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Applications of Virtual Reality-Based Exercise in Physical, Cognitive, and Psychological Health: Exploring Usability, Acceptance, and Effectiveness Across Diverse Populations

PhD Dissertation

By

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ABSTRACT

Given the proven difficulty in motivating individuals to exercise, especially if they face health problems or lack of time, the use of new technologies in recent years in this direction is of particular interest. The aim of this dissertation was to examine the effects of Virtual Reality-based exercise on various healthy and clinical populations concerning physical, cognitive, and mental health factors based on their needs, while evaluating its acceptance, usability, tolerance, and interest/enjoyment. We hypothesized that this innovative approach of combining exercise with VR (Virtual Reality) technology could produce positive physical and psychological outcomes across populations and motivate them to be more physically active.

The first study aimed to assess acceptance, intention for future use, interest/enjoyment, and usability of a VR exercise system among 40 female office workers who used it during their work break. Participants completed two consecutive 15-minute dual-task cycling sessions in two experimental conditions: the first involved cycling in a virtual environment while answering cognitive questions, and the second involved cycling on a stationary bike while verbally responding to cognitive tasks. The results showed that participants significantly preferred exercising in the VR environment compared to traditional cycling. High scores were observed for acceptance, interest/enjoyment, usability, and intention for future use. Qualitative data indicated increased intention for future use, a sense of control and presence, and most participants experienced no difficulties or need for extra assistance in understanding the VR system.

The second study aimed to investigate the acute effects of VR-based exercise on attention and self-efficacy expectations in individuals undergoing substance use disorder (SUD) treatment. Twenty participants completed a self-selected duration cycling session with the VR system. After the exercise, measurements showed significant improvements in self-efficacy expectations and attention (assessed via the Stroop test). Results indicated high intention for future use, interest/enjoyment, and positive attitudes toward the VR exercise system. Qualitative data suggested participants found the system enjoyable, had strong intentions for future use, and experienced no technical difficulties or negative emotions.

The third study aimed to investigate the effects of exercise in a virtual environment on biological and psychological parameters in patients with type 1

diabetes mellitus (T1DM) compared to typical exercise, as well as evaluate the acceptance, intention for future use, usability, and preference. Eleven patients completed 20 minutes of cycling on a cycle ergometer and 48 hours later, 20 minutes of VR-based exercise. According to our results, we observed a reduction in blood glucose levels after the VR-based exercise trial. There were, also, significant differences in mood and interest/enjoyment after VR-based exercise trial compared to typical cycling. The results showed high preference, acceptance, and usability of the VR exercise system. Participants found the system enjoyable and reported it as a motivator for physical activity. However, a small percentage stated they would not want to use it for regular exercise. The findings suggest that VR-based exercise can reduce blood glucose levels, improve mood and interest/enjoyment for exercise of T1DM patients. It is also a well-accepted and user-friendly tool to be used in T1DM management exercise programs.

The fourth study aimed to examine the effects of exercise in a VR environment compared to traditional exercise, both combined with Self-Determination Theory-based counseling, on overweight and obese individuals. Forty participants were randomly divided into a VR exercise group (intervention) and a traditional exercise group (control). Both groups received Self-Determination Theory-based counseling for four weeks. Measurements were taken pre and post intervention. Participants in the VR-based exercise group showed significant reductions in BMI, body fat mass, and hip circumference compared to the control group. Additionally, they showed a greater increase in physical activity levels and improvements in psychological factors such as basic psychological needs, self-efficacy, self-esteem, and attitudes toward the exercise and counseling program. Furthermore, the intervention group scored better in terms of interest/enjoyment and attitudes toward exercise compared to the control group, had positive perceptions of the VR exercise system, high ratings for system acceptance (enjoyment, intention for future use), and usability. Qualitative data revealed that the VR-based exercise was more enjoyable and engaging. The findings suggest that exercise using VR combined with counseling is more effective than traditional exercise in reducing weight, increasing physical activity levels, and improving psychological parameters in overweight and obese individuals.

In conclusion, the VR exercise system was well-received and user-friendly by all participants, demonstrating significant benefits across various populations based on their specific needs. As a result, its use is highly recommended for employees, both

during and outside work hours, as it can effectively promote exercise participation and maybe to enhance cognitive functions in individuals with Substance Use Disorder (SUD), support individuals with type 1 diabetes, and serve as a valuable tool for managing obesity.

Based on our encouraging findings, VR exercise systems appear to be an appealing and effective tool for motivating diverse populations to initiate or sustain regular exercise participation. However, the careful and methodical implementation of emerging technologies and VR-based exercise protocols presents a significant challenge, particularly in clinical populations. It is crucial that practical implementations are grounded in rigorous and systematic research. Future studies in this area should aim to expand the scope of application, exploring further possibilities for its use in diverse populations and settings.

Keywords: *Exercise, Physical education, Physical activity, Virtual Reality, Office-workers, SUD, Type 1 Diabetes, Obesity*

ΠΕΡΙΛΗΨΗ

Λαμβάνοντας υπόψη τη μειωμένη παρακίνηση των ατόμων για συμμετοχή σε άσκηση, ιδιαίτερα όταν αντιμετωπίζουν προβλήματα υγείας ή έχουν έλλειψη χρόνου, η χρήση των νέων τεχνολογιών προς αυτήν την κατεύθυνση, τα τελευταία χρόνια, παρουσιάζει ιδιαίτερο ενδιαφέρον. Σκοπός της παρούσας διατριβής ήταν να εξετάσει την επίδραση της άσκησης εντός εικονικής πραγματικότητας (ΕΠ) σε ποικίλους υγιείς και κλινικούς πληθυσμούς σε διάφορους παράγοντες σωματικής, γνωστικής και ψυχικής υγείας με βάση τις ανάγκες τους και να αξιολογήσει την αποδοχή, την ευχρηστία, την ανεκτικότητα και το ενδιαφέρον/ευχαρίστηση από την άσκηση αυτή. Υποθέσαμε ότι αυτή η πρωτοποριακή προσέγγιση του συνδυασμού της άσκησης με την τεχνολογία ΕΠ θα μπορούσε να επιφέρει θετικά σωματικά και ψυχολογικά αποτελέσματα σε διάφορους πληθυσμούς, όπως επίσης και να τους παρακινήσει να είναι πιο φυσικά δραστήριοι.

Η πρώτη μελέτη στόχευε να εξετάσει την αποδοχή, την πρόθεση για μελλοντική χρήση, το ενδιαφέρον/ευχαρίστηση και την ευχρηστία ενός συστήματος άσκησης ΕΠ από 40 εργαζόμενες γυναίκες σε γραφείο, οι οποίες ασκήθηκαν με αυτό κατά τη διάρκεια του διαλείμματος εντός του ωραρίου εργασίας τους. Οι συμμετέχουσες ολοκλήρωσαν δύο διαδοχικές “dual-task” συνεδρίες ποδηλασίας διάρκειας 15 λεπτών η καθεμία, που αντιστοιχούσαν σε δύο πειραματικές συνθήκες. Η πρώτη περιλάμβανε ποδηλασία σε εικονικό περιβάλλον και ταυτόχρονη απάντηση σε γνωστικές ερωτήσεις και η δεύτερη περιλάμβανε ποδηλασία σε στατικό ποδήλατο και ταυτόχρονη απάντηση σε γνωστικές ασκήσεις προφορικά. Τα αποτελέσματα έδειξαν ότι οι συμμετέχουσες προτίμησαν σημαντικά την άσκηση σε περιβάλλον εικονικής πραγματικότητας σε σύγκριση με την τυπική ποδηλασία. Σημειώθηκαν υψηλά σκορ στην αποδοχή, το ενδιαφέρον/ευχαρίστηση, την ευχρηστία και την πρόθεση για μελλοντική χρήση. Τα ποιοτικά δεδομένα έδειξαν αυξημένη πρόθεση για μελλοντική χρήση, αίσθημα ελέγχου και παρουσίας, ενώ οι περισσότερες συμμετέχουσες δεν αντιμετώπισαν δυσκολίες ή ανάγκη για επιπλέον βοήθεια για την κατανόηση του συστήματος ΕΠ.

Η δεύτερη μελέτη στόχευε να διερευνήσει τις άμεσες επιδράσεις της ποδηλασίας σε περιβάλλον ΕΠ στην προσοχή και τις προσδοκίες αυτο-αποτελεσματικότητας ατόμων που βρίσκονται σε θεραπεία διαταραχών χρήσης ουσιών(ΔΧΟ). Συμμετείχαν 20 άτομα που βρίσκονταν σε πρόγραμμα θεραπείας ΔΧΟ και ολοκλήρωσαν μια συνεδρία ποδηλασίας αυτο-επιλεγόμενης διάρκειας με το

σύστημα ΕΠ. Μετά τη συνεδρία άσκησης, οι μετρήσεις που διενεργήθηκαν πριν και μετά έδειξαν στατιστικά σημαντική βελτίωση των προσδοκιών αυτο-αποτελεσματικότητας και της προσοχής, που αξιολογήθηκε με το Stroop τεστ. Τα αποτελέσματα έδειξαν ότι οι συμμετέχοντες εξέφρασαν υψηλά επίπεδα πρόθεσης για μελλοντική χρήση και ενδιαφέροντος/ευχαρίστησης και θετικές στάσεις προς το σύστημα άσκησης ΕΠ. Τα ποιοτικά δεδομένα έδειξαν ότι οι συμμετέχοντες βρήκαν το σύστημα άσκησης ΕΠ ευχάριστο, είχαν έντονη πρόθεση για μελλοντική χρήση και δεν αντιμετώπισαν τεχνικές δυσκολίες ή αρνητικά συναισθήματα.

Η τρίτη μελέτη στόχευε να διερευνήσει τις επιδράσεις της άσκησης εντός εικονικού περιβάλλοντος σε βιολογικές και ψυχολογικές παραμέτρους ασθενών με σακχαρώδη διαβήτη τύπου 1 (ΣΔΤ1) συγκριτικά με τυπική άσκηση και να αξιολογήσει την αποδοχή, την πρόθεση για μελλοντική χρήση, την ευχρηστία και την προτίμησή τους. Συμμετείχαν 11 ασθενείς που υποβλήθηκαν σε 20 λεπτά άσκησης σε στατικό ποδήλατο και 48 ώρες μετά σε 20 λεπτά άσκησης εντός εικονικού περιβάλλοντος. Σύμφωνα με τα αποτελέσματά μας, παρατηρήθηκε μείωση των επιπέδων γλυκόζης στο αίμα μετά τη συνθήκη άσκησης ΕΠ. Επιπλέον, καταγράφηκαν σημαντικές βελτιώσεις στη διάθεση και στο ενδιαφέρον/ευχαρίστηση μετά τη συνθήκη άσκησης ΕΠ σε σύγκριση με την τυπική ποδηλασία. Τέλος, σημειώθηκαν υψηλά σκορ στην προτίμηση, την αποδοχή και την ευχρηστία του συστήματος άσκησης ΕΠ. Τα ποιοτικά δεδομένα έδειξαν ότι δεν υπήρξαν δυσκολίες στη χρήση και την κατανόηση του συστήματος, υπήρχε υψηλό αίσθημα παρουσίας και ελέγχου και οι συμμετέχοντες βρήκαν το σύστημα ευχάριστο και δήλωσαν ότι αποτελεί κίνητρο για τη συμμετοχή τους σε φυσική δραστηριότητα. Ωστόσο ένα μικρό ποσοστό δήλωσε ότι δε θα ήθελε να χρησιμοποιεί το σύστημα αυτό για να ασκείται συστηματικά. Τα ευρήματά μας υποδεικνύουν ότι η άσκηση σε ΕΠ μπορεί να μειώσει τα επίπεδα γλυκόζης στο αίμα, να βελτιώσει τη διάθεση και το ενδιαφέρον/την απόλαυση της άσκησης σε ασθενείς με ΣΔΤ1. Επιπλέον, αποτελεί ένα καλά αποδεκτό και φιλικό προς τον χρήστη εργαλείο που μπορεί να ενσωματωθεί στα προγράμματα άσκησης για τη διαχείριση του ΣΔΤ1.

Η τέταρτη μελέτη στόχευε να εξετάσει τις επιδράσεις της άσκησης σε περιβάλλον ΕΠ σε σύγκριση με την παραδοσιακή άσκηση, και οι δύο συνδυασμένες με συμβουλευτική βασισμένη στη Θεωρία του Αυτοκαθορισμού σε υπέρβαρα και παχύσαρκα άτομα. Συμμετείχαν 40 υπέρβαρα/παχύσαρκα άτομα, τα οποία χωρίστηκαν τυχαία σε ομάδα άσκησης ΕΠ (παρέμβαση) και ομάδα παραδοσιακής άσκησης (ομάδα ελέγχου), με τις δύο ομάδες να λαμβάνουν συμβουλευτική βασισμένη στη Θεωρία του

Αυτοκαθορισμού για 4 εβδομάδες. Μετρήσεις πραγματοποιήθηκαν πριν και μετά την παρέμβαση. Οι συμμετέχοντες της ομάδας άσκησης ΕΠ παρουσίασαν σημαντική μείωση στον ΔΜΣ και στη μάζα σωματικού λίπους, καθώς και στην περιφέρεια ισχίων, σε σύγκριση με την ομάδα ελέγχου. Επίσης, εμφάνισαν υψηλότερη αύξηση στα επίπεδα φυσικής δραστηριότητας και βελτιώσεις σε ψυχολογικούς παράγοντες, όπως οι βασικές ψυχολογικές ανάγκες, η αυτο-αποτελεσματικότητα, η αυτοεκτίμηση και οι στάσεις προς το πρόγραμμα άσκησης και συμβουλευτικής. Επιπλέον, η ομάδα παρέμβασης σημείωσε καλύτερα αποτελέσματα στο ενδιαφέρον/ευχαρίστηση και τις στάσεις προς την άσκηση σε σύγκριση με την ομάδα ελέγχου, είχε θετικές αντιλήψεις για το σύστημα ΕΠ, υψηλές βαθμολογίες στην αποδοχή του συστήματος (ευχαρίστηση, πρόθεση για μελλοντική χρήση) και την ευχρηστία του. Τα ποιοτικά δεδομένα έδειξαν ότι η άσκηση ΕΠ ήταν πιο ευχάριστη και ενδιαφέρουσα. Τα ευρήματα υποδεικνύουν ότι η άσκηση με τη χρήση ΕΠ σε συνδυασμό με συμβουλευτική είναι πιο αποτελεσματική από την παραδοσιακή άσκηση στη μείωση βάρους, την αύξηση των επιπέδων φυσικής δραστηριότητας και τη βελτίωση ψυχολογικών παραμέτρων υπέρβαρων και παχύσαρκων ατόμων.

Συμπερασματικά το σύστημα άσκησης ΕΠ ήταν αποδεκτό και εύχρηστο από όλους τους συμμετέχοντες, παρουσιάζοντας σημαντικά οφέλη σε διάφορους πληθυσμούς, ανάλογα με τις ανάγκες τους. Ως εκ τούτου, συνιστάται η χρήση του τόσο κατά τη διάρκεια όσο και εκτός του ωραρίου εργασίας, καθώς μπορεί να προάγει αποτελεσματικά τη συμμετοχή στην άσκηση και πιθανά να βελτιώσει τις γνωστικές λειτουργίες σε άτομα με ΔΧΟ, να υποστηρίξει άτομα με ΣΔΤ1 και να αποτελέσει πολύτιμο εργαλείο για τη διαχείριση της παχυσαρκίας. Με βάση τα ευρήματά μας, που ήταν ιδιαίτερα ενθαρρυντικά, τα συστήματα άσκησης ΕΠ φαίνεται να αποτελούν ένα ελκυστικό και αποτελεσματικό εργαλείο για την παρακίνηση διαφορετικών πληθυσμών να ξεκινήσουν ή να διατηρήσουν τη συστηματική συμμετοχή τους στην άσκηση. Ωστόσο, η προσεκτική και μεθοδική αξιοποίηση των νέων τεχνολογιών και των πρωτοκόλλων άσκησης μέσω ΕΠ αποτελεί σημαντική πρόκληση, ιδιαίτερα σε κλινικούς πληθυσμούς. Είναι κρίσιμο οι πρακτικές εφαρμογές να βασίζονται σε αυστηρή και συστηματική έρευνα. Μελλοντικές μελέτες σε αυτόν τον τομέα θα πρέπει να στοχεύουν στη διεύρυνση του πεδίου εφαρμογής, εξερευνώντας περαιτέρω τις δυνατότητες χρήσης του σε διαφορετικούς πληθυσμούς και πλαίσια.

Λέξεις κλειδιά: *άσκηση, φυσική δραστηριότητα, φυσική αγωγή, εικονική πραγματικότητα, εργαζόμενοι γραφείου, απεξάρτηση, διαβήτη τύπου 1, παχυσαρκία*

Publication List

Study 1: Published in *Sports Journal*

Touloudi E, Hassandra M, Galanis E, Goudas M, Theodorakis Y. Applicability of an Immersive Virtual Reality Exercise Training System for Office Workers during Working Hours. *Sports (Basel)*. 2022;10(7):104. doi: 10.3390/sports10070104.

Study 2: Published in *Brain Sciences Journal*

Touloudi, E.; Hassandra, M.; Stavrou, V.T.; Panagiotounis, F.; Galanis, E.; Goudas, M.; Theodorakis, Y. Exploring the Acute Effects of Immersive Virtual Reality Biking on Self-Efficacy and Attention of Individuals in the Treatment of Substance Use Disorders: A Feasibility Study. *Brain Sci.* 2024, *14*, 724.
<https://doi.org/10.3390/brainsci14070724>

Study 3: Submitted

Touloudi, E; Stavrou, V.T; Galanis, E; Bargiota, A; Goudas, M; Dafoulas, G; Hassandra, M; and Theodorakis, Y. Virtual Reality versus Conventional Exercise in Patients with Type 1 Diabetes: A Feasibility Randomized Crossover Trial

Study 4: Published in *Frontiers in Sports and Active Living Journal*

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CHAPTER I – INTRODUCTION

Exercise and health

Exercise is widely recognized as playing a crucial role in improving and maintaining individuals' health (WHO, 2024). Systematic participation in physical activity benefits the prevention and management of non-communicable diseases, such as cardiovascular diseases, hypertension, stroke, diabetes, and certain types of cancer. (WHO, n.d). According to the American Heart Association, exercise, and more specifically resistance training or a combination of resistance and aerobic training, can improve cardiovascular disease risk factors and promote cardiovascular health in various clinical and healthy populations (Paluch et al., 2024). Moreover, muscle-strengthening activities were found to be negatively associated with the risk of all-cause mortality and major non-communicable diseases, including cardiovascular disease, total cancer, diabetes, and lung cancer (Momma et al., 2022). Therefore, engaging in regular physical activity is essential for individuals of all ages to maintain and improve overall health and reduce the risk of chronic diseases.

Exercise plays a vital role also in enhancing mental health and cognitive function (Deslandes et al., 2009). Increasing physical activity across populations has the potential to significantly alleviate the burden of mental health issues, offering wide-ranging benefits for both physical and psychological well-being (Schuch et al., 2021). It is particularly effective as a primary treatment for mild to moderate depression, showing comparable results to antidepressant medications, and can further improve symptoms when combined with medication. Exercise offers a cost-effective and efficient approach to managing a range of anxiety disorders (Carek et al., 2011). Research indicates that a single session of aerobic or resistance exercise can lower state anxiety levels in individuals with or without clinical anxiety disorders. Regular physical activity is associated with reduced anxiety symptoms and a lower risk of developing such conditions. Additionally, structured exercise programs, including aerobic and resistance training, can help manage general anxiety symptoms in healthy adults and those with chronic illnesses while also alleviating condition-specific symptoms in individuals with clinical anxiety (Crombie & O'Connor, 2024). Notably, aquatic exercise has shown to decrease depression and anxiety, improve functional independence, and reduce oxidative stress in elderly individuals with depression (Silva et al., 2019). According to Bliss et al. (2021) evidence suggests that exercise can

enhance cerebrovascular health, cognition, and neuroplasticity, particularly in regions of the brain linked to executive function and memory, in adults aged 50 and older, regardless of their health condition. Moreover high-intensity resistance training is effective in boosting both cognitive function and physical performance in older adults experiencing cognitive frailty (Yoon et al., 2018). In addition, Insufficient physical activity is a significant risk factor for illness and early death (Santos et al., 2023). In summary, regular exercise emerges as a powerful and multifaceted intervention that not only enhances physical health by preventing and managing non-communicable diseases but also significantly contributes to mental well-being, cognitive function, and overall quality of life across diverse populations and age groups.

Concluding, according to WHO Guidelines on Physical Activity and Sedentary Behavior, 2020 healthy adults should undertake regular physical activity, at least 150-300 minutes of moderate intensity, or 75-150 minutes of vigorous intensity aerobic physical activity per week or more. They should also do muscle-strengthening activities at moderate or higher intensity for at least twice per week. Moreover, adults should decrease the amount of time spent in sedentary behaviors by replacing it with physical activities (Bull et al., 2020). Conclusively, regular physical activity is a cornerstone of both physical and mental health, offering preventative and therapeutic benefits across a wide spectrum of conditions, from chronic diseases to mental health disorders. By adopting the WHO-recommended guidelines for exercise, individuals can significantly improve their overall quality of life, reduce health risks, and promote long-term well-being.

Exercise and office workers

In the modern era, the increased use of technology has led to a significant reduction in manual labor (European Agency for Safety and Health at Work, 2021). The development of technology has created many opportunities for all workers, including individuals with disabilities, providing them with possibilities at every stage of life and their professional career. Advanced technology and teleworking have reduced the risks associated with hazardous jobs, but they have also brought challenges in defining boundaries between personal life and work, communication issues, and increased psychosocial risks (European Commission, 2021). Additionally, workers are increasingly facing demanding and complex tasks, with higher pressure for speed. A significant percentage report musculoskeletal problems as their main concern related to

work (European Agency for Safety and Health at Work, 2021). The costs arising from occupational diseases are notably high compared to the cost of well-being, which is why the implementation of mental and physical health promotion programs is encouraged (European Commission, 2021).

Many studies focus on the effectiveness of workplace exercise for improving employees' physical fitness, musculoskeletal health, productivity, and mental well-being. The evidence shows that both aerobic exercise and strength training can improve parameters such as body composition, mobility, musculoskeletal health, and cardiovascular fitness, as well as contribute to the prevention of health issues (Barranco-Ruiz & Villa-Gonzalez, 2020). Undoubtedly, exercise in the workplace, especially for office employees, can be beneficial for their physical fitness, functional capacity, maximum strength, lean mass, and musculoskeletal issues. This is important because musculoskeletal pain negatively impacts productivity and increases absenteeism from work (Karatrantou et al., 2020). According to a recent systematic review, workplace exercise interventions seemed to be beneficial for reducing employees' musculoskeletal disorders (Tersa-Miralles et al., 2022). Moreover, neck and shoulder strengthening exercises led to improved work ability (Ting & Johnston, 2019). A systematic review found that the most effective workplace exercise protocols were supervised programs and those incorporating video support. Short-duration sessions, lasting approximately 10–15 minutes, performed 3–5 times per week, were recommended for optimal results (Gobbo et al., 2019). Existing data, also, indicate that mental health improves through individuals' satisfaction with their participation in exercise programs, enhancing their personal relationships (Michishita et al., 2017), and boosting their perception of health (Genin et al., 2017). Additionally, implementing exercise programs in the workplace can lead to short-term cost savings by reducing healthcare expenses and increasing employee productivity (Baicker et al., 2010). Employee participation in exercise programs can lead to positive outcomes in work-related factors, such as reduced absenteeism, improved capability, and enhanced job performance (Grimani et al., 2019).

There are several barriers that prevent employees from engaging in exercise programs, with the most common being lack of time due to demanding work schedules and long hours. Low motivation, insufficient facilities, and the lack of space further discourage participation in physical activity initiatives (Safi et al., 2022). Virtual Reality (VR) exercise systems present an innovative solution to these challenges by

offering short, engaging sessions (10-15 minutes) that can be easily integrated into busy workdays, aligning with the effectiveness of brief workplace exercise interventions (Gobbo et al., 2019; Abdin et al., 2018). Additionally, VR systems can be used in small spaces, such as individual desks, reducing the need for traditional gym facilities and encouraging participation in a non-judgmental and immersive experience. These systems can also increase motivation and engagement, particularly for employees who find traditional exercise programs uninspiring. While existing studies have shown the benefits of workplace exercise for improving employees' physical and mental health, the use of VR-based programs remains underexplored. Incorporating VR and other emerging technologies into the workplace could provide accessible, engaging, and effective ways to enhance employees' physical activity levels and overall well-being.

SUD therapy and exercise

Drug use is a major public health issue with consequences such as substance use disorder (SUD), mental disorders, HIV infection, cancer, liver cirrhosis, hepatitis, overdose, premature death, and impaired cognitive function due to chronic use (United Nations Office on Drugs and Crime, 2020). Addiction, in general, is a disorder that affects how the brain processes information. The brain regions affected by SUD are involved in critical cognitive functions such as learning, memory, attention, reasoning, and impulse control. Chronic drug use can alter brain structure and function, leading to addiction (Nestler, 2013), while also impairing memory and cognitive abilities (Goldstein & Volkow, 2011). Exercise can play a positive role in recovery from SUD by improving attention (Kutlu & Gould, 2016), enhancing cognitive function, and supporting addiction management. Exercise programs appear to reduce cravings and support abstinence while offering multiple benefits, such as relapse prevention, restoration of cardiovascular and muscular systems, reduction of anxiety and depression symptoms, and mood improvement (Ellingsen et al., 2020). At the same time, confidence, self-esteem, and body image are improved, enhancing quality of life and encouraging the adoption of a healthy lifestyle (Rethorst et al., 2021; Panagiotounis et al., 2022). Exercise can also enhance self-efficacy and body awareness, factors that can positively affect the effort of individuals under SUD treatment (Tikac et al., 2022). Additionally, two studies highlight the critical role of exercise (Piché et al., 2023; Theodorakis et al., 2024), with the latter also suggesting that exercise combined with cognitive-behavioral therapy promotes mental and physical health, boosts self-

confidence, and reduces the risk of relapse. Additionally, it is noted that exercise programs, particularly those incorporating techniques for life skills, trust-building activities, support, and adventure, can maximize outcomes if tailored to participants' needs and preferences according to the phase of treatment (Theodorakis et al., 2024). Aerobic exercise during SUD treatment is associated with reduced stress levels, decreased cravings, and mood improvements (Brellenthin et al., 2021). Regarding anaerobic exercise, a systematic review indicates that while existing evidence is limited, there is a trend toward positive effects (Colledge et al., 2018). Current evidence highlights that both mind-body exercises and physical fitness programs are effective in alleviating mental health symptoms, reducing substance cravings, and enhancing overall quality of life in individuals with SUD (Giménez-Meseguer et al., 2020). There are not clear recommendations about the most effective type and intensity of exercise for this population. Individuals with SUD tend to lead highly sedentary lifestyles. Therefore, starting with light to moderate physical activity may be more suitable than vigorous exercise. Moderate-intensity exercise might also result in better adherence, although this remains to be fully confirmed. It is important to take into account the presence of comorbid conditions and the individual's stage of recovery when designing an appropriate exercise program (Linke & Ussher, 2015).

