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Review

Virtual Reality in the Treatment of Patients with Overweight and Obesity: A Systematic Review

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Abstract: Obesity is one of the world's most serious health issues. Therefore, therapists have looked for methods to fight obesity. Currently, technology-based intervention options in medical settings are very common. One such technology is virtual reality (VR) which has been used in the treatment of obesity since the late 1990s. The main objective of this study is to review the literature on the use of VR in the treatment of obesity and overweight to better understand the role of VR-based interventions in this field. To this end, four databases (PubMed, Medline, Scopus, and Web of Science) were searched for related publications from 2000 to 2022 using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). From the 645 articles identified, 24 were selected. The main strength of this study is that it is the first systematic review to focus completely on the use of VR in the treatment of obesity. It includes most research in which VR was utilized to carry out the intervention. Although several limitations were detected in the reviewed studies, the findings of this review suggest that employing VR for self-monitoring of diet, physical activity, and/or weight is effective in supporting weight loss as well as improving satisfaction of body image and promoting health self-efficacy in overweight or obese persons.

Keywords: virtual reality; virtual environment; obesity; overweight; weight loss; systematic review

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1. Introduction

Obesity is one of the world's most serious health issues. There has been a substantial increase in the prevalence of obesity in recent decades and it is now considered a global epidemic [1]. Over two billion adults around the world are overweight or at high risk of becoming obese, with over 650 million obese individuals worldwide in 2020 [2]. Since 1975, the global obesity rate has almost tripled [3]. Between 1975 and 2014, the prevalence of obesity in adult men increased from 3.2 to 10.8% and in adult women increased from 6.4 to 14.9% [4]. Owing to its widespread prevalence, obesity is regarded as one of the most serious health issues in both developed and developing countries and regarded as a chronic and progressive disease with high morbidity and mortality rates [5–7]. Moreover, obesity can lower an individual's quality of life and put them at risk for serious chronic conditions, such as heart disease, type 2 diabetes, and cancer [8–10].

As the first line for obesity treatment, behavioral lifestyle intervention (BLI) is recommended by therapists since it consistently results in clinically substantial weight loss [11].

BLI enhances weight loss by improving patterns of diet and physical activity through a number of behavioral strategies, such as self-monitoring, goal setting, stimulus control, problem-solving, and self-reinforcement [12]. Although BLI has been shown to be effective in clinical trials, it has not been widely used due to its prohibitive costs, as treatment often entails group or individual therapy sessions led by specialized trainers over a period of many weeks or months [12,13].

Given the limits of BLI, new intervention approaches based on technological potential have been created to improve the scalability, reach, and affordability of BLI [14–16]. Virtual reality (VR) is one of many appealing technologies now available to assist individuals to lose weight [13]. VR is a computer-created enhanced human–computer interface that creates a virtual environment and enables users to traverse and interact with it as if they were in another world. It is accomplished by fully immersing the user's senses through the use of high-performance computers and sensory equipment such as headsets, position trackers, and other tools [17]. VR is effective in terms of motivating emotional feelings, changing behavior, and changing lifestyle, thereby making it more appropriate for healthcare applications [17,18].

VR allows for the construction of virtual scenarios that are quite similar to those in the real world [19]. This enables for precise control of situational aspects while preserving ecological validity [20]. VR also provides a safe and adaptable setting in which individuals can approach frightening events at their own speed, lessening their resistance to exposure [21]. Other benefits include the ability to self-train and the ability for therapists to conduct treatments that are impossible or extremely difficult to implement in real-life situations [20]. Furthermore, VR is far more immersive than images exposure because it engages many sensory modalities (auditory, visual, and sensory) [22]. This makes it good choice for individuals who have trouble imagining scenes and allows them to be more emotionally involved [21].

VR has been used in the treatment of obesity since the late 1990s. Riva and his team were the most researched on this topic [23]. The increased scientific interest in finding novel therapy alternatives for obesity combined with the rapid technological advancement in the VR field has resulted in breakthrough VR-based applications for evaluating and treating obesity. The use of avatars is one of the most recent technological developments [24–27]. VR has been used to treat obesity by immersing patients in realistic avatars in stressful virtual scenarios, such as grocery shopping, which helps patients improve body image perceptions and encourage healthier habits [28]. The so-called Proteus effect, a phenomenon in which individuals are more likely to perform a certain behavior when they see an avatar of themselves performing that behavior in a virtual environment, has led to more interest in using VR to encourage healthy eating behavior [29–31]. New discoveries regarding the multimodal nature of body representations have resulted in the invention of novel protocols, such as "bodily illusions" [32]. Additionally, recent studies have focused on improving the outcomes of weight management commercial online programs [33] and the immersion of participants in a more realistic representation of space and narrative [34]. Due to the growing popularity of mobile devices, new VR-enabled dieting apps have also been developed [35,36].

The main objective of this study is to review the literature on the use of VR in the treatment of obesity and overweight to better understand the role of VR-based interventions in this field. It must be highlighted that the goal is not to examine every study that has employed VR to alter weight or a weight-related behavior. Instead, various novel techniques are presented and analyzed in the context of current clinical practice and future objectives. Furthermore, this review adds to the growing body of knowledge regarding VR in medical settings and helps in the development of new methodologies that include VR technologies.

2. Materials and Methods

The PRISMA guidelines were utilized to guide the review's conduct. PRISMA consists of a 27-item checklist intended to facilitate the preparation and reporting of a robust protocol for the systematic review [37]. We used PRISMA to identify, select, and critically appraise relevant research while minimizing bias in order to optimize the quality of reporting and make the peer review process more efficient. Using the PRISMA statement, we conducted a search to identify studies using VR in the assessment and treatment of overweight and obesity. Study selection and data extraction were carried out by two independent reviewers. The reviewers′ decision to include or exclude studies were recorded. Following the completion of the article review, the outcomes of the data abstraction were compared. Any conflicts or discrepancies were addressed by consensus, taking into account the defined selection criteria. In the event of a persistent disagreement between the reviewers, a third reviewer would decide on inclusion or exclusion. The article's full text was then retrieved, and its quality assessed in order to determine whether it was appropriate to include in the review. Finally, tables were created to organize the essential points of the selected articles.

