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Designing a Weight Management Virtual Reality Exergame for Obese and Overweight Healthy Adults

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Abstract

Obesity is one of the key challenges that our society faces today. Virtual Reality (VR) exergame technologies have indicated significant results in health, increased physical activity, and weight loss, but were not used based on the daily need of obese and overweight subjects (over 18 years of age) to burn calories needed to lose weight. Since the current VR does not offer exercises based on the individual's need to burn the necessary calories, this research focuses on two aspects to solve this problem. First, examines different sociodemo-graphic variables that influence the design of an effective VR tool regulating obesity. Second, evaluated the effectiveness of designing a VR-exergame prototype based on the user's in and out calories to suggest an appropriate exercise they need to burn extra calories. In addition, to track users' progress and update their exercise plan based on the user's weight loss result. The WMVR was designed based on the needs and requirements of the targeted people, and it was evaluated by them. The results show that the prevalence of obesity was higher in all groups, at more than 40%. Aerobic exercise was the most preferred exercise at 91.5%. Health practitioners who participated in the study were advised through an expert survey to use virtual reality to adopt healthy habits. The WMVR prototype evaluated result shows that 65% of participants felt that the VR aspect of choosing exercise and scenarios increased their motivation, and 90% of respondents liked to use or recommend this system to others.

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Keywords: Exercise, Obesity, Physical Activity, Virtual Reality, VR-Exergame, Weight management

1. Introduction

Over the past decades, the prevalence of obesity and overweight increased worldwide, reaching epidemic levels [1]. Kingdom of Saudi Arabia (KSA) has a high rate of overall obesity and overweight, which significantly increased over the years [2]. The growing obesity pandemic is taking a toll on afflicted people, the medical community, and our communities. It has a demonstrable influence on physical, mental health, and quality of life and has resulted in high direct and indirect costs [3, 4]. Weight loss is the solution to preventing and treating obesity and comorbidities [4]. Obesity and overweight are caused by complex factors that include biological, environmental, and psychological factors [4]. Although weight gain is affected by multiple factors, the underlying physiological cause of obesity and overweight is an energy imbalance between calories consumed (calories in) and calories expended (calories out). Hence, in theory, higher energy expenditure (EE) should help maintain energy balance and thus prevent weight gain. Accordingly, it suggested that increased physical activity increases EE and thus protects the body from weight gain [5]**.** Several studies reported an association between lower levels of PA and a high risk of obesity [6, 7]. Despite the fact that the relation between PA and health is widely recognized, many people are physically inactive [8, 9, 10, 11, 12, 13]. Because psychological factors such as enjoyment, self-efficacy, and social influence have an impact on motivation to exercise [14, 15, 16].

Motivation involves the biological, emotional, social, and cognitive forces that activate behavior, which motivates people to participate and engage in an exercise. The key to designing for health and well-being requires understanding the design trade-offs that are most likely to motivate and engage people [17]. VR-exergame provides powerfully engaging because they offer inherently enjoyable experiences [18-21]. Virtual Reality (VR) is as defined a technology capable of creating a simulated world in which perceptual stimuli (e.g., visual, and auditory) are combined into a series of manipulated events in which a person is prompted to react, making a user feel mentally immersed or present [22]. In the other hand, VR-exergame is defined as integrating indoor exercise equipment (e.g., cycle ergometer, rowing ergometer, treadmill) into an immersive video game environment to perform differing exercises tasks (e.g., cycling, rowing, and running) [20].

Most of the previous studies aimed at using VR to treat psychological problems related to obesity, such as: eating disorder [23-26], and disorder of body image [27-28], unlock negative body image [29-32], behavioral treatment [33, 34], using it as a relaxation tool to reduce emotional eating, anxiety, depression [35, 36], use avatar in VR for modeling weight loss behaviors [37], and to recovery of motivation for change in a severely obese patient [38, 39]. Another benefit of using an avatar in VR it's to effects positively on PA outcomes using Microsoft Kinect [40].

VR technology provides a safe environment for observing, learning, and practicing, which is used for weight management programs by creating a social eating scenario that begins with choosing a coach and food ending, providing feedback related to the amount and composition of the food and drink chosen, thus resulting in changing behavior in the real world [41, 42]. There is a gap in the literature due to the focus of previous studies on the use of VR in treating psychological factors related to obesity rather than using it to treat environmental factors such as performance of physical activity (exercise). Based on our knowledge, there is no study investigating VR's use to provide appropriate exercise for obese and overweight adults. Most previous studies offer physical activity and diet as an external adjunct program to VR [26, 31, 32, 42].