However, individuals with SUD often face several barriers to engaging in regular exercise, including low motivation, fatigue, and a lack of self-efficacy, which are linked to the mental and physical effects of addiction (Nock et al., 2023; Tate et al., 2008). Additional obstacles such as low self-esteem, anxiety about participating in group settings, and difficulties in establishing routines due to instability also contribute to these challenges (Abrantes & Blevins, 2019). VR-based exercise programs offer an innovative solution by providing engaging, immersive, and personalized experiences that can enhance motivation and self-efficacy, helping individuals overcome these barriers. VR allows users to adjust exercise intensity to manage fatigue and physical strain while incorporating relaxation techniques to support mental recovery. Moreover, the individualized nature of VR reduces anxiety about group settings and offers the flexibility to perform exercises in various environments, making it easier to establish consistent exercise routines. As an emerging technology, VR has the potential to revolutionize SUD treatment by integrating physical activity with psychological therapies in a way that increases engagement, supports cognitive recovery, and enhances overall outcomes. However, research on VR-based exercise programs in SUD

treatment remains limited, highlighting the need for further investigation into its efficacy and broader application in this field.

Type 1 diabetes mellitus and exercise

Type 1 diabetes mellitus (T1DM) occurs when the body produces little to no insulin, because of pancreas dysfunction. Insulin is essential for controlling blood sugar levels, so individuals with this condition must administer insulin daily to maintain proper glucose regulation (WHO, 2016). According to Liatis et al. (2016), the prevalence of T1DM in Greece is 0.24%, and this rate has been steadily increasing globally over the years, as noted in the Global Report on Diabetes (WHO, 2016). A key factor in diabetes management is exercise, while it can positively affect cardiorespiratory fitness, blood glucose levels, and lipid profile, while also reducing cardiovascular risk. Different types and intensities of exercise can improve insulin sensitivity and reduce daily insulin dosage (Aljawarneh et al., 2019). According to Reddy et al., 2019 resistance exercise has a potential to improve glycemic control in these patients. Moreover, exercise can positively impact the quality of life for individuals, especially when it is supervised by exercise specialists (Absil et al., 2019). According to Anaruma et al. (2016), patients with T1DM showed reduced blood glucose levels, which were maintained during the recovery period after 30 minutes of aerobic exercise at 40-60% intensity. The heart rate, measured before, during, and after exercise, returned to baseline values 30 minutes post-exercise, while indicators reflecting the integrity of parasympathetic tone did not return to baseline. These findings led to the conclusion that there is an imbalance in the autonomic regulation system, particularly regarding the integrity of the vagus nerve's connection to the heart in patients with T1DM. According to the American Diabetes Association, children and adolescents with T1DM should engage in moderate to vigorous aerobic exercise for at least 60 minutes daily and perform musculoskeletal strengthening exercises at least three times a week. Most adults should engage in at least 150 minutes of moderate-to-vigorous aerobic exercise or 75 minutes of vigorous exercise per week, spread over at least three days. They should also incorporate musculoskeletal strengthening and flexibility exercises 2-3 times per week. Additionally, prolonged sitting should be interrupted every 30 minutes to benefit blood glucose levels. However, special attention should be given to individuals on insulin therapy, as physical activity may cause hypoglycemia if insulin doses or carbohydrate intake are not adjusted accordingly.

Therefore, patients with T1DM should be trained to manage their blood glucose levels before and after exercise based on its intensity and duration (American Diabetes Association, 2022). Psychological factors like stress, depression and negative mood are associated with poor diabetes management and increased levels of blood glucose (McGrady & Horner, 1999). Exercise, and more specifically in moderate intensity, improves mood but also depressive and stress symptoms. However, evidence supports that high intensity exercise may lead to mood deterioration. Thus, exercise can improve diabetes management indirectly while it improves mood and decreases stress and depression symptoms (Peluso & Guerra de Andrade, 2005).

Individuals with T1DM often face barriers to regular exercise, including concerns about blood glucose fluctuations, the risk of hypoglycemia, lack of motivation, and difficulties maintaining a consistent routine due to time constraints or other health issues (Aljawarneh et al., 2019; Alobaid et al., 2023). VR-based exercise programs can provide controlled environments that allow individuals to monitor and adjust their blood glucose levels before, during, and after exercise. The immersive nature of VR can also enhance motivation and engagement, especially for individuals who struggle with routine adherence or lack social support. Additionally, new technologies, such as wearable devices and apps that track glucose levels and provide real-time feedback on exercise intensity, can further optimize diabetes management, improve safety, and encourage consistent exercise participation. While traditional exercise has shown positive effects on T1DM management, VR-based exercise offers the potential for more personalized and controlled environments that address both the physical and psychological factors, such as stress and depression, commonly associated with T1DM. Moreover, VR's interactive and immersive experience may particularly benefit younger populations by increasing engagement and adherence to exercise regimens. Thus, research into VR-based exercise approaches is crucial for improving diabetes management and enhancing long-term health outcomes.

Exercise and obesity

According to the World Health Organization (WHO), overweight and obesity are defined as abnormal or excessive fat accumulation that poses health risks. A person is classified as overweight with a Body Mass Index (BMI) above 25, while a BMI exceeding 30 indicates obesity (WHO, 2024). Obesity is often a multifactorial condition influenced by environments that promote weight gain, psychosocial factors,

and genetic predisposition. However, in a subset of individuals, specific primary causes can be identified, such as certain medications, underlying diseases, physical inactivity, medical treatments, or genetic disorders (WHO, 2024). Obesity is a significant risk factor for numerous non-communicable diseases (NCDs), including diabetes, cardiovascular diseases, and certain types of cancer (World Obesity Atlas, 2024).

Obesity is also associated with various mental health issues, such as depression (Morres et al., 2023), reduced quality of life (Stephenson et al., 2021), and dissatisfaction with body image (Weinberger et al., 2016). Many obese individuals experience psychological distress due to weight stigma and discrimination. This stigma often contributes to weight gain and worsened health outcomes, making its eradication essential (Tomiya et al., 2018). This may lead individuals to avoid participating in physical activity and sports, as it affects their enjoyment of exercise and thoughts about their appearance (Bevan et al., 2021). Given these serious health impacts, the development of effective obesity management strategies is crucial.

Physical activity is a fundamental component of obesity treatment. Beyond promoting weight loss by increasing energy expenditure, it also enhances metabolic and cardiovascular health. Participation in exercise programs can improve cardiorespiratory health, muscle strength, quality of life, and consistent engagement in physical activity. Furthermore, it provides significant brain health benefits, such as enhancing sleep quality and reducing symptoms of depression (Pojednic et al., 2022).

According to Stone et al., 2021, 300 minutes of physical activity per week can be effective for weight loss and maintenance. In general, lifestyle changes including participation in exercise programs and reducing calorie intake by following a proper nutrition plan can improve weight loss (Stone et al., 2021). Individuals can participate in various types of exercise to manage obesity. Moderate intensity aerobic exercise programs are recommended for weight loss, fat reduction and blood pressure improvements. Programs that combine moderate-intensity aerobic exercise with moderate-to-high intensity resistance training are particularly recommended for adults aiming to achieve these health goals (Oppert et al., 2021). Combined aerobic and resistance exercise can lead to improvements in cardiometabolic and mental health indicators (Al-Mhanna et al., 2024). However, other researchers argue that high-intensity interval training (HIIT) can significantly improve mental health indicators in overweight and obese adults, with improvements equal to or even greater than those observed with moderate-intensity exercise (Batrakoulis & Fatouros, 2022). Therefore,

according to researchers, regular exercise aids in weight loss and its maintenance, with endurance training being one of the most effective exercise methods (Petradiou et al., 2019).

Individuals with obesity often encounter barriers to regular exercise, such as physical discomfort, low motivation, negative body image, and fear of judgment or stigma, which can discourage participation in physical activity (Bevan et al., 2021; Tomiyama et al., 2018). VR-based exercise can address these barriers by offering a private, engaging, and non-judgmental space for exercise, thus enhancing motivation and providing customized programs suited to individual fitness levels. While traditional exercise methods for obesity management have been well-studied, VR-based exercise has yet to be fully explored as a treatment approach. By combining physical activity with immersive virtual environments, VR may offer a novel and motivating solution, particularly for individuals who struggle with conventional exercise. Additionally, VR-based exercise provides an enjoyable, accessible alternative to traditional methods, supporting weight management and improving adherence to exercise programs for individuals with obesity.

Psychological factors in enhancing exercise participation

Adherence to exercise programs is crucial for sustaining the health benefits of physical activity, and a range of psychological factors contribute to it. Increased self-efficacy is an important factor that can lead individuals to increase their participation in exercise programs (Caetano et al., 2020). Exercise self-efficacy is also associated with exercise behavior, and the beliefs formed during an intervention can play a key role in maintaining a regular exercise routine (Neupert et al., 2009). According to Theodorakis (1996), self-efficacy and goal commitment can influence exercise performance. Exercise self-efficacy acts as a mediator between goal-setting and increased physical activity. Physical activity promotion programs should be designed to boost participants' confidence in their ability to engage in exercise (Iwasaki et al., 2017). Thus, another fundamental factor that promotes physical activity participation and healthy lifestyle is goal-setting. It is crucial to encourage individuals to remain physically active and guide them in setting goals to initiate or sustain regular exercise for successfully managing their conditions. Regarding the types of goals, according to a study, SMART goals led to the highest levels of positive emotions and enjoyment in

active adults, while open-ended goals resulted in the most pleasure and enjoyment for insufficiently active adults (Hawkins et al., 2020). Moreover, the ability to choose the duration and intensity of exercise allows for flexibility, enabling interventions to be customized according to individual preferences and needs. This personalized approach can improve adherence to exercise programs, ensuring that participants are neither overburdened nor under-stimulated. As a result, by engaging in these programs, individuals can achieve improved physical and mental health outcomes (Abrantes et al., 2019). Verbal encouragement and use of motivational phrases during exercise can also be beneficial. According to Sahli et al. (2020) verbal encouragement can improve physical aspects, psychophysiological response, enjoyment and mood of individuals during exercise (Sahli et al., 2020; Romdhani et al., 2024). Additionally, literature supports that engaging in a variety of physical activities is linked to greater enjoyment and increased participation in it. Offering to individuals the chance to try different activities could help them discover what they enjoy and support the development of long-term physical activity habits (Michael et al., 2015). Motivation theorists suggest that when individuals view exercise as an enjoyable activity, it leads to positive outcomes such as increased enjoyment, higher motivation, a greater intention to continue, and persistence in exercising (Rodrigues et al., 2020). Therefore, by engaging in enjoyable and stimulating types of exercise or physical activity, such as exergames or VR-based exercise, individuals are more likely to stay motivated and continue exercising.

New Technologies in Exercise Environments

The use of technology to promote physical activity has its roots in the introduction of personal electronic devices, with the pedometer often considered one of the earliest examples. According to a meta-analysis, providing older adults with physical activity trackers increased their levels of physical activity and enhanced mobility, although it did not significantly impact their quality of life (Oliveira et al., 2020). Another study found that long-term use of activity trackers depends on how individuals see the future benefits of tracking data, their spontaneous engagement, and the sense of empowerment they experience. However, positive behavior changes were closely tied to their ability to set personal goals before using the trackers (Karapanos et al., 2016). These results, along with findings by Ryan and Deci (2000), emphasizing

that while enjoyment and spontaneous engagement can make exercise more appealing, reflecting on personal goals and finding intrinsic value in the activity are essential. Nowadays, enjoyment can be enhanced by the use of Virtual Reality (VR) environments in exercise. A recent review highlights that physical activity through exergames significantly boosts positive emotions. These findings support that exergames can be used not only as a leisure activity for well-being and emotional regulation but also as a valuable tool in health promotion, public health, and clinical settings (Marques et al., 2023). Research supports that VR systems are enjoyable for users and can serve as an effective tool to boost exercise participation, helping individuals meet health-related exercise guidelines (Dębska et al., 2019). Virtual reality, also, offers numerous benefits in rehabilitating patients with diverse conditions, such as enhancing motivation, tailoring programs to individual needs, providing data storage and remote access, and reducing overall healthcare cost (Burdea et al., 2003). VR-based exercise is not only enjoyable and motivating, but also can help individuals to overcome exercise participation barriers. For instance, according to a study, immersive VR can be an effective short-term pain relief method that, when integrated with exercise, can help address these challenges (Wender, 2022). Moreover, a systematic review found that technology-based exercise programs demonstrate strong adherence and may offer a lasting approach to encouraging physical activity among older adults (Valenzuela et al., 2018). Literature also supports that VR interventions can reduce symptoms of anxiety and depression, fatigue and pain compared with standard care (Ioannou et al., 2020). Another study found that VR positively influenced emotions and cognition, reducing negative emotions and enhancing positive ones. High presence in VR scenes, especially with interactive activities, was key to these effects. VR environments proved effective in improving emotions, cognition, and self-efficacy in individuals with mild-to-moderate anxiety and depression, with notable activation of the prefrontal lobe. These findings highlight the potential of VR in mental health support and cognitive recovery (Li et al., 2021). Overall, VR-based exercise has the capability to positively influence an individual's physical health, mental well-being, and rehabilitation outcomes, offering advantages over traditional exercise methods (Qian et al., 2020).

Virtual Reality

Virtual reality (VR) is a computer-generated simulation of a real or imagined 3D environment that allows users to explore and interact with it. The environment is created using computer software, and users often wear devices such as glasses, headphones, or suits to interact with it. The more users can immerse themselves in the virtual environment and block out the physical world, the more they may accept it as real, even if it seems unrealistic. The VR industry aims to create fully immersive environments that engage multiple senses in ways that mimic reality (TechTarget, n.d.) Extended reality (XR) is an umbrella term that includes augmented reality (AR), virtual reality (VR), and mixed reality (MR). In AR, interactive objects are placed in the real world but cannot be manipulated. VR immerses the user in a digital experience, cutting off contact with the real world. MR combines elements of both AR and VR, blending the real and digital worlds so that physical and digital objects can coexist and interact in real-time (TechTarget, n.d.)

Some devices used for virtual reality (VR) environments include head-mounted displays (HMDs), caves, gloves, 3D mice, space balls, video cameras with shadows, voice recognition systems, biological sensors, and full-body suits (Gandhi & Patel, 2018). These tools enable users to interact with the virtual world, enhancing immersion and engagement.

The recent years, VR systems are becoming more accessible and affordable for a wider audience globally. Recent technological advancements, such as the widespread adoption of smartphones, have greatly improved access to VR for the general public. Moreover, major corporations have significantly increased their investments to enhance the accessibility of these technologies in the coming years. Many domains are poised to benefit greatly from the improved accessibility of virtual technologies. The growing availability and affordability of VR technology hold the potential to revolutionize many areas like education, exercise, rehabilitation etc., breaking down the barriers and opening up new possibilities for immersive, interactive experiences (Martín-Gutiérrez et al., 2017).

Advantages and disadvantages

In recent years, VR has been widely used in various fields such as education, training, prevention, and rehabilitation. The advantages it offers are diverse, such as

enhancing "immersion", creating a sense of "presence," providing a sense of reality and integration, and improving spatial perception (Maroukakis et al., 2023). Its use allows for the creation of complex scenarios and experiments that are difficult to implement in the real world, reduces their cost and implementation time, and allows for their repetition multiple times. Additionally, it enables users to gain confidence in applying technical procedures and activities, allowing them to perform exercises in any space and time with increasing difficulty and safety. Furthermore, it has the ability to adapt and apply to various fields and allows communication and collaboration with individuals who are not in the same location (Paszkievicz et al., 2021).

However, the use of VR also carries certain risks, such as addiction to the virtual world, potential health problems, or the limitation of interpersonal interactions and experiences (Paszkievicz et al., 2021). A key disadvantage often cited in the literature is "cybersickness". Cybersickness is a phenomenon resulting from exposure to virtual environments, which can cause symptoms like nausea, dizziness, and disorientation. It is usually influenced by factors such as user characteristics, software and device quality, exposure time, control, and movement (Li et al., 2023). Additionally, VR replicates reality better or worse but cannot fully replace it, which can result in the disregard of basic laws of physics and the absence of real consequences for mistakes made. Finally, creating an appropriate virtual environment based on professional materials and software, with numerous scenarios and details, requires a lot of work and increased costs. There is also a lack of ready-made educational scenarios and applications (Paszkievicz et al., 2021).

Compared with real world

Several studies have compared VR to the real world in terms of individuals' responses. According to Ulsamer et al. (2020), who applied functional near-infrared spectroscopy (fNIRS) in experiments both in the real world and in virtual environments, no differences in brain activity were observed. Additionally, a 2023 systematic review supports that virtual reality technologies, such as those using head-mounted displays, are preferable for human behavior experiments compared to computer screens (Hepperle & Wolfel, 2023). Another similar study concluded that virtual reality leads to a higher sense of presence, engagement, and privacy, as well as more enjoyment compared to two-dimensional (2D) experiences. Overall, increased arousal was observed during the use of virtual reality. These findings provide important insights

into the use of virtual reality technology in education, shaping our understanding of its effects on users (Kuhne et al., 2023).

Use of VR

VR is increasingly used for various purposes such as entertainment, education, training in practical scenarios, therapeutic purposes, health-related topics, sports, fitness, and wellness (<https://virtualspeech.com/blog/vr-applications>). Its use in exercise can enhance athletic performance, increase engagement and enjoyment in exercise programs, and provide competitive interaction between individuals not in the same space. Additionally, VR is suggested to lead to increased effort, improved mood, and enhanced cognitive functions compared to control conditions (Neumann, 2016). VR can be used for training and practicing sports skills. For example, beginner golfers trained in both real and virtual environments and showed comparable improvements in performance. It is suggested that the core structures of skills learned in VR can transfer to real-life situations. However, perceptual limitations may pose constraints on its use (Harris et al., 2020).

Combination of exercise and VR

Integrating exercise into a VR environment is an innovative approach. Numerous studies have been conducted to demonstrate the benefits of VR-based exercise programs across various populations. According to the researchers, individuals can exercise through VR systems and respond realistically to virtual stimuli just as they would in real life (Tierl et al., 2018). This type of exercise is considered suitable and can lead to positive effects on physiological, psychological, and rehabilitation factors compared to traditional exercise (Qian, McDonough & Gao, 2020). A factor that contributes to the growing interest in VR-based exercise programs from other professionals is the fact that, nowadays, a sedentary lifestyle is one of the major global health issues and is linked to many chronic conditions, including mental health disorders, hypertension, metabolic syndrome, and cancer. Although health organizations recommend participation in physical activities, a disproportionately large percentage of individuals lead a sedentary lifestyle, even though they are aware of the health benefits that exercise offers. One of the main factors leading to these behaviors is the lack of motivation. Thus, technology has contributed to finding new alternatives

for exercises that may help people adopt a healthier lifestyle. One of these is exergames, which have many advantages, are easy to acquire, and are user-friendly. These video games are not only a potential strategy for reducing sedentary behavior, but also a good method for improving health and rehabilitation for populations with various conditions. The aim of a review was to demonstrate that the use of such games for health promotion is supported by the literature. According to the results, it is concluded that since exercise is considered to have therapeutic effects on chronic conditions, combining it with VR could enhance therapeutic outcomes. Particularly in certain cases, such as improving cognitive functions in the elderly, increasing balance, and enhancing functionality (Silva et al., 2018). According to another study, exercising in VR environment participants reported that they had more energy and felt less tired, compared with control group (Plante et al., 2003). A recent study, compared existing research and commercial VR-based exercise applications made a taxonomy and highlighted key similarities and differences, reflecting the distinct priorities and goals of each domain. The results revealed that research applications focus on scientific precision and the development of specific skills under controlled conditions, whereas commercial applications emphasize fun, motivation, and competitiveness, catering to a broader audience. Additionally, the study revealed that many VR applications effectively support learning but not social aspects (Elsholz, Pham, & Zarnekow, 2025).

VR-based physical and cognitive training

The combination of motor and cognitive tasks is very common in our daily life. According to MacPherson (2018), "dual-task" refers to the ability to perform two tasks simultaneously and measures a component of executive function, as participants are required to focus their attention on both tasks while performing them. According to studies, dual-task conditions can improve the diagnosis, prevention, and management of cognitive decline and falls (Bayot et al., 2018). Specifically, evidence shows that movement and posture involve both motor and cognitive functions. According to Yogev-Seligmann et al. (2008), during the execution of a dual-task, one or both tasks are impaired, unless the cognitive demand is very low. However, if the motor skill is automated, performing another task simultaneously may not affect performance. In older adults, when simple tasks are less automated, dual-task demands may increase.

Therefore, dual-task can serve as a useful indicator of cognitive decline and fall risk, as it can exacerbate cognitive or motor impairments (Bayot et al., 2018).

Exercising in VR has been shown to enhance both physical and cognitive function in older adults, while also boosting their enthusiasm and enjoyment (Sakhare et al., 2019). The combination of exercise in a virtual environment with cognitive training is increasingly being studied by researchers, particularly in patients with mild cognitive impairment. Hassandra et al. (2021) used a VR exercise system that included cognitive questions, designed for patients with mild cognitive impairment. According to the results, this system was acceptable, user-friendly, and well-tolerated by the patients, and it could be used to promote engagement in physical activity, thereby enhancing both their physical and cognitive health.

There is evidence showing that VR-based exercise can lead to numerous physical, cognitive and psychological benefits. Its combination with some psychological theories like Self-Determination Theory can increase more effectively motivation and adherence. More specifically, autonomy can be increased by the customizable features, allowing participants to select the intensity and duration of their exercise and also the landscape and music, empowering their sense of control. Feedback about their performance and progress can enhance their competence. Relatedness can be covered by creating exercise groups in the virtual world (Ryan & Deci, 2000).

The combination of dual-tasking and psychological theories can directly influence enjoyment and make exercise feel less like “chore” and more like an enjoyable activity, reducing dropouts (Mouatt et al., 2020; Tang et al., 2016). By covering basic psychological needs and incorporating cognitive engagement, individuals may stay motivated and maintain exercise participation and also be prepared for better reply to everyday challenges.

Aim and innovation

To the best of our knowledge, there are no studies in the literature evaluating psychological and physical parameters, as well as acceptance, usability, intention for future use, and enjoyment of exercise in a virtual reality environment among the aforementioned populations. This approach can highlight the flexibility and adaptability of VR exercise systems to cover the physical, psychological and/or cognitive needs of a wide range of different populations. Furthermore, the studied

populations have a need for participation in physical activity. However, the existing literature indicates that, for various reasons, these populations either do not engage in exercise or struggle to adhere to an exercise program. This innovative and appealing exercise approach can address common exercise participation barriers as lack of interest and motivation, time constraints and low self-efficacy. VR-based exercise includes gamified elements and interactive environments, and its immersive nature can lead to increased exercise participation. Moreover, the detailed assessment of acceptance, usability and interest/enjoyment adds a critical dimension to understanding how VR systems can be effectively implemented in real-world settings, while user preferences and challenges can provide significant insights for the design of future interventions.

This dissertation contributes to the advancement of knowledge regarding the motivation of these populations to engage in exercise. It aims to examine the effects of exercise within a virtual environment on diverse populations based on their specific needs, evaluate the role of VR in their treatment by improving physical or mental health parameters, and assess acceptance, usability, interest/enjoyment, and their intention for future use of this system as an alternative form of exercise. In Greece, the use of VR for regular exercise is not as widespread as in other countries, primarily due to the cost of the equipment. However, the cost is steadily decreasing worldwide, which indicates that it will soon become accessible to everyone, much like most new technologies. Therefore, this dissertation represents an innovative contribution. By combining innovative VR applications with well-established psychological frameworks, this dissertation represents a significant step forward in the field of exercise science because it not only validates VR as an effective tool for exercise of diverse populations, but also highlights the unique benefits this type of exercise can offer to them.

Hypotheses

Based on the existing literature and the objectives of this dissertation, it is hypothesized that:

- The implementation of VR-based exercise will enhance physical, psychological and cognitive aspects of diverse populations.
- The VR exercise system will be well-accepted, enjoyable, user-friendly and offer high interest/enjoyment and thereby increasing motivation and adherence to physical activity across diverse populations.

More specifically, it is hypothesized that VR-based exercise will be preferred over traditional exercise among office workers and they will report higher levels of interest/enjoyment and acceptance. VR -based exercise will improve attention and self-efficacy expectations in individuals undergoing SUD treatment and they will express high levels of enjoyment and intention for future use. VR-based exercise will result in greater reductions in blood glucose levels and improvements in mood compared to traditional exercise in patients with T1DM and they will report high usability and interest/enjoyment of the VR exercise system, with most viewing it as a motivator for physical activity. Finally, it is hypothesized that VR-based exercise, combined with counseling, will lead to greater reductions in BMI, body fat, and hip circumference than traditional exercise and the VR group will show greater improvements in psychological factors such as self-efficacy, self-esteem, and attitudes toward exercise.

Overall, new technologies, particularly VR, are increasingly being utilized across various fields, including education, exercise, rehabilitation, and prevention. The application of VR offers numerous advantages in all areas where it has been studied, despite the higher initial cost of the equipment. It is well-established that exercise plays a critical role in maintaining and promoting both physical and mental health, benefiting both healthy individuals and clinical populations. Combining VR with exercise represents a highly innovative approach that has the potential to amplify the benefits of physical activity. Additionally, the immersive and engaging nature of VR can significantly enhance motivation and adherence to exercise programs, making it an appealing tool for promoting long-term participation and improving overall health outcomes. Therefore, it is worth studying the effects of VR-based exercise in various factors of many different populations.