2.1. Data Collection

The scope of this study was limited to electronic databases. PubMed, Medline, Scopus, and Web of Science were used as data sources [38]. These sources were selected because they were considered relevant to weight loss, health interventions, and digital technologies. Searches were limited to studies published from 2000 to January 2022 because before the year 2000, VR research was rather limited. Furthermore, we utilized the English language for the search phrases. Additional articles were discovered by looking through the references of some articles founded in the search results.

2.2. Search Terms

The terminology employed in the search was pertaining to the use of VR in the treatment of overweight and obese patients. To guarantee that all studies satisfying the inclusion criteria were found, broad search phrases were utilized. The search string was created by combining key terms that best matched the study goal, which resulted in the following search terms: ((virtual reality AND obesity) OR (virtual reality AND overweight) OR (virtual reality AND weight loss) OR (virtual environment AND obesity) OR (virtual environment AND overweight) OR (virtual environment AND weight loss) OR (virtual world AND obesity) OR (virtual world AND overweight) OR (virtual world AND weight loss)).

2.3. Inclusion/Exclusion Criteria

The following aspects were the inclusion criteria of this study: (i) full-text publications written in English; (ii) articles with participants aged 18 or older, overweight or obese; and (iii) articles having protocols for VR intervention to treat obesity along with associated results.

The following aspects were the exclusion criteria of this study: (i) papers not connected to the study's subject or protocols of intervention with no results; (ii) reviews or meta-analyses; (iii) documents that are book chapters; and (iv) the presence of serious pathologies not related to obesity, such as mental illnesses and cancer.

2.4. Quality Assessment and Data Extraction

Two authors independently performed quality assessment of the included studies concurrently with data extraction. The data extracted from the articles include the year of publication (2000–2022), country of origin, participants' mean age, participants' mean weight, sample size, objective of the study, study type, duration of the intervention, number of groups in the study, technologies used in weight loss and/or the design of weight maintenance programs, and weight changes and other related intervention outcomes (such as improving self-efficacy for diet and physical activity). To critically evaluate the quality of selected studies, we used an adapted version of the Newcastle–Ottawa Quality Assessment

Scale [39]. Each study is given a maximum of nine points on this scale. Studies with a score of less than 6 are considered low-quality studies, whereas those with a score of 6 or more are considered high-quality studies and were therefore included in the review.

3. Results

Figure 1 depicts the study selection procedure. After a preliminary electronic search, we found 1151 studies that used VR-based environments in overweight or obese patients. In addition, hand-searching the references in the original and review papers yielded 22 research papers. We deleted 528 items due to duplication and then eliminated 587 items after reviewing their titles and abstracts. The remaining 58 articles were downloaded for a full-text review, after which we eliminated another 34 articles: ten articles presented a protocol without results, five articles reported previous studies, five articles evaluated healthy-weight participants, four articles did not target adults, three articles did not exist, three articles described non-VR intervention, two articles were book chapters, one article reported studies already included, and one study reported preliminary data. The resulting set of 24 distinct studies that matched the inclusion criteria were analyzed. Table 1 lists the articles included in this review and Table 2 explains the characteristics and results of the studies included.

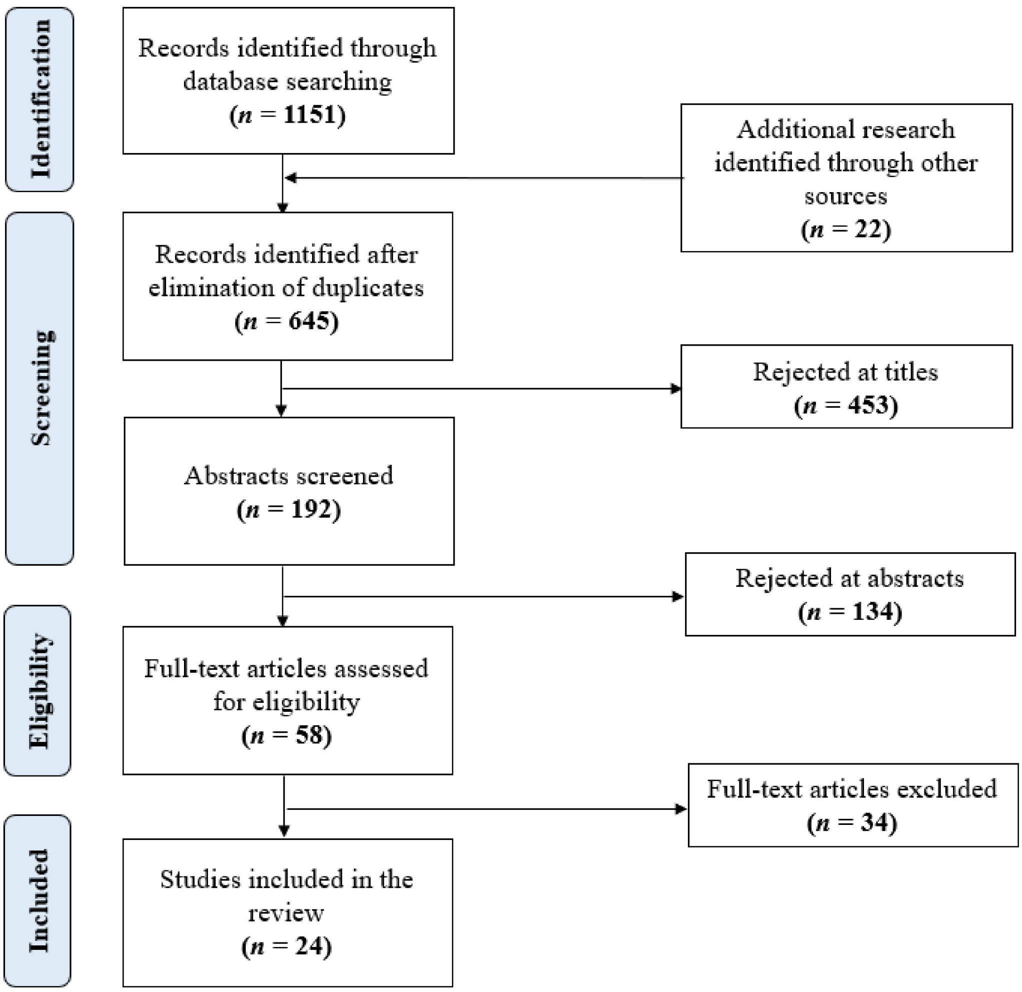

Figure 1. PRISMA flow diagram of study selection.