VR was initially applied in sports research in the 1990s, but interest in VR sports has revived in recent years. The ability to interact with the VR environment is an essential feature of VR. in the context of sport and PA; The interaction may occur through an interface effort [43]. The physical exertion of exercise equipment such as a bicycle ergometer, for example, can be connected to the speed of movement on a virtual racetrack. VR-exergame is defined as integrating indoor exercise equipment (e.g., cycle ergometer, rowing ergometer, treadmill) into an immersive video game environment to perform differing exercises tasks (e.g., cycling, rowing, and running) Fig.1 [20] Many researchers have repeatedly reported that athletes' success in sports and their persistence in exercise plans are closely related to their motivation [44, 45]. Motivation involves the biological, emotional, social, and cognitive forces that activate behavior, which motivates people to participate and engage in an exercise [46]. VR-exergame applications in PA have taken many forms, with different types of exercises task and equipment, motivational determinants, VR technologies, and types of users.

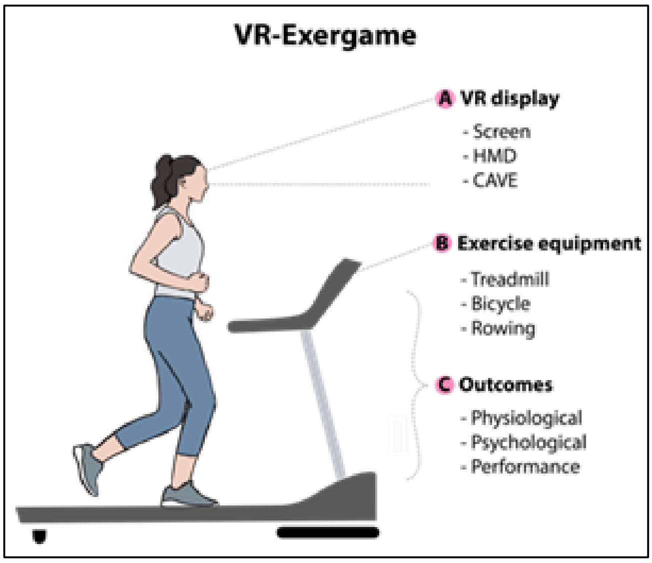

Fig 1: VR-exergame overview

Over the past years, researchers have improved the effective use of VR in experimenting with indoor exercise equipment. According to many studies, motivation is the key to an athlete's success in sports and the exerciser's perseverance in their exercise routine [44, 47]. Therefore, it is no surprise that many studies have been done on sports and physical exercise motivation. The concept of motivation can be defined as "the hypothetical construct used to describe the internal and/or external forces that produce the initiation, direction, intensity, and persistence of behavior" [48]. The emphasis on internal and external force fits very well with the existence of two primary motivational kinds, intrinsic and extrinsic motivation, which have been heavily researched in sports. Extrinsic and intrinsic motivation differ in terms of the source, the source of extrinsic motivation is from outside the individual, while the intrinsic motivation source is from within the individual [48].

Previous studies have studied several motivational determinants in applying virtual reality to sports summarized in Table 1. VR-exergame showed significant improvement in exercise performance and commitment, increased commitment, attendance, enjoyment, positive mood, and reduced fatigue and intensity [49, 50, 21]. Moreover, the addition of a virtual coach into the VR-exergame reduced stress, tension, and perceived control [51, 18]. The presence of competitors was used in the most previous studies to increase the intensity of the exercise compared to the individual exercise [52-54, 19, 20]. Self-selected VR task resulted in increased positive valence during the task compared to the exogenously imposed type of VR task [55, 20]. Furthermore, changing the VR environment during exercise based on the intensity of the exercise had a significant effect in directing the user to increase the intensity of his exercise [20].

Table 1: Motivational determinants of previous studies

Motivation Type	Reference	Frequency
Using VR	[24], [23], [21]	3
Virtual coach	[55], [18]	2
Competitor	[56], [57], [58], [19], [20]	5
self-selected	[59], [20]	2
Change VR environment during exercise	[20]	1

Most of the studies used cycling for exercise tasks 64% with a different type of indoor bicycle for exercise equipment. 3 out of 12 studies used an indoor rowing ergometer to perform a rowing task, and two studies used a treadmill for a running task. Fig.2 illustrates the most exercise task used in the previous studies.

