview that included self-reported height and weight, as well as the Patient Health Questionnaire (PHQ) assessment of depression. The study concluded that among middle-aged women, depression is associated strongly and consistently with obesity, lower physical activity, and (among the obese) higher caloric intake. Public health approaches to reducing the burden of obesity or depression must consider the strong association between these two common conditions.

METHODS

Study Design and Setting

An observational cross-sectional study was piloted in April 2020. Two questionnaires were used: one for *users* and the other for *experts*.

The user questionnaire aimed to understand the impact from social, economic, and psychological factors on the participant's physical activities and weight gain.

The expert questionnaire was Internet-based and distributed among practitioners (worldwide) in the medical field, at fitness centers, and in the VR field. It aimed to develop a better understanding of the uses and benefits of VR in hospitals, fitness centers, and other health facilities, as well as identify VR methods used to control obesity using practitioners' experience.

Study Sample

The user questionnaire was Internet-based and distributed among people living in different cities across Saudi Arabia through internet posting and word of mouth. The final sample of user questionnaire participants was 603 (402 male and 201 female).

The expert questionnaire was Internet-based too and was distributed among health practitioner around the world through internet posting and word of mouth. The final sample of expert questionnaire participants was 31.

User Questionnaire

To investigate different factors that might affect obesity, we designed the user questionnaire to include questions that capture participants' sociodemographic factors. In this section, we discuss the different questions included in the user questionnaire and our rationale behind them. To the best of our knowledge, our work is the first to have used a questionnaire to investigate the user's characteristics and preferences to help make the design of any obesity-control VR tool effective and satisfactory for a wide range of users. The questions in the questionnaires were determined based on factors discussed in the literature as being of significance. However, no single work – to the best of our knowledge – have incorporated all these factors in a questionnaire to confirm users' opinions, characteristics and preferences.

The questionnaire starts by asking users about their gender. Over the past decade, obesity grew dramatically only among women (Hales, Fryar, Carroll, Freedman, & Ogden., 2018), reflecting a gender-specific sensitivity to expression of this disease. According to the data in (Finucane, et al., 2011), the gender-specific obesity rate was highest in North America, with a percentage of 29.2% among men, and in southern Africa, with a percentage of 36.5 percent among women. Women living in North America, Latin America, North Africa, and the Middle East registered obesity rates greater than 30%. Such high rates strongly suggest a high correlation between gender type and obesity rate.

The second question in the user questionnaire concerns participants' ages. According to (Hales, Fryar, Carroll, Freedman, & Ogden., 2018), obesity rates increase across a person's lifespan, reaching their peak at adulthood (40-59 years old), with a percentage of 42.8%, and 41.0% in older adulthood for seniors older than or equal to 60 years old. Therefore, we included an age question to investigate the correlation between age and obesity further.

To calculate BMI, the questionnaire asked users about their height and weight. BMI is an important screening method used to determine different weight categories: underweight; healthy weight; overweight; and obese (About Adult BMI, n.d.).

The next question in the user questionnaire concerns marital status. Existing research indicates a strong association between marital status and BMI (Lipowicz, Gronkiewicz, & Malina, 2002). Married women and men have a higher BMI and are more likely to be overweight and/or obese than their never-married counterparts, regardless of education level.

The questionnaire also asks users about their city of residence. According to (Caballero, 2005), there is a lower prevalence of obesity among people living in wealthier areas than among those living in low-income areas, likely due to access to a high standard of health education, enough income to afford nutritious food, sufficient time for recreation and physical exercise, and access to decent health care (Caballero, 2005).

Another factor that the questionnaire measured is education level. Several research studies have proved a strong negative correlation between obesity and education level (Flegal, Harlan, & Landis, Secular trends in body mass index and skinfold thickness with socioeconomic factors in young adult women, 1988) (Galobardes, Morabia, & Bernstein, 2000) (Caballero, 2005) (Pei, Cheng, Kangx, Yuan, & Yan, 2015) (Webbink, Martin, & Visscher, 2008). It was found that people with higher education levels are less likely to be overweight or obese. Similarly, people with more education are more likely to exercise and adopt a healthy lifestyle (Cutler & Lleras-Muney, 2006). However, obese individuals have fewer opportunities to pursue higher education (McLaren, 2007).

The user questionnaire also measures the impact from participating individuals' monthly income. Several studies have examined the correlation between income level and BMI. (Galobardes, Morabia, & Bernstein, 2000) found that in a Swiss working population, occupation was associated with BMI. Another study (Pei, Cheng, Kangx, Yuan, & Yan, 2015) found that the likelihood of overweight/obesity is higher in men with high incomes compared with people with low income. (Yoon & Park, 2006) confirms that income significantly impacts BMI among men.

A negative association between obesity and physical activity levels has been demonstrated in the literature such as (Chamieh, Moore, Summerbell, & Tamim, 2015). To assess such a correlation

further, the questionnaire asks participants whether they work from home, and whether they participate in any sporting activities. If participants exercise, the questionnaire asks about the type of physical activity they perform. The questionnaire also asks participants about the probable reasons behind excess weight, and whether they believe that a lack of physical activity is one of the reasons.

The final factor measured in the questionnaire is self-image and the psychological factor, in which participants were asked whether they are satisfied with their BI, and if they are not, it asks them about their feeling(s) toward themselves (anger, depression, anxiety, sadness, and/or hatred). A study that assesses the relationship between obesity and the psychological factor (Simon & Evette, 2008) found that among middle-aged women, depression is associated strongly with obesity, lower physical activity, and higher food consumption. (Collins & Bentz, 2009) found that people with weight problems use food as a coping mechanism, especially when they suffer psychologically. Therefore, the questionnaire also asks the participants about the type of diet they consume and whether they believe it is healthy or not.

Independent Variables: Sociodemographic Factors

The most important factors of the sociodemographic features used in our analysis include gender, age, marital status, education level, and average monthly earnings. Age in years was classified into five groups: child (<19); youth (20-29); adult (30-39); mature (40-49); and senior (>50) years. Marital status was categorized as single, married, divorced, or widowed. Education level was classified as lower education, high school, university, and higher education. Finally, average monthly earnings were classified into four groups, less than \$1,000, \$1,000-2,400, \$2,400-4,000, and greater than \$4,000. Participants' data were divided into two categories: practicing exercises and non-practicing exercises. Two factors were added to sociodemographic factors. The first is diet type, with three categories: healthy food; unhealthy food; and specific diet regimen. The second factor concerns participants' feelings about their bodies, with two answers: happy or not happy.

Statistical Methods

The questionnaires were designed using Google Forms, then the data were exported directly to Google Sheets. Finally, the data were coded and exported to *R* program for analysis.

Descriptive statistics were computed and expressed through sociodemographic characteristics and the BMI, which was calculated by dividing body weight (kg) by height squared (m^2). Overweight and obesity were defined as recommended by WHO (James, 2008): Overweight ranges from 25.0–29.9 kg/m², and obesity ³ 30.0 kg/m². Underweight < 18.5, and normal or healthy weight ranges from 18.5–24.9. The estimates for BMI type (underweight, healthy weight, overweight, and obesity) were computed as percentages with the total sample size as the denominator. To check the factors associated significantly with overweight and obesity ($p < 0.05$) in the bi-variable analysis, the chi-square test of independence was used to determine whether a significant relationship exists between two categorical variables such as gender, age, marital status, education level, average monthly earnings, diet type, and feelings from one side and BMI type from the other side.

When the chi-square test of independence indicated significance, i.e., a significant relationship existed between two categorical variables, we were interested in finding what values in this relationship were driving this significance. To do that, the adjusted Pearson residuals were computed to detect any correlations between variables. For example, if a correlation existed between BMI and gender, which gender type affected the relationship more: the male or the female?

RESULTS

Participants' Characteristics

Of the 603 user participants, 360 (59.7%) practice exercises, while 243 (40%) are of the non-practicing-exercises type. The percentage of males who practice exercises is higher than females, at 68.5%. Of the users who practice exercises, 37% are seniors older than 50, 78.2% are married, 56.8% are at

university education level, and 46.7% have more than \$4,000 in average monthly earnings. As for diet type, 71.9% of users who do not practice exercises consume unhealthy food, which makes them unhappy about their bodies (cf. Table 1).

Prevalence of Underweight, Healthy Weight, Overweight, and Obesity

The mean and median height, weight, and BMI of users who practice exercises are 167.8 ± 8.8 cm, 168 cm (Interquartile range (IQR) = 175–161), 79.1 ± 18.8 kg, 78 kg (IQR = 89.5–68), and 28 ± 6.2 kg/m², 27.6 kg/m² (IQR = 30.1–24.6). The mean and median height, weight, and BMI of users from the non-practicing group are 166.3 ± 10.2 cm, 166 cm (IQR = 173–160), 83.5 ± 23.7 kg, 80 kg (IQR = 95.5–69), and 30.1 ± 7.8 kg/m², 29.1 kg/m² (IQR = 33.2–24.8) (cf. Table 2). To visualize the BMI for all groups, the boxplot Figure 1 shows that the BMI median and mean for the non-practicing group are higher than other groups (the line in the middle of the box), and the outliers are higher for the practicing group and all participants compared with the non-practicing group (white circles).

To compare BMI types for practicing and non-practicing groups, the boxplots depict these differences in Figures 2 and 3. It can be observed that the number of obese was higher for both groups but is still lower in the practicing vs. the non-practicing group.