Table 1. List of studies included in the review.

Ref.	Country	Mean Age	Mean Weight	Sample	Objective	Study Type
[34]	USA	43	BMI ≥ 25	15 participants	Testing the viability of using VR in a traditional behavioral weight-loss program.	Pilot randomized study
[40]	Spain	31.9	BMI = 28.7	42 women	Analyzing the impact of avatar body dimensions on the efficacy of an online intervention to raise PA levels as well as the impact on other related variables (self-efficacy, enjoyment, anxiety, PA motivation, and PA goals).	Randomized controlled study
[33]	USA	18–70	BMI = 25–45	Total: 146 Men: 32 Women: 114	Evaluating the impact of a web-based VR program on behavioral skill training and weight loss when used in conjunction with a commercially available online weight-loss program.	Randomized controlled study
[41]	USA	49.62	BMI = 31.67	13 women	(i) Comparing weight, waist circumference, nutrition knowledge, and self-efficacy for diet and PA before and after the GoWoman intervention; (ii) assessing intervention feasibility (fidelity, attrition, engagement, and acceptability).	Non-controlled study Pilot test
[32]	Italy	32 obese 29 healthy	BMI = 45 obese 22 healthy	Total: 30 15 obese 15 healthy	Investigating whether patients with obesity can successfully experience ownership of a virtual body with a thin abdomen.	Non-randomized controlled study
[24]	Australia	18–79	BMI ≥ 25	Total: 145 Men: 27 Women:118	Evaluating the impact of a personalized future self-image developed by a computer on weight loss.	Randomized controlled study
[42]	Brazil	40	BMI ≥ 25	Men The number is N/A	Discussing how the Internet of Things (IoT) can be used in the virtual world to assist obese individuals in learning more about self-care and losing weight.	Non-controlled study
[25]	USA	18–61	BMI ≥ 25	90 women	Examining the usefulness of VR and play in a virtual social world (Second Life) in promoting health self-efficacy in overweight people.	Randomized controlled study
[26]	Italy	18–50	BMI > 40	163 women	Testing the long-term efficacy of VR-based CBT to open the body's negative memories and changing its emotional and behavioral associations with obesity.	Randomized controlled study
[43]	Spain	39.26 obese 24.75 ED 23 NC	BMI = 36.33 obese 20.45 ED 21.16 NC	62 women 19 obese 20 ED 23 NC	Comparing the reality judgments of ED and obese patients in a virtual environment meant to normalize their eating patterns.	Non-randomized controlled study
[44]	Italy	37	BMI = 62.2	One woman	Discussing the impact of the illusion of body ownership over a different body (a virtual body with a little tummy) on the recovery of motivation for change with a severely obese patient.	Case study/report
[45]	Mexico	18–50	BMI > 30	Total: 24 women and men	Discussing the role of VR in tackling obesity as part of a comprehensive cognitive behavioral approach.	Randomized controlled study

Table 1. *Cont.*

Ref.	Country	Mean Age	Mean Weight	Sample	Objective	Study Type
[46]	Mexico	M = 37	BMI ≥ 25	Total: 3 Men: 1 Women: 2	Discussing the potential impact of VR in improving body image after LAGB surgery within the context of an integrated cognitive behavioral approach.	Case study/report
[47]	USA	M = 55	BMI = 34.6	37 women	Developing a system for building and distributing automated VR scenarios for online BWL skill training as well as collecting feedback from test users using a social dining scenario as an example.	Randomized controlled study
[27]	Italy	18–50	BMI > 40	66 women	Testing short- and long-term clinical efficacy of enhanced CBT including VR in obese patients with BED compared with standard CBT and IP on weight loss, weight loss maintenance, BED reduction, and improvement in body satisfaction.	Randomized controlled study
[48]	USA	Phase 1: 34.10 Phase 2: 44.13	Phase 1: 34.30 Phase 2: 33.32	136 women Phase 1: 128 Phase 2: 8	Examining using avatar-based technologies to model weight-loss behaviors.	Non-controlled study
[49]	USA	M = 31.1	BMI = 32.8	Total: 20 Men: 3 Women:17	Comparing between an FtF weight management clinic and a VR clinic regarding weight loss and maintenance.	Randomized control study
[50]	USA	46.3 COI 37.5 FtF	BMI = 32.0	Total: 54 Men: 9 Women: 45	Examining the weight reduction and behavior modification effectiveness of a virtual weight loss program.	Quasi experiment
[51]	Italy	18–60	BMI = 30	60 women	Evaluating the effectiveness of a relaxation treatment augmented by VR and portable mp3 players in reducing emotional eating.	Randomized controlled study
[52]	Italy	18–60	BMI ≥ 30	60 women	Developing a relaxation routine employing VR and portable mp3 players to decrease stress and accompanying emotional eating episodes in obese individuals.	Randomized controlled study
[53]	Italy	18–50	BMI > 40	211 women	Proposing a biopsychosocial treatment strategy ECT for severely obese patients (BMI > 40).	Controlled study
[54]	Italy	18–45	BMI = 43.97	28 women	Evaluating the efficacy of a multi-dimensional VR-based strategy to treating body image attitudes and related components.	Controlled study
[55]	Italy	18–45	BMI = 42.11obese 41.82 BED 39.01 EDNOS	57 women 18 obese 25 BEDS 14 EDNOS	Investigating the possibility of causing a significant shift in behavior and body image perception in obesity and related disorders using a psychological VR-based approach.	Non-controlled study
[56]	Italy	18–45	BMI = 41.82	25 women	Describing and evaluating a VR-based approach for the treatment and assessment of obesity and binge eating disorders (ExCT).	Non-controlled study