Fig.2: Exercise task

The classification of all VR systems is challenging, most settings can be divided into three main categories, and each category can be evaluated according to the level of immersion or presence it provides. As indicated in Table 2, these categories include fully-immersive systems, semi-immersive display systems, and non-immersive systems [60].

Table 2: Types of VR systems

VR system	Non-immersive VR	Semi-immersive VR	Fully-immersive VR
Input\Output devices	(Joystick-keyboard-trackball-Mouse) /High Resolution Monitors	(Joystick-data gloves-space balls) /(Large screen monitor-large screen projector-multiple TV projection systems)	(Voice commands-gloves) /(HMD-CAVE)
Resolution	High	High	Low–medium
Sense of immersion	Non-low	Medium–high	High
Interaction	Low	Medium	High
Price	Low	High	Very High

As seen in Fig.3 most studies used a screen, 55% as a VR display, and 27% used a projector; In both types, they used different exercise equipment, but on the other hand, VR headsets were only used to perform cycling tasks with the cycling equipment. Because the VR headset can be safely combined with a bike or rowing equipment instead of a treadmill to avoid falls, and for treadmill use, there is a treadmill designed for use with a VR headset. Cycling was the most commonly used exercise in previous studies, probably because cycling is safer and more popular among users.

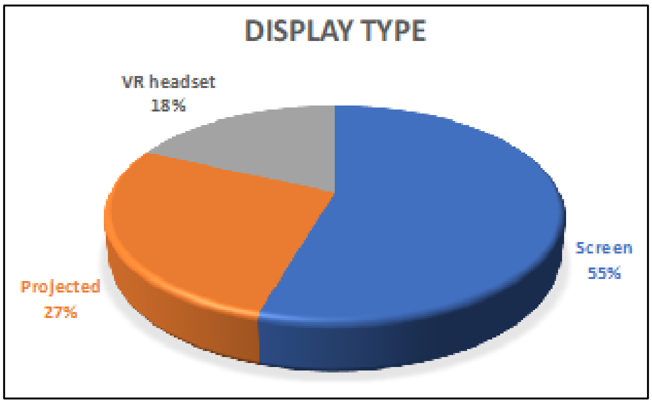

Fig.3: Display type

Despite the many benefits of VR-exergame, these VR-exergames are intended for athletes or healthy people. Therefore, they are not suitable for people who are obese or overweight because it does not depend on the user's needs and calories. To design a VR-exergame for obesity and overweight management in this thesis, we aim to design a VR-exergame prototype based on the user's in and out calories to suggest an appropriate exercise they need to burn extra calories. In addition, to track the users' progress and update their exercise plan based on the user's weight loss result.

There has been little focus on giving players the ability to track the effort gained from playing VR games, such as using a virtual coach to feed players feedback that their heart rates are low, and they need to increase their exercise intensity [55, 18]. Our VR-exergame obesity management prototype needs to track user activity to provide them with appropriate exercises to manage their weight, such as calories, exercise intensity, and HR. In addition, the ability to track weight loss progress in VR and create weight management plans based on user data in VR.

2. Materials and methods

This section will describe the methodology and process for designing VR-exergame requirements for weight control for obese and overweight adults through the prototyping design stages. The main steps to achieve the goal of this research were as follows: First, two surveys first survey for users 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 second survey is for experts to solicit the opinions of health practitioners to identify the best health aspects that should be available in the design of any VR tool for obesity control, second: surveys analysis and findings, third: designing the VR prototype, lastly, test the effectiveness of the VR prototype by distributing another survey about the design that has been tested before its use by five volunteers.

2.1. Pre-design survey

To recognize the fittest VR exercises for such a wide range of society, we need to examine the most affecting factors on the lifestyle and weight gain of the targeted audience and exercise preferences. In addition, learn about the beneficial uses of VR from different experts. We have conducted two surveys, one for users and the other for experts.

A. User survey

An online survey has been created using Google Forms. It provides clear interfaces and graphics and is easy to make and use. It also represents the responses in various charts with precise analysis to improve understanding of the data. The survey was distributed on social media -such as WhatsApp, Twitter, and Telegram. The main goal of the survey is to illustrate the relationship between sociodemographic and obesity and to know people's exercise preferences (the type of exercise and equipment they use, where/with whom they use it). Also, to find out the reasons for obesity and how they feel about themselves. Fig.4 illustrates the two-level survey map for user survey: participants' characteristics, practicing participants, and non-practicing participants. We separated the survey into two parts, a part for practicing participants; who are exercising and a section for non-practicing participants; who are not exercising.