Table 1. Study participants' sociodemographic characteristics; all users = 603; practicing = 360; non-practicing =243

Characteristics	All participants (n) 603	All participants (%) 100	Practicing (n) 360	Practicing (%) 59.7	Non Practicing (n) 243	Non Practicing (%) 40.3
Sex						
Male	402	66.7	246	68.5	153	64
Female	201	33.3	113	31.4	86	35.9
Age groups						
Child (<19)	7	1.2	2	0.5	5	2.1
Youth (20–29)	114	18.9	56	15.5	58	23.9
Adult (30–39)	108	17.9	69	19.2	38	15.6
Mature (40–49)	171	28.4	99	27.5	69	28.4
Senior (>50)	203	33.7	133	37	69	28.4
Marital status						
Single	123	20.4	64	17.8	59	24.6
Married	454	75.3	281	78.2	168	70.3
Widowed/divorced	26	4.4	14	3.89	12	4.93
Education level						
Lower education	8	1.3	3	0.8	5	2
High school	63	10.4	31	8.6	31	12.9
University	335	55.6	204	56.8	129	53.9
Higher education	197	32.7	121	33.7	74	30.9
Average monthly earnings						
< \$1,000	119	19.7	54	15	65	27.2
\$1,000–2,400	70	11.6	42	11.6	27	11.3
\$2,400–4000	169	28	95	26.4	72	30.1
> \$4000	245	40.6	168	46.7	75	31.4
Diet type						
Healthy	224	37.1	167	46.5	57	23.8
unhealthy	336	55.7	159	44.2	172	71.9
Diet regimen	43	7.1	33	9.2	10	4.2
Feeling						
Happy	310	51.4	216	60	94	38.7
Unhappy	293	48.5	144	40	149	61.3

Table 2. Height, weight, and BMI by participant type (practicing or non-practicing)

	Height (cm)	Weight (kg)	BMI, (kg/m ²)
Practicing			
Mean	167.8	79.1	28.0
Median	168.0	78.0	27.6
SD ^a	8.8	18.8	6.2
IQR ^b	175–161	89.5–68	30.1–24.6
Non Practicing			
Mean	166.3	83.5	30.1
Median	166.0	80.0	29.1
SD ^a	10.2	23.7	7.8
IQR ^b	173–160	95.5–69	33.2–24.8
All participants			
Mean	167.2	80.9	28.8
Median	167.5	80.0	28.0
SD ^a	9.4	20.9	7.0
IQR ^b	174–160	90–68	31.3–24.6

a SD, standard deviation, b IQR, interquartile range

Figure 1. Box plot of BMI for all participants and the practicing and non-practicing-exercises groups

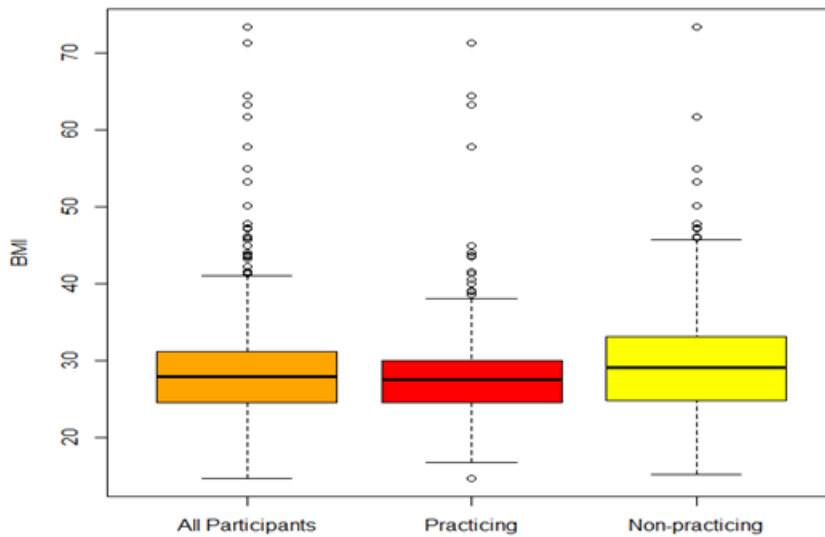
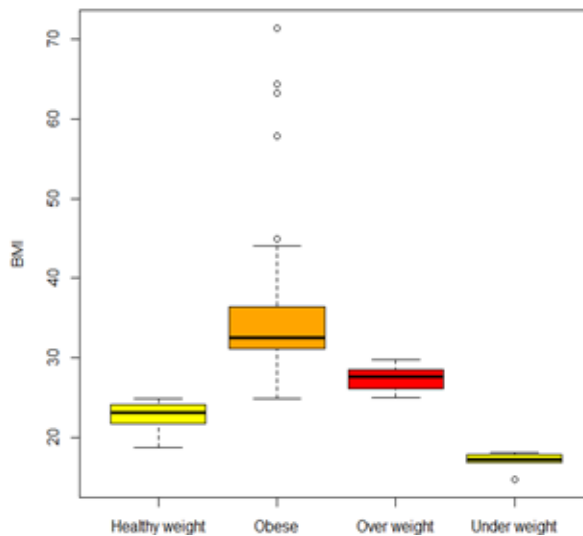


Figure 2. Boxplot of distribution of BMI for the practicing group



The prevalence of overweight is higher in the practicing group, at 44.4%, vs. 29.2% for the non-practicing group ($p < 0.001$) (cf. Table 3).

Obesity was observed in 44.7% of the non-practicing group, with significant differences in gender, at 30.9% of males vs. 19.5% of females ($p < 0.001$). The occurrence of underweight is similar in the practicing and non-practicing groups, at 1.4% and 1.6%, respectively (cf. Figures 4 and 5). Healthy weight is more common in the practicing group (26.8%) vs. the non-practicing group (24.2%) ($p < 0.001$) (cf. Tables 4 and 5).

Figure 3. Boxplot of distribution of BMI for the non-practicing group

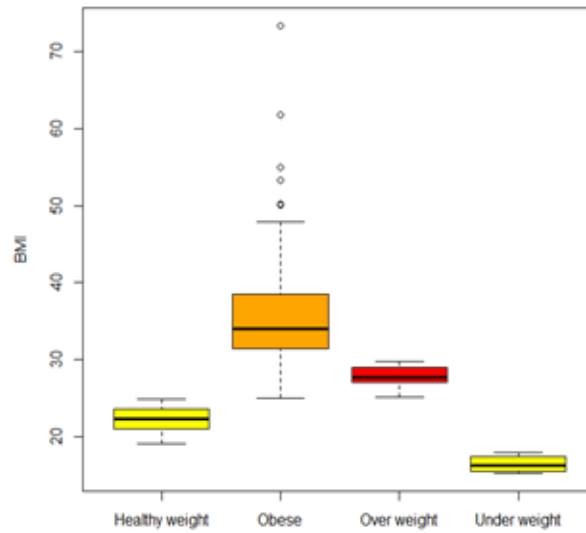


Table 3. Distribution of BMI for practicing and non-practicing participants

Group	Under weight %	Healthy weight %	Over weight %	Obesity %	Chi-square value, p-value
Practicing	1.4	26.8	44.4	27.3	21.61, <0.001
Non-practicing	1.6	24.2	29.2	44.7	

Figure 4. Boxplot of the distribution of BMI for the practicing group according to gender

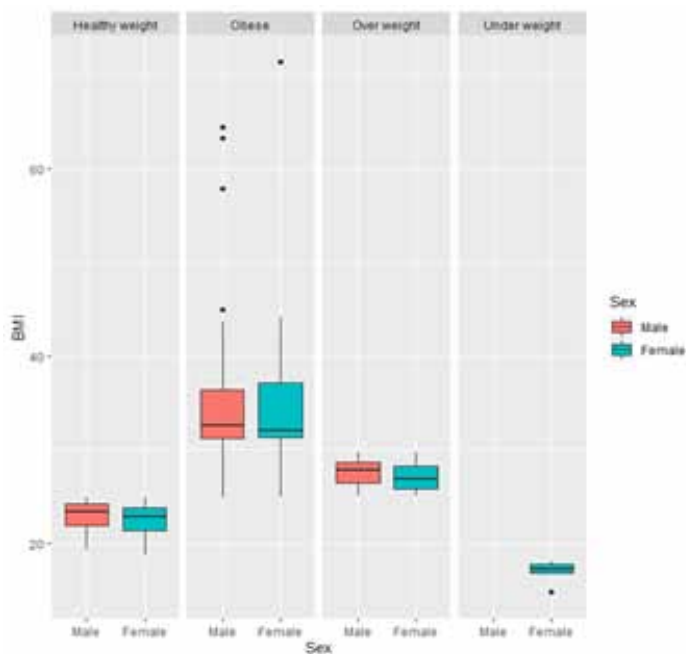


Figure 5. Boxplot of the distribution of BMI for the non-practicing group according to gender