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CHAPTER II – STUDY 1

Applicability of a virtual reality system on office workers during working hours

Touloudi E, Hassandra M, Galanis E, Goudas M, Theodorakis Y. Applicability of an Immersive Virtual Reality Exercise Training System for Office Workers during Working Hours. *Sports (Basel)*. 2022;10(7):104. doi: 10.3390/sports10070104.

Abstract

Virtual reality is a computer-generated simulation of a real or imaginary three-dimensional environment, that has entered our lives, particularly for gaming. Lately, it is permeating into many aspects of our everyday life, like exercise. It is important to ascertain whether exercise in a virtual reality environment can be accepted from employees and lead to positive outcomes for them. The aim of this exploratory study was to examine the acceptance, future adoption, interest/enjoyment and usability of a virtual reality system for exercise training by office workers during breaks of their working hours. A total of 40 female employees participated in the study with mean age 42.58 years (SD 10.77). Participants were requested to complete two sequential 15-minute dual task cycling sessions corresponding to two experimental conditions. The first condition (A) involved cycling in a virtual environment, wearing a virtual reality mask, and responding to cognitive tasks by answering multiple choice questions - on a screen, using a joystick. The second condition (B) involved cycling on a static bicycle and simultaneously responding to cognitive tasks by answering multiple choice questions in real environment. After completion of the two conditions, participants responded to a series of scales regarding each of the experimental conditions and to a semi-structured interview. The results showed that participants noted a significant preference for the virtual reality exercise condition A, compared to condition B (bike only); and their acceptance, interest/enjoyment, usability and intention for future use were high. The qualitative data showed increased intention for future use, feelings of control and presence and most of the participants didn't encounter any difficulties or needed extra help to understand the virtual reality system. Overall, exercising during working hours with a virtual reality exercise system was well perceived by office workers and applicable. However, the effects of the virtual reality training system on physical and mental health and the employees' adherence to the exercise program should be tested with a longer intervention program.

Keywords: VR exercise system, office workers, sedentary, acceptability, usability

Introduction

According to the World Health Organization (WHO) a great percentage of adults don't regularly meet the recommendations of physical activity needed to maintain or improve their health. This has as a result poor health outcomes like all-cause mortality, cardiovascular disease, type-2 diabetes, but also poor mental health and low general well-being. A strong recommendation is to limit the amount of sedentary time by replacing it with any intensity of physical activity (WHO, 2020). The American College of Sports Medicine (ACSM) recommendation about physical activity is the daily goal of 30 minutes or more of moderate intensity exercise. To attain the daily goal, individuals can have multiple 10-minute or more bouts of exercise (Garber et al., 2011). Many studies have examined the effects of short bouts of exercise versus one continuous bout per day. According to the results, multiple short sessions may enhance adherence to the exercise program, help to the weight loss and show similar improvements in cardiorespiratory function compared with the long session (Jakicic et al., 1995). In sedentary adults, multiple 10-minute sessions of exercise may have positive effects in fitness and health benefits (Lee et al., 2000).

Specifically, according to a recommendation of WHO, it is crucial for the sedentary employees' health to take a break from their job and exercise for 10-15 minutes. Regular exercise can lead to positive effects not only for the overall health of employees, but also to help them be more productive and decrease absenteeism. Employees can include multiple 10-minute or more exercise bouts in their daily program to meet the WHO recommendations (>30 min per day) (WHO, 2020).

Currently, increased computer use has replaced manual work to a good extent (European Agency for safety and health at work, 2021). The development of technology offered new opportunities to all employees, included the disabled ones, for all stages of their lives and careers. Also, the advanced technology and remote work reduced the risk of dangerous tasks, but led to difficulties of determination of the boundaries between private life and work, lack of communication and generally psychosocial risk (European Commission, 2021). Additionally, employees face increased demands for performing faster and more complex tasks. A great percentage of employees report musculoskeletal disorders as the most serious work-related problem (European Agency for safety and health at work, 2021). The costs of work-related illnesses are high,

compared with the cost of wellbeing, therefore mental and physical health promoting programs are encouraged (European Commission, 2021).

Many studies have been focusing on the efficacy of exercise in the workplace to improve the employees' physical health, fitness, musculoskeletal problems, their productivity and mental health. Evidence shows that both endurance and muscle strengthening exercise can improve employees' health parameters like body composition, motor, musculoskeletal and cardiorespiratory fitness and prevent health issues (Barranco-Ruiz & Villa-Gonzalez, 2020). Undeniably, exercise in the workplace, especially for the white-collar workers, can be beneficial for many parameters of their physical health, like their fitness level, functional capacity, maximal strength, fat-free mass and musculoskeletal problems. This is very important because musculoskeletal pain has a negative effect on productivity and increases absenteeism (Karatrantou et al., 2020). Simultaneously, evidence shows that mental health can be improved because individuals showed satisfaction for their participation to training programs, improved their personal relationships (Michishita et al., 2017) and the perception about their health was increased (Genin et al., 2017). Additionally, implementing exercise programs in the workplace, can lead to short-term financial savings by reducing healthcare costs and increasing the productivity of employees (Baicker et al., 2010). Work-related factors like absenteeism, workability and work performance can also show positive effects from the employees' participation to exercise programs (Grimani et al., 2018).

Virtual reality (VR) is a computer-generated simulation of a real or imaginary three-dimensional environment. According to researchers, individuals can exercise through the VR system and respond realistically to the virtual stimuli just like in real life (Tierl et al., 2018). The VR training is considered appropriate and can lead to positive effects in physiological, psychological and rehabilitation factors compared to conventional exercise (Qian et al., 2020). Additionally, it is a feasible way of exercising and a powerful asset to increase physical and cognitive activity in both young and old individuals, since the elderly reported similar experiences with the younger adults (Sakhare et al., 2019). So, a VR exercise program can be used for different ages, not only for aerobic, but also for muscle strengthening activities (Feodoroff et al., 2019).

Recently, virtual reality is widely used for many reasons, like rehabilitation, training and prevention. For instance, exercise in a virtual environment has been used to help obese children to reach health recommendations (Polechonski et al., 2020), and

healthy adults to improve balance and decrease the risk of falls (Prasertsakul et al., 2018). Additionally, training in a virtual reality environment has been used from coaches to their athletes, especially in team ball sports, to fit them properly for any situation in the field (Faure et al., 2020).

A recent survey supports that since exercise is considered to have therapeutic effect in chronic diseases, a combination of virtual reality and exercise can enhance the therapeutic results (Silva et al., 2018). At the same time, VR exercise programs have a positive effect on cognitive ability, attention, memory but also to non-cognitive factors like depression and anxiety (Ge et al., 2018). The combined exercise with cognitive training in a VR environment has increasingly been studied, especially in patients with mild cognitive impairment symptoms. Hassandra et al., 2021 employed a VR system including physical and cognitive training to exercise patients with mild cognitive impairment. Their results showed that the system was acceptable, usable and tolerable from patients and maybe it could be used to promote their physical and cognitive health. Moreover, evidence shows that VR exercise can lead to positive effects for mental health, particularly on depression and anxiety symptoms (Zeng et al., 2018).

Combined motor and cognitive dual-task is very common in our everyday life. According to studies (Bayot et al., 2018) dual-task situations can improve diagnosis, prevention and management of cognitive impairment and falls. Specifically, evidence shows that movement and posture include motor and cognitive components. According to Yogev-Seligmann et al., 2008 (Yogev-Seligmann et al., 2008) during dual-tasking, one or both tasks are deteriorated, except for the situation when the cognitive demanding is very low. However, if the motor skill is automated, the simultaneous execution of another task may not affect the task performance. In older adults, when simple tasks are less automatic, dual task costs may be increased. Hence, dual-task can become a useful clinical marker of cognitive impairment and fall risk, because it can worsen cognitive or motor disfunctions (Bayot et al., 2018).

In the present study, a VR training system was selected to be used by sedentary workers, as an exercise option during working hours. One of the reasons of the selection of the VR bike is that it is a safe and attractive way to exercise in the workplace during the work break. Additionally, it's not time consuming, employees can choose their exercise duration by themselves and the cost is lower compared with a gym room in the workplace. Thus, in this way employees can take advantage of their work break to exercise.

The VR training system used is called VRADA (VR exercise App for Dementia and Alzheimer's patients), Version 4.1. This VR system (Version 3.7) was used with university students and patients with mild cognitive impairment as a dual task training aimed promote their physical and cognitive health and assess its acceptability, tolerability and usability (Hassandra et al., 2021). The results of this study were very encouraging, so it could be interesting to assess its applicability in different populations. The VRADA system has advantages that can meet the needs of employees, like lack of time to exercise. Additionally, it is a very pleasant and attractive way to exercise and it might also be applicable to the employees, to have short breaks from work to exercise in their workplace, in order to maintain their physical health and avoid the negative effects from their sedentary work.

Virtual reality systems have recently started to be used in workplace environments for workers' stress reduction, relaxation, wellbeing improvement, work safety and work-related duties and thoughts distraction and showed great expectation and supporting of the VR intervention (Naylor et al., 2019; Ahmaniemi et al., 2017; Grassini et al., 2020). However, we have not detected a study that compared the perceptions of office workers regarding a VR exercise system versus a static bicycle during the working hours for training during working time. Therefore, the aim of this study was to examine the applicability of a VR exercise system (compared to condition B: bike only) that allows office workers to exercise during their break of working hours. More specifically we explored the employees' acceptance, future adoption, interest/enjoyment and usability of the VR training system, because it can be used as a motivational tool for them to be more physically active. We expect that participants will prefer and enjoy the VR training condition compared to the bike only condition. The novelties of this study are new data for the acceptance, usability, future adoption, interest/enjoyment of office workers towards the VR training system during their working hours.

Materials and Methods

Participants and setting

A total of 40 female office workers participated in this study. They ranged in age from 20 to 61 years old, with mean age 42.58 years (SD 10.77). Their educational level, habits of physical activity and technology use are presented in Table 1. The setting was administration offices in a public sector organization, in Volos, a city in

central Greece. The administration offices employ 202 office workers, with 65 men and 137 women.

Table 1. Educational Level, Habits Of Physical Activity And Technology Use

Baseline Characteristic	n	%
Educational Level		
Secondary Education	5	12.5%
Higher Education	35	87.5%
Exercise Program		
Yes	17	42.5%
No	23	57.5%
Times Per Week		
One Time Per Week	2	5%
Two Times Per Week	4	10%
Three Times Per Week	7	17.5%
Four Times Per Week	2	5%
Five Times Per Week	6	15%
Six Times Per Week	2	5%
Hours Per Time		
45 Minutes	5	12.5%
1 Hour	14	35%
1,5 Hours	4	10%
Phone Use		
Never	1	2.5%
1-2 Hours Per Day	17	42.5%
3-4 Hours Per Day	16	40%
5-6 Hours Per Day	4	10%
Up To 6 Hours Per Day	2	5%
Pc Use		
Never	2	5%
1-2 Hours Per Day	5	12.5%
3-4 Hours Per Day	4	10%
5-6 Hours Per Day	5	12.5%
Up To 6 Hours Per Day	24	60%
Video Game Use		
Never	35	87.5%
1-2 Hours Per Day	5	12.5%

Ethics approval and consent to participate

A permission for the study was granted by the institution's ethics committee (approval number: 1829, 13 October 2021). The confidentiality of personal data will be assured with regulation (EU) 2016/679 (General data protection regulation). The

participants were informed orally for the procedure, provided written information and signed the consent form. Additionally, they were encouraged to ask questions and they received complete and detailed answers.

VR system (Apparatus and application)

A cycle-ergometer (stationary seated bike type; Toorx, Chrono Line, BRX R 300) with Bluetooth capability has been used for the measurements, as an ideal solution for the participants to control their training conditions and minimize the risk of falls. The cycle-ergometer was connected with the VR application which includes motivational techniques to address the issue of low motivation to exercise and the VR mask and joysticks (Oculus Quest 2). (Figure 1, Figure 2) For example, participants could choose their exercise goal (exercise duration), have feedback for their training performance (cycling time, total distance, correct answers on cognitive exercises), task crafting (selection of music to enjoy while practicing) and self-monitoring (screen shows distance, time and speed data). The participants had the opportunity to choose the landscape in which they would like to practice (forest, beach, snowy landscape). In this study, all participants performed in the forest. The VR system was developed by ORAMA-VR and the Biomechanical Solutions Engineering, on the basis of interviews with older people with mild cognitive impairment. Firstly, it was tested in university students and then in older people with mild cognitive impairment (Hassandra et al., 2021). (Appendix 1 – VRADA video demo)

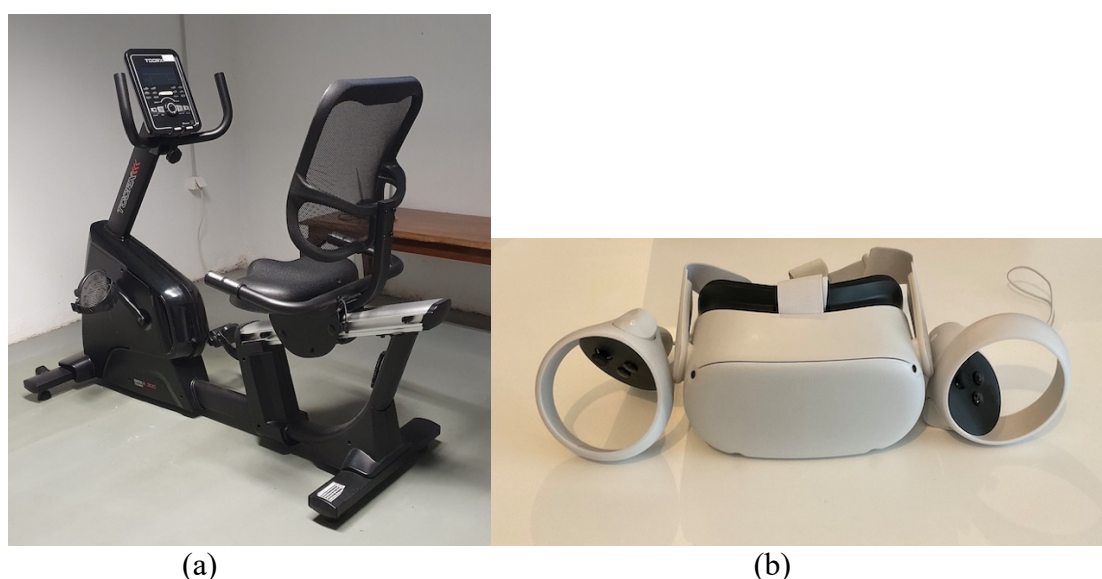


Figure 1. (a) The cycle-ergometer; (b) The VR mask and joysticks

Application description

Firstly, the user must select the landscape for their training and then their cycling goal (training duration) within the VR. As a selection mechanism, a VR controller has been used with a raycast allowing the user to choose an answer by pointing the ray at the button and pressing the trigger button on the controller.



Figure 2. Selection of exercise duration

Afterwards, they selected which word or phrase they would like to hear and repeat during their performance like “Calmly”, “I can”, “I will do well”, “Very nice” or no words. Then, the participants could begin their performance on the cycling-ergometer. They had also the opportunity to change the song they were listening to, from a list of preloaded tracks. At the end of the cycling program, they received feedback from the application about the correct and incorrect answers from the cognitive tasks and they could evaluate their experience through questions, e.g. “Are you tired today?”, “Did you like the way you exercised today?”, “How many animals did you see?”, “How often did you repeat the word or phrase during the exercise?”.

Measures

Personal innovativeness

A personal innovativeness questionnaire was used to find out users’ beliefs about technology adoption decisions, with a Cronbach’s α 0.77. (Agarwal et al., 1998). The questionnaire included 4 items e.g. “I am the kind of person who looks forward to experimenting with new technologies” and participants were requested to answer

through a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). (Appendix 2)

Acceptance

Three factors were used to assess participants' acceptance for the VRADA app:

1. Perceived enjoyment, 2. Attitudes, 3. Intended future use.
1. Perceived enjoyment, with a Cronbach's α 0.94: 6 items were used to assess feelings of pleasure during exercise, e.g. "I really enjoyed exercising in the VR environment" and participants were requested to answer through a 5-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree) (Rasimah et al., 2011).
2. Attitudes, with a Cronbach's α 0.89: on the basis of guidelines from theory of planned behavior, 6 bipolar items were used to assess attitudes towards VRADA app e.g. "pleasant-unpleasant", "beautiful-ugly" and scored on a 7-point semantic differential scale (Ajzen et al., 2006).
3. Intended future use, with a Cronbach's α 0.94: on the basis of guidelines from the theory of planned behavior, 3 items were used to assess the extent to which an individual consciously wants to use the VR system to exercise, e.g. "assuming I have access to the system, I intend to use it". Participants were requested to answer through a 5-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree) (Rasimah et al., 2011; Ajzen et al., 2006). (Appendix 3)

Usability

Subjective usability was assessed with the system usability scale (SUS), a self-report questionnaire, with a Cronbach's α 0.71, which includes 10 items: 5 positive e.g. "I think that I would like to use this system frequently" and 5 negative e.g. "I found the system unnecessarily complex" (Brooke et al., 1996). Participants were requested to answer through a 5-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree). (Appendix 4)

Preferences

To assess the preference for the exercise with or without the VR system, 8 questions were used e.g. "Exercise was more pleasant...", "the numerical calculations were more fun..." - "when exercising with or without the VR system". Responses were dichotomous, scoring 0 (against VR) or 1 (in favor of VR). Respectively scoring was 0 (against the static bicycle) or 1 (in favor of the static bicycle). A composite score (total

of the scores on the 8 questions) was computed for preference for the static bicycle and for preference for the VR system. Thus, two preference scores, ranging from 0 – 8 were derived – one for the static bicycle and one for the VR system. (Appendix 5)

Interest/enjoyment

The Intrinsic Motivation Inventory questionnaire, with a Cronbach's α 0.94, was used to assess the participants' interest/enjoyment for exercise with and without the VR system with 6 items, e.g. "I enjoyed doing this activity very much", "This activity was fun to do". The questionnaire was used for both training conditions. Participants were requested to answer through a 5-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree) (Goudas et al., 1994; Goudas et al., 2000). (Appendix 6)

VR equipment

Participants' perceptions of using the VR system (headset and controller) were assessed by a questionnaire with 9 questions related to usability-pleasantness, with a Cronbach's α 0.64 (4 items e.g. "I felt comfortable using the mask"), usability-learning, with a Cronbach's α 0.58 (2 items e.g. "It was easy to read the numerical questions") and tolerability, with a Cronbach's α 0.38 (3 items assessing dizziness, boredom and anxiety). Participants were requested to answer through a 5-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree) (Mrakic-Sposta et al., 2018). (Appendix 7)

Additional assessments

Additional information was collected with a semi-structured interview. The semi-structured interview (Pedroli et al., 2018) was designed to collect qualitative data related to participants' subjective feelings and perceptions about the reasons of using VRADA e.g. "Why would you use VRADA training system?", their expectations - 2 items e.g. "Given the opportunity, would you be willing to use this training system regularly?", usability or utilization - 5 items e.g. "What difficulties did you encounter during the training session?", usability or learning - 2 items e.g. "What exactly did you like most and least?", sense of presence or spatial presence - 2 items e.g. "Did you feel you had control over the environment?", sense of presence or engagement - 2 items e.g. "Did you get distracted during exercise? By what?", sense of presence or realism e.g.

“How did you find the environment, realistic or too artificial?” and tolerability - 2 items e.g. “Did you feel bad during exercise? When and where exactly?”. There were also 4 questions about the adoption of exercise with the VR system to the participants’ working environment, e.g. “How do you think using the VR system to exercise can help you be more productive at work?”, “If there were the VRADA system in your workplace, would you use it regularly? When? Why?”. The interview guide can be found in Appendix 8.

Procedure

Initially, participants were informed about the procedure, completed the consent form, adjusted their position on the cycle-ergometer and they were encouraged to ask questions about the procedure. The VR training system was easy to use and instructions given were adopted from a previous study (Hassandra et al., 2021). There were two different training conditions, condition A in a virtual environment and condition B in real environment, included a combination of cognitive and physical exercise. The two conditions were performed in half of the participants in the order indicated and in the other half, inversely. For the first two minutes, each individual had time to familiarize themselves with the cycle-ergometer, the headset and the controller and then they were requested to perform the condition A: to cycle for 15 minutes in a virtual reality environment, using the VRADA system and answer 20 simple math calculations, displayed at the screen, using the controller. They could receive feedback about the cycling time, their speed, distance and correct answers on cognitive exercises on their screen. After completing this process, they had a 10-minute break and then they started condition B: to cycle for 15 minutes in real environment and answer 20 numerical questions orally. During the cycling process each subject could receive feedback about the cycling time, their speed and distance on a connected computer and at the end they were informed about their score in cognitive questions. The cycling performance was at a constant speed ranged from 15 to 20 km/h. In every trial, the bike workload and speed were adjusted according to the exercise protocol, which was the same for both conditions. Finally, after a 5-minute rest, they completed a questionnaire and discussed the interview questions with the experimenter. The duration of the procedure was approximately 60 minutes.



Figure 3. Participant performing an experiment

Data analysis

Quantitative data were analyzed using SPSS Statistics version 26 (IBM Corporation). Summary statistics were calculated for demographic characteristics and correlations among all examined variables were assessed using the Pearson coefficient. To examine the preference among exercise conditions, and identify statistical differences of interest/enjoyment between the two exercise conditions, paired-samples t-test was performed. Data of the semi-structured interview were analyzed using thematic analysis (Braun et al., 2006), which can offer rich insights into attitudes and beliefs by identifying patterns of ideas and responses. The topics of the discussion were based on previous studies, the main themes were predetermined (deductive approach). Second-order themes were analyzed using an inductive approach, allowing the data to determine subthemes.

Results

Table 2 presents descriptive statistics including the means, Cronbach's α and Pearson correlations for all the examined variables. The visualization of the examined variables is presented using boxplots in Appendix 9.

Table 2. Descriptive Statistics, Means, Sd, Cronbach's α and Pearson Correlations.

Variables	PI	PE	IFU	SUS	AT	IMI_A	IMI_B	PRE_A	PRE_B	UP	UL	MEAN	SD	Cronbach's α
PIa												3.55/5	0.68	0.77
PEb	.22											4.34/5	0.80	0.94
IFUc	.25	.80**										4.02/5	0.97	0.94
SUSd	.07	.41**	.26									80.38/100	11.13	0.71
ATe	.23	.87**	.87**	.31*								6.06/7	1.00	0.89
IMI_Af	.27	.83**	.68**	.42**	.82**							4.21/5	0.78	0.94
IMI_Bg	.40*	-.00	-.06	-.01	-.15	.02						2.86/5	0.85	0.94
PRE_Ah	.07	.68**	.72**	.18	.73**	.64**	-.19					6.03/8	2.29	-
PRE_Bi	-.05	-.69**	-.71**	-.20	-.75**	-.66**	.21	-.99**				1.90/8	2.30	-
UPj	.18	.46**	.29	.71**	.32*	.52**	.03	.25	-.25			4.18/5	0.56	0.64
ULk	.17	.09	.06	.52**	.00	.15	.20	.08	-.63	.66**		4.25/5	0.62	0.58
TOLl	-.17	-.21	-.20	-.17	-.24	-.36	-.03	-.32*	-.32*	-.31	-.14	1.77/5	0.69	0.38

Note.

*Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

aPI = Personal Innovativeness, bPE = Perceived Enjoyment, cIFU = Intended Future Use, dSUS = System usability Scale, eAT = Attitudes, fIMI_A = Interest/Enjoyment for condition A (VR) (Intrinsic Motivation Inventory), gIMI_B = Interest/Enjoyment for condition B (Intrinsic Motivation Inventory), hPRE_A = Preference for condition A (VR), iPRE_B = Preference for condition B (bike only), jUP = Usability – pleasantness, kUL = Usability – learning, lTOL = Tolerability

Personal Innovativeness, SUS and Acceptance

The participants scored moderately to high on personal innovativeness and the SUS score was well above the acceptability threshold. Acceptance was assessed by three sub-factors: perceived enjoyment, attitudes and intended future use. Participants scored highly on all three factors: perceived enjoyment, attitudes and intended future use.

Relationships between variables

Personal innovativeness was low related to interest/enjoyment without VR variable. Perceived enjoyment was moderately related to usability, preference for condition A and usability-pleasantness, strongly with intended future use, attitudes and interest/enjoyment for condition A and moderately negative to preference for condition B. Intended future use was moderately related to interest/enjoyment for condition A, strongly positive to attitudes and preference for condition A and strongly negative to preference for condition B. Usability had low relation with attitudes, moderate with interest/enjoyment for condition A and usability-learning variable. Preference for condition A had a low negative relation with tolerability a moderate positive relation with interest/enjoyment for condition A and a strong positive relation with attitudes. Attitudes is strongly related with preference for the condition A and interest/enjoyment for the condition A, has low relation with usability-pleasantness and moderately negative related to preference for the condition B. The interest/enjoyment variable has

moderate negative relation with preference for the condition B. Finally, the usability-pleasantness variable is moderately related to interest/enjoyment for condition A and usability-learning and strongly with usability.

Preferences and Interest/Enjoyment

A paired-samples t-test was conducted to compare the participants' preference between condition A and condition B. There was a significant difference in the scores favoring condition A ($M= 6.03$, $SD= 2.29$) in comparison to condition B ($M=1.90$, $SD= 2.30$); $t(39)= 5.81$, $p<.001$.

A paired-samples t-test was performed to determine whether there was a statistically significant interest/enjoyment for either of the exercising conditions. There was a significant difference in the scores favoring condition A ($M= 4.21$, $SD= 0.78$) in comparison to condition B ($M= 2.86$, $SD= 0.86$); $t(39)= 7.43$, $p<.001$.