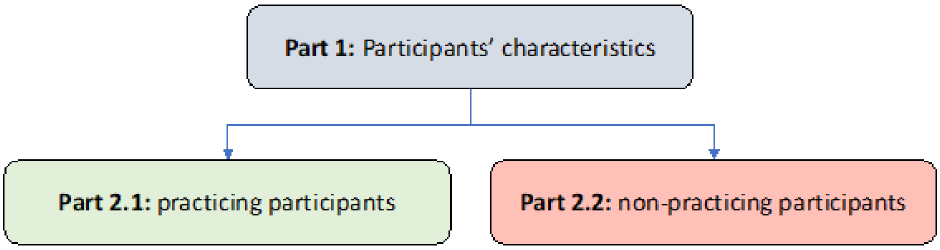

Fig 4: Survey structure

Part 1: Participants' characteristics

To investigate the relationship between sociodemographic factors and the prevalence of obesity and overweight in Saudi adults. We designed a user survey to include questions that capture the participants' sociodemographic characteristics. The user survey was created using Google Forms, a tool used in online surveys distributed among people living in different cities across Saudi Arabia.

Part 2.1: Practicing participants

In this part, to determine the type of exercise and machine to be used in our VR-exergame, we asked practicing participants about their preferences in performing exercises (type of exercises, equipment used, and where to perform them, as well as whether they prefer group or individual exercises). Then to capture psychological factors, we asked the user about the reason behind the weight gain from their point of view and how they feel about their current body.

Part 2.2: Non-practicing participants

In this part, we asked the non-practicing participants what exercise they would like to do to determine the type of exercise to be used in our VR-exergame. Then to capture psychological factors, we asked the user about the reason behind the weight gain from their point of view and how they feel about their current body.

B. Expert survey

The survey was designed to assess the contribution of VR to obesity to help us gain a better understanding of the uses and benefits of VR in fitness centers, facilities, and hospitals. In addition, it will assist in identifying the methods used to control obesity from the expert experience.

2.2. Post-Design Survey

A. Prototype evaluation

The prototype was evaluated using the results of the user survey as well as their suggestions. The sample used in the study was non-probability. Therefore, the survey was distributed to those who met the target demographic, which included males and females over 18. There were thirty people in the sample.

3. Designing the VR Prototype

This section provides a detailed description of the developed Weight Management Virtual Reality system (WMVR) prototype in terms of functionalities, beginning with a description of functional prototype parameters and the game's content. The prototype is then defined and depicted using system architecture, interfaces, and flowchart. Lastly, the different user interactions with the application are described.

3.1. Prototype functionality

The prototype consists of three major components

1. Smartwatch: will provide information about out-calories and HR and send it to the database (DB) then the DB will send this information to the VR system.
2. Calories counting App: will provide information about in-calories and send it to the DB then the DB will send this information to the VR system.
3. Speed sensor: will provide information about the player's actual speed and send it to the DB, then the DB will send this information to the VR system to determine the intensity of the exercises.
4. VR system: The VR system contains a VR headset that provides the user with our VR-exergame and a stationary bike on which the user can perform the exercise provided by our VR-exergame and extract the user's speed. The

VR system will extract the user information from the DB, which contains the user's personal information, out calories collected by the smartwatch, user speed from the speed sensor, and in calories collected by the calorie-counting phone app or VR System (entered by the user). Then the VR system will calculate the number of extra calories that need to be burned based on the user target and information. After that, the VR system displays the right set of exercises with different intensities to burn the extra calories to reach the target weight (i.e., the calories that were not burned during daily activities) consecutively. The VR system creates a monthly or weekly exercise plan for weight loss, which is then updated daily based on the user's calories.