Notes: BED = binge eating disorders; BWL = behavioral weight loss; BWLT = behavioral weight loss treatment; CBT = cognitive behavioral therapy; COI = Club One Island™; CTRL = control condition group; ED = eating disorders; ENDOS = eating disorders not otherwise specified; ES = experience success; ECT, ExCT = experiential cognitive therapy; FtF = face to face; HMD = head-mounted display; IP = inpatient program; LAGB = laparoscopic adjustable gastric banding; NC = non-clinical group; NT = nutritional; PA = physical activity; PNI = psych nutritional; RCT = randomized controlled trial; SBP = standard behavioral program; SD = standard deviation; SL = second life; VEBIM = VR for body image modification; VR = virtual reality; VR-FBI = virtual full body illusion; WL = waiting list. WW = weight watchers.

Table 2. Characteristics and results of the examined studies.

Ref.	Intervention Duration	No. of Groups	Technology	Study Design	Results
[34]	4 weeks	2 groups: G1: intervention G2: control)	SW: VR scenarios via an app (Restaurant, food cue, activity cue) HW: iPhone6+ VR headsets	-G1: 4 weeks BWLT + 3 weeks 15 min weight related VR scenario 3 times a week + 3 weight-control lessons -G2: 4 weeks BWLT + 3 weeks 15 min non-weight related VR scenario 3 times a week	Throughout the trial, both groups lost statistically significant amounts of weight. Over the course of four weeks, the control group and the intervention group shed an average (SD) unadjusted mean of 2.3% (3.6) and 3.4% (2.7), respectively, as a percentage of their original body weight. When comparing the proportion of participants who lost 5% or more of their primary body weight, 16% (1/6) of those in the control group and 43% (3/7) of those in the intervention group met this criterion.
[40]	4 weeks	3 groups: IAC: avatars with ideal body dimensions RAC: avatars with existing body dimensions NAC: no avatars	SW: The VR scenario representing a park where an avatar runs HW: Kinect and 150 × 150 cm screen	- IAC: 1-week online PA + 1-week daily PA in the VR scenario for 4 min (default avatar) + 1-week PA 3 times a week. - RAC: same instructions, with changing avatar dimensions. - NAC: same instructions, with no avatar.	The online intervention was successful in increasing PA practice and self-efficacy expectations among overweight and obese women. Manipulation of avatar body dimensions had no effect on the outcome of this intervention. The use of ideal avatars appears to minimize anxiety during PA and the use of avatars that are identical to the individual themselves may have a stronger impact on PA and variables related to long-term practice.
[33]	6 months	2 groups: Participants accessed (WW) program alone Participants accessed (WW + ES)	SW: WW ES HW: PC and/or mobile device with online connectivity	- WW: 6 months access to WW program. - (WW+ES): WW+ 4 scenarios at weeks 2, 4, 6, 8 (home, work, gym, social situations)	Both groups lost statistically significant amounts of weight, with no difference in mean standard error weight loss between WW and WW+ES at three months (2.7 ± 1.1 kg vs. 4.2 ± 1.1 kg, respectively), but greater weight loss in WW+ES at six months (2.6 ± 1.3 kg vs. 4.9 ± 1.3 respectively). After a six-month trial, 20% of the WW group and 23% of the WW+ES group had lost 5% of their baseline weight.
[41]	6 months	Single group	SW: GoWoman program based on SL MyFitnessPal App HW: PC with Internet connection	16 weekly virtual meetings in SL. The workshops included speaking exercises, discussion, and question/answer sessions. Participants created weekly action plans at the end of each session and used MyFitnessPal to track food intake and exercise.	Thirteen women attended eight of the sixteen GoWoman weekly sessions and lost an average of 5.97 pounds (2.71 kg) (3.31%) and 1.44 inches (3.66 cm) (3.58%) in body weight and waist circumference. Diet, PA, and self-efficacy for diet and PA all improved significantly. GoWoman demonstrated feasibility (fidelity = 97.81%, attrition= 46%, engagement (SD = 2.44), acceptability (SD = 0.48)).
[32]	N/A	2 groups: G1: experimental G2: control	SW: Unity3D MakeHuman HW: HMD Portable computer	- G1: synchronization between tactile and visual stimulation. - G2: asynchronization between tactile and visual stimulation.	Obese as well as healthy-weight subjects claimed to have experienced the illusion. In terms of the body size estimation task, neither group reported any variations other than alterations in the estimation of the abdomen's circumference following the experimental condition.
[24]	6 months	2 groups: G1: Early image G2: delayed image	SW: "Future Me" app HW: iPad	- G1: hard copy of future self-image at the time of recruitment. - G2: hard copy of future self-image after 8 weeks.	In the delayed-image group, more than a fifth of those who completed the study lost 5% or more of their primary weight. Those in the group with the delayed image lost more weight than those in the group with the immediate image. In addition, men lost weight more quickly than women. Between the early and late image groups, there was no significant difference in the change in waist circumference or the proportion of people who lost 5% of their body weight.
[42]	NA	One group	SW: HIGIA system (Individual Habitat and Attitude Interactive Guide) HW: Smartphone Motion Sensor	- Stage 1: visiting the virtual world to experience a fitness virtual environment. - Stage 2: performing PA through the user's avatar.	There was a significant weight loss. In the first stage, the average weight loss was 5 kg, and in the second stage, the average weight loss was 2.5 kg. In addition, there was a 70% increase in body motion compared to the average amount stated by the participants in the initial interview.