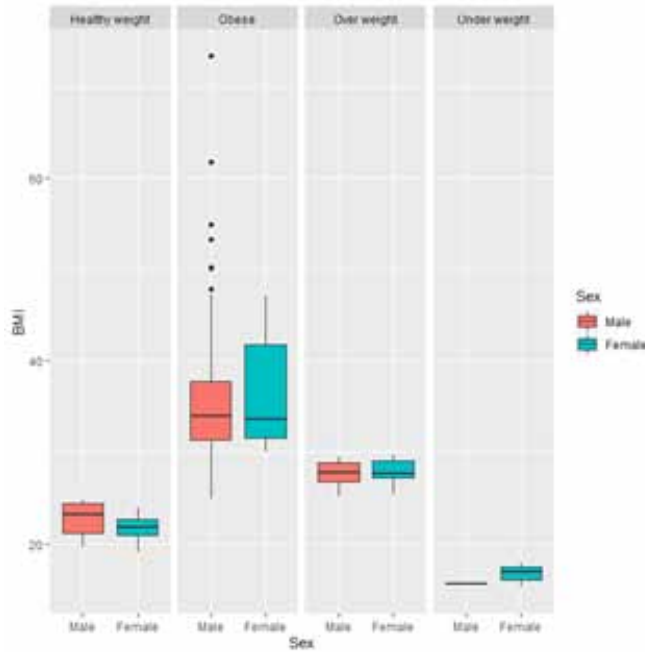


Table 4 Distribution of BMI of practicing participants by gender, age, marital status, education type, average monthly earnings, and diet type

Characteristics	Underweight %	Healthy weight %	Overweight %	Obesity %	Chi-square value, p-value
Sex					
Male	0.0	22.0	47.2	30.9	24.92, < 0.001
Female	5.3	37.2	38.1	19.5	
Age groups					
Child (<19)	0.0	100.0	0.0	0.0	47.51, < 0.001
Youth (20-29)	5.4	46.4	32.1	16.1	
Adult (30-39)	4.3	37.7	33.3	24.6	
Mature (40-49)	0.0	21.2	53.5	25.3	
Senior (>50)	0.0	15.8	48.9	35.3	
Marital status					
Single	7.8	45.3	32.8	14.1	43.92, < 0.001
Married	0.0	22.1	47.7	30.2	
Divorced	11.1	33.3	22.2	33.3	
Widowed	0.0	40.0	40.0	20.0	
Education level					
Lower education	0.0	33.3	33.3	33.3	11.01, 0.274
High school	0.0	19.4	41.9	38.7	
University	2.5	28.4	39.2	29.9	
Higher education	0.8	25.6	53.7	19.8	
Average monthly earnings					
< \$1,000	7.4	44.4	22.2	25.9	32.86, < 0.001
\$1,000-2,400	2.4	26.2	50.0	21.4	
\$2,400-4000	1.1	29.5	41.1	28.4	
> \$4000	0.0	19.6	51.8	28.6	
Diet type					
Healthy	1.8	25.7	47.3	25.1	2.88, 0.823
unhealthy	1.9	28.9	40.9	28.3	
Diet regimen	0.0	21.2	45.5	33.3	
Feeling					
Happy	2.3	34.3	45.4	18.1	29.92, < 0.001
Unhappy	0.7	15.4	42.7	41.3	

The prevalence of overweight is high in males who practice exercises, at 47.2%, and among older participants in the age group 40–49 years, at 53.5%. In the younger age group (adult), 30–39 years, the prevalence of healthy weight is high among participants who practice exercises (37.7%) compared with those who do not practice exercises (28.9%). In the youngest age group (<19), participants who practice exercises have a 100% healthy weight compared with only 20% of participants who do not

Table 5. Distribution of BMI of non-practicing participants by gender, age, marital status, education type, average monthly earnings, and diet type

Characteristics	Underweight %	Healthy weight %	Overweight %	Obesity %	Chi-square value, p-value
Sex					
Male	0.7	17.0	28.1	54.2	20.65, < 0.001
Female	3.5	37.2	31.4	27.9	
Age groups					
Child (<19)	0.0	20.0	20.0	60.0	58.43, < 0.001
Youth (20-29)	6.9	53.4	20.7	19.0	
Adult (30-39)	0.0	28.9	26.3	44.7	
Mature (40-49)	0.0	10.1	34.8	55.1	
Senior (>50)	0.0	11.6	33.3	55.1	
Marital status					
Single	5.1	47.5	22.0	25.4	32.48, < 0.001
Married	0.6	16.1	32.1	51.2	
Divorced	0.0	30.0	20.0	50.0	
Widowed	0.0	0.0	50.0	50.0	
Education level					
Lower education	0.0	0.0	60.0	40.0	15.6, 0.075
High school	0.0	9.7	41.9	48.4	
University	3.1	22.5	27.9	46.5	
Higher education	0.0	35.1	24.3	40.5	
Average monthly earnings					
< \$1,000	4.6	46.2	24.6	24.6	36.2, < 0.001
\$1,000-2,400	3.7	22.2	25.9	48.1	
\$2,400-4,000	0.0	11.1	37.5	51.4	
> \$4,000	0.0	18.7	26.7	54.7	
Diet type					
Healthy	0.0	36.8	28.1	35.1	13.78, 0.032
unhealthy	1.7	21.5	29.1	47.7	
Diet regimen	10.0	0.0	40.0	50.0	
Feeling					
Happy	2.2	41.3	34.8	21.7	37.37, < 0.001
Unhappy	1.4	13.6	25.9	59.2	

practice exercises. The second age group of youths, 20 to 29 years, has the largest percentage of healthy weight for the non-practicing group, at 53.4%. The occurrence of obesity is high (55.1%) among the non-practicing group in age groups 40-49 years and >50 years, while the prevalence of obesity among the non-practicing group is the highest (60%) in the age group <19 years (cf. Table 4 and Table 5).

To compare BMI for both gender and age among practicing and non-practicing-exercises groups, Figures 6 and 7 show the boxplots that depict the comparison. It can be observed that young males (<19) have higher BMIs among the non-practicing group, compared with the practicing group. Also, for non-practicing participants, the BMI mean for males is higher than females for all age groups, while the difference in BMI means between males and females are smaller for practicing participants.

Both singles and widowed participants in the practicing group comprise a high percentage of those with a healthy weight, at 45.3% and 40%, respectively. Also, among the overweight participants who practice exercises, 47.7% are widowed and 40% are married. The occurrence of obesity is higher in divorced practicing participants than in other groups, at 33.3%, $p < 0.001$. On the other hand, among the non-practicing group, percentages of people with a different marital status differ significantly from the practicing group. First, the occurrence of obesity is highest in the married group, at 51.2%. Also, divorced, and widowed participants comprise a high percentage of the obese, at 50%; the other 50% of the divorced and widowed comprise the overweight. The single participants group comprises a high percentage of those at a healthy weight, at 47.5% (cf. Tables 4 and 5).

Figures 8 and 9 depict the differences of BMI of different educational-level groups among practicing and non-practicing groups. The differences between education-level groups are insignificant based on chi-square testing on both practicing and non-practicing groups, with p-values of 0.274 and 0.075, respectively. The overweight can be observed at the higher education level of practicing participants, at 53.7%, as illustrated in Figure 8. Regarding non-practicing participants, the lower-education-level group has the highest percentage of overweight, at 60% (cf. Figure 9). Also, the prevalence of obesity is high in all groups, with a percentage greater than 40% (cf. Tables 4 and 5).

Figure 6. Boxplot of the distribution of BMI for the practicing group according to gender and age

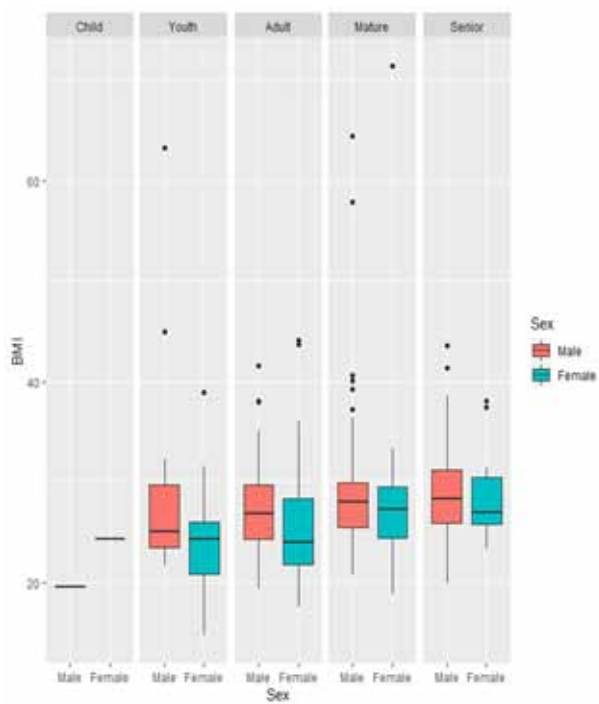


Figure 7. Boxplot of the distribution of BMI for the non-practicing group according to gender and age