3.2. WMVR Environment description

A. Game description

The user rides the stationary bike and wears the smartwatch and VR headset. Bicycle racing starts with virtual competitors. Along the race, there are colored rings. These green, yellow, and red rings represent low, medium, and high exercise intensity. HR and out calories obtained in real-time through the smartwatch are in the upper right corner. In the lower right corner, there is a shape to measure the actual user's intensity exertion obtained from the real-time bike speed sensor; the user must make the shape color match the color of the rings by increasing or decreasing the speed of his bike. The virtual competitors and rings of the race are designed based on the desired intensity during the game:

- **In the case of HIIT**

The game starts with an automatic movement when the user press starts, the calories burned and HR are calculated from the smartwatch then displayed to the user, and the user’s speed is calculated from the speed sensor on the stationary bike and represented to the user in speed shape. The race begins with a warm-up of 3-5 minutes in low intensity (40%–50% of HR max), the circles are green, and the competitors are behind the user. Then the first interval is a 5-minute consisting of 3 rounds of high intensity for 30-60 seconds interspersed with two rounds of low intensity for 30-60 seconds. At high intensity (85%–100% HR max), the circles are red, and competitors are in front of the user to encourage them to increase their exercise intensity. After the end of the first interval, the user enters recovery mode for 3-5 minutes at a moderate intensity (65-75% HR) round in which the circles are yellow, and the competitors are next to the user. These intervals are repeated alternately until the calories are burned completely. The race ends with a cooldown of 3-5 minutes, the rings are green, and the competitors are behind the user. Fig.5 shows the HIIT exercise, and how it is represented in a VR environment.

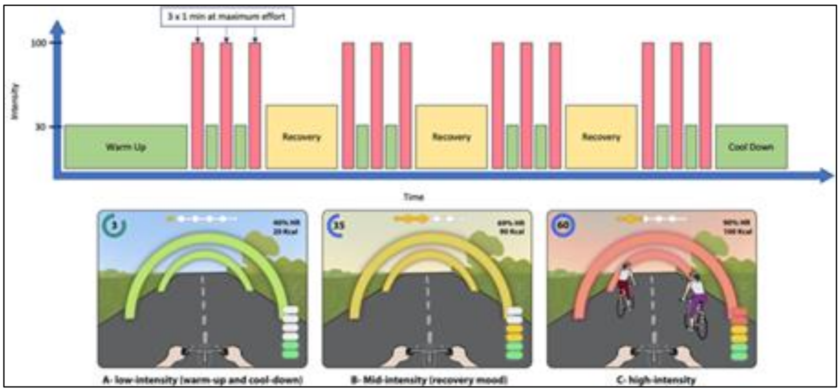

Fig 5: HIIT case.

- **In the case of MICT**

The race begins with a 3-5 minute warm-up at low intensity (40%-50% of max HR), in which circles are green and competitors are behind the user, followed by one interval at moderate intensity (65%-75% of max HR) where the circles are yellow, for 20 minutes or more, based on the calories the user needs to burn. The competitors are next to the user. Finally, the race ends with low intensity for 3-5 minutes. Fig.6 shows the MICT exercise, and how it is represented in a VR environment.

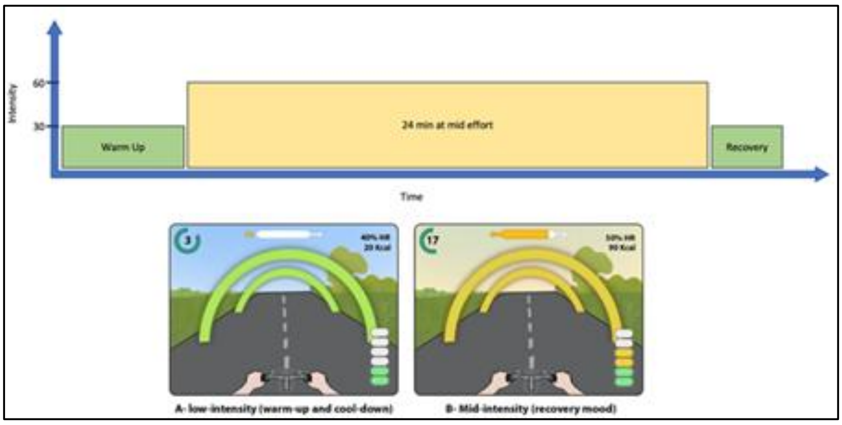

Fig 6: MICT case

- **Competitor**

Competitors have been used to encourage the player to increase exercise intensity in previous studies depending on the game purpose, so we designed our competitors based on our needs. We designed our competitors based on the types of exercise intensity in the game: low, mid, and high intensity. The game starts with a low-intensity race where the competitors are behind the player to give the player the impression that he is in the front and his speed is appropriate and does not need to increase it. After that, the game moves to high intensity, as the competitors' speed increases, and thus the player tries to beat them by increasing his speed. Before the end of the high-intensity interval, the player can advance over competitors as the game moves to a mid-intensity and competitors near the player to urge him to continue at a mid-Intensity. The Fig.7 below shows the competitors' function in the game with different intensities.