Table 2. *Cont.*

Ref.	Intervention Duration	No. of Groups	Technology	Study Design	Results
[25]	4 weeks	3 groups: 3D social virtual world 2D social networking No intervention group	SW: SL (using an avatar) + virtual health social networking site HW: 2D screen Desktop computer	- 3D: users utilized SL sessions at least twice a week in groups of 3–4. - 2D: users engaged in a virtual health community. - No intervention: no virtual interaction.	There was an increase in the exercise efficacy of the SL group, but not that of the control group. However, the SL intervention had no effect on nutrition efficacy—F (1, 38) = 1.99, $p = 0.17$. Weight loss was significantly different between the experimental and control groups: t (18) = 2.15, $p = 0.04$. Participants in the SL group lost 1.75 pounds compared to 0.91 pounds lost by participants in the control group. The weight reduction difference is insignificant, and the use of SL for long-term weight loss is only cautiously optimistic. Further, self-presence was associated with improved nutrition ($p = 0.05$), but not with exercise efficacy. Self-presence and avatar efficacy items had significantly positive relationships ($p = 0.01$).
[26]	6 weeks + 1 year follow-up	3 groups: SBP CBT VR-enhanced CBT	SW: NeuroVR HW: HMD	- SPB: 6 weeks standard treatment. - CBT: SPB + 5 weekly group weight loss sessions + 10 biweekly individual sessions (body image + weight maintenance). - VR-enhanced CBT: SPB + 5 weekly group weight loss sessions + 10 biweekly individual VR sessions.	The entire group lost a large amount of weight. On average, the control group lost 6.2% of their baseline body weight, whereas the CBT group lost 7.4% and the VR group lost 6.25% of their baseline body weight. After inpatient therapy, psychological variables such as eating behavior features and body satisfaction increased significantly (effect size 0.16–0.26). Surprisingly, despite the VR group demonstrating greater increases across the board, there was no statistically significant difference between the three conditions. At the one-year follow-up, the VR group is more likely than the SBP group (48 percent vs. 11 percent; $p = 0.004$) and the CBT group (48 percent vs. 29 percent; $p = 0.08$) to maintain or enhance weight reduction.
[43]	NA	3 groups: Obese ED NC	SW: Non-immersive VE (graded exposure to feared foods in a virtual kitchen) HW: Laptop with 2D mouse	One VR session. The VE comprised of a kitchen where the participant could make, serve, and consume a meal "virtually." The VR session lasted for 30 min.	- The ED group had the highest ratings in attention, presence, emotional involvement, reality judgment, and unpleasant feelings about the "forbidden" meal. - Obese people have the lowest ratings in terms of judging reality and presence, satisfaction, and a sense of physical space in a virtual world. In VR food, obese people are in a middle position. - The level of participation in the virtual world for ED patients and the level of attention for obese patients predicts the likelihood of consumption of the "forbidden" virtual meal.
[44]	5 weeks	Single patient	SW: VR body-swapping illusion protocol HW: HMD	Multidisciplinary program (PA + psychological counseling). VR treatments (optical and the tactile estimation of body parts + VR body swap illusion).	Full-body illusion successfully induced identification with a thinner body in an individual suffering from severe obesity, improving body satisfaction, increasing motivation to engage in healthy behavior, and reducing anxious feelings related to the clinical condition. The woman lost 5.1 kg, which equates to a decrease of 3.7% of her baseline weight.
[45]	12 weeks + 3-month follow up	3 groups: CBT ECT CTRL	SW: Neuro VR 2.0 HW: NA	- CBT: weekly group sessions + 10 biweekly individual sessions. - ECT: 12 individual discovery sessions in 12 weeks.	The findings suggest that adding VR therapy to an obesity treatment program improved the cognitive-behavioral approach, increased weight loss (15–20% of beginning weight) and improved psychological well-being. This decrease was accompanied by an overall improvement in mental health. After a three-month follow-up, both the weight loss and the level of well-being had improved even more.
[46]	6 weeks + 3-month follow up	Single group	SW: Neuro-VR 2.0 HW: PC	ECT treatment (5 weekly group sessions + 10 biweekly VR sessions).	The patients lost an additional 15–20% of their weight by the completion of the regimen. This decrease was accompanied by a general increase in psychological well-being: clinical data revealed significant improvements in anxiety and body image. As a result of this alteration, the number of avoidance behaviors decreased, while the number of adaptive behaviors increased.