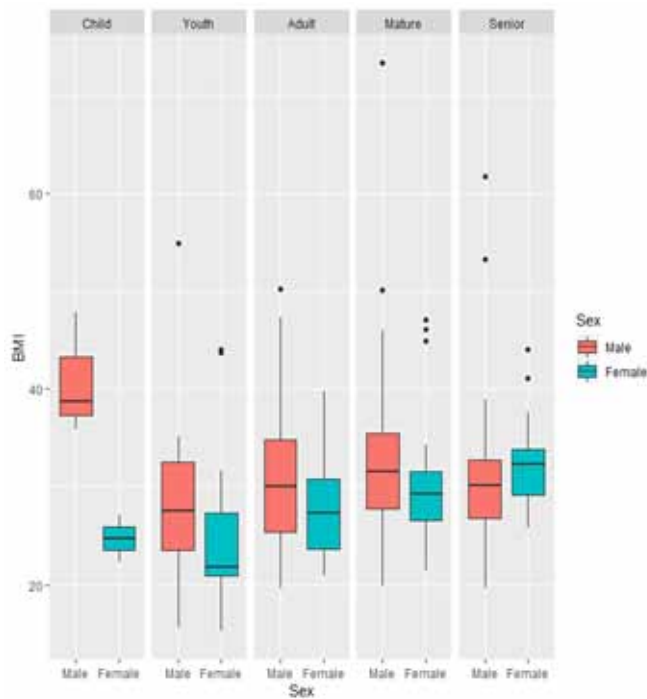


Figure 8. Boxplot of the distribution of BMI for the practicing group according to education level

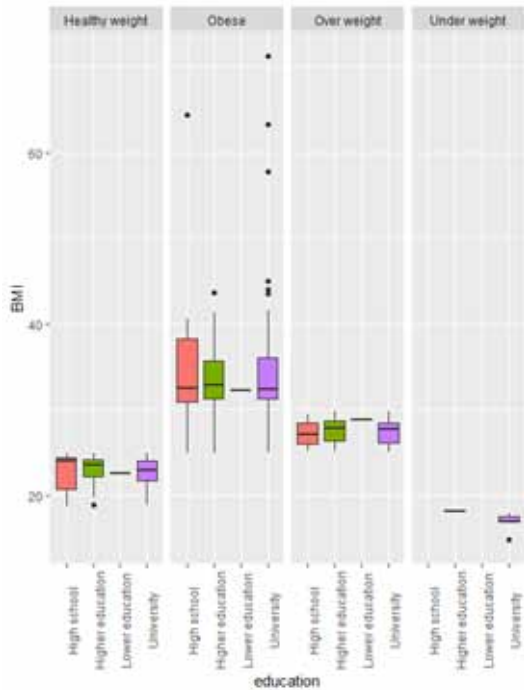
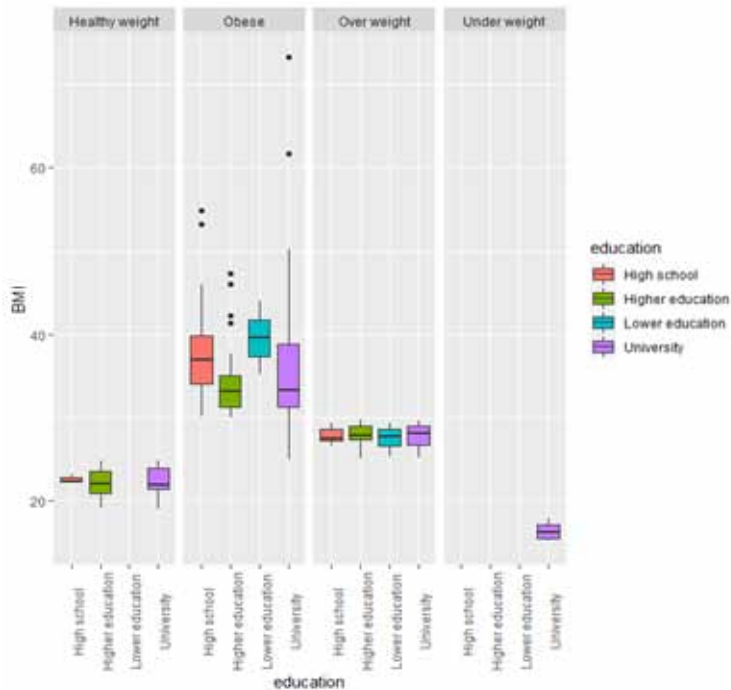


Figure 9. Boxplot of the distribution of BMI for the non-practicing group according to education level



Overweight is prevalent in the high-income group (>\$4,000) and average-income group (\$1,000-2,400) for practicing participants, at 51.8% and 50%, respectively. Occurrence of obesity is also high in the high-income group (>\$4,000) and average high-income group (\$2,400-4,000) for non-practicing participants, at 54.7% and 51.4%, respectively. The prevalence of healthy weight is high in the low-income group (<\$1,000) for both practicing and non-practicing participants, at 44.4% and 46.2%, respectively (cf. Tables 4 and 5).

The differences between the diet type groups are insignificant based on chi-square testing for practicing participants, with a p-value of 0.823. It is observed that the differences are significant for the non-practicing group, with a p-value of 0.032, as the significance level used in this case is 0.05 (cf. Tables 4 and 5).

Finally, participants' feelings about their bodies are significant, with p-values of <0.001 for both practicing and non-practicing groups. Most unhappy participants are those who are obese and in the non-practicing group, at 59.2% (cf. Tables 4 and 5).

Next, the adjusted Pearson residuals were computed for practicing and non-practicing participants for significant chi-square testing only (cf. Table 6 and Table 7). The best advantage of the adjusted Pearson residual is that it follows a standard normal distribution (0,1), which enables us to run post-hoc hypotheses tests on any number of the standardized residuals. To use the adjusted Pearson residuals for multiple cells, the significance level ($\alpha = 0.05$) should be corrected using a Bonferroni correction, and the alpha level would be adjusted by dividing it by the number of tests and comparing the absolute value of the adjusted residual with a new critical value.

Using Bonferroni corrected critical values, 17 of the cells of practicing participants (Table 6) have Pearson residuals that are significantly different than expected under the null hypothesis of no association. The first cell was underweight males, at -3.64, which is less than the corresponding Bonferroni corrected critical value of -2.734, i.e., the number of underweight males was lower than expected. On the other end, underweight females are at 3.64, which is greater than the absolute value of the corresponding Bonferroni corrected critical value of -2.734, i.e., the number of underweight females was higher than expected. Similar results are shown for healthy males and females. Regarding the age factor, the number of healthy youths, with a residual value of 3.62, is higher than expected, while the number of healthy seniors, with a residual value of -3.62, is lower than expected. As for marital status, the value of underweight and healthy singles is higher than expected, while the value

Table 6. Adjusted Pearson's residuals for chi-square tests of distribution of BMI of practicing participants by gender, age, marital status, average monthly earnings, and feelings

Characteristics	Underweight %	Healthy weight %	Overweight %	Obesity %	Bonferroni corrected critical value
Sex					
Male	-3.64	-3.03	1.61	2.26	-2.734
Female	3.64	3.03	-1.61	-2.26	
Age groups					
Child (<19)	-0.18	2.35	-1.26	-0.87	-3.023
Youth (20-29)	2.34	3.62	-1.99	-2.05	
Adult (30-39)	1.93	2.28	-2.04	-0.55	
Mature (40-49)	-1.52	-1.46	2.18	-0.54	
Senior (>50)	-1.89	-3.60	1.34	2.62	
Marital status					
Single	4.23	3.70	-2.04	-2.62	-2.955
Married	-4.69	-3.80	2.46	2.38	
Divorced	2.24	0.45	-1.35	0.41	
Widowed	-0.29	0.67	-0.19	-0.37	
Average monthly earnings					
< \$1,000	3.57	3.19	-3.54	-0.25	-2.955
\$1,000-2,400	0.38	-0.09	0.79	-0.91	
\$2,400-4,000	-0.55	0.70	-0.74	0.29	
> 4,000	-2.32	-2.85	2.68	0.51	
Feeling					
Happy	1.17	3.96	0.51	-4.83	-2.734
Unhappy	-1.17	-3.96	-0.51	4.83	

Table 7. Adjusted Pearson's residuals for chi-square tests of distribution of BMI of non-practicing participants by gender, age, marital status, average monthly earnings, and feelings

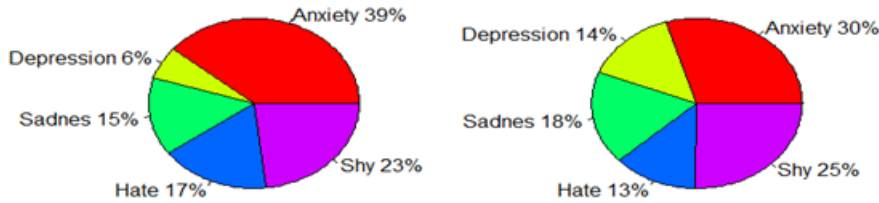
Characteristics	Underweight %	Healthy weight %	Overweight %	Obesity %	Bonferroni corrected critical value
Sex					
Male	-1.64	-3.5	-0.54	3.93	-2.734
Female	1.64	3.5	0.54	-3.93	
Age groups					
Child (<19)	-0.29	-0.22	-0.46	0.69	-3.023
Youth (20-29)	3.56	5.96	-1.65	-4.54	
Adult (30-39)	-0.88	0.73	-0.44	0.00	
Mature (40-49)	-1.28	-3.24	1.19	2.04	
Senior (>50)	-1.28	-2.91	0.88	2.04	
Marital status					
Single	2.35	4.79	-1.41	-3.44	-2.955
Married	-2.00	-4.55	1.49	3.07	
Divorced	-0.42	0.43	-0.66	0.34	
Widowed	-0.19	-0.80	0.65	0.15	
Average monthly earnings					
< \$1,000	2.17	4.82	-0.97	-3.83	-2.955
\$1,000-2,400	0.87	-0.26	-0.41	0.37	
\$2,400-4,000	-1.32	-3.12	1.83	1.35	
> 4,000	-1.36	-1.37	-0.60	2.08	
Feeling					
Happy	0.48	4.86	1.48	-5.66	-2.734
Unhappy	-0.48	-4.86	-1.48	5.66	

of underweight and healthy married participants is lower than expected. As for average monthly earnings, Table 6 shows that underweight and healthy practicing participants with low incomes (<\$1,000) have residual values that are higher than expected, while overweight participants with low incomes have residual values that are lower than expected. Finally, the value of healthy, happy practicing participants is higher than expected (3.96), while the value of obese happy practicing participants is lower than expected (-4.83).