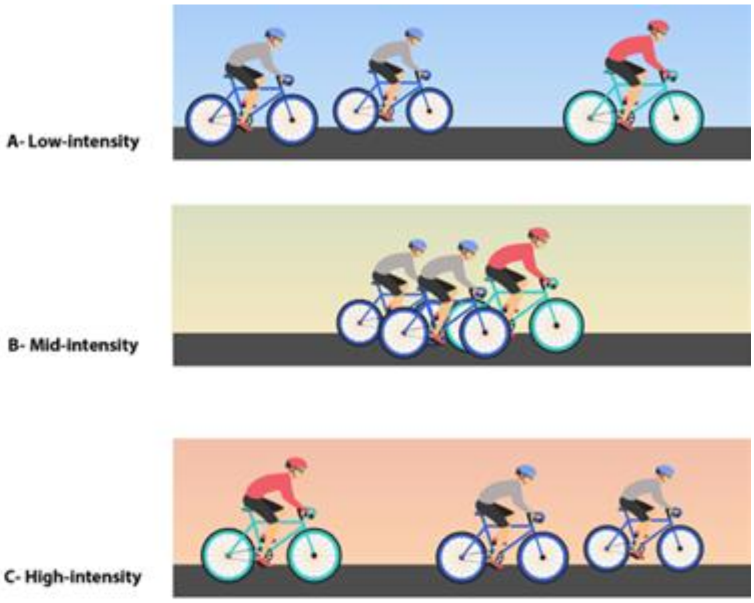

Fig 7: The player in the red shirt and competitors' gray shirt

B. Motivational Determinants

In our WMVR we have added many characteristics based on previous studies and survey results that motivate players, improve exercise performance and commitment, increase commitment, attendance, enjoyment, positive mood, and reduce fatigue and intensity.

- Self-selected: By allowing the user to choose the type of exercise and the environment they want to play.
- Virtual coach: Messages guide the user within the game; for example, if the user's speed is low, a message will appear telling users to increase their intensity.
- Presence of competitors: The role of virtual competitors in the virtual reality game depends on motivating the user to perform exercises with the required intensity; for example, Competitors appear in the case of high intensity in front of the user to encourage the user to make a higher effort.
- Changing the VR environment during exercise based on the intensity of the exercise: The virtual reality environment changes according to the type of exercise intensities we built in the game, thus teaching the player when to increase or decrease his speed. Changing the environment during the game increases the excitement and enjoyment of completing the exercise. Changing the VR environment is not affected by player performance.

  In our VR-exergame design, the weather, circles, and competitors are changed based on the design of the VR environment.

C. Type of exercise task and machine for WMVR

In our WMVR, we compared three kinds of exercise machines (Stationary Bike, Rower, and Treadmill) to execute three types of exercise tasks (Cycling, Rowing, and Running) based on previous studies, and user survey as shown in Table 3.

In previous studies, 64% of studies used the stationary bike with a VR to perform the exercises, while 22% used the rowing machine to improve the players' performance. In contrast, 14% of the studies used a regular treadmill with low-immersive VR (such as a screen or projector) to avoid falls, making it difficult to use a VR headset with the treadmill. The use of a VR headset requires a specific treadmill to prevent falls. In our project, we will be using a VR headset due to its advantages; thus, it is difficult to use a VR headset with a treadmill. Although 59.40% of users use a treadmill, it is not intended for use with VR headsets. On the other hand, 40.60% of users use a bike. The bike provides a seat on which the user can sit during exercises; therefore, it is considered safer with VR headsets. We excluded the use of the rowing machine because it was not available among the users.

Table 3: The type of exercise task and equipment we choose for WMVR

Exercise task	Exercise Equipment	Literature review	Survey Most used	Survey-Availability In Home (used with VR)	point
Cycling	Stationary Bike	64%	40.60%	Yes	2
Rowing	Rowing	22%	0	No	0
Running	Treadmill	14%	59.40%	No	1

D. Software and Materials

WMVR prototype interfaces were designed using Adobe Illustrator and Figma. Next, we created the VE virtual environment prototype using Unity® to enable us to show how the system works and usability test for the user. VE was run and recorded using Oculus Quest 2. Finally, we ran the recorded VE prototype for users via Zoom, a leading platform for setting up virtual meetings, video conferencing, live messaging, and collaboration tasks.