Semi-structured interview

The collected data from the semi-structured interview related to the participants' subjective feelings, expectations and perceptions about the VRADA's system usability and tolerability are presented in Table 3. A great percentage of participants reported that they would use this VR system to exercise and that they didn't encounter any difficulties. Most of them didn't have any problems with the equipment (headset and joystick) but more than half of the participants noted a difficulty to aim the correct answers with the joystick. None of them needed extra help or time to understand the VR system and most of them had feelings of control and presence in the VR environment. Concerning the use of the VR system in the workplace many participants reported that the system may have advantages for the employees like that it can help them to relax, to be more physically active and improve their mood and wellness. Finally, many of the participants reported that they find it realistic to exercise in their workplace with the VRADA system and the majority reported that they could use it systematically. However, some of the participants noted that they don't find realistic to exercise with the VR system during their working hours in the workplace. Most of them supported their answer by saying that they are working in high pressure and they don't have enough time for an active break.

Table 3. Subjective Feelings, Expectations and Perceptions About the VRADA System, Usability and Tolerability

Main Theme	Subthemes	n	(%)
Reasons to use VRADA	Why would you use VRADA?		
	It is pleasant	25	62,5%
	Time passed fast and delightfully	12	30%
	It is interesting	7	17,5%
	It is relaxing	6	15%
	Future personal use of the system		
	Yes	24	60%
	So-so	5	12,5%
	No	11	27,5%
Expectations	Useful for other populations		
	People who can't exercise outdoors	12	30%
	People who don't like to exercise, motivation	9	22,5%
	Children and adolescents	9	22,5%
	People with disabilities	7	17,5%
	Everybody	6	15%
	People with limited free time	5	12,5%
	People with mental disorders	5	12,5%
	General difficulties		
	None	27	67,5%
Usability or utilization	Combination of questions and searching for animals	4	10%
	Questions placed very low	4	10%
	To find animals	4	10%
	Technical issues		
	To aim the correct answers with the joystick	22	55%
	None	16	40%
	The system was disconnected	2	5%
	Joystick Use		
	Ok	36	90%
	Ineffective	2	5%
Usability or learning	The button	1	2,5%
	VR mask use		
	Ok	27	67,5%
	Didn't fit properly	9	22,5%
	It was heavy	6	15%
	Need for extra help		
	No	40	100%
	Need more time to understand the system		
	No	40	100%
Usability or pleasantness	Most enjoyable parts		
	The environment	32	80%
	Music	17	42,5%
	Least enjoyable parts		
	Repeated virtual parts	15	37,5%
	Graphics	9	22,5%
	Questions	8	20%
	Feel uncomfortable		
	No	38	95%
	I felt alone	1	2,5%

Sense of presence or spatial presence	When I was searching for the animals	1	2,5%
	Control of the system		
	Yes	33	82,5%
	Not really	3	7,5%
	Almost yes	2	5%
Sense of presence or engagement	No	2	5%
	Feel part of the VR environment		
	Yes	26	65%
	Almost yes	9	22,5%
	No	3	7,5%
Sense of presence or realism	Not really	2	5%
	Distraction of attention		
	No	34	85%
	Yes (eg.when the animals appeared)	6	15%
	Duration of the experience		
Tolerability	Enough	20	50%
	It could be more	19	47,5%
	It could be less	1	2,5%
	VR environment was realistic or artificial?		
	Artificial	33	82,5%
Use in workplace	Realistic	7	17,5%
	Feel bad during training		
	No	36	90%
	Yes (anxiety,fear)	4	10%
	Advantages of the system for employees		
	Help them to relax	17	42,5%
	Help them to be physically active	10	25%
	Improve mood and wellness	9	22,5%
	Have a delightful break from work	8	20%
	Strengthen physical and mental health	4	10%
	Help to be more productive		
	Allow my mind to rest	13	32,5%
	Calm down from stress and tension	12	30%
	Have a delightful break from work	11	27,5%
	It can't help	3	7,5%
	How realistic is systematically exercise in workplace with the VR system		
	Very realistic	16	40%
	Not at all	10	25%
	Not very realistic	9	22,5%
	Quite realistic	5	12,5%
	Systematically use		
	Yes	29	72,5%
	No	11	27,5%

Discussion

The aim of this study was to examine the applicability of a virtual reality system for exercise training by office workers during breaks of their working hours. The acceptance of a new technology is mediated by various factors related to the user's psychology, the design of the system and the quality of the technology (Dillon & Morris, 1996). In addition, the effects of exercise in a virtual reality environment

depends on the feeling of presence, the task and the VR system (Neumann & Moffitt, 2018). In this study, participants provided moderate to high scores on personal innovativeness implying that they were familiarized with new technologies. They also indicated good acceptance of the VR system as denoted by the relatively high scores in the three acceptance factors and in two usability facets. As we hypothesized, a greater preference to condition A and high scores on interest/enjoyment in favor of VR cycling have been found, too. Correlation results showed a positive and strong relationship between perceived enjoyment, intention for future use, attitudes and interest/enjoyment for the VR training system. According to motivation theorists, when individuals perceive exercise as a pleasant activity, there are also positive associations with enjoyment, increased motivation, intention to continue exercise and persistence (Rodrigues et al., 2020).

According to the results of the semi-structured interview, the majority of the participants reported that they preferred the VRADA exercising system in comparison to the condition B. There were not many difficulties reported, except for the sensitivity of the joystick. All participants affirmed that they didn't need extra help or time to understand the system and many of them reported that they would use it for exercising systematically. Concerning the use of the VR system in the workplace, although most of the participants noted that they found it realistic to use the system frequently during their working hours, there was a notable percentage reported that they didn't find it realistic for many reasons, such as occupational stress and lack of time. In Greece, occupational stress is a frequent phenomenon because of economic instability. Most companies or organizations in the private and public sector are trying to manage this changing situation resulting in stressful conditions for employees (Fotinos-Ventouratos, 2021). Stress and quality of life are factors affected from Greece's economic crisis and high stress levels are related to low job satisfaction and quality of life (Alexopoulos et al., 2014). In turn, this limits the possibility for scientifically proven interventions to be implemented in the workplace (Fotinos-Ventouratos, 2021). However, in European Union (EU), many organizations are preparing and trying worksite health and wellness strategies to promote employees' health and prevent diseases. The concept of occupational safety and health differs across the EU countries, but it consists of some common elements such as healthy eating, smoking abstinence, mental health promotion, increased exercise and physical activity and health monitoring. According to the occupational safety and health campaign, a workforce

which is healthy, motivated and well-qualified can become a key pillar of a healthy society with economic wellbeing (Guazzi et al., 2024).

Participants, also, reported many advantages of the VR training system to the employees' productivity. Employees' productivity depends - among others - on mental health, physical health, job characteristics and support from the organization and colleagues (Stepanek et al., 2019). Except for job characteristics, all of them can have positive effects from exercise in the workplace. According to a study, possible benefits can be offered for employees' productivity and absenteeism, from a workplace exercise intervention, by improving their musculoskeletal disorders and physical health (Pereira et al., 2019). Additionally, mental health can be improved from an exercise program in the workplace (Proper et al., 2019) as well as the personal relationships between employees (European Commission, 2021). The VRADA system has also been tested with different groups of adults and reported high acceptability, usability and tolerability indexes by students and older people with mild cognitive impairment (Hassandra et al., 2021). All things considered, we can safely claim that the VR app had a great applicability in this population, in this Greek city, in their working environment.

Strengths and limitations

To the best of our knowledge no previous study has examined the perceptions of office workers for a VR exercise system using a static bicycle during the working hours. The VRADA system includes motivational techniques to address the issue of low motivation to exercise, for example, goal setting, feedback etc. Additionally, the users have the opportunity to choose their pace, velocity, landscape and music. The system can be adjusted to individual needs and installed in the workplace to be easily accessible from the employees.

Despite these encouraging results about the acceptance, usability, interest/enjoyment and intention for future use, there are some limitations. Since the VRADA system has been tested for one session, long term interventions have to be tested to examine if this way of training will remain enjoyable and interesting as well as the training effect (Hassandra et al., 2021; Mouat et al., 2020). Additionally, the sample size was small and participants were women only, because more women volunteered to participate in this study and the offices where we addressed were female-dominated. Therefore, the emerged results can't be generalized to the general

population because male participants were not included. There is a need for more studies to examine the VR system training in the workplace during the working hours with a larger sample and gender balance. The aim of this study was to examine the applicability of the VRADA system and not the efficacy and the user's adherence in the exercise program. Future studies can evaluate the effects of regular training with the VRADA system on physical and mental health and quality of life.

Conclusions

Overall, exercising during working hours with a VR exercise system was well perceived by office workers and applicable. Nevertheless, we need long intervention studies to explore the effectiveness on long term benefits for several health and fitness dimensions and cost effectiveness of VR exercise in sedentary workplace settings.

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CHAPTER III – STUDY 2

Exploring the acute effects of immersive virtual reality biking on self-efficacy and attention of individuals in the treatment of substance use disorders: A feasibility study

Touloudi, E.; Hassandra, M.; Stavrou, V.T.; Panagiotounis, F.; Galanis, E.; Goudas, M.; Theodorakis, Y. Exploring the Acute Effects of Immersive Virtual Reality Biking on Self-Efficacy and Attention of Individuals in the Treatment of Substance Use Disorders: A Feasibility Study. *Brain Sci.* **2024**, *14*, 724. <https://doi.org/10.3390/brainsci14070724>

Abstract

The role of exercise programs during Substance Use Disorder (SUD) treatment is considered particularly supportive in fostering positive psychological and behavioral changes. The treatment of SUD is a challenging and demanding process. Therefore, it is crucial to discover innovative methods to enhance and facilitate it. Integrating exercise into a virtual environment is an innovative approach for drug rehabilitation, offering multiple benefits to individuals undergoing treatment. The aim of this feasibility study was to explore the acute effects of cycling exercise in an immersive virtual reality (VR) environment on attentional control and self-efficacy expectations of individuals undergoing SUD treatment. A total of 20 individuals (mean age of 37.75 years) enrolled in a SUD treatment program participated in the study. They were instructed to complete a single session of cycling with a self-selected duration within the VR system. Following the cycling session, pre-post measures indicated a statistically significant improvement in self-efficacy expectations and attentional control measured with the Stroop test. The results revealed that participants expressed high levels of intention for future use, interest/enjoyment, and positive attitudes toward the VR exercise system. Qualitative data indicated that participants found the VR exercise system enjoyable, expressed a strong intention to use it, and did not encounter technical difficulties or negative emotions. In conclusion, it seems that engaging in a brief period of self-selected exercise within a virtual environment can result in temporary activation of cognitive changes, heightened self-efficacy expectations, and a motivating approach to increasing physical activity participation among individuals with SUD, thus suggesting the feasibility of this approach.

Keywords: virtual reality, exercise, substance use disorders, self-efficacy, attention

Introduction

Drug use represents a major issue for public health, with potential consequences including substance use disorders (SUD), mental health disorders, HIV infection, cancer, cirrhosis of the liver, hepatitis, overdose, premature death, and impaired cognitive function with chronic use (World Drug Report, 2020). In general, addiction is a disorder that affects how the brain processes information. The areas of the brain impacted by SUD are the same ones involved in important cognitive functions like learning, memory, attention, reasoning, and controlling impulses. Chronic drug use can alter brain structure and function, leading to addiction (Nestler, 2011), affecting memory and cognitive functions (Goldstein & Volkow, 2011). Drugs have negative effects on natural cognitive function, promote drug use, and hinder the development of behaviors supporting abstinence. During substance abstinence, individuals may experience cognition-related withdrawal symptoms caused by many drugs that are usually temporary, in contrast with long-term use symptoms that lead to lasting cognitive declines. Moreover, cognitive deficits related to drugs may have negative effects on the individual's well-being (Gould, 2010).

Individuals undergoing SUD treatment experience notable physical and cognitive benefits when incorporating exercise into their regimen. Research suggests that physical activity positively influences attention (Kutlu & Gould, 2016), contributing to enhanced cognitive functioning and potentially supporting addiction recovery. Exercise programs and physical activities appear to effectively reduce substance cravings and support abstinence. They serve as beneficial elements for both prevention and intervention, enhancing the impact of traditional therapy. Some of the benefits of exercise are prevention of relapse, repair of cardiovascular and muscular damage, reduced symptoms of anxiety and depression and improved mood, increased self-confidence, self-esteem, and body image, improved well-being and quality of life, personal satisfaction, optimism and adopting a healthy lifestyle (Ellingsen et al., 2020; Rethorst et al., 202; Panagiotounis et al., 2022). Systematic reviews have highlighted the critical role of physical activity and exercise programs in the treatment of SUD (Ding et al., 2023; Piché et al., 2023).

Cognitive functions are significantly impaired by substance use, leading to reduced memory, attention and executive functioning (Caetano et al., 2021). These cognitive deficits are a critical risk factor for treatment dropouts (Brorson et al., 2013).

Attention is a large and complex topic involving psychology and neuroscience. Generally, attention could be described as the flexible control of limited computational resources (Lindsay, 2020). Many researchers have studied the influence of acute exercise on the Stroop effect (used widely to assess attention deficits) in healthy and clinical populations. The findings of a recent study, in which the Stroop test was applied pre, post, and 40 minutes post-resistance exercise, supported that acute exercise can lead to improved scores (Chou et al., 2021). The use of a virtual reality platform can also offer cognitive flexibility and selective attention improvements in young males, as exercise does offer such benefits (Sanudo et al., 2020). Therefore, a combination of VR and exercise may contribute to cognitive development. Furthermore, current investigations are delving into the potential advantages of high-intensity interval training for enhancing cognitive function in individuals with SUD (Haberstroh et al., 2022). Additionally, a recent randomized controlled trial revealed significant enhancements in cognitive functions and emotional well-being among patients with SUD engaging in a group aerobic exercise program (Zhu et al., 2022). Notably, these findings underscore the promising role of exercise interventions in addressing cognitive deficits associated with SUD.

Self-efficacy is defined as the expectation that one can successfully perform a specific behavior required to produce a certain outcome (Bandura et al., 1977). Positive self-efficacy is related to individuals' perceptions of their capability to control their own functioning and the events that affect their lives while decreased self-efficacy may lead to doubt and easily giving up in the face of obstacles (Bonny-Noach et al., 2023; Zemore et al., 2014). Research by Schwarzer et al. 2014 indicates a strong connection between self-efficacy and both physical and mental health. There are, also, studies supporting that the consumption of illicit drugs is likely to impair individuals' self-control and self-efficacy (Kadden et al., 2011). Additionally, other studies support the low levels of self-efficacy during the treatment process (Tate et al., 2008). According to Kadden and Litt (2011), self-efficacy plays a crucial role in the treatment SUD and significantly influences treatment outcomes. Therefore, it is essential to identify effective strategies to enhance self-efficacy in individuals undergoing this process. In accordance with that, other researchers support that there is a significant positive correlation between self-efficacy and treatment motivation (Mohamed et al., 2022). Higher levels of self-efficacy, quality of life, and social support were found to be inversely related to the likelihood of relapse in individuals with drug addiction

(Nikmanesh et al., 2017; Jia et al., 2023). The role of attitudes and intentions toward participation in sports and exercise programs has been documented. Positive attitudes and intentions towards substance abuse treatment contribute to higher rates of completing the treatment program. Attitude and control components are positively associated with intention and treatment participation or completion (Bonny-Noach et al., 2023; Zemore et al., 2014). Furthermore, engaging in exercise during drug addiction therapy can enhance physical fitness outcomes and positively impact psychological well-being, fostering improvements in personality traits and psychological aspects such as self-confidence. Finally, exercise-induced improvements in self-efficacy can contribute to overall well-being and quality of life, promoting a positive mindset and sense of achievement throughout the recovery journey (Panagiotounis et al., 2022).

Self-efficacy expectations, as outlined by Bandura (1977), pertain to an individual's belief in their capability to successfully execute behaviors required to produce specific outcomes in particular situations. This concept emphasizes the confidence an individual has in their ability to achieve desired results through their actions within specific contexts. The distinction between self-efficacy and self-efficacy expectations lies in their scope and focus. Self-efficacy encompasses a broader sense of overall competence and belief in one's abilities across various tasks and situations. In contrast, self-efficacy expectations are more specific, relating to an individual's confidence in their capacity to perform particular behaviors to attain specific outcomes in defined circumstances (Bandura et al., 1977).

Virtual reality (VR) is a computer-generated simulation of a real or imaginary three-dimensional environment that allows users to explore and interact with it. In recent decades, VR has been increasingly used not only for entertainment and leisure but also for exercise, educational purposes, rehabilitation, health, and other applications (VirtualSpeech, 2024). Virtual environments can simulate reality without limitations in space and time, which makes them more attractive (Freina et al., 2015). Exercise in a VR environment has been a rising method of exercise in recent years. Several studies were involved with VR exercise and support that it is suitable to offer beneficial effects on physiological, psychological, and rehabilitation factors compared to traditional exercise methods (Qian et al., 2020). It has also been shown that VR exercise has favorable effects on cognitive factors such as functional ability, attention, and memory and mental health conditions like anxiety and depression (Ge et al., 2018). Exercise in VR environment combined with cognitive tasks, according to another study, appeared

to be appropriate and had positive effects even in people with mild cognitive impairment (Hassandra et al., 2021). Additionally, recent research by Krommidas et al. (2022) has highlighted the potential of acute exercise and VR tasks to positively impact children's memory function and exercise preference, providing valuable insights into the broader applications of VR-based exercise interventions. VR environments are also a reliable way for providing information about addictive disorders, such as the desire to use, and can influence emotional state, attention, and cognitive function. Individuals with attention deficits, or those who face difficulties participating in group activities, may benefit from the virtual environment (Mazza et al., 2021).

To the best of our knowledge, there are few studies in the literature evaluating the effect of exercise in a VR environment in populations in the treatment of SUD. According to what was mentioned above, it would be important to explore whether exercise in a VR environment could help to improve the self-efficacy expectations and attentional control of individuals in drug addiction treatment and be a useful and attractive tool to enhance their participation in an exercise program.

Research questions and hypotheses

In the present study, we sought to address several key research questions related to the utilization of VR exercise as an intervention for individuals undergoing SUD treatment. Firstly, we investigated whether engaging in exercise with the VR environment would lead to a significant improvement in self-efficacy expectations among participants in the SUD treatment program. We hypothesize that participation in VR exercise would be associated with a noteworthy increase in self-efficacy expectations. Additionally, we explored potential differences in attentional control levels, as measured by the Stroop test, before and after a single session of cycling using the VR system. We hypothesize that this intervention will decrease Stroop reaction time in people undergoing SUD treatment. Lastly, we delved into participants' attitudes, intentions for future use, and levels of interest/enjoyment regarding exercise within the VR system. We hypothesize that individuals in the SUD treatment program would exhibit positive attitudes, express strong intentions for future use, and report high levels of interest/enjoyment concerning VR-based exercise. Overall, these research questions and hypotheses were designed to comprehensively investigate the potential benefits of VR exercise within the context of SUD treatment.

Therefore, the aim was to explore the acute effects of a pre- and post-exercise in a VR environment on self-efficacy expectations and attentional control of individuals in SUD treatment. Additionally, their attitudes, intentions for future use, and interest/enjoyment about this type of exercise were investigated.

Materials and Methods

Participants & Setting

A convenience sample of 20 individuals in SUD treatment of KETHEA ITHAKI therapeutic community participated. KETHEA ITHAKI is a therapeutic community located in Sindos, Thessaloniki, Greece, that aims to help individuals struggling with addiction and substance abuse with a residential program without substitution (<https://www.kethea.gr>). The inclusion criteria encompassed individuals between the ages of 18 and 60, who were functionable and capable of participating in exercise, without colorblindness, and without significant psychiatric conditions including severe anxiety disorder, psychosis, aggressive and violent behavior, psychopathic, schizophrenic, or paranoid personality disorders, or hallucinations. Screening based on the inclusion criteria for participants in the study was conducted by the staff of KETHEA, where the study took place. It is important to mention that most participants had multiple unsuccessful attempts at SUD treatment before the study was conducted. Table 1 presents the days they were in treatment during their latest attempt. According to an article from KETHEA (Therapy Center for Dependent Individuals) published in 2017, the ratio of women to men participating in SUD treatment programs is approximately 1 to 5. This indicates that approximately 20% of all participants in the program are women. (<https://www.kethea.gr/nea/oie-anagki-gia-ypostiriksi-ton-eksartimenon-gynaikon/>). Their demographic characteristics are presented in Table 1.

Table 1. Demographic Characteristics.

N=20		Mean	SD	Minimum	Maximum
Age	years	37.75	8.33	24	54
Sex	male, %	90	-	-	-
Educational level	Primary, %	85% secondary 10% primary	-	-	-
	Secondary, %				
Exercise during treatment	yes, %	50	-	-	-

N=20		Mean	SD	Minimum	Maximum
Current engagement in SUDs treatment	days	138.8	106.25	6	341
	times	1.80	1.642	0	4 and more
Previous attempts	Frequency (%)	Never 35%			
		1 time 15%			
		2 times 5%			
		3 times 25%			
		4 plus 20%			
Drug use	years	19.4	9.88	7	37

Study design

The study employed a quasi-experimental research design, chosen for its appropriateness in the context of being both exploratory and constrained by practical considerations. The rationale for adopting this design stems from the exploratory nature of the research, as only a limited number of studies have utilized VR exercise for this particular population. Furthermore, the feasibility of alternative designs was restricted by the fact that the therapeutic community KETHEA ITHAKI had only 20 participants. Additionally, ethical and practical concerns were highlighted, as raised by the SUD therapists. They believed that it would be considered unethical or problematic to expose only a limited number of participants to the proposed VR exercise experience.

Ethics approval and consent to participate

The studies involving human participants received approval from the institution's ethics committee (approval number: 1829, 13 October 2021). Personal data confidentiality is guaranteed under regulation (EU) 2016/679 (General Data Protection Regulation). Everyone involved in KETHEA, including participants and medical staff, received verbal explanations of the procedure. Participants were given written information and signed consent forms. They were also encouraged to ask questions and received thorough responses.

VR System

In our study, we employed a mixed methods approach, integrating both quantitative and qualitative methodologies. This comprehensive strategy allowed us to benefit from the strengths of each method, enhancing the depth and completeness of our findings. The methodology followed was based on our previous studies examining the

effects of the VR exercise system on patients with mild cognitive impairment and female office workers (Hassandra et al., 2021; Touloudi et al., 2022).

The VR system consists of a cycle-ergometer connected to a computer, the VR head-mounted display and controllers, and the VR application. Detailed description of the equipment is well described in our previous study (Touloudi et al., 2022).

The VR application allows users to set their exercise goals (such as duration) (Figure 1), receive feedback on their training performance (including cycling duration and total distance), customize tasks (such as selecting music), and monitor their progress (displaying distance, time, and speed data on screen). Additionally, users could select their preferred virtual landscape (forest, beach, snowy terrain) and choose motivational words or phrases (like "calmly", "I can", "I will do well", "Very nice", or option for no verbal cues). The exercise duration was determined beforehand by the participants. In general, participants were allowed to choose the duration, landscape, motivational words or phrases, and music to enhance their experience and motivation. A VR controller with ray casting serves as the selection tool, allowing users to interact by pointing the ray at buttons and pressing the trigger button.

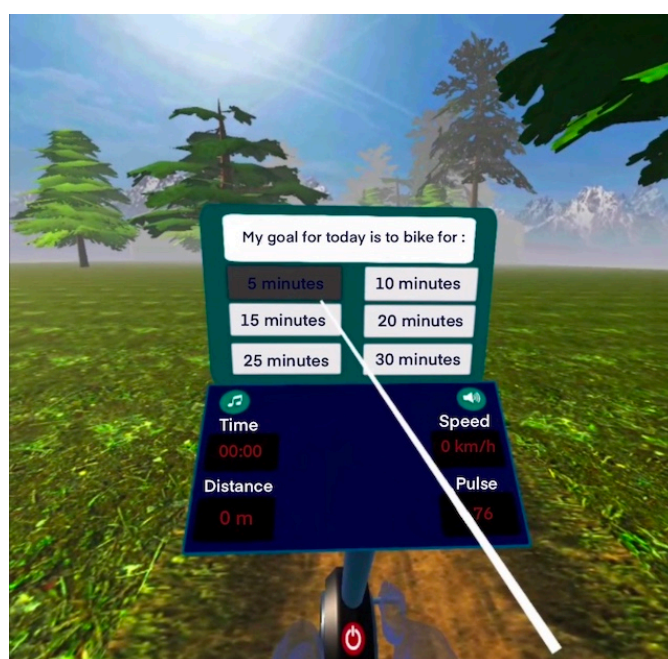


Figure 1. Selection of exercise duration in the VR system (Touloudi et al., 2022).

After that, each participant starts the cycling performance (Figure 2), and at the end, they receive feedback from the application about the time and distance they achieved and they can assess their experience through structured evaluation questions., e.g., “Are

you tired today?”, “Did you like the way you exercised today?”, “How often did you repeat the word or phrase during the exercise?”



Figure 2. Participant cycling in the VR environment

The VR training system employed is named VRADA (VR Exercise App for Dementia and Alzheimer’s Patients), Version 4.4. This VR system (Version 3.7) was utilized with university students and patients experiencing mild cognitive impairment. It functioned as a dual-task training tool designed to enhance both physical and cognitive health. The study aimed to evaluate its acceptance, tolerance, and usability among participants (Hassandra et al., 2021). Additionally, Baldimtsi et al., 2023 utilized the same VR system with older adults diagnosed with MCI, conducting 32 sessions focusing on both physical and cognitive training. Their findings suggest that the VR system effectively improves cognitive abilities. Given the promising results from both studies, further investigation into the applicability of VRADA across diverse populations could be warranted. The VRADA system, originally intended for dementia or Alzheimer's patients, underwent modification in our study. We utilized an updated version excluding cognitive tasks during exercise, opting for questionnaires more suitable for this population, focusing on aspects such as attention and self-efficacy expectations.

The VRADA system offers benefits that cater to the needs of individuals in the treatment of SUD, such as mood improvement, anxiety and depression reduction. According to the results of a study, that examined the impacts of acute VR exercise

paired with cognitive activities on children's memory function and their preference for exercise, children who experienced VR exercise noted higher scores in memory tests compared with children who experienced a traditional cycling session and control group. Additionally, children showed high levels of enjoyment, intention for future use, and attitudes toward cycling in a VR environment (Krommidas et al., 2022). Acute VR exergaming can also lead to mood improvement according to Ochi et al. (2022). Furthermore, it serves as an enjoyable and appealing method of exercise that could potentially benefit individuals struggling with addiction by promoting physical health and mitigating adverse effects of treatment factors such as withdrawal symptoms, relapse, treatment burnout etc.