The adjusted residuals for non-practicing participants are provided in Table 7. With Bonferroni corrected critical values, 19 cells of non-practicing participants have Pearson residuals significantly different than expected under the null hypothesis of no association. The first cell is healthy males, at -3.5, which is less than the corresponding Bonferroni corrected critical value of -2.734, i.e., the value for healthy males was lower than expected. However, the value for healthy females was 3.5 – greater than the absolute value of the corresponding Bonferroni corrected critical value of -2.734, i.e., the value for healthy females is higher than expected. In the non-practicing group, the value for obese males is higher than expected, at 3.93 residual value, compared with -2.7, while obese females' value was lower than expected, suggesting that among non-practicing participants, obesity level is higher in males than in females. Regarding the age factor, underweight and healthy youth are higher than expected, with residual values of 3.56 and 5.96, respectively, compared with the absolute value of the Bonferroni corrected critical value of -3.02. However, the value for healthy mature participants was lower than expected, at -3.24. As for marital status, single participants are healthier than non-practicing married participants, who are more obese than healthy. As for average monthly earnings, Table 7 shows that the low-income group (<\$1,000) is healthier and less obese, while average income participants (\$2,400-4,000) are less healthy than expected. Finally, healthy, happy, non-practicing participants' value was higher than expected (4.86), while obese, happy, non-practicing participants' residual value was lower than expected, at -5.66, compared with the critical value of -2.73.

To understand what specific feelings the participants feel about themselves, a multiple-response question is analyzed for both practicing and non-practicing groups. The pie chart in Figure 10 shows the results from the participants' responses. The feeling with the highest percentage is anxiety. The anxiety level of practicing participants is higher than that of non-practicing participants, at 39.8% compared with 29.7%. The feeling with the second highest percentage is shyness. The results show

Figure 10. Pie chart for practicing participants' feelings about their bodies (left); pie chart for non-practicing participants' feelings about their bodies (right)



that the non-practicing group has a higher percentage of shyness than practicing participants, at 25.3% compared with 23.2%.

As for the question of probable reasons behind overweight and obesity, the answers were analyzed, and the results are provided in Figure 11. The bar charts show the responses for both practicing and non-practicing participants. The most probable reasons for practicing participants are food choices and not practicing enough exercises, at 47.1% and 41.7%, respectively. For non-practicing participants, the reason with the highest percentage is not practicing exercises, at 48.1%, compared with 35.4% for food choices. The other two reasons are hereditary causes and health problems, which have the lowest percentages, not exceeding 9.1 for both practicing and non-practicing groups.

To investigate how practicing participants engage in exercises, they were asked about the types of exercises they practice, whether they use exercises equipment, and what kinds of equipment they use. In addition, they were asked about where they prefer to practice exercises and if they like to practice exercises individually or in groups. Table 8 provides the responses from 360 participants who practice exercises. The participants had the option of choosing more than one answer (to multiple-choice questions). The table has three columns: frequency; percentage of responses; and percentage of the 360 cases. Regarding the kinds of exercises, participants' responses were classified into four groups: aerobic; strength; flexibility; and balance exercises. Most participants practice aerobic exercises, at 91.5%. Altogether, 27.5% of the participants use exercises equipment, and 92.1% of those use aerobic

Figure 11. Bar charts of the reasons for overweight among both practicing and non-practicing groups

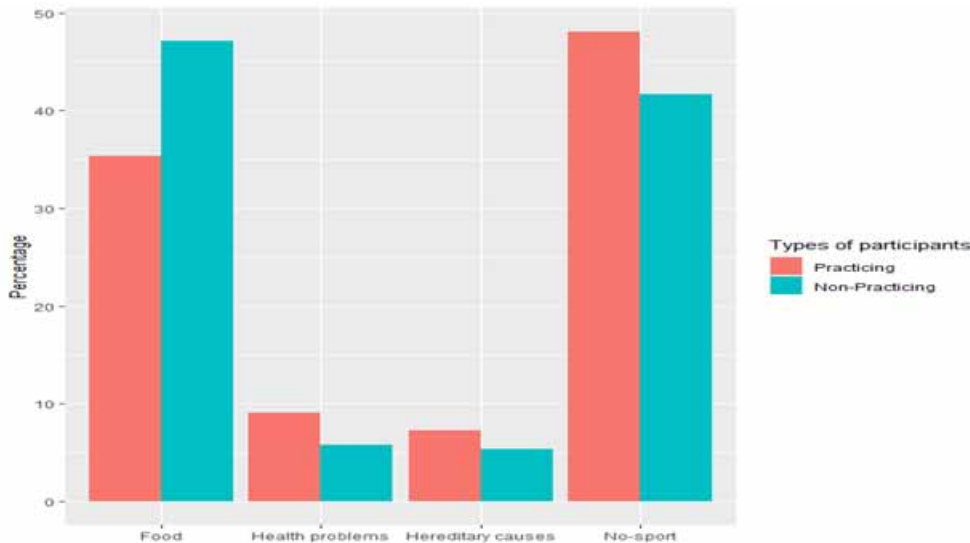


Table 8. Exercises, machines, and other information about how practicing participants perform exercises

Characteristics	Frequency (n)	Percentage of responses (%)	Percentage of (360) cases
Kind of Exercises			
Aerobic exercises	353	91.5	98.3
Strength exercises	20	5.2	5.6
Flexibility exercises	13	3.4	3.6
Balance Exercises	0	0.0	0.0
Total of responses	386	100	107.5
Using machine			
Yes	99	27.5	27.5
No	261	72.4	72.4
Kind of machine			
Aerobic machine	82	92.1	22.8
Strength machine	23	25.8	6.4
Flexibility machine	0	0.0	0.0
Balance machine	0	0	0
Total of responses	89	118.0	29.2
Place of exercises			
Home	103	28.6	28.6
Gym	56	15.6	15.6
Outdoor	201	55.8	55.8
How to exercises			
Individual	228	63.3	63.3
With group	132	36.7	36.7

equipment. Regarding exercise locations, most participants prefer practicing exercises outdoors, at 55.8%. Altogether, 63% of the participants prefer exercising alone.

STATISTICAL ANALYSIS

The Welch's two t-test for unequal variances is used to compare practicing and non-practicing groups' mean values, and the results show significant differences between the two groups, with a t-value = -3.391 and a p-value <0.001. The sample-estimate means for practicing and non-practicing participants were 28.01 and 30.06, respectively.

To understand the relationships between BMI and other quantitative variables, the Pearson's correlation coefficient was computed. The most significant correlation was between BMI and weight, with p-values < 0.001 for both practicing and non-practicing groups.

Multiple linear regression analysis of BMI as a continues dependent variable and all other variables in the user questionnaire were performed. A backward procedure for variable selection was used. From the full model, the variable that contributed least (largest p-value) was removed. This process was repeated until all the remaining variables were significant (p-value ≤ 0.05). Finally, the model was tested by bringing back the variables that had been eliminated, but none contributed significantly to the model.

Table 9 shows the results of two best models of multiple linear regression analysis of practicing participants. In the first model, the regression equation includes a binary variable gender (with reference level male), a categorical variable marital status with (reference level divorce/widowed), and a binary variable feeling (with reference level happy). The intercept represents mean BMI at the reference level for all variables. Thus, the regression analysis estimates that the mean BMI for men, divorced or widowed and happy feeling was 30.311. In total, BMI was significantly associated with gender-female ($\beta = -2.528$, $p < 0.001$), status-single ($\beta = -4.173$, $p=0.016$), and feeling-unhappy ($\beta= 3.272$, $p < 0.001$). The fact that the coefficient is negative indicates that being a female for example is associated with a decrease in BMI (relative to male). Also, it can be seen that being a single is significantly associated with an average decrease in BMI compared to other types of marital status. In the second model, two more variables were added to the first model, the reasons of food and laziness from the questions of reasons for overweight among practicing group. It shows that the R^2 increased from 11.4% to 15.2% from the first to the second model, which is the variation of a BMI that is explained by the independent variables collectively.

Table 9. Multivariate linear regression analyses of body mass index (BMI) of Practicing participants and obesity-related variables, Dependent Variable BMI

	<i>Coefficient β</i>	<i>Standard error (SE)</i>	<i>p-value (t-test)</i>	<i>R²</i>	<i>F-statistic</i>	<i>AIC</i>
First model						
Intercept	30.311	1.654	<0.001	11.4%	11.43*	2296
Gender-female	-2.528	0.725	<0.001			
Status-single	-4.173	1.734	0.016			
Status-married	-2.631	1.65	0.111			
Feeling-unhappy	3.272	0.639	<0.001			
Second model						
Intercept	27.469	1.758	<0.001	15.2%	9.137*	1983.4
Gender-female	-1.988	0.748	<0.001	15.2%		
Status-single	-1.638	1.813	0.366			
Status-married	-0.461	1.728	0.789			
Feeling-unhappy	1.474	0.712	0.039			
Food	1.05	0.695	0.132			
Laziness (No-exercise)	2.924	0.708	<0.001			

* p-value < 0.0001 for all tests for overall significance

To choose the final model, the likelihood ratio test (F-test) was employed, also, we compared models using the Akaike information criterion (AIC) that defined as:

$$AIC = -2\log\left[L\left(M\right)\right] + 2k$$

where L is the likelihood, M the given model, and k the number of parameters in the model (Akaike, 1974).