4. Results

- **User Survey**

Six hundred and three users answered the survey, 66.7% of users were males, and 33.3% were females. Of the 603 users, 360 (59.7%) participated in exercises, while 243 (40%) did not. Male participation in the exercise was higher than that of females, at 68.5%. 37% of exercise users were seniors over 50, 78.2% were married, 56.8% had a university education level, and 46.7% earned more than $4,000 on average per month. In terms of diet, 71.9% of users who did not exercise ate unhealthy food, which made them feel unhappy with their bodies as shown in Table 4.

Table 4: Study participants' sociodemographic characteristics; all users = 603; practicing = 360; non-practicing =243

Characteristics	All participants (n)	All participants (%)	Practicing (n)	Practicing (%)	Non Practicing (n)	Non Practicing (%)
	603	100	360	59.7	243	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

Prevalence of underweight, healthy weight, overweight, and obesity

The practicing group had Mean and median values for height, weight, and BMI 167.8 ± 8.8 cm, 168 cm (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), respectively. The non-practicing group had mean and mean values of height, weight, and BMI of 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), respectively as shown in Table 5.

Table 5: Height, weight, and body mass index (BMI) by participant type (practicing or non-practicing)

	Height (cm)	Weight (kg)	BMI, (kg/m²)
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

The prevalence of obesity was higher in both groups, although it was still lower in the practicing group than in the non-practicing group. At 44.4% versus 29.2% for the non-practicing group, the prevalence of overweight was higer in the practicing group (p = <0.001) (see Table 6).

Table 6: Distribution of body mass index for practicing and non-practicing participants

Group	Underweight %	Healthy weight %	Overweight %	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	

Reasons for obesity/overweight from participants' perspective

According to the practicing group perspective, the most likely causes of obesity were poor eating habits, lack of exercise and food choices, at 47.1% and 41.7%, respectively. Lack of exercise accounted for the largest number of non-practicing group (48.1%), followed by eating choices (35.4%).

A. Exercise preferences

They were asked about the activities they did, whether they used exercise equipment, and what types of equipment they used in order to better understand how the participants participated in the exercises. They were also asked about their preferred exercise locations and whether they like to exercise alone or in groups. When the 360 participants answering the multiple-choice questions, the participants had the option to choose more than one answer. The frequency, percentage of responses, and percentage of the 360 cases are listed in the three columns of the table. Participants' responses to the question about types of exercise were divided into four groups: aerobic, strength, flexibility, and balance exercises. In 91.5% of the participants, aerobic exercise was performed. Overall, 27.5% of the subjects used exercise equipment, and aerobic equipment accounted for 92.1% of this use. In terms of exercise locations, 55.8% of the subjects said they would prefer to exercise outside. 63% of the subjects liked to exercise alone.

4.1. Expert Survey

Thirty-one participants from various professions and occupational functions were given the expert survey. The responses to the first two questions were shown in Fig.8. The institutions that the specialists worked for are depicted in the pie chart on the left, with hospitals accounting for 61.2% of the institutions. Regarding their occupations, doctors and physical therapists accounted for the majority of experts at 23.3% and 22.5%, respectively (see pie chart on the right).

When asked how familiar they are with the idea of VR, 77.4% of the expQerts said that they are not sufficiently familiar with it, while 9.6% said that they have already started using it. In addition, 12.9% of expert have used VR in their clinics, compared to 87% who have never used it.

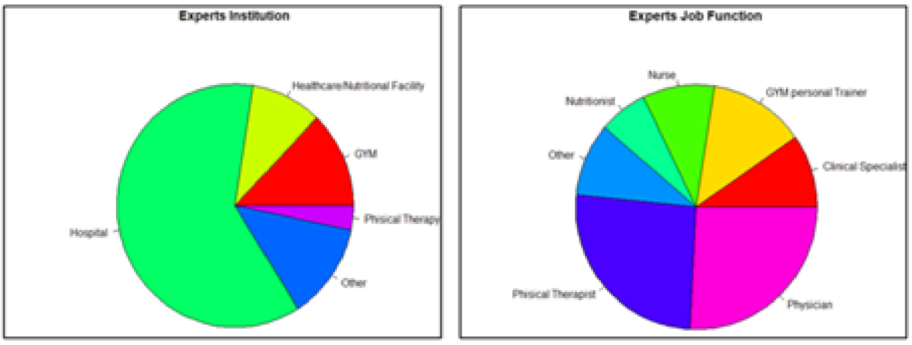

Fig 8: Pie charts of the expert institutions (left) and their job functions (right)

When asked by experts about the main advantages of using VR to control obesity, they gave two main answers: encouraging patients and visitors to exercise and enabling patients and visitors to exercise at home. Together, these two features accounted for 33.3% of their answers and 6.5% of 31 cases as shown in Table 7.