Procedure

All participants were briefed on the purpose of this study and completed the consent form. The experimental procedure was completed in one visit and based on our previous study (Touloudi et al., 2022). Then, they filled in a questionnaire with questions about their demographic characteristics, the TCU Drug screening questionnaire (Knight et al., 2002) and the IPAQ (Craig et al., 2003).

After that, each participant adjusted their seat on the stationary bike and familiarized themselves with the equipment of the VR system. They simultaneously were informed in detail about the procedure, and how to use the equipment and were encouraged to ask questions. There were given 5 minutes to familiarize themselves with the virtual environment and understand how to use the equipment. Then, they completed the self-efficacy expectations scale (Bandura et al., 2006; Theodorakis et al., 1996) and underwent Stroop Test (MacLeod et al., 1991).

They were encouraged to choose the landscape (forest, beach, snowy landscape) and the duration of their cycling performance in the VR environment. They could cycle from 5 to 30 minutes and were asked to cycle at a certain speed between 15-20 km/h. During their performance, they were informed on their screen about their speed, covered distance and time remaining, and could select the music they were listening to from a list of songs.

When they completed the cycling session, they underwent the Stroop test (MacLeod et al., 1991) and completed the self-efficacy expectations scale (Bandura et al., 2006; Theodorakis et al., 1996), a questionnaire assessing their attitudes and intention for future use (Ajzen et al., 2002) and their interest/enjoyment (intrinsic

Motivation Inventory) (Goudas et al., 2000) toward the VR exercise system. In the end, they answered a semi-structured interview with questions about their experience. The duration of the process was approximately 1 hour (Table 2).

Table 2. Experimental procedure.

Pre VR exercise		Post VR exercise	
•	Consent form-Demographics	•	Stroop test
•	TCU Drug Screening	•	Self-efficacy expectations
	• IPAQ	•	Attitudes
•	Familiarization (5min)	•	Intention for future use
•	Self-efficacy expectations	•	Intrinsic motivation inventory
•	Stroop test	•	Semi-structured interview

Note: VR= Virtual Reality, TCU= Texas Christian University Questionnaire, IPAQ= International Physical Activity Questionnaire, DASS-21= Depression Anxiety Stress Scales - 21 items.

Measures

All participants first completed a questionnaire collecting data for their age, gender, educational level, years of substance use, days of treatment, participation in an exercise program, type of exercise, days per week, and minutes, TCU Drug Screen 5 according to Knight, Simpson & Hiller, 2002, IPAQ questionnaire according to Craig et al., 2003. Pre- and post-VR exercise they completed the Self-Efficacy Expectations Scale according to Bandura, 2006 and Theodorakis, 1996 (Appendix 10) and the Stroop Test consisting of 3 tabs (naming, reading, and interference) according to Stroop, 1935.

Self-efficacy expectations were evaluated by asking subjects to rate the strength and magnitude of their self-efficacy expectations for ten performance levels from 10 to 30 minutes. The format used is comparable to that of Bandura, 2006 recommendation (e.g. "I can perform this test by 10 minutes", Yes-No) and "How certain you are?" answered on a 10-point scale anchored by "certain" (10) and "uncertain" (1). The strength of perceived self-efficacy was the sum of the certainty scores for the ten levels of performance. Cronbach's alpha for the scale was .88.

After their performance, they completed questionnaires about attitudes (Ajzen et al., 2002) toward the VR exercise and were assessed with 5 pairs of opposite words e.g. "I find VR exercise..." - "good-bad", "healthy-unhealthy" etc. with scores on a differential scale of 7 points. The scoring scale ranged from 1 to 7 with higher scores indicating more positive attitudes. Intention for Future Use (IFU) of the VR system was assessed with 3 questions e.g. "I intend to use the VR exercise system when available" with responses from "Yes sure" to "Not at all". The scoring scale ranged from 1 to 5 with higher scores indicating greater intention for future use.

Interest/ enjoyment was assessed with the relative items of the Intrinsic Motivation Inventory (IMI) (Goudas et al., 2000) with 6 items e.g. “I liked very much the VR exercise” with responses on a 1-5 Likert scale from “Not sure” to “Very sure”. The scoring scale ranged from 1 to 5 with higher scores indicating high interest/enjoyment. And at the end, they responded to a semi-structured interview consisting of 14 questions about the participants’ experience with the VR system. They were asked to describe why they would like to use the VR system to exercise, usability or utilization was assessed with 4 questions e.g. “What difficulties did you encounter while exercising with the VR system?”, usability or learning was assessed with one question e.g. “Did it take long to figure out how the VR system works?”, usability or pleasantness was assessed with 2 questions e.g. “What did you like the most and what did you like least about the VR system?”, sense of presence or engagement was assessed with 2 questions e.g. “Were you easily distracted while exercising with the VR system?”, sense of presence or realism was assessed with one question e.g. “How did you find the environment? Realistic or artificial?” and tolerability with 3 questions e.g. “Did you feel bad at any moment when exercising with the VR system?” (Appendix 11)

Statistical analysis

All data are presented as means (M), Standard Deviation (SD), range, and percentages (%). Descriptive statistics, scatter plots, and frequencies were used for demographic characteristics, the VR system questions, Stroop test scores, psychological factors, and VR performance. The Kolmogorov-Smirnov Test was used to assess the normality of the distribution. Correlation among variables was assessed using the Pearson coefficient and Cronbach’s α reliability analysis was performed for all questionnaires. Paired samples t-test was used to identify self-efficacy expectations differences pre- and post-VR exercise. Repeated measures ANOVA analysis was used to test the effect of days of treatment on the Stroop performance. Qualitative data from the semi-structured interview were analyzed using thematic analysis, providing valuable insights into attitudes and beliefs through the identification of recurring patterns in ideas and responses (Braun et al., 2006). All statistical analyses were performed with IBM SPSS (Statistics Version 29) and the level of significance was set at $p < .05$. The analysis was not pre-registered and the results should be considered exploratory.

Results

Pre- and Post- VR exercise measures

Stroop Test

Participants experienced a statistically significant reduction in completion time for the color (Naming), word (Reading), and word-color (Interference) tasks of the Stroop test following the VR exercise. Additionally, there was a decrease in the number of errors made, although this difference did not reach statistical significance. Table 3 presents the means, standard deviations (SD), and levels of significance for all 3 tabs of the Stroop test. Furthermore, a moderate negative correlation ($r = -.45$, $p < .05$) was observed between the time taken to complete the reading task before the VR exercise and the duration of the treatment days ($M = 44.94$, $SD = 5.44$). The Repeated Measures ANOVA analysis, including treatment days as a covariate, revealed non-significant effects across all tabs of the Stroop test. For Tab 1 (naming), $F(1,18) = .10$, $p = .756$; Tab 2 (reading), $F(1,18) = 1.982$, $p = .176$; and Tab 3 (interference), $F(1,18) = .09$, $p = .767$.

Table 3. Stroop test reaction time and mistakes and self-efficacy expectations. All data are presented as means and Standard Deviation (SD).

Stroop test		Pre VR	Post VR	P value, df	Cohen's d
Naming	Reaction time	60.9±13.1	51.9±7.6	$t(19) = 4.178$, $p < .001$	0.84
	Mistakes	1.1±1.2	0.6±0.9	$t(19) = 1.308$, $p = .21$	
Reading	Reaction time	41.9±5.4	40.2±6.2	$t(19) = 3.202$, $p < .005$	0.29
	Mistakes	0.1±0.2	0.1±0.2	$t(19) = .152$, $p = 1.0$	
Interference	Reaction time	94.8±22.9	78.0±14.1	$t(19) = 6.242$, $p < .001$	0.88
	Mistakes	4.4±4.1	2.6±0.7	$t(19) = 1.966$, $p = .06$	
Self-efficacy expectations		49.8±13.19	56.8±4.87	$t(19) = -2.78$, $p < .01$	-

Self-efficacy expectations

A paired-samples t-test was conducted to compare the self-efficacy expectations pre- and post-VR exercise. There was a statistically significant improvement in self-efficacy expectations after the VR experience compared with self-efficacy expectations before the VR experience. Table 3 presents the means, standard deviations (SD), p value, df.

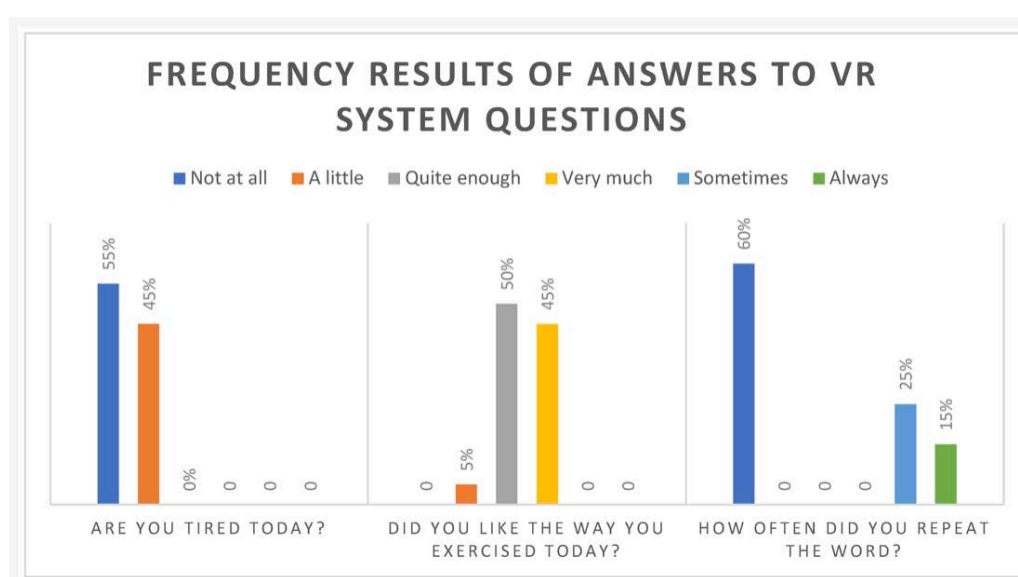
Post-VR exercise measures

Attitudes, Intention for future use, Interest/Enjoyment

The participants expressed high levels of intention for future use ($M= 4.5$, $SD= 0.6$, Cronbach $\alpha .85$), interest/enjoyment ($M= 4.4$ $SD= 0 .6$, Cronbach $\alpha .89$), and positive attitudes towards the VR exercise system ($M= 6.6$, $SD= 0.4$, Cronbach $\alpha .79$).

VR system experience

Following the completion of the cycling program within the VR system, participants were asked to respond to three questions evaluating their VR cycling experience. The responses indicated that the majority of participants did not feel tired from the cycling activity and expressed a positive liking towards it. Graph 1 presents the results of these questions.



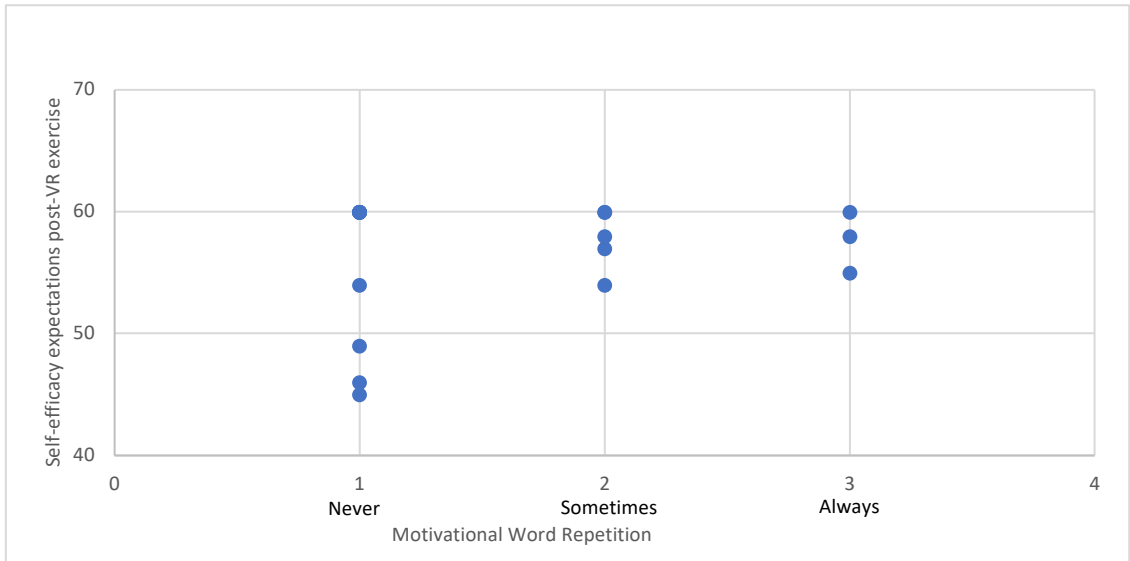
Graph 1. Frequency of answers to VR system questions.

VR performance

In the self-selected duration of the VR exercise, 25% of the participants chose to practice for 15 minutes, 45% for 20 minutes, and 30% for 30 minutes. All participants achieved their exercise goal and we didn't have dropouts. The Mean and SD of their cycling time was 21.8 ± 5.9 (Range 15.0-30.0). Their average speed was 19.05 with the guidance to cycle between 15 and 20 km/h ($M= 19.1$, $SD= 0.7$, Range 17.14-20.21) and an average of covered distance of 6.19 km ($M= 6.2$, $SD= 1.7$, Range 4.0-8.9).

The scatter plot (Graph 2) observation indicates that those who used motivational words had higher scores in self-efficacy expectations. Nevertheless, despite this observation, both regression and correlation analyses failed to yield statistically significant findings. Specifically, the regression analysis indicated a multiple R of .021, which did not significantly deviate from zero ($F(1,18) = .387$, $p =$

.542). Similarly, Spearman’s correlation analysis also did not reveal a statistically significant correlation between the variables ($p = .715$).



Graph 2. Scatter plot: Relationship between self-efficacy and motivational word usage.

Technical functionality, user experience, and emotional responses toward the VR exercise system

A thematic analysis was conducted to analyze the qualitative data obtained from the semi-structured interviews, and the findings are presented in Table 4. According to the participants' reports, they did not encounter any technical issues and did not require additional time to understand the VR exercise system. The majority of participants expressed satisfaction with the VR system equipment, including the head-mounted display and joystick, although a few mentioned that the mask felt slightly heavy or tight. None of the participants experienced negative emotions, discomfort, or unusual thoughts during the cycling activity, except for one individual who initially felt some dizziness for a few seconds at the beginning of the VR experience. All participants expressed a desire to continue using the VR system for exercise, emphasizing that they found it enjoyable, relaxing, motivating, interesting, challenging, and capable of evoking feelings of happiness. They also mentioned that the system provided a means of escaping from reality and was easy to use.

Table 4. Thematic analysis of the semi-structured interview table.

Main Theme	Subthemes	N	(%)
Reasons to use VRADA	<i>Why would you use VRADA?</i>		
	It is pleasant	14	70%
	It is relaxing	8	40%
	It is motivating	3	15%

Usability or utilization	<i>General difficulties</i>		
	None	16	80%
	Difficulty adjusting to the speed limits	3	15%
	<i>Technical issues</i>		
	None	20	100%
	<i>Joystick use difficulty</i>		
	No	20	100%
	<i>VR mask use difficulties</i>		
	None	16	80%
	It was a little heavy	2	10%
	It was a little tight	2	10%
Usability or learning	<i>Need more time to understand the system</i>		
	No	20	100%
Usability or pleasantness	<i>Most enjoyable parts</i>		
	The VR environment (landscape)	15	75%
	Music	3	15%
	Peacefulness and relaxation	3	15%
	<i>Least enjoyable parts</i>		
	Repeated virtual parts, monotonous	9	45%
	Graphics	8	40%
	Music	5	25%
	<i>Feel uncomfortable</i>		
	No	20	100%
Sense of presence or engagement	<i>Distraction of attention</i>		
	No	19	95%
	Yes	1	5%
	<i>Duration of the experience</i>		
	It could be more	10	50%
	It was enough	7	35%
	It could be more but I didn't have time because of our demanding schedule	3	15%
Sense of presence or realism	<i>VR environment was realistic or artificial</i>		
	Artificial	20	100%
Tolerability	<i>Feel bad during training</i>		
	No	20	100%
	<i>Thinking of weird things</i>		
	No	20	100%
	<i>Nausea, dizziness or other physical symptoms</i>		
	No	19	95%
	A little for the first seconds	1	5%

Discussion

In our feasibility study, our objective was to investigate the self-efficacy expectations and attentional control differences of individuals in SUD treatment pre- and post-exercise with the VR system and to investigate their attitudes, intentions for future use, and interest/enjoyment about this type of exercise, immediately after the exercise session. The results of this study offer insights into the impacts of an VR exercise system on exercise self-efficacy expectations and performance in the Stroop test. Additionally, the results indicated positive outcomes and acceptance of the VR exercise system for people under SUD therapy, thus suggesting the feasibility of this approach.

The effects of VR exercise on self-efficacy expectations of individuals in SUD treatment

In our study, we evaluated self-efficacy expectations before and after the VR exercise. Consistent with Bandura's definition (Bandura et al., 1977), these expectations reflect an individual's belief in their capability to complete tasks essential for desired outcomes in specific situations. Our findings revealed a significant improvement in self-efficacy expectations following the VR experience. Panagiotounis et al., 2020 assessed self-efficacy in individuals in the treatment of SUD. According to this study, the intervention lasted 5 days and was an adventure-based therapy for the promotion of participants' therapeutic change involving physical activity. The results have shown that the participants' self-efficacy and self-esteem were positively affected (Panagiotounis et al., 2020). Our findings did not unveil any significant relationship between self-efficacy and the repetition of motivational words; rather, this observation was discerned solely from the scatter plot. It is possible that the limited sample size may account for this outcome. According to our results, there were statistically significant differences in self-efficacy expectations, that can be positively influenced by one bout of exercise. This can be elucidated by emphasizing that, as previously noted, self-efficacy expectations are more precise, and engaging in exercise provides immediate successful experiences that strengthen individuals' confidence in their ability to participate in physical activity (Bandura et al., 1977). From our perspective, VR exercise shows promise as a tool for indirectly enhancing self-efficacy after a few times of exercising as we found improvements in self-efficacy expectations scores in acute exercise.

The effects of VR exercise on the attentional control of individuals in SUD treatment

According to our results, there was a statistically significant reduction in reaction time in the Stroop test after the VR exercise. It was observed that individuals with important positions with many demands and responsibilities for the community, such as drivers and coordinators noted better scores in all tabs of the Stroop test compared with members who were less active in their community. Nevertheless, covariate analysis didn't find a significant effect. Our results are consistent with those of Smith et al., 2021 supporting that participants who engaged in a VR exercise program as part of their treatment showed significant improvements in Stroop test performance after VR exercise (Zimmer et al., 2016). Based on our findings, it is plausible to suggest

that VR exercise may contribute to enhancing cognitive restoration during therapy. Likewise, previous research has indicated that individuals with SUD demonstrated decreased reaction time in the Stroop test following an acute bout of Tai Chi or high-intensity interval training, with the latter demonstrating superior improvement (Yin et al., 2022). To investigate the potential influence of a practice effect on the substantial improvement of reaction time observed in the Stroop test, our Stroop test effect sizes (Cohen's *d*) were compared with those of Zimmer et al., 2016, who utilized the same test in a pre-post design with a control group, notable differences emerged. The comparison of our Stroop test effect sizes with those of Zimmer et al., 2016 provides valuable insights into the potential impact of exercise intervention on cognitive function. Despite the acknowledged vulnerability of the Stroop test to practice effects, our study revealed significant differences in effect sizes, particularly in the naming and interference tabs, indicating a potential contribution from acute exercise. The higher Cohen's *d* values observed in these tabs compared to the control group of Zimmer et al., 2016 suggest temporary cognitive changes that extend beyond mere familiarity with the test. We also found significant relations between days in the treatment and the Stroop test pre-exercise score in the second tab of the Stroop test. There was a moderate negative relation between these variables and this can be a clue that maybe the days spent in abstinence from drugs may influence positively the cognitive function. Nevertheless, repeated measures ANOVA with covariate analysis on the relationship before and after VR training Stroop test scores showed a non-significant effect of days in treatment. Research has consistently shown that longer durations of abstinence from drugs are associated with improved cognitive function, including attention, working memory, and executive control (Scott et al., 2007; Verdejo-García et al., 2006).

In our study, all participants were poly-users, but the vast majority of them reported that heroin was the substance that was the most difficult to abstain process. Heroin addiction adversely impacts impulse control, attention, and flexibility. Additionally, heroin craving levels can predict how quickly someone reacts to heroin-related cues (Lundqvist, 2005). However, because the sample size was small and all participants used multiple substances, no comparative analyses were done to assess the impact of specific drugs on their Stroop test performance.

The attitudes, intention for future use, and interest/enjoyment of individuals in SUD treatment toward VR exercise

According to the results, most participants showed increased levels of interest/enjoyment, intention for future use, and positive attitudes toward the VR exercise system indicating positive perceptions and high motivation. Interest/enjoyment is a dimension of intrinsic motivation and the high scores indicate positive motivation. These results suggest that the participants after using the VR exercise system, had a favorable attitude toward the VR exercise system, intended to use it in the future, and expressed strong interest and enjoyment during the VR cycling experience. These results align with participants' feedback regarding their virtual experience from the interview. Notably, there were no reports of adverse effects such as nausea or dizziness, and overall comments on the VR exercise application were highly positive. However, several participants mentioned that they found the landscape to be somewhat monotonous. While this feedback is valuable, it should be considered for future studies utilizing the VRADA application. Furthermore, the feedback gathered from questions presented on the screen following the cycling performance was overwhelmingly positive. The majority of participants expressed satisfaction with their exercise experience and reported no feelings of fatigue. However, there were fewer positive responses regarding the word repetition task, indicating that some participants found this aspect less enjoyable or engaging.

In our study, participants chose their preferred landscape (forest, beach, snowy landscape) and cycling duration (5 to 30 minutes) in the VR environment, receiving real-time feedback on speed, distance, and remaining time, while also having the option to select music from a list of songs. Research consistently demonstrates that incorporating choices into individuals' exercise routines significantly enhances their experience and motivation. By allowing participants to select key elements such as exercise duration, preferred music, and the surrounding landscape, exercise programs become powerful tools for providing autonomy. This practice aligns with motivational techniques rooted in self-determination theory, fostering intrinsic motivation and a greater sense of ownership over one's fitness journey (Teixeira et al., 2019). The ability to tailor exercise programs to individual preferences not only makes them more personalized but also increases engagement and enjoyment. Ultimately, these autonomy-supportive strategies contribute to a positive and individualized exercise experience, promoting sustained adherence and overall well-being.

VR exercise arose as a promising tool for individuals in SUD treatment, as it offers a unique and immersive approach to physical activity. Studies assessing the effects of VR exercise on individuals in SUD treatment have found positive outcomes in terms of interest/enjoyment, attitudes towards exercise, self-efficacy, and cognitive function measured through the Stroop test. For instance, a study by Nesbitt et al., 2020 investigated the use of VR exercise among individuals in SUD treatment and found that participants reported high levels of interest and enjoyment during VR exercise sessions (Teixeira et al., 2019). Another study demonstrated that VR exercise interventions were associated with improved attitudes towards exercise and increased self-efficacy among individuals in SUD treatment (Fleming et al., 2016). Furthermore, other researchers investigated the effects of VR exercise on cognitive function using the Stroop test in individuals with SUD and found significant improvements in attention and inhibitory control following VR exercise sessions (Keshavarz et al., 2020). According to Worley (2019), VR can be a promising tool to help individuals under SUD treatment to manage cravings and pain, reduce psychological issues, learn life skills and exercise. However, there aren't many studies comparing VR exercise programs with traditional exercise. Qian et al. 2020, highlight that engaging in VR exercise can offer significant benefits to physical health, mental well-being, and the recovery process across various populations, providing distinct advantages compared to traditional exercise methods (Qian et al., 2020). VR is, in general, increasingly recognized as a valuable tool for exercise therapy across various disorders requiring rehabilitation. It addresses the limitations of traditional exercise methods by offering a more engaging and effective approach. VR programs have demonstrated superior outcomes compared to conventional exercise therapies, making them a preferred choice in many cases. These programs are versatile and can be tailored for numerous therapeutic purposes, including pain management, enhancing functional abilities, increasing range of motion, promoting muscular strength, and boosting motivation. Consequently, VR represents a promising advancement in the field of exercise therapy, providing comprehensive benefits for various populations including individuals in SUD treatment (Asadzadeh et al., 2021). Therefore, exercise in virtual environments offers all the benefits of traditional exercise, such as improved physical health and well-being, while also enhancing enjoyment and motivation.

Practical implications

The findings of our study have several practical implications for the integration of VR exercise systems in SUD treatment programs. The significant improvements in self-efficacy expectations and attentional control observed after a single session of VR cycling suggest that this type of intervention could be a valuable addition to traditional SUD treatment modalities. Firstly, the high levels of interest, enjoyment, and positive attitudes towards the VR exercise system indicate that such technology can make exercise more appealing to individuals undergoing SUD treatment. By increasing motivation and engagement through enjoyable and immersive experiences, VR exercise systems can help in maintaining regular physical activity, which is crucial for the overall well-being and recovery process of individuals with SUD (Furzer et al., 2021). Also, the observed improvements in attentional control, as evidenced by the Stroop test results, highlight the potential cognitive benefits of incorporating VR exercise into SUD treatment. Enhanced attentional control can contribute to better decision-making and impulse control, which are critical components in preventing relapse and promoting sustained recovery (Verdejo-Garcia et al., 2019). The significant increase in self-efficacy expectations post-exercise suggests that VR cycling can boost confidence in one's ability to engage in and benefit from physical activity. Higher self-efficacy is associated with greater persistence in the face of challenges, which can be particularly beneficial for individuals recovering from SUD (Kadden et al., 2011). The ability to engage in VR exercise sessions at self-selected durations and intensities provides flexibility, making it easier to tailor interventions to individual preferences and needs. This personalized approach can enhance adherence to exercise programs and ensure that participants are neither overwhelmed nor under-challenged. Hence, by participating in exercise programs, these individuals can achieve better physical and mental health outcomes and more positive substance use outcomes (Abrantes et al., 2019). Implementing exercise through a VR environment can further enhance motivation and engagement and offer access to safe and appealing exercise environments leading to increased self-efficacy and improved cognitive functions. These improvements are inversely related to relapse and craving symptoms, making exercise an essential component of effective SUD treatment strategies. A VR exercise system can be an effective tool to increase their participation to exercise programs, maintain a regular exercise routine and provide substantial benefits, reducing the risk of dropout and enhancing recovery outcomes.