From Table 9, the AIC for second model 1983.4 is less than the AIC of the first model with 2296. Therefore, we suggest that the second model with gender, marital status, feeling, food, and laziness (no-exercise) are the most important variables associated with BMI for practicing group.

Table 10 shows the results of two best models of multiple linear regression analysis of non-practicing participants. In the first model, the regression equation includes a binary variable gender (with reference level male), a binary variable food (from the question of the reasons of overweight) which coded as 0 (food is not a reason) or 1 (is a reason), and a one-unit difference represents switching from one category to the other. In the same manner, the other two variables laziness and health which represents an answer to the question of reasons for gaining overweight. In total, BMI was significantly associated with gender-female ($\beta = -3.232$, $p = 0.001$), food ($\beta = 3.496$, $p < 0.001$), laziness ($\beta = 4.474$, $p < 0.001$), and health ($\beta = 4.543$, $p = 0.001$). In the second model, two more variables were added to the first model, the categorical variable education (with reference level high school), and a binary variable feeling (with reference level happy). In total, BMI was significantly associated with gender-female ($\beta = -3.132$, $p = 0.001$), food ($\beta = 2.653$, $p = 0.013$), laziness ($\beta = 4.409$, $p < 0.001$), health ($\beta = 4.496$, $p = 0.002$), education-higher ($\beta = -4.061$, $p = 0.009$), and feeling-unhappy ($\beta = 2.317$, $p = 0.035$). It shows that the R^2 increased from 28.3% to 32.1% from the first to the second model, which is the variation of a BMI that is explained by the independent variables collectively.

Table 10. Multivariate linear regression analyses of body mass index (BMI) of Non-Practicing participants and obesity-related variables, Dependent Variable BMI

	<i>Coefficient β</i>	<i>Standard error (SE)</i>	<i>p-value (t-test)</i>	<i>R²</i>	<i>F-statistic</i>	<i>AIC</i>
First model						
Intercept	26.817	0.922	<0.001	28.3%	20.03*	1388
Gender-female	-3.232	0.998	0.001			
Food	3.496	1.021	<0.001			
Laziness (No-exercise)	4.474	1.058	<0.001			
Health	4.543	1.435	0.001			
Second model						
Intercept	28.415	1.482	<0.001	32.1%	11.76*	1382
Gender-female	-3.132	0.984	0.001			
Food	2.653	1.063	0.013			
Laziness (No-exercise)	4.409	1.074	<0.001			
Health	4.496	1.436	0.002			
Education-Higher education	-4.061	1.539	0.009			
Education-Lower education	-4.568	3.589	0.204			
Education-University	-2.674	1.412	0.059			
Feeling-unhappy	2.317	1.096	0.035			

* p-value < 0.0001 for all tests for overall significance

Also, the AIC for second model 1382 compared to AIC of the first model with 1388. Therefore, we suggest that the second model with gender, food, laziness (no-exercise), health, education and feeling are the most important variables associated with BMI for non-practicing group.

EXPERT QUESTIONNAIRE

The expert questionnaire was administered to 31 participants from healthcare with different job functions. Our paper is the first to design a questionnaire that solicits the opinions of health practitioners to identify best health aspects that should be available in the design of any VR tool for obesity control.

Figure 12 provides the answers to the first two questions. The pie chart on the left identifies the institutions that the experts work for, with 61.2% of the experts working in hospitals. Regarding their job functions (pie chart on the right), most of the experts are physicians and physical therapists, at 23.3% and 22.5%, respectively.

As for the question of how familiar the expert is with the concept of VR, 77.4% answered that they are slightly aware of VR, compared with 9.6% who already have begun using VR. Also, 12.9% have tried VR in their practices, compared with 87% who have never tried VR.

Table 11 provides the answers to the question of which areas of VR the experts have used. Physical therapy comprised the largest percentage of responses, at 37.5%, and 9.7% of 31 cases.

When the experts were asked about the major benefits from using VR to control obesity, 33.3% of the responses concerned encouraging patients/visitors to exercise, and another 33.3% concerned enabling patients/visitors to exercise from home; both options have a percentage of 6.5% of 31 cases (cf. Table 12).

Figure 12. Pie charts of the expert institutions (left) and their job functions (right)

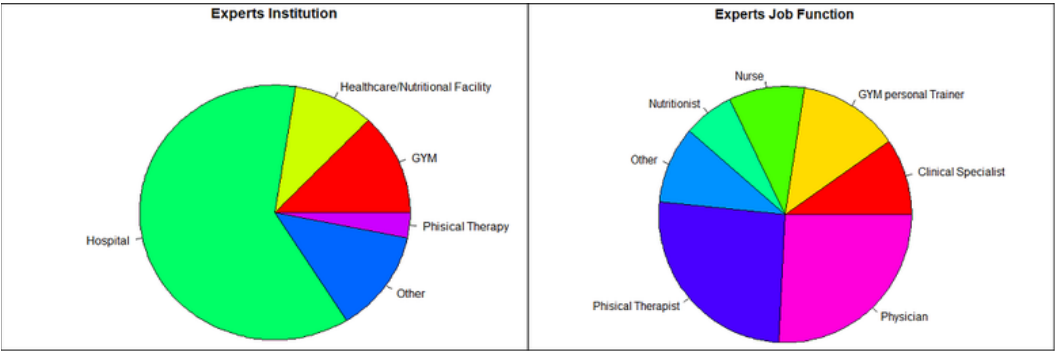


Table 11. What are the areas in which you have tried VR in your institutions?

Options	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
Exercise	2	25.0	6.5
Control weight	1	12.5	3.2
Control emotional eating	0	0.0	0.0
Monitor eating habits	1	12.5	3.2
Physical therapy	3	37.5	9.7
Other	1	12.5	3.2
Total of responses	8	100	25.8

Table 12. What are the major benefits of using VR technology to control obesity?

Options	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
Encourage patients/visitors to control their eating habits	0	0	0
Significantly lower the cost of using fitness equipment	0	0	0
Makes difficult exercises easier to perform	1	16.7	3.2
Encourages patients/visitors to exercise	2	33.3	6.5
Enables patients/visitors to exercise from home	2	33.3	6.5
Other	1	16.7	3.2
Total of responses	6	100.0	19.4

As for the question of top concerns regarding VR technology, the response with the highest percentage is about not having enough VR content available yet, at 27.1% of responses and 61.3% of 31 cases. Expensive or difficult to implement and too hard to manage during fitness/medical sessions options registered the next highest percentage, at 24.3 of responses and 54.8% of 31 cases (cf. Table 13).

When the experts were asked whether they would expect or plan to use VR in the future, 58% said they were “not sure.”

The last three questions are open questions that asked the experts about using VR tools to control obesity.

First, they were asked to recommend methods that can be used to control obesity. Table 14 shows that 36.8% suggested using the VR in psychological circumstances, such as calorie counting, giving instructions, educating users, changing users’ lifestyles, and using media as a tool to control obesity. As for the best method that experts recommended for controlling obesity, eating healthy food, and performing exercises comprised 26.3% of the responses. Furthermore, when the experts were asked

Table 13. What are the top concerns regarding VR technology?

Options	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
May cause headaches or sickness	8	11.4	25.8
Expensive or difficult to implement	17	24.3	54.8
Too hard to manage during fitness/medical sessions	17	24.3	54.8
Not enough VR content available yet	19	27.1	61.3
It isolates patients/visitors	4	5.7	12.9
None, I have no concerns about VR	5	7.1	16.1
Other	0	0	0
Total of responses	70	100	225.8

Table 14. The methods that experts recommend for obesity control in VR

Methods	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
Psychological (calories counting, instructions, education, change life style, media)	7	36.8	22.6
Healthy food	5	26.3	16.1
Exercises	5	26.3	16.1
Games	1	5.3	3.2
No Idea	1	5.3	3.2
Total of responses	19	100.0	61.3

which age group would benefit the most from using VR to control obesity, 37.5% suggested two age groups which are 5-16 and 38-50, as shown in Table 15.

Finally, the experts were asked about the VR system's importance, with 43.3% responding "I have no idea," and 26.7% recommending the use of VR for knowledge learning and teaching, as depicted in Table 16.

DISCUSSION

In this study of 603 user participants, depending on whether physically active or not, we found several factors that are associated with being overweight or obese, namely gender, age, marital status, monthly

Table 15. Which age group would benefit the most from using a VR system to control obesity?

Age group	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
5-16	3	37.5	9.7
17-37	1	12.5	3.2
38-50	3	37.5	9.7
Above 50	1	12.5	3.2
Total of responses	8	100.0	106.5

Table 16. What is the importance of VR? What do you need the VR system for?