Table 7: 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

Table 8 reveals that 36.8% of the respondents advised the use of VR in psychological contexts, such as calorie counting, education, education, changing users' behaviours, and using media as a tool to reduce obesity. And 26.3% of the responses indicated that healthy eating and exercise are the best ways to control obesity, according to experts.

Table 8: 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

4.2. Post-Design Survey

Thirty people, 15 women and 15 men, between the ages of 20 and 29, responded to the survey. We can certify that there was no significant gender bias in this study and that it is representative of our population. According to the results of the WMVR prototype evaluation, 90% of participants liked using or recommending the system to others, and 65% of participants felt that the VR aspect of selecting exercises and scenarios boosted their motivation. This indicates a strong positive response to the system provided. Furthermore, 73% of participants said that the approach supported their weight management goals.

5. Discussion
Pre-Design Survey
User survey
When comparing the practicing and non-practicing groups, there were more people with obesity in both, but the prevalence in the non-practicing group was higher than in the practicing group. In contrast to the non-practicing group, which had a prevalence of overweight of 29.2%, the prevalence of overweight in the practicing group was high at 44.4% ($p = < 0.001$), indicating that practicing groups are less likely to be obese than non-practicing.

Reasons for obesity/overweight from participants' perspective
The practice group's perspective indicated that poor eating habits, inactivity, and food choices accounted for 47.1%, 41.7%, and 50% of the causes of obesity, respectively. The largest proportion of the non-practicing group (48.1%) was due to lack of exercise, followed by food choices (35.4%).

A. Exercise preferences
Most of the participants (91.5%) performed aerobic exercises, (27.5%) of them using exercise equipment and (92.1%) of equipment was aerobic equipment. In terms of exercise settings, 63% of the participants prefer to exercise alone, while 55.8% prefer to exercise outside.

Expert survey
The vast majority of experts in our study were medical professionals who used VR for various purposes in their work environments, including physical therapy. 36.8% of experts' suggestions for managing obesity were in response to a question. These strategies included using VR to encourage users to adopt healthy habits such as tracking calories, educating and informing users, changing their lives, and using media as a tactic to raise awareness. Furthermore, experts mentioned the age groups 5–16 and 38–50 37.5% of the time when asked which age groups would benefit from using VR for managing obesity.

Post-Design Survey
According to the evaluation data, the WMVR prototype met the weight management goals of the general population. 65% of participants said they were more motivated to choose their own VR workouts and scenarios. 90% of respondents said they would like to use or recommend the solution to others, and 87% of participants said they were happy with the WMVR system.

6. Conclusion
Virtual reality experience has proven to be a promising way to motivate people to become more active and help overcome sedentary lifestyles. VR-exergame provides immersive virtual worlds that can distract players by reducing exercise effort, making exercise more enjoyable and less intense, and promoting self-efficacy and a positive mood. Also, adherence to exercise was higher among those using the VR-exergame compared to standard exercise alone. Thus, VR-exergame can be used as a weight management tool by suggesting exercises based on users' needs. However, VR-exergame lacks the ability to produce exercises suitable for obese and overweight users according to their individual needs. As a result, in this research, we designed a virtual reality weight management exergame (WMVR) prototype that can calculate a user's calories (calories in and out) and suggest an exercise plan based on the users' individual needs for weight loss. In addition, the ability of WMVR to track users' performance and weight loss progress and then improve the exercise plan based on their results.

We designed a WMVR prototype based on previous studies and the results of a user and expert survey. The WMVR prototype presented in this research tracks in and out calories. Based on the target goals, together with user information, the WMVR will suggest the most effective virtual scenario to exercise. Moreover, users can choose their favorite scenes that motivate them to interact with the virtual world and get encouraged to continue this journey. The prototype aims to evaluate the potential of VR applications in the weight management journey.

Evaluation results showed that the WMVR prototype met weight management goals for the general population. 65% of participants felt that the VR aspect of choosing exercise and scenarios increased their motivation. Regarding using or recommending this system, 90% of respondents liked to use or recommend this system to others. Additionally, 87% of the participants expressed satisfaction with the system's usability. These results indicate that the implementation of virtual reality is attracting the population and that the prototype has been successful.

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