Strengths & Limitations

This study contributes significantly to the emerging field of VR exercise interventions for individuals undergoing SUD treatment. One of its primary strengths lies in its holistic approach, exploring not only the cognitive benefits but also participants' attitudes, intentions, and interest/enjoyment related to VR exercise. The utilization of both quantitative measures, such as the Stroop test for attentional control, and qualitative data offers a comprehensive understanding of the intervention's impact.

Despite its strengths, this study has several limitations that warrant consideration. The findings may not be widely applicable to a larger population due to the relatively small sample size. The study's focused exploration within a specific population undergoing SUD treatment, coupled with resource constraints for intensive assessments, necessitated a smaller sample size of 20 participants. While limited in generalizability, this approach allowed for in-depth insights and laid the groundwork for future, more extensive investigations. Recruiting participants from this population posed a considerable challenge. Despite accessing the largest treatment center in the country, achieving a more homogeneous sample was unattainable. In general, recruiting participants from this population is challenging because of their uncertain retention in the SUD treatment program, limited availability of participants, the need for special consent due to the sensitive nature, and the variability in participants' drug use history and treatment duration. The heterogeneity of the sample should be considered when interpreting the results, as they may influence the findings in ways not entirely accounted for by our analyses. Future research should aim to recruit a larger and more homogeneous sample to validate and extend the findings of this study. Despite these limitations, the study provides valuable insights into the experiences of individuals undergoing treatment for SUD, highlighting the need for tailored treatment approaches that consider individual variability. The absence of a control group and random assignment is acknowledged, posing challenges in establishing causal relationships. The quasi-experimental design, while providing initial insights, necessitates caution in generalizing findings to long-term effects, highlighting the need for future studies with extended interventions and control conditions. According to Edwards et al., 1996, it is possible that the practice effect from the Stroop test may have influenced the positive results regarding attention. Therefore, because our study design did not include a control group, we might have had the effect of practice when we compared the before–

after Stroop test scores. Nevertheless, previous studies examining the effect of exercise on Stroop performance, indicated that an acute bout of exercise led to improved scores in the Stroop test, compared with a control group (Sibley et al., 2006). According to our findings the effect size of the Stroop task in our study was higher compared to the control group of Zimmer et al., 2016. These findings underscore the nuanced effects of exercise on cognitive performance and underscore the necessity for additional research to elucidate the mechanisms underlying these effects. Additionally, in this study, we observed that individuals with important positions and numerous demands and responsibilities in the community, such as drivers and coordinators, achieved better scores in all tabs of the Stroop test compared to members who were less active in their community. This observation underscores the importance of considering such factors in future studies on this topic. In conclusion, there is a need for further research involving extended exercise interventions utilizing VR environments, larger sample sizes, randomized controlled trials, and prolonged follow-up periods. These endeavors will serve to validate and expand upon the current findings, shedding light on whether such exercise modalities could contribute to reduce drug use, and cravings or enhanced recovery self-efficacy.

Conclusions

In conclusion, VR exercise can be a useful and promising tool to be used supplementally for SUD treatment. A short bout of self-selected exercise in a virtual environment can lead to increased scores in cognitive factors, enhance self-efficacy expectations levels, and can be a motivating way to improve physical activity participation levels of individuals with SUD. Further research in this field could explore the long-term effects and sustained benefits of VR exercise interventions for individuals undergoing SUD treatment. Additionally, investigations employing randomized controlled trials with larger and more diverse samples, extended intervention periods, and robust control conditions would contribute to establishing the efficacy and generalizability of such interventions, providing valuable insights for clinical applications.

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CHAPTER IV– STUDY 3

Virtual Reality versus Conventional Exercise in Patients with Type 1 Diabetes: A Feasibility Randomized Crossover Trial

Submitted

Abstract

Background: Exercise plays a key role in managing Type 1 Diabetes Mellitus (T1DM) and Virtual Reality (VR)-based exercise offers an innovative solution to increase motivation and deliver meaningful health benefits to patients who are often hesitant to engage in physical activity. The purpose of the study was to investigate the effects of VR-based exercise on biological and psychological parameters of individuals with T1DM compared to conventional exercise, as well as to assess acceptance of the VR application, intention for future use, usability and preference. **Method:** Eleven patients with T1DM underwent two low-intensity exercise trials. In particular, the first trial consisted of cycling on a cycle ergometer, while the second trial utilized a VR-based cycling application. **Results:** The results showed a notable, no statistically significant, decrease in biological parameters such as blood glucose, blood pressure, and heart rate levels following the VR-based trial in comparison to the conventional cycling trial. Nevertheless, there was a statistically significant improvement in psychological parameters such as mood following the VR-based cycling trial, as well as an increase in interest/enjoyment compared to conventional cycling trial. Additionally, high scores were observed for preference, acceptance, and usability of the VR-based cycling application. **Conclusions:** In conclusion, the use of VR technology in the field of cycling exercise has great significance in improving the mood and engagement of T1DM patients in exercise programs, providing a user-friendly and well-accepted application; subsequently, it has also shown a preliminary potential for the regulation of biological parameters. Healthcare professionals could easily expand exercise protocols with the strengths of the VR technologies along with other health-related programs.

Keywords: diabetes management, VR technology, mood, motivation, blood glucose, cycling

Introduction

According to the World Health Organization (WHO), diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it does produce. In 2019, diabetes was the direct cause of 1.5 million deaths, with 48% of these deaths occurring before the age of 70. In particular, Type 1 Diabetes Mellitus (T1DM) is characterized by insufficient insulin production, requiring daily insulin administration. In 2017, there were 9 million people with T1DM worldwide, with the majority living in high-income countries. The exact cause and prevention methods for T1DM remain unknown [1,2].

The importance of exercise in the prevention and management of diabetes has been extensively documented in literature [3,4]. However, for individuals with T1DM, exercise can pose risks, such as hypoglycemia [5]. Another critical factor influencing diabetes management is an individual's psychological state. Increased stress can negatively impact glycemic control and overall disease management in individuals with diabetes [6,7]. Stress triggers the release of hormones like cortisol and adrenaline, which impair insulin effectiveness, often resulting in hyperglycemia [8]. Additionally, blood glucose levels and mood are closely interconnected, with elevated glucose levels having an adverse impact on mood [9]. According to Van Tilburg et al., glycemic control in individuals with T1DM is significantly impacted by subclinical depressive moods, while diabetes management may be positively influenced by improved mood [10]. Another systematic review and meta-analysis support that regular exercise improves health-related quality of life and consequently glycemic control in patients with type 2 diabetes mellitus [11].

In this context, enjoyment emerges as an essential factor in promoting adherence to exercise programs [12]. Patients with T1DM experienced improved quality of life, heightened motivation to exercise, and increased enjoyment—key contributors to psychological well-being—after participating in a 6-week HIIT exercise program [13]. Intrinsic motivation plays a vital role in participation and commitment to exercise programs [14]. Notably, enjoyment and intrinsic motivation for exercise are strongly linked; when individuals find an activity enjoyable, their intrinsic motivation to engage in it increases [15]. In addition, according to Bandura's [16] theory, self-efficacy refers to an individual's belief in his or her ability to organize and execute the actions required to achieve specific goals. It influences motivation,

effort, resilience, and performance in various tasks, with higher self-efficacy leading to greater persistence and success in challenging situations [16]. It is highlighted by literature that increased self-efficacy has great potential on exercise performance and maintaining exercise behaviors [17]. Moreover, self-efficacy, along with its interaction with expectations of positive outcomes, is strongly associated with adherence to diabetes self-management and better glycemic control, while the influence of self-efficacy may be stronger when patients have a strong belief that adherence to diabetes management would lead to positive outcomes. Thus, increasing self-efficacy through could improve diabetes self-management [18].

The use of Virtual Reality (VR) technologies/applications is increasingly being incorporated into the management of diabetes, particularly in education, prevention, and treatment strategies [19]. VR-based education programs are considered powerful tools for promoting self-management of diabetes due to their immersive learning experiences and enhanced communication with patients [20]. Studies have shown that VR-based interventions effectively reduce pain and anxiety while improving glycemic control, adherence to treatment protocols, and satisfaction in children with T1DM [21]. The improvements in balance and fall prevention were supported by a systematic review and meta-analysis, but the findings indicated no significant reduction in glycated hemoglobin (HbA1c) levels [22]. It is also important to be mentioned that VR-based exercise can be an attractive tool that decreases dyspnea symptoms and can enhance performance during exercise, and consequently can increase exercise engagement in patients [23].

Research on VR-based exercise in diabetes management is still in its early stages. VR technologies/applications has shown promising results among patients with Type 2 Diabetes, demonstrating high adherence to exercise programs and improving diabetes-related factors. For instance, VR-based exercise programs can enhance exercise outcomes while reducing the risk of falls in Type 2 Diabetes patients [24]. According to Lee et al., such interventions can positively affect blood glucose levels, muscle mass, physical activity, and glycemic control [25]. Furthermore, another study indicated that physical activity levels significantly increased after participating in a VR-based exercise program [26]. For T1DM, the available research is even more limited. Preliminary findings suggest that video games and VR environments are being explored for T1DM education and management. These tools have proven to be safe, engaging,

and effective in fostering confidence in diabetes management and promoting positive behavior changes [27,28].

The purpose of the present study was to investigate the effects of VR-based exercise on biological (heart rate, blood glucose, mean arterial pressure) and psychological (mood, interest/enjoyment, self-efficacy, attitudes) parameters in individuals with T1DM and to compare these effects with conventional exercise. In addition, the acceptability, usability, intention for future use, and preference of a VR-based exercise application were also assessed.

Materials and Methods

Trial design and Ethics Approval

The present study followed a randomized crossover design consisting of two cycling exercise trials. The study experimental protocol was approved by the Institutional Ethics Committee (ref: 1829/13.10.2021) and all patients gave written informed consent according to the Helsinki Declaration on Human Research Participation [29].

Participants

Originally, 20 patients with T1DM (recruited from the Endocrinology Clinic of the General University Hospital of Larissa, Greece) were sampled (from October 2022 to February 2023). For the baseline 17 patients completed the initial assessment. Among the remaining 17 patients, six did not participate in the second visit. As a result, the final study sample consisted of 11 patients (6 male, 5 female) (see study flow, Figure 1). The patients had a mean age of 31.7 years (± 9.7 years), a mean Body Mass Index (BMI) of 22.8 kg/m², and a mean waist circumference was less than 1.00 m, while all of them were inactive, with a mean exercise duration of less than 100 minutes per week according to the International Physical Activity Questionnaire (IPAQ) [30]. Patients were excluded from the study if they had ophthalmological disorders (and/or wore glasses), a history of COVID-19 infection and hospitalization [23], contraindications to exercise including physical limitations such as neurological, orthopedic, cognitive, and/or psychiatric problems [31], sleep quality score >5 according to the Pittsburgh Sleep Quality Index (PSQI) [32,33], quality of life score <45 according to the 12-item Short Form Survey (SF-12) [34], and anxiety and depression symptoms score <7

according to the Hospital Anxiety and Depression Scale (HADS), for each subscale [35,36].

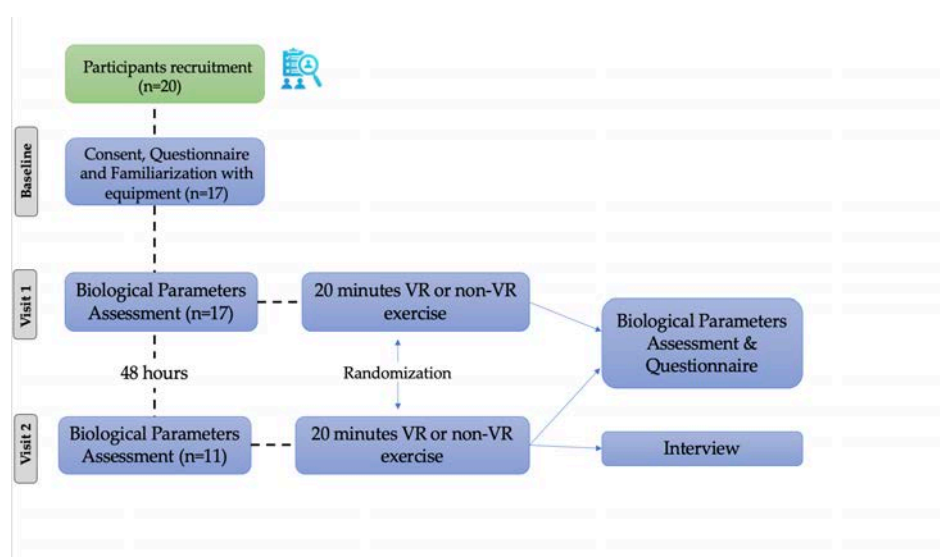


Figure 1. Study flow.

VR Application and Measures

The study consisted of two exercise trials that were performed on a stationary seated cycle ergometer (Toorx, Chrono Line, BRX R 300). Each trial comprised 20 minutes of low-intensity cycling exercise, with one trial conducted using a conventional exercise method and the other using a VR-based application (referred to as “VRADA”, which was originally developed for use in patients with dementia and Alzheimer’s disease), following the methodology outlined in previous studies [23,31,37,38]. Specifically, for the VRADA application [38], the selection was based on the hypothesis that it would reduce stress, potentially resulting in a reduction in blood glucose levels, increased motivation to engage in exercise, and a safe and controlled approach to managing glucose levels during exercise. Patients were able to receive feedback on aspects of the exercise (e.g., duration, distance, speed, etc.), but also to customize other aspects, such as the choice of virtual landscape (forest, beach, snowy terrain), music, and motivational phrases during the exercise (using a VR controller with ray-casting interaction for choices). In addition, the duration of the exercise was determined by the participant, allowing for personalization to increase motivation. Finally, the present study used version 4.1 of the VRADA application, with the exception of some parts that were originally designed for patients with dementia and

Alzheimer's disease (e.g., cognitive tasks) and adapted for the T1DM population; this adaptation allowed us to provide a safe, controlled, and immersive exercise environment tailored to this population.

Furthermore, a series of additional measures and questionnaires were used in the present study. Initially, anthropometric characteristics were measured (e.g., weight and height). After that, a number of questionnaires were used during the baseline and first visit phase. All patients were asked about demographic characteristics (e.g., gender, age, etc.) and technology use (e.g., frequency of using mobile phones, computers, video games) before participating in the trials (VR or non-VR condition). In addition, they completed the Profile of Mood States (POMS) before and after each trial, which consists of 14 items assessing mood states (e.g., "I feel calm") (5-point Likert scale) [39,40]. Afterwards, and specifically after each trial, they completed the Intrinsic Motivation Inventory (IMI) consisted of six items assessing interest and enjoyment of the task (e.g., "This exercise was enjoyable") (5-point Likert scale) [41,42], the Exercise Self-Efficacy scale consisted of 10 items assessing how confident they are in completing the exercise (e.g., "I will exercise even when I am tired") (5-point Likert scale) [43,44], the Self-Efficacy Expectations scale assessing perceived ability to sustain exercise for increasing durations (e.g., 20–40 min) (answered Yes/No, e.g., "I can sustain the task for 30 minutes" and rated confidence on a 10-point scale) [43,44], and Attitudes were assessed using six bipolar items (e.g., "Pleasant-Unpleasant") (7-point semantic differential scale) [45].

Furthermore, after exercise in the VR environment, patients also completed the following questionnaires regarding to Personal Innovativeness, which consisted of four items (e.g., "I am eager to experiment with new technologies") [45], Usability, which consisted of 10 items (e.g., "I found this virtual reality system complex") [46], VR Equipment Satisfaction, which consisted of nine items (e.g., "I felt comfortable using the headset") [47] and Acceptance, such as perceived enjoyment consisted of six items (e.g., "I enjoyed exercising with the virtual reality system") [48] and intention for future use consisted of three items (e.g., "I intend to use VR-based exercise when it becomes available") [48,49]. All questionnaires were scored on a 5-point Likert scale.

At the end of the last visit, and after getting the experience of the two trials (VR or non-VR condition), patients also completed the final questionnaire about Preference for the two cycling exercise protocols, which consisted of eight items (e.g., "Exercise was more pleasant..."). Finally, a semi-structured interview was conducted to gather additional

qualitative information allowing us to identify important topics regarding patients' experiences, attitudes, and perceptions of VR versus conventional exercise protocols.

2.4 Procedure and Experimental Protocol

Initially, patients were randomly assigned to groups using a block randomization technique [50]. Then, at the baseline and first visit, patients were informed of the study objectives, signed the informed consent form, and were encouraged to ask questions. Patients subsequently adjusted their position on the cycle ergometer and, for those exercising with the VR application for the first time, familiarized themselves with the equipment of the VR system. The principles of cycling biomechanics were followed, including proper spinal alignment, joint angle adjustments, and optimal foot positioning on the pedals, as outlined in the relevant literature [52]. The cycling protocol in our experiment was adapted accordingly to ensure comfort, symmetric force distribution, and minimal musculoskeletal stress. Finally, they were given detailed instructions on the procedure and use of the equipment.

Thereafter, biological parameters such as heart rate (chest strap sensor, Polar H9, Kempele, Finland), blood glucose (manual sphygmomanometer BP, Mac, Nagoya, Japan), and arterial pressure (using a device placed on the patient's arm that provides glucose readings via smartphone scanning, Freestyle Libre) were assessed before and after each trial; a 20 minutes low-intensity (approximately 30% of the predicted watts) cycling exercise trial. It is noted that the mean arterial blood pressure (MAP) has been calculated according to the following equation [52]:

$$\text{MAP}_{(\text{mmHg})} = \frac{\text{systolic blood pressure (mmHg)} + 2 \times \text{diastolic blood pressure (mmHg)}}{3}$$

The environment provided optimal conditions to facilitate cycling exercise. The temperature was $21 \pm 1^{\circ}\text{C}$, and the relative humidity was maintained at $48 \pm 5\%$. The room was quiet, with noise levels maintained below 20 decibels. Adequate ventilation was provided, and patients exercised without the use of protective face masks, allowing for natural breathing and comfort. Lighting was adequate, further supporting a conducive exercise environment. The intervention was conducted by an exercise-specialized researcher and a doctor with expertise in diabetes, ensuring appropriate instruction and safety throughout the study. Finally, before and after the bicycle exercise trail, all patients completed a few questionnaires at each visit (as described in

the previous section), and at the very last stage, patients participated in the semi-structured interview.

With regard to the cycling exercise protocols, patients participated in 20 minutes of low-intensity cycling exercise on both trails (VR or non-VR condition). The cycling trails consisted of three consecutive stages: the first stage was a warm-up and familiarization with the procedures and equipment (1 minute duration, 15-20 rpm, 0 watts load), the second stage was a cycling trail with a constant resistance work rate (20 minutes duration, 50-60 rpm, 30% of the predicted values load), and the third stage was a recovery stage (1 minute duration, 15-20 rpm, 0 watts load). All predicted values and maximum loads were calculated according to the equation of Wasserman et al. [53]:

$$\dot{V}O_{2\max} [\text{mL} \cdot \text{min}^{-1}] = (\text{height}_{(\text{cm})} - \text{age}_{(\text{yrs})}) \times 14 \text{ (female) or } \times 20 \text{ (male)}$$

$$\dot{V}O_{2\text{unloaded}} [\text{mL} \cdot \text{min}^{-1}] = 150 + (6 \times \text{body mass}_{(\text{kg})})$$

$$\text{Load} [\text{work rate}/\text{min}^{-1}] = \frac{(\dot{V}O_{2\max} - \dot{V}O_{2\text{unloaded}})}{100}$$

The two cycling exercise trials were conducted 48 hours apart, more specifically, the experimental procedures were performed every Tuesday and Thursday; the remaining time the participants continued their usual daily routine.

Statistical Analysis

A power of 85% and a confidence interval of 95%, with an estimated Type I error of 5%, were assumed for the sample size calculation in this study. The Kolmogorov-Smirnov test was used to assess the normality of the data and determine whether parametric or non-parametric statistical analyses were appropriate. Based on the results, the Mann-Whitney U test was used for between-group comparisons where applicable and the Wilcoxon Signed Rank test for distributed data was conducted to compare the two cycling exercise conditions (VR or non-VR condition). Cohen's d was calculated from the mean difference between groups (M1 and M2), and by the pooled SD:

$$\text{Cohen's } d = \frac{M2 - M1}{SD_{\text{pooled}}} \text{ and } SD_{\text{pooled}} = \sqrt{\frac{SD1^2 + SD2^2}{2}}$$

The IBM SPSS 21 statistical package (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

Results

Biological Parameters and Mood

The results of the biological parameters showed no statistically significant changes from pre- to post cycling exercise trials (in either condition) for blood glucose and mean arterial pressure. However, notable clinical changes were observed in both conditions, with the VR condition showing greater changes; lower values for blood glucose, and smaller increases in mean arterial pressure (Figure 2). In addition, no statistically significant changes were observed in heart rate at baseline or during any minute of exercise between the two conditions, but a statistically significant changes was found during the recovery phase ($p < 0.05$), with lower heart rate values following the VR condition (80.83 ± 14.35) compared to the non-VR condition (87.55 ± 8.97) (Figure 3). Furthermore, the examination of the patients' mood revealed statistically significant improvement in patients' mood following the cycling exercise in the VR condition, with mean mood scores increasing from pre- to post-intervention ($p = 0.05$). This suggests that engaging in exercise within a virtual reality environment had a positive effect on participants' mood. The values of the patients' biological parameters and mood presented in Table 1.

Table 1. Values of the biological parameters and mood.

Variable	Unit	VR condition				non-VR condition			
		Baseline	After trial	p-value	Cohen's d	Baseline	After trial	p-value	Cohen's d
HR	bpm	83.0±10.6	80.8±14.3	0.594	0.17	83.5±9.2	87.3±8.8	0.202	0.42
BG	mg/dL	173.2±61.6	144.6±55.1	0.091	0.49	185.9±64.4	181.6±58.2	0.990	0.07
MAP	mmHg	92.1±24.3	95.7±10.7	0.858	0.19	88.2±25.8	96.7±10.9	0.328	0.43
Mood	score	59.1±5.9	64.0±3.9	0.05*	0.98	59.7±6.6	61.5±5.0	0.439	0.31

Abbreviations: HR = Heart Rate, BG = Blood Glucose, MAP = Mean Arterial Blood Pressure

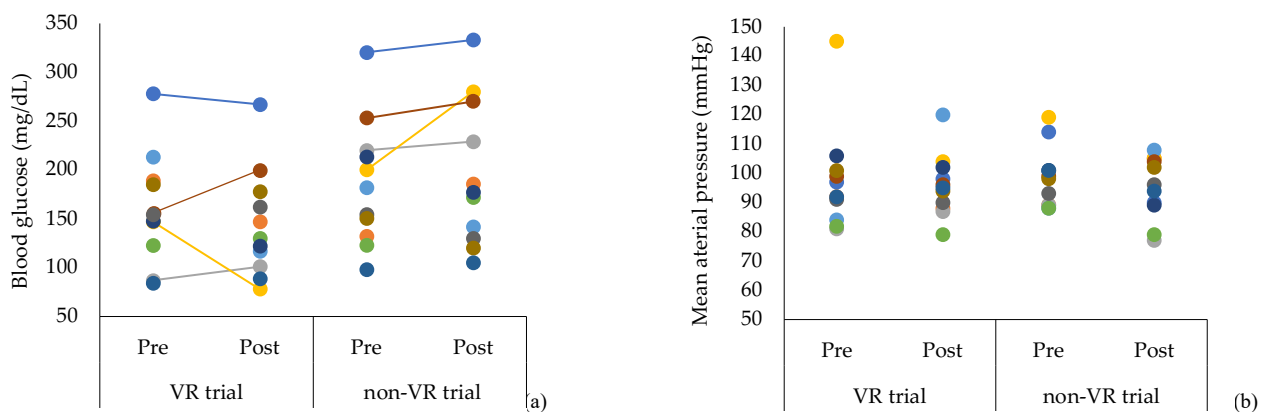


Figure 2. (a) Blood glucose levels for each participant across trials, (b) Mean arterial pressure levels for each participant across trials.

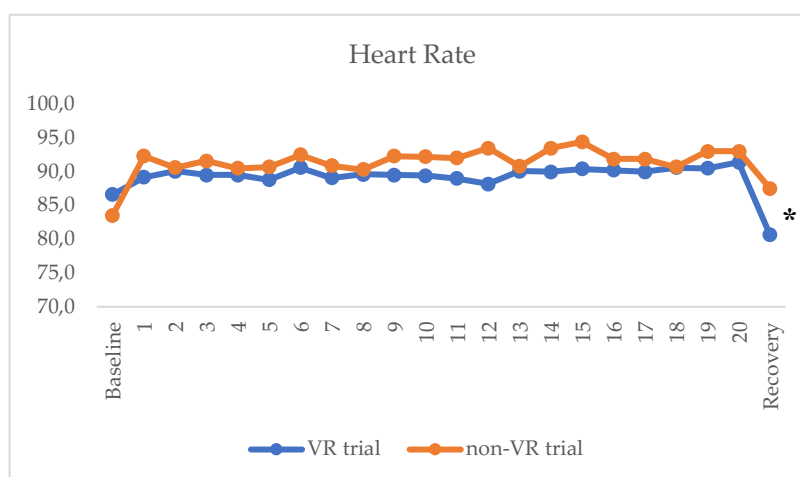


Figure 3. Mean heart rate of the patients at the baseline, during the trial (every minute), and during the recovery phase for each trial.