Table 2. *Cont.*

Ref.	Intervention Duration	No. of Groups	Technology	Study Design	Results
[47]	18 months	A single group	SW: ES HW: PC + mouse	The ES social eating scenario: - Selecting a virtual coach. - Entering a virtual house. - Facing two categories of difficulties: interpersonal and practical. - Providing comments and suggestions on the total calorie content.	Participants described the scenario as "very realistic," and mentioned that they had improved their capacity to deal with the issues it posed. Acceptability and feasibility were rated 6.5 out of 7 on a scale that included comprehensibility, believability, relevance, usefulness, applicability, ease of use, likeability, and likelihood of suggesting the VR scenario to others.
[27]	6 weeks + one-year follow-up	3 groups: ECT CBT IP	SW: Neuro-VR 2.0 HW: PC	CBT: routine care + 15 weekly sessions in 5 weeks. ECT: routine care + 5 weekly group sessions + 10 biweekly VR sessions. IP: 5-week hospital stays for routine care.	Weight loss was significant in all three treatments (ECT: 6.17 kg, CBT: 7.1 kg, IP: 6.6 kg), with no significant differences among groups. All groups witnessed significant increases in body satisfaction, with no variations among them. Both ECT and CBT were successful in maintaining or enhancing weight loss during the one-year follow-up. The majority of the weight lost throughout the inpatient program was recovered by control subjects. Binge eating episodes reduced to zero during the in-patient program; however, at the one-year follow-up, they were reported again in all three groups, but there was no discernible difference among the groups.
[48]	4 weeks	One group in each phase	SW: SL HW: PC + mouse + Internet connection	Phase 1: online survey to obtain feedback about using avatars for modeling weight loss behaviors. Phase 2: 4-week usability test using 4 virtual environments (supermarket, home gym, dining room/kitchen, living room).	The average weight loss after four weeks was 1.6 kg (SD = 1.7). Usability: 100% of users indicated that they would recommend the program to others and that it has changed their eating and exercise habits. User preference: 25% of users stated they did not want an avatar that looked like them, but 75% stated they wanted an avatar that changed size and shape as they progressed through the program.
[49]	9 months	2 groups: VR FtF	SW: SL HW: Computer + internet connection + headset	VR: 3 months SL classes and activities (e.g., grocery shopping, dining in a restaurant, working out in the gym). FtF: 3 months BWL program delivered FtF in a weight loss clinic. + 6-month maintenance program delivered via SL for all participants.	While the weight loss achieved through SL (7.6% of initial body weight) was smaller than that achieved through FtF treatment (10.8% of initial body weight), the degree of weight loss achieved through SL was equivalent to that of numerous FtF programs. Furthermore, individuals who got SL for the full six months lost more weight, thereby resulting in a total weight loss of 14% of their baseline body weight, compared to those who were initially randomized to FtF and regained some weight, thereby resulting in a 9.5% end-of-treatment weight loss.
[50]	12 weeks	2 groups: VR FtF	SW: COI HW: PC + mouse + Internet connection	- VR: COI users (4 h/week), taking classes on nutrition, movement, and emotional issues regarding weight via their avatar. - Ftf: normal gym users.	Patients in both groups had dropped a significant amount of weight after 12 weeks (VR: 3.9 kg; FtF: 2.8 kg). When compared to their initial weight, the VR group lost an average of 4.3% of their body weight, with 33% of the patients losing a clinically significant (5%) amount of weight while FtF participants lost an average of 3.0%, with 29% losing a clinically significant amount of weight (5%). In addition, COI participants showed significant improvements in almost all behavioral change indicators except sleep (i.e., increased physical activity, fruit and vegetable intake, and the number of days on which breakfast is eaten). On the other hand, FtF participants exhibited no significant gains in any of the indicators. Participants in the COI group increased their confidence in their capacity to engage in physical exercise and resist eating, whereas those in the FtF group did not.

Table 2. *Cont.*

Ref.	Intervention Duration	No. of Groups	Technology	Study Design	Results
[51]	3 months	3 groups: VR (relaxation protocol enhanced by VR) IM (relaxation protocol using imagery) CTRL	SW: VE (Green Valley) showed mountain landscape with relaxing lake scenes HW: HMD	- CTRL: 5-week hospital-based weight-loss program and rehabilitation program. -VR and IM: CTRL program + 12 individual relaxation training sessions provided traditionally (IM condition) or virtually (VR condition).	In all groups, emotional eating episodes dropped to zero and weight loss was significant. The VR and IM conditions increased self-efficacy for eating control and depression, whereas the CTRL group showed no change. Three-month follow-up revealed significant improvements in all variables in the VR and IM conditions. When compared to IM, VR resulted in a larger reduction in emotional eating. In the CTRL group, there were no noteworthy changes.
[52]	3 weeks	3 groups: VR (relaxation protocol enhanced by VR IM (relaxation protocol using imagery) WL	SW: Green Valley (mountain landscape with relaxing lake scenes) HW: - laptop - HMD + (visual and an audio device) - position tracker - joystick	- WL: 5-week hospital-based weight-loss and rehabilitation program. - VR and IM: WL program + 12 individual relaxation training sessions provided traditionally (IM condition) or virtually (VR condition).	The VR and IM treatments improved food management self-efficacy and reduced depression levels. The WL condition did not lead to these changes. During stressful scenarios, the VR and IM conditions both reduced state anxiety, improved a feeling of calmness, and decreased heart rate. There were no differences between VR and IM. All the situations resulted in significant weight loss.
[53]	6 weeks + 6-months follow-up	3 groups: ExCT CBT NT	SW: VREDIM (Enhanced version of VEBIM) HW: PC-based workstation graphic card HMD	- NT: 5 weekly nutritional sessions held by dieticians (low calories diet and physical activity). - CBT: NT + 5 weekly group sessions on weight and primary goals + 10 biweekly individual sessions on maintaining weight loss. - ExCT: NT + 5 weekly group sessions on improving motivation to change and assertiveness + 10 biweekly VR sessions.	Each of the three therapy groups lost significantly more weight than those on the waiting list, but there was no difference among groups in terms of weight reduction or the primary psychological characteristics (e.g., anxiety and body satisfaction). In contrast to the other approaches, experiential CT resulted in improvements in body image satisfaction and self-efficacy at the six-month follow-up. ExCT was the only method that was able to significantly improve both BI satisfaction and self-efficacy at the six-month follow-up, thereby implying a decrease in avoidance behaviors and an increase in adaptive behaviors.
[54]	6.5 weeks	2 groups: VR PNI	SW: VREDIM HW: HMD Motion tracker joystick.	- VR: 7 VREDIM sessions + low-calorie diet + exercise (walking for 30 min at least twice a week). - PNI: low-calorie diet + exercise + PNI sessions (3/week).	The VREDIM group outperformed PNI in terms of enhancing body satisfaction, self-efficacy, and motivation to change (although the difference was not significant). After therapy, those in the VREDIM group underwent a significant decrease in body dissatisfaction, anxiety, and overeating, as well as a significant gain in self-efficacy. Only the PNI group showed a significant reduction in anxiety and increased exercise. Those in the VREDIM group lost 11.33 kg on average, compared to 7.58 kg in the PNI group.
[55]	6 months	3 groups: Obese BED ENDOS	SW: VEBIM 2 (Enhanced version of VEBIM system) HW: HMD joystick	Biweekly 5 individual VR sessions associated with CBT + Diet + biweekly psycho nutritional group sessions + weekly psychological support.	Respondents in all three samples reported lower overall body satisfaction, more realistic limb impressions, higher social activity, and less use of apparel that disguises body obesity.
[56]	6–8 weeks	2 groups: Obese BED	SW: VEBIM 2 HW: HMD joystick	Biweekly 5 VR sessions associated with CBT + Diet + biweekly psycho-nutritional group sessions. The VE comprises several zones, each of which is employed by the therapist during a patient session.	Body dissatisfaction level was significantly reduced, social activity was improved, and use of disguising clothes was reduced in both groups.