Methods	Frequency (n)	Percentage of responses (%)	Percentage of (31) cases
Changing behavior	1	3.3	3.2
Knowledge learning and teaching	8	26.7	25.8
Objective measures	1	3.3	3.2
Focusing on the real goal	1	3.3	3.2
Pain control	1	3.3	3.2
Attain content	1	3.3	3.2
Motivation, positive, acceptable by people	4	13.3	12.9
No Idea	13	43.3	41.9
Total of responses	30	100.0	96.8

income, and psychological factors. In this section, we focus on the results as they pertain to obesity and overweight (but not on the healthy and underweight categories). Determining which factors affect obesity and overweight could help us identify the group(s) to which the VR treatment should be applied. We also discuss health practitioners' opinions, captured through the expert questionnaire, to help identify how best to use VR to target overweight and obesity.

Physical Activities

When comparing obesity levels among the practicing and non-practicing-exercises groups, it can be observed that the number of obese participants is higher for both groups, but it is higher in non-practicing than practicing participants (cf. Figures 2 and 3). However, the prevalence of overweight is high in the practicing group, at 44.4%, vs. 29.2% for the non-practicing group ($p < 0.001$) (cf. Table 3).

This suggests that non-practicing participants suffer from obesity more than practicing participants who suffer from overweight.

Gender

Obesity was observed in 44.7% of non-practicing participants, with significant differences in gender, at 54.2% of males vs. 27.9% of females (cf. Table 5) ($p < 0.001$). The prevalence of overweight is high in males who practice exercises with 47.2% (cf. Table 4). This shows that among the practicing participants, the overweight is higher in males with the age group (40-49 years old). Similarly, obesity level is higher in males than in females among the non-practicing group.

Age

The occurrence of obesity is high (55.1%) among non-practicing participants in both the 40-49 and >50 years age groups, while the prevalence of obesity among non-practicing participants is the highest (60%) in the <19 years age group (cf. Tables 4 and 5). On the other hand, the prevalence of overweight is high in older participants who practice exercises, in age groups 40-49 years with 53.5%.

This suggests that among non-practicing participants, the obesity level is higher for children younger than 19 and adults aged 40 and up. However, overweight is highest among practicing participants in the 40-49 years age group.

Marital Status

The occurrence of obesity is higher in divorced practicing participants than in other groups, at 33.3% ($p < 0.001$). However, among the non-practicing group, the percentages of people with a different marital status vary significantly from the practicing group. First, the occurrence of obesity is highest for the married group, at 51.2%. Also, divorced and widowed participants comprise a high percentage of the obese, at 50%; the other 50% of the divorced and widowed comprise the overweight (cf. Tables 4 and 5).

This suggests that among practicing participants, obesity is highest among divorced participants, but among non-practicing participants, obesity is highest among married, divorced, or widowed non-practicing participants.

Educational Level

Overweight can be observed in practicing participants with higher education levels, at 53.7%, as illustrated in Figure 8. Regarding non-practicing participants, those with lower education levels have the highest percentage of overweight, at 60% (cf. Figure 9). Also, the prevalence of obesity is high in all groups, with a percentage greater than 40% (cf. Tables 4 and 5).

This indicates that among practicing participants, the prevalence of overweight is high among the high-education-level group. However, among non-practicing participants, the lower the education level, the higher the overweight rate.

Income

For the practicing group, the prevalence of overweight is high in the high-income group (>\$4,000) and average-income group (\$1,000-2,400), at 51.8% and 50%, respectively. In addition, the occurrence of obesity is also high in the high-income group (>\$4,000) and average high-income group (\$2,400-4,000) for non-practicing participants, at 54.7% and 51.4%, respectively.

This shows that obesity and overweight are the highest among average and high-income groups among both practicing and non-practicing participants.

Psychological Factors

Participants' feelings toward their bodies are significant, with p-values of <0.001 for both practicing and non-practicing groups. The most unhappy participants are those who are obese among the non-practicing group, at 59.2% (cf. Tables 4 and 5).

However, practicing participants' anxiety level is higher than that of non-practicing participants, at 39.8% compared with 29.7%.

Reasons for Obesity/Overweight From Participants' Perspective

From practicing participants' perspective, the most probable reasons for obesity are food choices and not practicing exercises, at 47.1% and 41.7%, respectively. For non-practicing participants, the reason for the highest percentage is not practicing exercises, at 48.1%, compared with 35.4% for food choices.

Exercise Preferences

Most participants practice aerobic exercises, at 91.5%, with 27.5% of the participants using fitness equipment and 92.1% of those using aerobic equipment. Regarding exercise locations, most participants prefer to practice exercises outdoors, at 55.8%, and 63% of participants prefer to exercise alone.

Overall Factors Effect on BMI

The analysis of multiple regression of BMI for both groups, practicing and non-practicing, suggests some variables for both groups together and other variables for each of them separately. The variables gender, feeling, food, and laziness as reasons for overweight from user's perspective were significantly associated with BMI for practicing and non-practicing participants. For practicing participants, the marital status was added to these variables, while for non-practicing participants the health and education are the variables that were used for this group specifically.

In line with the literature, our results show that more men are overweight than women. (Kanter and Caballero, 2012) stated that there is a global obesity pandemic. Nonetheless, the prevalence of overweight and obesity between men and women varies greatly within and between countries, and overall, more women are obese than men. These gender differences in overweight and obesity are aggravated among women in developing countries. However, in developed countries, more men are overweight than women. Current knowledge suggests that uncountable sociocultural changing aspects through the world soothe gender disparities in excess weight gain.

Experts' Recommendations

Most of the experts in our study are health practitioners who use VR in their facilities for many reasons, such as physical therapy. When the experts were asked to recommend the methods that can be exploited to control obesity, 36.8% suggested using VR to adopt healthy habits, such as calorie counting, and for increasing awareness by providing instructions, educating users, changing users' lifestyles, and using the media as a tool to control obesity. In addition, when the experts were asked which age groups would benefit the most from VR use to control obesity, 37.5% cited both the 5-16 and 38-50 age ranges, as shown in Table 15.

CONCLUSION

In this section we discuss the summary of our work, the conclusions of our research, the implications of our research and the future work.

Summary

In this paper, we examined how VR can be exploited to further overcome the obesity crisis. We examined the various sociodemographic variables that impact the use of VR to regulate obesity. Such knowledge will be of great help to VR scientists in designing an effective tool to control obesity.

Two questionnaires were conducted, one for *users* and the other for *experts*. The user questionnaire sought to understand the effects of social, economic, and psychological variables on individuals' physical activities and weight gain. In clinics, fitness centers, and other health services, the expert questionnaire sought to help us develop a deeper understanding of the applications and advantages of augmented reality, as well as recognize VR approaches used in clinicians' practice to control obesity. Participants were split into practicing-exercises and non-practicing-exercises categories.

Conclusions

Our statistical analysis indicated the variables among participants in the sample that influence obesity/overweight. Overweight prevalence is high among males from the practicing-exercises class, in the 40-49 years age group. On the other hand, within the non-practicing group, obesity levels are greater in males than in females.

With respect to participants' age ranges, the incidence of obesity is greater between youths younger than 19, and among adults aged 40 and up for non-practicing participants. However, among practicing participants, overweight is highest in the 40-49 years age group.

The findings also revealed that among the practicing group, obesity is highest among divorced participants, while among married, divorced, or widowed non-practicing participants, obesity is significantly higher.

The differences concerning education level are insignificant based on the chi-square test for both practicing and non-practicing groups, with p-values of 0.274 and 0.075, respectively. Overweight can be observed among practicing participants with higher education levels, at 53.7%. Regarding non-practicing participants, those with lower education levels have the highest percentage of overweight, at 60%. Also, the prevalence of obesity is high in all groups, with a percentage greater than 40%.

The findings also indicate a positive association between obesity and monthly earnings among practicing and non-practicing groups. Participants' feelings about their bodies are significant among both practicing and non-practicing groups, with p-values <0.001. Regarding exercise preferences, at 91.5%, most participants favor aerobic workouts. With respect to exercise location, most people tend to practice outdoor exercises, at 55.8%, and 63% of the participants prefer to exercise alone.

The analysis of BMI exhibits that overweight or obesity could be associated with gender, feeling and user's perspective about themselves. Furthermore, marital status may be associated with practicing participants while, education may be associated with non-practicing participants especially of people with higher education.

Health practitioners who participated in the study through the expert questionnaire advised using VR to adopt healthy habits, such as calorie counting, providing guidance, teaching people about healthy habits, improving individuals' lifestyles, and using the media to control obesity. In addition, the experts in the study recommended age ranges that would benefit the most from VR to control obesity, with 37.5% including both the 5-16- and 38-50 years-old age groups.

Research Implications

The sociodemographic study will aid the development of the knowledge society by giving enough information on user patterns and expert viewpoints. Our research provides of semantic information

that is more domain-oriented, resulting in more intuitive VR app and tool for obesity control. Organizations, health centers, businesses, and people will be able to readily augment such obesity-control technologies on the semantic web as well as on personal and mobile devices.

The intuitiveness and user-friendliness of such applications, as well as their exposure to a broad range of users, will not only contribute to the knowledge society, but will also foster a collaborative and supportive society that is more inclined to add to the available knowledge and use semantic web features to link findings in the domain of obesity-control and VR-based applications.