Psychological Parameters and VR Environment

The results immediately after each cycling exercise trail showed no statistically significant differences for self-efficacy ($p= 0.869$, Cohen's $d= 0.05$), self-efficacy expectations ($p= 0.399$, Cohen's $d= 0.40$), and attitudes ($p= 0.22$). In addition, regarding interest/enjoyment, the results revealed a statistically significant difference ($Z= -2.874$, $p< 0.001$) with participants in the VR condition reporting higher scores after the exercise. Furthermore, according to the assessment of VR environment, the results showed high scores of personal innovativeness, perceived enjoyment, intention for future use, usability, and VR equipment satisfaction. Means scores and standard deviations for psychological variables and VR environment are presented in Table 2. Finally, patients after the experience of the two cycling exercise trails (VR conditions and non-VR condition) highlighted a statistically significant preference for the VR condition ($Z= -2.836$, $p<0.05$).

Table 2. Means scores and standard deviations for psychological variables and VR environment.

	VR condition	non-VR condition
Variables	Mean±SD	Mean±SD
Self-Efficacy	41.4 ±6.4	40.2 ± 10.9
Self-Efficacy Expectations	54.5 ±10.2	49.5 ± 13.5
Interest / Enjoyment	4.5±0.5	3.4±0.9
Attitudes	6.2±0.7	5.7±1.0
Personal Innovativeness	3.9±0.7	-
Perceived Enjoyment	4.6±0.3	-
IFU	4.4±0.6	-
Usability	83.4±12.1	-
VR Equipment	4.1±0.5	-

Abbreviations: IFU = Intention for Future Use

Semi-Structured Interview

The semi-structured interview included questions related to the patients' emotions, expectations, and perceptions of the usability and tolerability of the VR application and equipment. Most patients reported that they would use this VR application for exercise, had no difficulty, and did not require additional time to understand how it worked. In addition, most of the patients felt a sense of presence and control, although they noted that the VR environment appeared artificial. None of them reported any feelings of discomfort, and only one patient mentioned that he was distracted during the experience. Furthermore, patients described the exercise using the VR application as enjoyable, motivating to engage in physical activity, and effective in making time pass more quickly. However, a small percentage of patients (27,3%) reported that they would not want to use the VR application for a regular exercise. Finally, patients suggested that young people, individuals unable to exercise outdoors, and those who do not typically enjoy exercise would find this type of exercise (VR application) particularly beneficial.

Discussion

The purpose of the present study was to investigate the effects of VR-based exercise on biological and psychological parameters in individuals with T1DM, and to compare these effects with a conventional exercise, as well as to assess acceptance, intention for future use, usability, and preference of the VR application. The findings provide preliminary insights into the effects of the VR-based exercise on the investigated biological and psychological variables compared to conventional exercise in patients with T1DM and highlight the use of VR-based exercise applications. The results of the present study are consistent with those of previous studies, suggesting that VR-based exercise is well accepted, user-friendly, and provides positive benefits in diverse populations [23,31,37].

Additionally, relevant research indicates that VR-based interventions are effective in reducing pain and anxiety, improving glycemic control, promoting adherence to treatment protocols, and increasing satisfaction in children with T1DM [21]. It is also supported that VR-based interventions can have a positive impact on blood glucose levels, muscle mass, physical activity, and overall glycemic control [21].

Similarly, Senior et al. reported a significant increase in physical activity levels after participating in a VR-based exercise program [26]. Moreover, a recent study by Elsholz et al. [54] explored the taxonomy of research and commercial VR-based exercise applications, highlighting the different priorities of each domain [54]. Research applications often focus on scientific precision and skill development under controlled conditions, whereas commercial applications emphasize motivation, fun, and competitiveness, catering to a broader audience. This distinction is critical to designing VR-based interventions that not only target biological and psychological outcomes of T1DM patients, but also ensure long-term engagement and adherence [54].

As expected, positive results were found regarding patients' acceptance and usability of the VR-based exercise and application, as well as in their preference for this type of exercise, supporting the potential of this approach as a complementary tool in T1DM management. The results showed an 8% decrease in blood glucose levels after 20 minutes of exercise in the VR condition compared to the non-VR condition, which showed a smaller decrease. It is well known that aerobic exercise increases glucose uptake by the muscles [4]. Additionally, previous studies have shown that increased stress raises blood glucose levels and leads to poor glucose control [55]. As it is supported by Shaw & Lubetzky, a short bout of VR-based exercise can reduce stress and anxiety [56]. Therefore, VR-based exercise could provide an enjoyable activity in a pleasant environment, which might help reduce stress and, consequently, lead to a greater reduction in glucose levels compared to regular exercise. According to Lee et al. [25] a VR-based exercise program can positively affect glucose control in patients with Type 2 Diabetes Mellitus (T2DM) [25]. Further, a two-week VR exercise program consisting of 30-minute sessions at an intensity of 65-70% of maximum heart rate produced effects similar to running, with fewer hypoglycemic episodes in T1DM patients [57]. However, a systematic review and meta-analysis concluded that longer duration VR-based exercise programs did not show statistically significant improvements in glycated hemoglobin in diabetic patients [22]. There are only a few studies in the literature that have evaluated the direct effects of VR-based exercise in comparison to conventional exercise on biological parameters. One study found that biological responses to exercise stimuli were similar in both exercise trials (VR and non-VR conditions) when conducted at the same duration and intensity [58], which is consistent with the results of the present study. Also, the decrease in glucose levels was much lower in the non-VR condition.

Regarding the psychological variables, the present findings support a statistically significant improvement in patients' mood following exercise in the VR condition, while no significant change was observed after exercise in the non-VR condition. Similar results were found regarding patients' interest/enjoyment and preference for VR-based exercise. The combination of exercise and VR increases enjoyment, boosts energy, and reduces fatigue, as supported by other studies [e.g., 59]. Also, according to Plante et al. using VR without exercise increased fatigue and tension (approximately 60%), and decreased energy levels (approximately 7%) [59]. Consistent with this, Gomes et al. [58] found that participants found VR gaming exercises more enjoyable than running [58]. Mood improvements following VR-based exercise compared to conventional cycling are also supported by Ochi et al., who concluded that this type of exercise could improve well-being in diverse populations [60]. In addition, intrinsic motivation plays a key role in exercise participation and adherence [14]. The strong relationship between enjoyment and intrinsic motivation suggests that when people enjoy exercising, their motivation to continue exercising increases [15]. However, another study comparing VR-based cycling exercise to outdoor cycling reported that while VR-based exercise positively influenced engagement and physiological responses, and outdoor cycling provided greater benefits in terms of motivation, enjoyment, and exercise adherence [61].

Patients with T1DM, in addition to the inability to produce insulin, are at risk for developing cardiovascular diseases, as hyperglycemia and insulin deficiency are associated with strain on the cardiovascular system [62]. Changes in mean arterial pressure levels are influenced by cardiac output and systemic vascular resistance [52]. Additionally, the autonomous nervous system plays a crucial role in the regulation of mean arterial pressure. When mean arterial pressure is elevated, parasympathetic activity increases, resulting in a decrease in cardiac output [52]. Conversely, when mean arterial pressure is low, sympathetic tone increases, resulting in an increase in cardiac output and systemic vascular resistance [52]. Increased sympathetic tone also occurs during exercise and periods of psychological stress [52]. The autonomous nervous system plays a critical role in the body's response to stress. Stress reduces parasympathetic tone and increases sympathetic activity, leading to an elevated heart rate, blood pressure, and the release of hormones such as cortisol. Reduced parasympathetic activity negatively affects the regulation of the vagus nerve, which is important for heart rate variability and recovery. Long-term, this can impact

cardiovascular health. Strengthening parasympathetic tone through exercise or relaxation techniques can help mitigate these effects [63]. According to the present results, the mean arterial pressure did not show significant changes overall; however, it was observed that there was a greater increase in mean arterial pressure in the non-VR condition, with an increase of 9.6%. This phenomenon can be attributed to the fact that during the VR condition, stress was reduced, leading to a lower sympathetic tone and consequently a smaller change in mean arterial pressure, with a 3.9% increase. This is important because during this form of exercise, there is a reduced need for blood circulation from an already burdened cardiovascular system due to the disease [64]. Finally, in terms of patients' experiences during the VR condition, they scored high on personal innovativeness, indicating a preference for experimenting with new technologies, which likely contributed to the high scores for perceived enjoyment and future use intention. Patients also rated the usability of the VR application and equipment highly, suggesting it could increase acceptance and engagement [65]. Moreover, enjoyment is directly correlated with adherence to VR condition, and VR application can be used as a tool to improve adherence [66]. Lastly, the semi-structured interviews yielded encouraging results regarding participants' experiences with the VR application and equipment. The reported sense of presence in the VR environment could lead to changes in attitudes towards this exercise modality and increased enjoyment. Positive attitudes may increase intentions for future use [67].

Strengths and Limitations of the Study

To the best of our knowledge, no studies have assessed the biological and psychological parameters in individuals with T1DM while comparing VR-based exercise to non-VR exercise. Based on our results, it appears that exercise performed in a pleasant environment can have a positive impact on both biological and psychological parameters in individuals with T1DM. Therefore, we recommend the inclusion of outdoor activities, VR exercise, or the integration of new technologies into their exercise programs to improve both their physical and psychological well-being. Despite the preliminary encouraging results, the present study has several limitations that should be mentioned. First, the small sample size limits the generalizability of the findings and the statistical power to detect potential differences in biological and psychological parameters. Although 20 patients were initially recruited from the wider hospital area, a significant number of patients failed to attend the first or second visit;

personal and economic issues were identified as reasons for dropout. Recruitment of patients was subsequently stopped due to the high workload of the clinic. Second, the short duration of the intervention prevents conclusions about long-term effects or adherence to VR-based exercise, although the study showed improvements in mood and enjoyment. the lack of a non-exercising control group limits the ability to isolate the specific effects of VR-based cycling exercise compared to a non-exercise condition. Although efforts were made to control for potential confounding factors such as diet, sleep, and insulin use by instructing participants to follow their usual routines, individual variations in these factors could not be entirely eliminated. The results of the present study provide preliminary insights that can inform larger-scale studies with extended intervention periods and more diverse samples to validate these findings.

Future studies should include larger, more diverse samples and extended intervention periods to confirm these findings and further investigate the role of VR-based exercise in T1DM management. Additionally, exploring bioinformatic indicators could provide deeper insights into the underlying mechanisms of VR-based exercise benefits, while at the same time aiding in the development of more engaging and enjoyable VR environments. In furthermore, studies could also consider implementing single-blind designs where possible, such as blinding raters to the condition, to further minimize potential bias. Finally, the implementation of rigorous monitoring procedures, such as dietary logs, continuous glucose monitoring before and after exercise, and sleep assessments, would help to better control for potential confounders.

Conclusion

In conclusion, a single session of VR-based exercise improved mood and increased interest/enjoyment compared to conventional exercise. However, no statistically significant differences were observed in the other biological parameters examined in the present study. Patients showed a strong preference for using the VR exercise application, with high scores in acceptance, usability, and future use intention, and no negative emotions reported. Healthcare professionals could easily expand exercise protocols with the strengths of the VR technologies along with other health-related programs.

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CHAPTER V– STUDY 4

Effectiveness and Acceptance of Virtual Reality Versus Traditional Exercise in Obese Adults: A Pilot Randomized Trial

Touloudi, E., Hassandra, M., Galanis, E., Pinnas, G., Krommidas, C., Goudas, M., & Theodorakis, Y. (2025). Effectiveness and acceptance of virtual reality vs. traditional exercise in obese adults: A pilot randomized trial. *Frontiers in Sports and Active Living*, 7. <https://doi.org/10.3389/fspor.2025.1520068>

Abstract

Obesity is a significant global health concern, increasing the risk of various diseases and health complications. Effective and engaging exercise interventions are urgently needed for obesity management. This pilot study examines the effectiveness of virtual reality (VR)-based exercise compared to traditional exercise, both combined with Self-Determination Theory (SDT)-based counseling, individuals with obesity. Forty individuals with overweight/obesity were randomly assigned to either a VR-based exercise group (intervention) or a traditional exercise group (control), with both groups receiving SDT-based counseling over 4 weeks. Assessments were conducted pre- and post-intervention. Participants in the VR-based exercise group showed significant reductions in BMI (2.6%) and body fat mass (5.3%) and consequently in hips circumference, compared to the control group. They also exhibited greater increases in physical activity levels, and improved psychological outcomes, including basic psychological needs (BPN), self-efficacy, self-esteem, and attitudes toward the program comparing with the control group. Moreover, the intervention group scored higher in interest/enjoyment and attitudes towards exercise compared with the control group and showed great results in perceived enjoyment, intention for future use, usability, and positive perceptions of using the VR system. Based on the participants' interviews, VR-based exercise was found to be more enjoyable and engaging.

These findings suggest that VR-based exercise combined with counseling is more effective than traditional exercise in reducing weight, increasing physical activity, and improving psychological outcomes individuals with obesity. The immersive nature of VR may enhance motivation and adherence to exercise programs, offering a promising alternative for obesity management. However, the study's small sample size, short duration, and reliance on self-reported measures may limit its generalizability. Future research should explore long-term adherence, effectiveness in diverse populations,

psychological mechanisms behind engagement, and comparisons with emerging fitness technologies like AI-powered platforms.

Keywords: obesity, VR, exercise, behavioral change, counseling, SDT

Introduction

Obesity is a major risk factor for numerous noncommunicable diseases (NCDs), such as diabetes, cardiovascular diseases, and certain types of cancer (World Obesity Atlas, 2024). It is also associated with numerous mental health issues like depression, poor quality of life and body dissatisfaction. Many individuals with obesity experience psychological distress due to being subjected to weight stigma and discrimination. Given these serious health implications, effective management strategies for obesity are crucial (Morres et al., 2023; Stephenson et al., 2021; Weinberger et al., 2016).

The role of exercise programs and physical activity is crucial, as they are key components in the treatment of obesity. Beyond promoting weight loss through increased energy expenditure, physical activity also enhances overall metabolic and cardiovascular health. It can lead to significant improvements in biomarkers for people with obesity, such as lower serum triglycerides and reduced arterial stiffness. Participation in exercise programs can also lead to improved cardiorespiratory health muscle strength, quality of life, and sustained exercise behavior. Additionally, physical activity offers notable benefits for brain health, including better sleep quality and reduced depressive symptoms. It also positively impacts emotional well-being and overall quality of life (Pojednic et al., 2022). Individuals can engage in various forms of exercise to manage obesity. Programs incorporating moderate-intensity aerobic exercise and moderate-to-high intensity resistance training are particularly recommended for adults aiming to achieve these health goals (Oppert et al., 2021). Other researchers support that high-intensity interval training (HIIT) can significantly improve mental health-related indices in overweight and obese adults, with improvements equal to or greater than those observed for moderate-intensity continuous training (Batrakoulis & Fatouros, 2022). Nonetheless, regular exercise and healthy nutrition contribute to weight control, disease prevention, maintenance, and metabolic fitness in obesity, with endurance training being the most effective (Liu et al., 2024; Petridou et al., 2019).

Effective obesity management requires a multifactorial approach that addresses not only diet and exercise but also psychological and behavioral factors to foster long-

term change (Sheer & Lo, 2023). Multi-component interventions that incorporate behavioral modification, cognitive strategies, and values-based approaches have been shown to enhance adherence, confidence, and intrinsic motivation, leading to improved health outcomes (Vallis et al., 2020; Perperidi et al., 2023). Individualized nutrition counseling plays a crucial role, influencing both physical and mental well-being, as it has been linked to reduced depressive symptoms and sustained weight loss (Milligan et al., 2023). Obesity is often linked to lower self-esteem, with studies highlighting a negative relationship between excess weight and body image (Byth et al., 2022; Weinberger et al., 2016). A positive body image and a flexible approach to eating restraint have been associated with better weight control outcomes (Teixeira et al., 2015). Similarly, self-efficacy—one's confidence in their ability to adopt healthy behaviors—has been identified as a strong predictor of successful weight management and increased physical activity, enhancing adherence to dietary and exercise guidelines (Barnhart et al., 2021). Self-regulation skills, such as self-monitoring, also contribute to weight loss success, with research showing a direct link between self-monitoring and higher weight loss rates in individuals with obesity (Goldstein et al., 2019). Additionally, positive attitudes toward nutrition and physical activity are key determinants of long-term behavioral change, reinforcing intention, perceived control, and engagement in healthy habits (Naughton et al., 2013; Choi et al., 2017). Among behavioral strategies, goal setting has been recognized as an effective tool in obesity management, with studies demonstrating its role in increasing effort and commitment to physical activity (Knittle et al., 2018). Recent findings highlight the importance of setting Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) goals, which have been positively associated with weight loss outcomes in community-based programs (Wren et al., 2023). In clinical settings, goal-setting has been successfully applied in cardiac rehabilitation and nutrition interventions, further emphasizing its relevance to weight management (Barrett et al., 2020; Wakabayashi et al., 2022). Therefore, counseling, behavioral change strategies, and traditional exercise interventions are beneficial, and in recent years, innovative approaches like Virtual Reality (VR) have shown promise in improving obesity management outcomes.

VR is a computer-generated simulation of a real or imaginary three-dimensional environment that allows users to explore and interact with it. Over recent decades, VR has expanded beyond entertainment and leisure, finding applications in exercise, education, rehabilitation, health, and various other fields (VirtualSpeech, accessed on

8 July 2024). Several studies have explored the effects of VR exercise and support the idea that it is suitable for yielding positive outcomes in physiological, psychological, and recovery-related factors when compared to traditional exercise (Qian, McDonough & Gao, 2020). A systematic review found that VR technology has great potential for assessing and treating obesity due to its interactivity, flexibility, and customization to individual needs, making it compatible with existing psychological theories and practices (Al-Rasheed et al., 2022). Research shows that people tend to respond to virtual environments as if they were real, and individuals generally accept this technology (Abd-Alhamid et al., 2019). A study found that VR self-conversations based on motivational interviewing can help individuals with obesity improve habit change readiness, self-efficacy, and reduce dysfunctional eating behaviors and anxiety (Anastasiadou et al., 2023). VR, when combined with cognitive behavioral therapy or weight loss programs, supports significant weight loss, though maintaining it is challenging (Al-Rasheed et al., 2022). Another study suggests that VR integration into behavioral weight loss treatments may help sustain weight loss (Phelan et al., 2021). Additionally, incorporating VR into physical activity programs could counteract reduced engagement due to weight-based victimization (Skogen et al., 2022).

Despite the growing use of VR in health interventions, little research has examined its combination with Self-Determination Theory (SDT)-based counseling for obesity management. SDT posits that motivation and well-being are enhanced when individuals experience autonomy, competence, and social support, which are crucial for sustaining behavioral changes (Ryan & Deci, 2000; Teixeira, et al., 2012). In obesity treatment, SDT-based interventions have shown positive effects on promotion of health behavioral change like physical activity adherence, and psychological well-being (Silva et al., 2008; Ntoumanis et al., 2020). While existing studies have demonstrated encouraging results, most have focused on VR or counseling as standalone approaches. VR interventions have been effective in promoting physical activity, improving self-efficacy and self-esteem, managing psychological distress and supporting weight loss (Ferrer-García et al., 2013; Gaggioli et al. 2014; Al-Rasheed et al., 2022). Furthermore, research suggests that VR reduces perceived exertion, making exercise feel easier and potentially increasing engagement in physical activity (Naugle et al., 2024). Additionally, VR interventions combined with cognitive-behavioral techniques have improved motivation and self-esteem while reducing disordered eating behaviors (De Carvalho et al., 2017). However, the potential combination of VR-based exercise and

SDT-based counseling remains largely unexplored. It is highlighted the importance to address this gap by the evaluation of the combined effects of VR exercise and SDT-based counseling on physical activity, psychological well-being, and behavioral outcomes in individuals with obesity. Given that obesity management requires sustainable behavioral modifications (e.g., eating habits, physical activity, medication adherence), integrating behavioral change strategies—such as SDT-based motivation—with VR's engaging and immersive exercise experience may provide a more holistic and effective approach (Vallis et al., 2020).

For the management of obesity, a combination of exercise and counseling appears to be effective. Additionally, individuals can exercise using VR systems and respond to virtual stimuli in a way that closely mirrors real-life experiences (Tieri et al., 2018). However, there are few studies in the literature that have examined the impact of VR-based exercise combined with SDT-based counseling in individuals with obesity. VR systems have been successfully used and well-accepted by obese individuals to change behaviors and lifestyles for combating obesity through virtual self-talk and psycho-educational counseling (Anastasiadou et al., 2023). It is supported that it effectively improves body image satisfaction and promotes health self-efficacy individuals with overweight or obesity through self-monitoring of diet, physical activity, and weight (Al-Rasheed et al., 2022). Additionally, according to a study involving overweight women, it was found that exercise in a virtual environment had a positive effect on exercise enjoyment, immersion in exercise, reduction in BMI, and depressive symptoms (Seo et al., 2023). Lastly, according to a systematic review, exercise in a virtual reality environment has been shown to have a positive impact and is a promising tool for managing smoking, diet, obesity, and increasing physical activity levels (Tatnell et al., 2022).

The primary aim of this study was to evaluate the impact of a VR-based exercise intervention combined with SDT-based counseling on key anthropometric, psychological and behavioral outcomes in individuals with overweight and obesity. Specifically, the study compared changes in BMI, body fat mass, basic psychological needs, attitudes towards the program, self-esteem, self-efficacy, and physical activity engagement between participants performing VR-based exercise and those engaging in traditional, self-selected exercise paired with SDT-based counseling. The secondary aim was to assess participants' attitudes, interest, and enjoyment regarding each

exercise modality, as well as the acceptance, usability, and overall enjoyment of the VR exercise platform.

Materials and Methods

Trial design

This study followed a Randomized Controlled Trial (RCT) design with a control group. The study protocol was approved by the Institution Ethics Committee (Approval No. 1829, 13 October 2021).

Participants

In our study, 40 individuals with overweight/obesity (24 female and 16 male) with a BMI > 25kg/m², aged from 18 to 65 years old participated. Demographic characteristics of the participants are presented in Table 1. All participants were informed about the study's objectives and signed the consent form for participation in research studies. Two groups of 20 individuals each were assigned: a) VR exercise group, and b) No VR exercise group (control group). The randomization process proceeded as follows: The first participant was randomly assigned to a group using a coin flip. Following this, participants were alternately assigned to the experimental and control groups. Specifically, after the initial random assignment, one participant was allocated to the experimental group, while the next was assigned to the control group, continuing this alternating pattern until the desired number of participants was reached.

Table 1. Demographic characteristics and anthropometric values

	Units	Group	Mean ± SD	Frequency
Age	years	Intervention	40.60 ± 11.93	-
		Control	45.65 ± 12.17	-
Height	m	Intervention	1.67 ± 0.10	-
		Control	1.73 ± 0.08	-
Weight	kg	Intervention	90.36 ± 16.69	-
		Control	97.86 ± 11.54	-
BMI	kg/m ²	Intervention	32.69 ± 5.25	-
		Control	32.64 ± 2.70	-
Body fat mass	kg	Intervention	36.81 ± 9.47	-
		Control	37.40 ± 8.06	-
Gender	-	Intervention	-	30% male, 70% female
		Control	-	50% male, 50% female
Education	-	Intervention	-	Secondary 30%, Tertiary 70%
		Control	-	Secondary 25%, Tertiary 75%

Recruitment – Setting: Community setting intervention

Participants were recruited through an open call to the community of Volos, an urban city in central Greece. This initiative aimed to inform local residents and provide them with the opportunity to express their interest in participating in the study. Then, more specifically, individuals were informed about the project and agreed to participate.

An informational brochure was created to inform the public about this initiative and encourage their participation (Appendix 12). The brochure was published on social media and distributed in various crowded locations, including sports facilities. On the brochure, there was a QR code that directed them to an online participation form which included study inclusion and exclusion criteria such as age, weight, height, and if they have been diagnosed with neurological, orthopedic, cognitive, or psychiatric conditions, poor or no vision, and vertigo, as well as their contact details (phone number or email) to invite them to the first meeting.

Intervention

The intervention program was grounded in SDT to facilitate behavior change in participants with overweight and obesity. Based on the core principles of SDT, which include autonomy, relatedness, and competence, the following intervention was designed including exercising in VR environment combined with 3 counseling sessions to promote engagement in physical activity among individuals with overweight and obesity and guide them toward a healthier lifestyle for the intervention group. The behavior changes techniques (Teixeira et al., 2019) used and applied in the intervention for every need are presented in Appendix 13.

Materials

Brochure, Forms and Booklet

To cover the needs of the intervention, the following materials were created. An informational brochure about the existence of the VR exercise program and counseling, a consent form describing in detail the study procedures and ensuring personal data privacy according to GDPR ("I hereby consent to the collection, processing, and secure handling of my personal data in accordance with data privacy and protection regulations."), a booklet that includes information and advice about exercise, diet and ways to overcome psychological difficulties in their efforts to systematically participate in exercise and nutrition programs (Appendix 14) a Daily Self-Monitoring Form in

which participants recorded daily step count, water intake, consumption of sugary foods, the quantity of fruits and vegetables eaten, and the duration of physical activity and a Goal-Setting Form in which participants recorded their goals for physical activity, nutrition, and water intake for the next week and complete the Implementation Intention Plan for each goal (Appendix 15,16). The goal-setting forms were completed after every counseling session and based on the goal-setting theory (Locke & Latham, 2006).

VR exercise application

The VR exercise app used for the intervention program is called PowerBeats VR. PowerBeatsVR is an immersive VR exercise application designed to enhance physical activity through an engaging and interactive environment. Participants engage in a variety of workout routines that combine cardio and strength training exercises with rhythmic movements and music. All of them are transported into visually stimulating VR worlds, ranging from futuristic settings to natural landscapes (such as desert, sky, space, and medieval), which make the workout experience more enjoyable. The application offers a range of pre-designed workout routines catering to different fitness levels and goals. Participants can choose routines based on their preferences, focusing on cardio, strength, or a combination of both. The exercises are synchronized with energetic music, motivating participants to move in time with the beat. This feature not only makes the workout fun but also helps maintain a consistent exercise rhythm. During the workout, participants engage in interactive gameplay elements such as punching orbs, dodging obstacles, and performing various body movements. This gamified approach keeps participants engaged and focused throughout the session. The exercise sessions typically lasted for 15 to 60 minutes, with participants encouraged to engage in at least three sessions per week. The intensity of the workouts varied from moderate to vigorous, based on the participants' fitness levels and preferences. Real-time feedback provided metrics such as calories burned and exercise duration, helping participants track their progress and stay motivated. Participants could set personal fitness goals within the app and monitor their achievements over time and have a personalized exercise experience throughout the intervention. The app kept a detailed record of completed workouts, allowing users to see their progress and make adjustments to their fitness plans as needed. PowerBeatsVR allowed participants to customize their workout sessions by selecting different difficulty levels, workout

durations, and types of exercises, ensuring that the workout remained challenging and suitable for the participant's fitness level (Appendix 17).