3.1. *Study Authors, Year of Publication, and Country of Origin*

There was a total of 24 articles included in this review. Riva and his team were the most researched on this topic (10/24, 42%). To the best of our knowledge, there is no single review dedicated to using VR in the treatment of obesity. However, there are a few reviews that included this topic, such as [21], which included articles that were published up to 2013 and reported six studies on obesity. Since then, 18 (75%) of the articles in our selection have been published, thereby indicating an increase in interest in using VR for obese patients

(Figure 2). All articles were in English and were published between 2000 and 2021. Most trials were conducted in Europe and the USA.

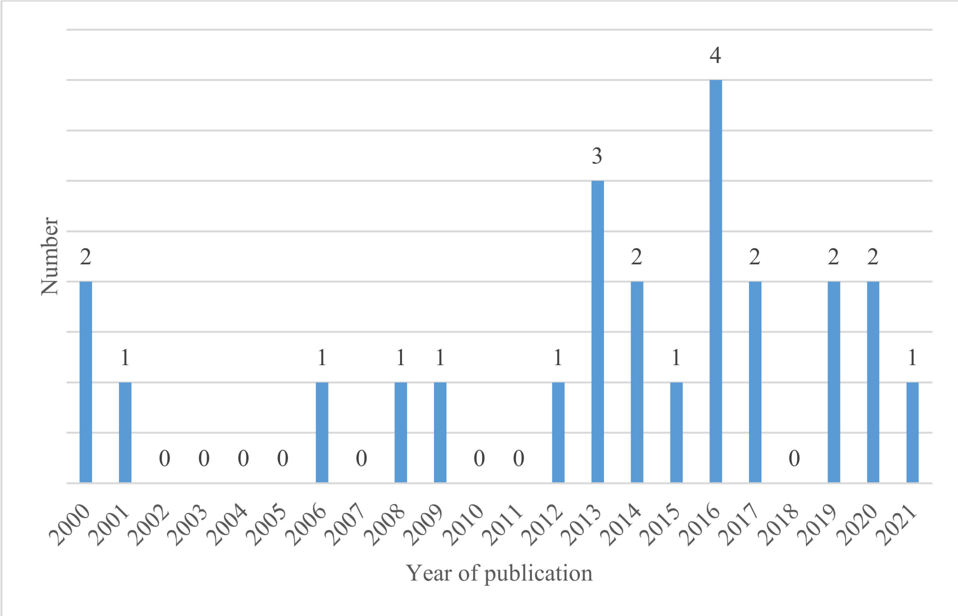

Figure 2. The number of articles included in the review by year of publication.

3.2. Population, Sample Size, and Study Type

In total, more than 1493 people participated in the 24 trials. There were 15 trials that had only women, and 1 trial in which there were only men. In the remaining eight studies, there were both men and women. Approximately 93% of the participants were women, whereas only 7% were men. All the trials were conducted on adults. The average age of the participants was between 18 and 79 years. The majority of the inclusion criteria were based on body mass index (BMI). The review study participants had a BMI of at least 25 kg/m^2. Further, in terms of study methodology, there were 11 randomized controlled studies, 2 clinical case studies, and 11 studies had a variety of other study designs.

3.3. Objectives of the Studies

The studies included in this review focused mostly on exposure to psychological, diet, or physical activity as virtual stimuli to promote behavioral weight loss treatment. The most commonly utilized verbs in study objectives statements were "evaluate" ($n = 4$), "examine" ($n = 4$), and "describe" ($n = 4$). Researchers also used "investigate" ($n = 2$), "test" ($n = 2$), or "compare" ($n = 2$). The majority of studies were centered on the participants' weight loss ($n = 14$) and/or on experiences related to certain phenomena related to weight loss ($n = 10$).

3.4. Technology Used

To provide a greater sense of immersion, isolation, and possible vulnerability, half of the trials used visual immersive technology with a head-mounted display (HMD) and voice communication (12/24, 50%). A total of 11 studies used audio and visual stimuli via PC or mobile device and headsets to enable interaction between the user and the virtual world (11/24, 46%). One more study used a motion sensing input device with RGB cameras and infrared projectors and detectors (1/24, 4%). Motion sensors are used to measure the movement of the participants in order to motivate them.

3.5. Outcomes

The most important findings from the articles studied indicate that patients' weight loss was greater in the VR intervention groups, although the differences between the control and comparison groups were not statistically significant. However, this result cannot be generalized for weight maintenance, as most studies have not addressed this issue. In addition to weight loss, there were interesting weight-loss related results. For example, the effectiveness of VR in the development of health self-efficacy, body image satisfaction, and motivation to change has been demonstrated.

4. Discussion

This systematic review of the use of VR-based settings in the treatment of overweight and obese people complemented previous reviews [21,35,57,58] by focusing solely on weight management in overweight and obese people and including more recent research in the field. From the 24 studies selected, 14 were classified as treatment studies because they investigated the utility of VR as a potential therapeutic strategy for weight loss, and 10 studies were classified as assessment studies because they investigated the impact of VR on various obesity-related aspects. Based on the papers reviewed, the use of VR in the treatment of overweight and obese people is still a developing field that requires additional research.

This review can lead to a number of inferences. First, the findings support the hypothesis that patients with overweight and obesity who were immersed in VR environments had a sense of presence, thereby enhancing the ecological validity of the processes in this group of individuals. Second, the findings imply that using VR technology for monitoring diet, physical activity, and/or weight can help individuals who are overweight or obese to lose weight. Third, studies involving VR technologies in conjunction with cognitive behavioral procedures or behavioral weight loss interventions reveal that they have the potential to enhance clinically significant weight loss; however, regaining weight is a problem, and a substantial percentage of participants do not maintain their weight loss over time [34,59]. Finally, commercial online weight loss programs have emerged as a potentially cost-effective alternative to standard empirically validated behavioral weight-loss programs, which differ greatly in terms of the extent to which they combine evidence-based weight loss methods and skills [60].