Future Work

Our future objective is to exploit the findings of this research to design a novel framework for obesity management. The framework should be directed towards satisfying the needs of groups that are more prone to obesity. Such groups include certain age groups, groups of a particular marital, social, or economic status. In addition, the framework should include a platform that incorporate the health strategies outlined by the health practitioners. The framework will undergo iterative design process with several phases in which users' opinions will be used to further enhance the framework. The design phase will also consider ways of augmenting the framework in the semantic web as well as on personal and mobile devices. Our future work also aims at developing a methodological proposition for VR social impact, developing guidelines for innovative VR, and promoting the impact of this research through dissemination and awareness activities.

ACKNOWLEDGMENT

This work was funded by the Deanship of Scientific Research at Princess Nourah bint Abdulrahman University, through the Research Groups Program Grant no. (RGP-1440 -0026).

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APPENDIX A: USER QUESTIONNAIRE

Background

We are a group of researchers from Princess Nourah Bint Abdulrahman University (PNU) and King Abdulaziz University (KAU). This is a research questionnaire that is run by PNU to assess the contribution of virtual reality for obesity. The questionnaire is for scientific purposes only. This questionnaire is designed to help us gain a better understanding of the uses and benefits of virtual reality in the center / facility / hospital. In addition, it will assist in identifying the methods used to control obesity, from your experience. Your answers will be kept strictly confidential, and you will not be identified.

For any questions or concerns please contact Prof. Wadee Alhalabi, Email: wsalhalabi@kau.edu.sa

* Required

1. Gender: *
 - *Male*
 - *Female*
2. Age Group: *
 - *Less than 19 years old*
 - *20 to 29 years old*
 - *30 to 39 years old*
 - *40 to 49 years old*
 - *Older than 50 years old*
3. Height: * *[Type Answer]*
4. Weight: * *[Type Answer]*
5. Marital Status: *
 - *Single*
 - *Married*
 - *Divorced*
 - *Widowed*
6. Region: *
7. Educational Level: *
8. Monthly Income in Saudi Riyals (S.R.): *
 - *Less than 4000 S.R.*
 - *4000 S.R – 8000 S.R.*
 - *9000 S.R. – 15000 S.R.*
 - *More than 15000 S.R.*

Table 17. Region table

Riyadh	Makkah	Madina	Qassim	Eastern Province
Asir	Tabuk	Hail	Northern Borders	Jazan
Najran	Albaha	Aljouf	Jeddah	Other

Table 18. Education level table

Illiterate	Primary	Intermediate
Secondary	Graduate	Postgraduate

9. Do you work outside your home? *
 - *Yes*
 - *No*
10. How can you describe your daily eating habits? *
 - *Healthy*
 - *Not healthy*
 - *I am on a diet*
11. Do you practice any physical exercise? *
 - *Yes*
 - *No [skip to question 17]*
12. What kind of exercise you practice? *
 - *Walking and/or running*
 - *Jumping rope*
 - *Basketball*
 - *Football (soccer)*
 - *Volleyball*
 - *Tennis*
 - *Dancing*
 - *Swimming*
 - *Yoga*
 - *Others: [please specify]*
13. Do you use any equipment to practice your physical exercise? *
 - *Yes*
 - *No*
14. If you answered yes to the previous question, what type of equipment do you use for your physical exercise? *[Type Answer]*
15. Where do you prefer to do your physical exercise? *
 - *Home*
 - *Gym*
 - *Outdoors*
16. How do you like to practice your physical exercise? *
 - *Alone*
 - *With a group*
17. Do you suffer from being overweight or obese? *
 - *Yes*
 - *No*
18. If you answered yes to the previous question, what do you think are the reasons? *
 - *Overeating*
 - *Lack of exercise*
 - *Health reasons*
 - *Genetic reasons*
 - *Others: [please specify]*
19. How do you feel about your looks? *
 - *Satisfied*
 - *Not satisfied*

20. If you answered by 'not satisfied', how do you generally feel about yourself? *
- *Anxious*
 - *Depressed*
 - *Sad*
 - *Hate*
 - *Shy*
 - *Other: [please specify]*
21. If you wish to volunteer to join the research program, please write your email or mobile number to contact.

APPENDIX B: EXPERT QUESTIONNAIRE

Background

We are a group of researchers from Princess Nourah Bint Abdulrahman University (PNU) and King Abdulaziz University (KAU). This is a research questionnaire that is run by PNU to assess the contribution of virtual reality to obesity. The questionnaire is for scientific purposes only. This questionnaire is designed to help us gain a better understanding of the uses and benefits of virtual reality in fitness centers, facilities, and hospitals. In addition, it will assist in identifying the methods used to control obesity, from your experience. Your answers will be kept strictly confidential, and you will not be identified.

For any questions or concerns please contact Prof. Wadee Alhalabi, Email: wsalhalabi@kau.edu.sa

* Required

1. Which of the following best describes your institution? *
 - *Hospital*
 - *Physical Therapy Center*
 - *Healthcare/Nutritional Facility*
 - *Rehabilitation Center*
 - *GYM*
 - *Other: [Type Answer]*
2. Which of the following best describes your job function? *
 - *Physician*
 - *Physical Therapist*
 - *Clinical Specialist*
 - *Nutritionist*
 - *Nurse*
 - *GYM Personal Trainer*
 - *Non-health related*
 - *Other:*
3. In which region are you located? *
 - *North America*
 - *Latin America*
 - *Europe, Middle East, Africa*
 - *Asia Pacific*
4. How familiar are you with the concept of virtual reality (VR)? *
 - *I am only slightly aware of virtual reality*
 - *I am aware of VR and we are beginning to investigate the topic*
 - *We have a plan to make use of virtual reality over the next year or two*
 - *We have already begun making use of virtual reality*
5. Have you ever tested VR or tried it in your center/facility/hospital? *
 - *Yes, I have tested/ tried VR in the center setting [Skip to question 6]*
 - *No, I have not tested/ tried VR in the center setting [Skip to question 14]*

Experts who have used VR

6. If you have tried VR in center/facility/hospital, in what area(s)? (Check all that apply) *
 - *Exercise*
 - *Control weight*
 - *Control emotional eating*
 - *Monitor eating habits*
 - *Physical therapy*
 - *Other:*

7. Please describe your experience with VR and your opinion of it. *
8. What are your needs/expectations of a VR system, based on your expertise? *
9. If you are a physician or a gym trainer: which methods/tools do you think are useful to control obesity for each of the following age groups: 1) For children 5 to 16 2) 17 to 37 3) 38 to 50 4) Above 50
10. What are the major benefits of using virtual reality to control obesity from your opinion? (Please choose the top 2)
 - *Encourage patients/visitors to control their eating habits*
 - *Significantly lower the cost of using fitness equipment*
 - *Makes difficult exercises easier to perform*
 - *Encourages patients/visitors to exercise*
 - *Enables patients/visitors to exercise from home*
 - *Other: [please specify]*
11. What are your top concerns regarding VR technology? (Please choose between 1 and 3 options) *
 - *May cause headaches or brain damage*
 - *Expensive or difficult to implement*
 - *Too hard to manage during fitness/medical sessions*
 - *Not enough VR content available yet*
 - *It isolates patients/visitors*
 - *None, I have no concerns about VR*
 - *Other:*
12. Does your center/facility/hospital train the staff on virtual reality? *
 - *Yes*
 - *No*
 - *No, but we use virtual reality*
13. Please Choose your answer from 1 to 5. 1 is not at all; 5 is very much. (see Table 19)*

Table 19. Question table

Questions	1	2	3	4	5
<i>Were you successful in augmenting the VR devices into your facility/hospital?</i>					
<i>Were you able to use it the system efficiently?</i>					
<i>Were the visitors to your center/facility/hospital able to customize the system?</i>					
<i>Does augmenting the VR devices into the treatment plan of your patients/visitors accelerate the desired positive outcomes?</i>					
<i>Does the use VR devices in your facility/hospital have a positive long impact?</i>					

Experts who have not used VR

14. Do you expect or plan to use VR in the future?
 - *Yes, I plan or expect to use VR in the future*
 - *No, I do not plan or expect to use VR in the future*
 - *I'm not sure*
 - *Other: [please specify]*

15. What are your top concerns regarding VR technology? (Please choose between 1 and 3 options) *
- *May cause headaches or brain damage*
 - *Expensive or difficult to implement*
 - *Too hard to manage during fitness/medical sessions*
 - *Not enough VR content available yet*
 - *It isolates patients/visitors*
 - *None, I have no concerns about VR*
 - *Other: [please specify]*
16. If you are a physician or a gym trainer: which methods/tools do you think are useful to control obesity for each of the following age groups: 1) For children 5 to 16 2) 17 to 37 3) 38 to 50 4) Above 50.
17. What are your needs/expectations of a VR system, based on your expertise? *

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Wadee Alhalabi started working as an electronic technician in 1989 when he got his associate degree in industrial electronics. He then worked as a full time technician at Jeddah Desalination and Power Generation Plant. By the end of year 1990, he moved to work for Saudi Arabian Monetary Agency (SAMA) as a system technician. His primary task was to supervise the security system: electronic security, CCTV, and computer security. In 1996, he got his bachelor degree in engineering from Umm Alqura University. In 2000, he started his master and PhD at the University of Miami in 2001. He eventually got his PhD in May 2008. Dr. Alhalabi worked for different academic and industrial organizations until September 2010 when he joined King Abdulaziz University, then Effat University and has become a faculty member. His research contribution is in virtual reality, machine learning and rehabilitation. He is now associate professor and the director of the virtual reality research center.

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