In fact, even though the quality of studies included in this review was moderate to high, on average, the different types of interventions and time durations of the interventions as well as the different study designs made it impractical to have a direct comparison of outcomes. However, the evidence suggests that weight loss was greater in groups in which VR was used as part of or as a complement to the intervention [24–27,33,34,41,42,45,46,48–50,54], even if in certain studies the differences between the control and comparison groups were not statistically significant. Nevertheless, this cannot be affirmed with regard to weight maintenance because most studies did not include this outcome. In addition to weight loss, there were interesting weight loss-related results. For example, the effectiveness of VR in improving health self-efficacy, body image satisfaction, and motivation to change has been proved.

Although VR treatment has a few advantages over reality, its goal is not to replace actual experiences but to serve as a substitute for fictitious exposure. VR exposure has the ability to overcome the limits of traditional behavioral weight loss by enabling users to engage in desired weight management activities with the frequency and intensity required to form long-term habits. The evidence presented in this systematic review suggests that using VR combined with low-calorie meals and exercise could help individuals lose weight and feel satisfied about themselves while also lowering anxiety and emotional eating [61]. Furthermore, in the VR exposure condition, exposures can be specifically adjusted by the therapist, which can assist patients to cope with stimuli or complex surroundings in a more practical and controlled manner. The ability to monitor the patient's responses is also a benefit over actual exposure [62]. Moreover, it has already been reported that patients may go through their VR exposure hierarchy more quickly due to a sense of improved control and safety [63]. Additionally, VR exposure can aid to disrupt the reconsolidation of negative food/situation memories by reducing the anxiety associated with eating during and after exposure to virtual meals and surroundings [64]. Apart from these benefits, these VR-based devices are affordable and have a strong cost–effectiveness ratio [65].

The increased scientific interest in finding novel therapy alternatives for obesity combined with the rapid technological advancement in the VR field has resulted in breakthrough VR-based applications for evaluating and treating obesity. The use of avatars is one of the most recent technological developments. Therapists employed realistic "avatars" of their patients as a first step in the treatment of obesity because many obese persons have a distorted perspective of their own body, which makes therapy more difficult. The findings of this review imply that incorporating avatar technology into weight reduction therapies results in more weight loss and weight maintenance than standard interventions; however, the differences are not statistically or clinically significant [24–27]. Moreover, avatar personalization may provide a few extra benefits by engaging and maintaining interest and motivation to adhere to a predetermined weight loss program, but the evidence for this is limited [24,48]. Further, discoveries made recently regarding the multimodal nature of body representations have resulted in the invention of novel protocols, such as "bodily illusions." Research on body ownership illusions has recently shifted from the embodiment of a single body part (such as the hand [66,67] or the foot [68]) to the full body. Scarpina et al. (2017) were the first to employ the full body illusion in obese patients [32]. They compared the effects of illusionary ownership over a slim virtual body (i.e., the VR-FBI) on body images in a group of obese people with a group of healthy people. Their studies demonstrated that obese people can effectively experience illusory ownership over a full virtual body, with possible modifications in hip circumference measurement. Consequently, VR-FBI could be a viable tool for use in rehabilitative settings, including obesity [32]. Recent studies have also focused on improving the outcomes of weight management commercial online programs [33] and the immersion of participants in a more realistic representation of space and narrative [34].

One of the important observations that draws attention in this study is the weak participation of males in studies included in this review. This is in accordance with a review study of the management of obesity in males, which indicated that men were less likely than women to participate in mixed-gender weight loss programs [69]. While the reason for women's appetite for weight loss programs appears to be the social pressures they are exposed to, the reasons behind the recruitment gender polarization remains unclear and merit further exploration [69].

It goes without saying that the most important key to the success of weight loss interventions is adherence. However, the common problems that face all weight loss programs are attrition and non-adherence. Attrition in weight loss programs reported rates ranging from 10% to over 80% [70]. It is noted that reasonable recruitment and attrition rates were attained in the studies included in this review. This is inconsistent with another review that suggests a general interest and acceptability of VR as a weight loss tool [57].

The main strength of this study is that it is the first systematic review to focus completely on the use of virtual reality in the treatment of obesity. It includes most research in which VR was utilized to carry out the intervention. However, it has some limitations. First, the vast range of study designs included in this review limits the conclusions that can be drawn. Second, the search was limited to English-language publications, which may not have incorporated all available studies. Third, the time periods of the intervention were heterogeneous, as were the sample sizes, which may have influenced the strength of outcomes and conclusions. Future research could build on these constraints to figure out the best way to use virtual reality in clinical settings to cure obesity.

Although VR for weight loss will undoubtedly continue to advance at a rapid pace in the coming years, the time and price required to perform these trials imply that the results will frequently not be available until the next generation of technology is ready.

Nonetheless, it is critical that this research continues, as there are valuable lessons to be learned about how VR may be utilized to help people lose weight that can be applied to a number of intervention platforms.

5. Conclusions

As the studies in this review demonstrate, virtual reality technology has the potential to be used to assess and treat obesity. Virtual reality has a lot of potential benefits: it is highly interactive, flexible, tailored to the individual, and it fits well with established psychological theory and practice. The evidence that people react to virtual worlds as if they were real is compelling, and patients are generally accepting of the technology. Studies reveal that VR technologies have the potential to promote clinically significant weight loss when used in conjunction with cognitive behavioral procedures or behavioral weight loss therapies; nevertheless, regaining weight is yet a challenge.

The use of VR in the treatment of overweight and obese people is still a developing field that requires additional research. Future research should include more high-quality randomized control trials, with large sample numbers and long-term follow-ups to investigate deeply the effects of VR-based interventions on obesity. Upcoming research should also compare VR-based interventions in more homogenous groups of obese patients with healthy subjects.

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