Counseling sessions

The 3 counseling sessions were designed to promote behavioral changes towards exercise, diet, and a healthy lifestyle. These sessions were provided to both groups at the beginning of the first week, the end of the second week, and the end of the fourth week of the intervention. Each session was based on the core principles of SDT, focusing on enhancing autonomy, relatedness, and competence. The content of the sessions included:

- **Session 1:** Introduction to the importance of physical activity and healthy eating, initial goal setting using SMART principles (Specific, Measurable, Achievable, Relevant, Time-bound) - a framework known to enhance goal effectiveness (Brown et al., 2016; Lawlor & Hornyak, 2012; MacLeod, 2012), and strategies to overcome psychological barriers.
- **Session 2:** Review of progress, adjustment of goals, strategies for maintaining motivation, and discussion on the importance of social support and relatedness.
- **Session 3:** Final evaluation of progress, setting long-term goals, strategies for maintaining behavior changes post-intervention, and discussion on competence and self-efficacy.

Goal-setting techniques were used throughout the sessions to help participants set and achieve both short-term and long-term goals related to daily steps, exercise duration, types of physical activities, nutrition choices, and water intake. The control group followed the counseling sessions without the opportunity to use the VR exercise system.

Procedures

After their categorization into the Intervention group (VR exercise) and Control group (No VR exercise), based on systematic allocation, all participants were contacted by phone, the study's procedure was explained and the first meeting was organized. All phases of the intervention (VR-based exercise sessions and counseling) were delivered by an exercise specialist with expertise in exercise psychology.

During the initial meeting, participants from both groups were informed in detail about the study phases, provided their consent, and completed the first questionnaire. Participants were informed about the aim of the study, that it was to evaluate the effects of each exercise intervention, in combination with counseling, on physical, psychological, and behavioral factors. However, individuals were not explicitly told that the primary focus was on comparing VR-based exercise with traditional exercise. This approach aimed to minimize potential bias in their responses and engagement levels. Each participant received printed Daily Self-Monitoring Forms to fill out daily for the following week. This session also included counseling, goal-setting, and the distribution of the booklet with information and advice (Baillot et al., 2021). Participants completed the goal-setting form with their goals for the following week and were encouraged to complete the goal-setting form every week, check their achievements, and adjust their goals according to SMART goal-setting (Brown et al., 2016; Lawlor & Hornyak, 2012; MacLeod, 2012). Additionally, all, scheduled an appointment with our partner nutritionist for body measurements, including height, weight, waist, hip and neck circumference, and body fat mass.

Subsequently, only participants from the intervention group conducted a trial exercise session with the VR application, familiarizing themselves with the VR equipment, receiving detailed usage instructions, and having the opportunity to ask questions before starting the first VR exercise session. Safety measures were implemented to ensure participant well-being during the VR exercise sessions. To minimize the risk of motion sickness, participants were gradually introduced to the VR environment, starting with low-intensity movements and progressively increasing intensity based on individual tolerance. Additionally, regular breaks were encouraged, and participants could stop the session at any time if they experienced discomfort. The exercise specialist was present during all VR sessions to monitor participants, provide immediate assistance if needed, and ensure proper use of the equipment to prevent injuries.

From this point, both groups had 4 weeks to exercise, with the Intervention group having the option to use the VR system as an additional exercise method whenever desired. All participants from the Intervention group were allowed to exercise in the VR environment as much as they wanted, from 3 to 7 times per week. Participants arranged an appointment with the exercise specialist and had access to the VR device in an agreed convenient place (home or gym). The VR exercise was tailored to the

individual fitness levels of each participant. Needed adjustments were made for participants who experienced physical discomfort or other constraints. These modifications ensured the safety and comfort of participants without compromising the overall intervention goals. Participants in the control group were free to engage in various forms of exercise, with an emphasis on aerobic activities such as cycling, swimming, gym-based group fitness classes (moderate to high intensity), and running. However, no structured exercise program was assigned, and no dietary intervention was implemented. The same counseling intervention as the experimental group was provided, but without the VR-based exercise component. Similarly, participants in the intervention group also had the option to engage in these types of exercises. Both the intervention and control groups had the flexibility to select preferred types of physical activity, ensuring that intensity ranged from moderate to vigorous. All participants were encouraged to engage in exercise at least three times per week, with each session lasting more than 30 minutes. Self-monitoring and progress tracking were also encouraged. Daily Self-Monitoring Forms were completed during the first, third, and final week of the program. Communication with the exercise specialist was maintained via Viber, providing the opportunity to discuss any issues—including barriers to physical activity faced by individuals with overweight and obesity—and seek solutions, instructions, or support regarding the exercise regimen. Additionally, general dietary tips for maintaining a healthy and balanced diet were available, but no structured dietary intervention was provided. Viber was used as a direct communication channel, allowing continuous support throughout the study. Whenever guidance, motivation, or clarification was needed, the exercise specialist was available. This real-time accessibility helped address concerns immediately, reinforce adherence to the intervention, and enhance accountability. The ability to maintain constant communication also fostered a sense of connection and encouragement, which is crucial for sustaining behavioral changes and promoting long-term engagement in physical activity. Participants had the opportunity to create small groups and exercise together. Both groups were free to choose their preferred way of exercising, selecting the hours and type of exercise according to individual schedules, goals, and advice from the exercise specialist. However, participation in an organized and structured exercise program was not required.

At the end of the second week, an additional meeting was held for counseling, discussion, and feedback on their progress. The participants completed once again the

goal-setting form and set new goals for the following week. After the 4-week intervention, we conducted a final meeting where participants from both groups underwent body measurements again with our partner nutritionist, completed final questionnaires and interview, and attended the last counseling session. This session included discussions about their progress with the intervention and goal-setting for the future.

Follow-Up

Four weeks post-intervention, participants from both groups were invited to complete a follow-up questionnaire assessing their adherence to exercise. Measures included self-reported physical activity levels and goal-setting progress. Additionally, participants were asked about their long-term intentions for physical activity, motivation levels, and any challenges they faced in maintaining their exercise routines post-intervention.

Measures

Anthropometric measures

Each participant scheduled an individual appointment with our partner nutritionist at a convenient date and time. To ensure consistency, the follow-up assessment was conducted at approximately the same time of day as the initial measurement. Anthropometric assessments, including weight, body fat percentage, and fat mass, were conducted using the CHARDER MA601 body composition analyzer. Participants were instructed to follow standard pre-assessment guidelines, including avoiding food, caffeine, and vigorous physical activity for at least 3 hours prior to the measurement and emptying their bladder before the assessment to minimize variations due to fluid retention. Wearing light clothing and no shoes were encouraged to ensure accuracy. Height was measured using the Charder HM250U ultrasonic stadiometer.

First meeting questionnaire

Both groups filled in questionnaires including questions about demographic characteristics (birth date, gender, occupation, educational level), use of technology (Personal Innovativeness questionnaire, Agarwal et al., 1998), psychological distress (GHQ-12, Goldberg & Williams, 1988), body image (BI-AAQ, Papageorgiou et al., 2019), self-efficacy (exercise self-efficacy scale, Bandura, 2006) (Appendix 18), level

of physical activity (Leisure-Time Exercise Questionnaire (LTEQ), scored using the formula: $(9 \times \text{Vigorous}) + (5 \times \text{Moderate}) + (3 \times \text{Light})$ calculated and utilized as a Leisure Index Score, Godin, 2011), self-esteem (Rosenberg self-esteem scale, Rosenberg, 1965), the degree to which participants' psychological needs are met within an exercise context (BPNES, Vlachopoulos et al., 2010), attitudes toward participation in the program, intention, perceived behavioral control and subjective norms (TPB Questionnaire, Ajzen, 2006) (Appendix 19).

Last meeting questionnaire

Participants filled in questionnaires with questions about the level of physical activity (LTEQ), the degree to which participants' psychological needs are met within an exercise context (BPNES), attitudes toward participation in the program, intention, perceived behavioral control and subjective norms (TPB Questionnaire), attitudes towards exercise (VR exercise for the Intervention group) (Ajzen, 2006), interest/enjoyment of exercise (VR exercise for the Intervention group) (IMI, Goudas et al., 2000), self-efficacy, self-esteem, and a semi-structured interview (Appendix 20) with questions about their exercise (with the VR system for the Intervention group) and counseling experience, their adherence to the exercise program and if they achieved their goals, such as “How do you think your participation in the program helped you change your behavior regarding exercise and nutrition?” and “How do you intend to continue exercising in the future?”. Participants of the Intervention group also responded to questions about perceived enjoyment from the VR exercise program (Rasimah et al., 2011), intention for future use (Rasimah et al., 2011; Ajzen, 2006), system usability (SUS, Brooke, 1996) and VR equipment (Mrakic-Sposta, 2018).

Retention Strategies

In the study, participant retention strategies were employed to maintain the number of participants throughout the study. Some sample retention strategies that were used include:

- *Communication*: Regular communication with participants through Viber and encouraging them not to drop out of the process. The Viber chat was always active to discuss tips for adherence to the exercise program or diet, problems that may appear, and other issues including barriers of people with overweight or obesity towards physical activity and exercise.

- *Self - Rewards*: During the goal-setting process, each participant was encouraged to plan their goal and a reward for themselves upon successfully achieving their goal. For instance, if they manage to reach a daily step count of 8000 for two weeks, they could treat themselves to a spa day as a reward.

- Encouraging communication and monitoring: Active engagement by monitoring participants' involvement and addressing issues that arise promptly. Self-monitoring their daily exercise and nutrition is a nice way to enhance their behavior change effort.

The adherence to the intervention was monitored through the Daily Self-Monitoring Forms which were checked at the end of each week, and participants received regular feedback from the exercise specialist. Additionally, participants from the VR group were asked to track their VR exercise sessions through the application, which recorded metrics such as calories burned and session duration. The exercise specialist maintained regular communication with participants via Viber to address any barriers to participation and provide motivation.

Data Analysis

For the quantitative data analysis, a power of 85% and confidence interval of 95% were adopted, with an estimated value for a type I error of 5% for the sample size calculation in this study. Descriptive statistics and frequencies were used for demographic characteristics and baseline measurements. The Kolmogorov-Smirnov Test was performed, confirming that the sample followed a normal distribution, and Mauchly's Test of Sphericity was conducted, indicating that the assumption of sphericity was also met. The two-way repeated measures ANOVA analysis was used to determine the influence of the intervention and differences between the two groups in all variables. The two-way repeated measures ANOVA analysis was used due to the controlled structure of the study, where all participants completed assessments at fixed time points, and there were no missing data. Correlation analysis was also conducted to examine the relationship between the baseline measures and pre-post-intervention measures. All statistical analyses were performed with IBM SPSS (Statistics Version 29) and the level of significance was set at $p < .05$.

Semi-structured interviews were audio-recorded and transcribed verbatim. The qualitative data were then analyzed using thematic analysis. Two independent researchers familiarized themselves with the transcripts by reading them multiple times and engaged in an inductive coding process to identify initial codes reflecting emerging

patterns. These codes were collated into potential themes and iteratively refined through discussions to resolve any discrepancies, ensuring consistency and rigor. This systematic approach allowed us to identify key themes related to participants' experiences, attitudes, and perceptions of both VR-based and traditional exercise interventions.

Results

Baseline measurements: Personal Innovativeness, General mental distress, Body image

Descriptive statistics were applied to calculate the means and standard deviations for baseline measures of personal innovativeness, general mental health, and body image. The results are presented in Table 2. A correlation analysis was conducted and the results revealed several significant relations. Personal innovativeness was found to have a strong positive correlation with self-efficacy pre-intervention ($r = .59, p < .001$), a significant positive correlation with interest/enjoyment (IMI) ($r = .42, p = .008$) and with physical activity levels at follow-up (LTEQ) ($r = .40, p = .010$). General mental distress showed a significant positive correlation with body image ($r = .31, p = .049$). Finally, body image demonstrated a small positive correlation with physical activity levels at follow-up (LTEQ) ($r = .33, p = .035$).

Table 2. Psychometric scores at pre-intervention for each group

Variable	Intervention group			Control group		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
Personal Innovativeness	4.11±.72	3.00	5.00	3.49±1.02	1.25	5.00
General mental distress	4.3±2.87	1.00	10.00	4.95±3.47	0	11.00
Body Image	4.13±1.61	1.30	7.00	2.86±1.34	1.0	5.10

BMI & Body fat mass

A two-way repeated measures ANOVA was conducted to examine the differences in BMI and body fat between the intervention and control groups for two measurements (pre- and post-intervention). The results revealed a statistically significant group-time interaction for both BMI $F(1,38) = 30.89, p < .001, 95\% \text{ CI } [30.39, 34.13]$, and body fat $F(1,38) = 28.35, p < .001, 95\% \text{ CI } [31.86, 39.80]$. Additionally, there were statistically

significant differences between the pre-intervention and post-intervention measurements within the intervention group for both BMI $F(1,38) = 79.15, p < .001$ 95% CI [pre: 30.796, 34.574; post: 29.983, 33.687] and body fat $F(1,38) = 68.40, p < .001$ 95% CI [pre: 32.83, 40.79; post: 30.88, 38.83], with post-intervention scores being lower than pre-intervention scores. However, no statistically significant differences in BMI were found between the two groups at either pre- $F(1,38) = .001, p = .97$, or post-intervention measurement $F(1,38) = .30, p = .59$. Similarly, no statistically significant differences in body fat were observed between the two groups at either pre- $F(1,38) = .04, p = .84$ or post-intervention measurement $F(1,38) = .73, p = .40$. The means and SD are presented in Table 3.

Table 3. Statistics at post intervention for each group

Variable	Intervention group			Control group		
	Mean±SD pre	Mean±SD post	Cohen's d	Mean±SD pre	Mean±SD post	Cohen's d
BMI (kg/m²)	32.69±5.25	31.84±5.08**	0.16	32.64±2.71	32.54±2.77	0.04
Body fat mass (kg)	36.81±9.47	34.86±9.28**	0.21	37.40±8.06	37.22±8.25	0.02
Body fat (%)	39.75±6.03	39.09±6.58	0.10	38.05±6.12	37.97±6.10	0.01
Hips (cm)	114.45±6.00	112.80±5.88**	0.28	113.85±7.29	113.68±7.19	0.02
BPN	4.09±0.77	4.53±0.52*	0.67	3.95±0.54	4.08±0.58	0.23
Autonomy	4.14±0.83	4.48±0.68	0.45	3.95±0.55	4.11±0.69	0.26
Competence	4.00±0.81	4.44±0.48*	0.59	3.85±0.75	3.94±0.67	0.13
Relatedness	4.11±0.77	4.64±0.63*	0.75	3.99±0.81	4.20±0.74	0.27
Attitudes toward the program	6.40±0.68	6.92±0.23*	1.02	5.96±1.02	6.34±0.80	0.41
Intentions to exercise	6.21±1.01	6.55±0.73	0.39	5.77±1.50	6.05±1.17	0.21
Perceived control	5.66±1.28	6.14±1.02	0.41	5.09±1.59	5.35±1.67	0.16
Subjective norms	6.68±0.57	6.75±0.53	0.13	6.30±1.03	6.5±0.76	0.22
Self-esteem	42.60±5.20	45.20±3.74*	0.57	42.80±4.96	43.80±3.35	0.24
Self-efficacy	24.95±7.56	29.70±5.39*	0.72	23.85±7.03	25.75±7.25	0.27
Physical activity	43.10±31.42	65.15±22.24*	0.81	37.80±24.35	43.00±24.59	0.21

*Note: Physical activity classification: Active (≥ 24), Moderately active (14–23), Insufficiently active (< 14), $p < 0.05$, ** $p < 0.01$.*

Hips circumference

A two-way repeated measures ANOVA was performed to examine the differences in the variable hips circumference between the intervention and control group for two measurements (pre- and post-intervention). The results revealed that there was a statistically significant group-time interaction $F(1,38)=45.46, p<.001$. There were also statistically significant differences between the pre-intervention and post-intervention measurements of the hip circumference in the intervention group $F(1,38)=113.77, p<.001$ with the post-intervention scores being lower than the pre-intervention. However, there were no statistically significant differences between the two groups neither pre- $(1,38)=.081, p=.778$ nor post-intervention $F(1,38)=.178, p=.676$. There were no statistically significant differences in waist and neck circumferences observed. The means and SD are presented in Table 3.

Basic psychological needs, attitudes toward the program and intentions to exercise, self-efficacy & self-esteem

A two-way repeated measures ANOVA examined the differences in Basic Psychological Needs (BPN) (Autonomy, Competence, Relatedness), Attitudes toward the program and intentions to exercise, self-efficacy, and self-esteem between the intervention and control groups across pre- and post-intervention measurements. For BPN, no significant group-time interaction was found, but the intervention group scored significantly higher post-intervention compared to the control group ($F(1, 38) = 6.74, p = .050$) 95% CI [3.81,4.23] , with significant pre-post improvement in the intervention group ($F(1, 38) = 8.19, p = .013$) 95% CI [4.28,4.78]. In Autonomy, Competence, and Relatedness, no significant group-time interactions were observed. Competence showed significant group differences at the second measurement ($F(1, 38) = 7.33, p = .010$), 95% CI [3.67,4.70] and significant pre-post improvement in the intervention group ($F(1, 38) = 4.46, p = .041$), 95% CI [pre: 3.65,4.35; post: 4.17,4.70]. Relatedness also improved significantly pre-post in the intervention group ($F(1, 38) = 8.41, p = .006$), 95% CI [pre: 3.76,4.47; post: 4.33,4.95]. Attitudes toward the program, as per the Theory of Planned Behavior, showed no group-time interaction but significant group differences post-intervention ($F(1, 38) = 9.81, p = .003$), 95% CI [6.44,6.81] and significant pre-post improvement in the intervention group ($F(1, 38) = 4.68, p = .037$) 95% CI [pre: 6.01,6.79; post: 6.65,7.18]. No significant differences were found in other TPB components. For self-efficacy and self-esteem, no significant

group-time interactions were noted, but both showed significant pre-post improvement within the intervention group ($F(1, 38) = 5.50, p = .024$, 95% CI [pre: 21.68,28.25, post: 26.81,32.59] and $F(1, 38) = 4.35, p = .044$, 95% CI [pre: 40.30,44.90, post: 43.59,46.81], respectively). The means and SD are presented in Table 3.

Physical activity level

A two-way repeated measures ANOVA was performed to examine the differences in the variable physical activity between the intervention and control group for three measurements (pre-, post-, and one month after the intervention). The results revealed that there was no statistically significant group-time interaction, $F(1,38) = 1.65, p = .20$. However, there were statistically significant differences between the post-intervention $F(1,38) = 8.93, p = .005$, 95% CI [54.54, 75.76] and follow-up $F(1,38) = 9.50, p = .004$, 95% CI [46.88, 68.42] scores between the two groups, with the intervention group having a mean 57.65, SD= 19.58, and the control group 34.45, SD=27.37. Finally, there were statistically significant differences between the pre-intervention and post-intervention scores of the physical activity variable within the intervention group, $F(1,38) = 3.66, p = .035$, 95% CI [pre: 30.38, 55.82, post: 54.54, 75.76], with the post-intervention scores being higher than the pre-intervention scores. There were no differences between post-intervention and follow-up scores in ($p = .88$) and no differences in the physical activity scores within the control group, $F(1,38) = .74, p = .48$. The means and SD are presented in Table 3.

Attitudes towards exercise & Interest/Enjoyment

An independent samples t-test was conducted to examine the differences in interest/enjoyment and attitudes towards exercise between the intervention and control groups. The analysis revealed significant differences in both variables, with the intervention group scoring significantly higher than the control group. For interest/enjoyment, the t-test results were $t(38) = 4.247, p < .001$, with the intervention group having a mean of 4.99, SD = 0.45 compared to the control group's mean of 4.08, SD = 0.96. Similarly, for attitudes towards exercise, the t-test results were $t(38) = 3.477, p < .001$, with the intervention group scoring a mean of 5.95, SD = 0.99 compared to the control group's mean of 5.37, SD = 0.74. These findings suggest that the VR exercise had a positive impact on both interest/enjoyment and attitudes towards exercise.

Perceived enjoyment, intended future use, usability, equipment

The descriptive statistics analysis revealed that participants expressed high levels of perceived enjoyment, intention for future use, usability, and positive perceptions of using the VR system. The maximum score for perceived enjoyment, intention for future use, and equipment was 5, while for usability it was 100. The mean and SD for each variable were as follows: perceived enjoyment had a mean of 4.93, SD = 0.12, intention for future use had a mean of 4.90, SD = 0.25, usability had a mean of 92.50, SD = 7.95, and equipment had a mean of 4.82, SD = 0.27. These results indicate that participants found the VR system highly enjoyable, intended to use it in the future, found it highly usable, and had positive perceptions of the equipment.

Semi-structured interview

A thematic analysis of the semi-structured interviews was conducted to explore participants' perceptions of the intervention for both groups. The results revealed that the intervention group consistently described the VR-based exercise as highly engaging, motivating, and beneficial for their psychological well-being, while the control group emphasized the positive impact of counseling on behavior change and goal-setting. The participants' responses are summarized in Table 4. Frequencies of the responses in the semi-structured interview are presented in Appendix 21,22.

Table 4. Results of the semi-structured interview

Theme	Intervention group responses	Theme	Control group responses
Overall experience	- Innovative, highly entertaining, motivating, interesting, pleasant, comfortable, easy, accessible, and attractive. -It positively impacted their psychological well-being and they highlighted the importance of the support and guidance they received	Overall experience	-Positive, efficient, pleasant, and interesting experience, which significantly helped them achieve their goals. Their participation in the program helped them change their behavior through the goal-setting process, the guidance they received, and learning more about exercise and nutrition. -Positive sentiments towards counseling, deeming it effective,

			enjoyable, and instrumental in achieving personal goals. -They attributed their behavioral changes to the goal-setting process, personalized guidance, and increased knowledge about exercise and nutrition.
Counseling experience	-Enhanced consistency in the exercise regimen -Altered their perspective on exercise and nutrition -Improved their psychological state -Helped them deal with obstacles and underscored the importance of determination and concentration on their goals -Goal-setting was particularly beneficial, helping them learn how to set goals correctly, assess their needs, and use goal-setting forms effectively. This allowed them to evaluate their progress weekly and set new, more challenging goals, with advice from the exercise specialist. - Self-monitoring forms were useful for better progress evaluation and mistake monitoring. -Counseling helped them learn important information and realize the importance of psychological support and motivation for achieving their goals	Counseling Experience	-The goal-setting process helped them learn to set goals correctly using the SMART method and to properly assess their needs. -Weekly evaluations and goal-setting forms facilitated progress tracking and encouraged participants to set increasingly challenging goals. -Self-monitoring forms were useful for evaluating progress, focusing on goals, and easily monitoring mistakes.
Communication, support & digital booklet	-They valued the support and guidance provided, particularly through online communication, as it helped them stay focused on their goals -The booklet was useful and interesting, providing valuable advice on managing stress and anxiety through exercise, emphasizing dedication to the program and patience, and offering	Communication, support & digital booklet	-Digital booklet was deemed very useful, as they found interesting advice and tips for exercise, overeating, nutrition, and behavior change ideas. -They appreciated support and guidance, noting that online communication helped them remember their incentive and feel that there was always an expert

	tips for an active lifestyle through daily choices		to advise them without being time-consuming
Psychological Outcomes & Self-Efficacy	- Increased levels of self-efficacy. - Positive changes in their mood, feeling more optimistic, motivated, self-confident, full of energy and vitality, and experiencing a sense of wellness, joy, relaxation, and reduced anxiety and stress. -Positive shift in body image, deciding to take better care of their bodies. -Increased self-confidence, reduced dropout rates, improved focus on their goals, and a feeling of being "in control.	Psychological Outcomes & Self-Efficacy	-Heightened levels of self-efficacy. -Some of them did not experience the same increase in self-efficacy. -Being in a better mood, feeling optimistic, and having a sense of wellness -A few felt some pressure not to deviate from the program -Body image improved for half of the participants, while others always had a positive body image and wanted to take care of their bodies.
Barriers & Challenges	-Challenges participants faced were time constraints and lack of energy - Communication and support combined with composure and persistence towards their goals and the digital booklet, helped them manage obstacles and challenges.	Barriers & Challenges	-Challenges were lack of free time, numerous obligations, motivation, inability to access public sports facilities all day long and the need for closer monitoring and guidance by exercise and nutrition experts -Communication with the exercise specialist, optimism, persistence in their incentive, composure, self-restraint, and discipline helped them manage obstacles and challenges.
Future intentions	-Desire to continue exercising with the same or increased frequency, though time constraints remained a significant inhibitor. -Intentions to utilize behavior change techniques were high, but more likely they would use them if they had motivation and guidance, participated in a community with similar goals, or had an application that could provide feedback and encouragement	Future intentions	-They would exercise with the same or greater frequency, though time constraints were an inhibitor. -Their intention to use behavior change techniques was similar, with most participants scoring highly

VR-Based exercise	-Scored highly on its contribution to their increased levels of physical activity, noting that being able to choose the duration and intensity of their exercise reduced the stress of failure and allowed them to control the exercise program -One participant mentioned needing more challenging goals from an external source -Intended to continue exercising with the VR system and increase exercise frequency and intensity
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Discussion

The primary aim of this study was to evaluate the impact of a VR-based exercise intervention combined with SDT-based counseling on key physiological and psychological outcomes in individuals with overweight and obesity. Specifically, the study compared changes in BMI, body fat mass, basic psychological needs, attitudes towards the program, self-esteem, self-efficacy, and physical activity engagement between participants performing VR-based exercise and those engaging in traditional, self-selected exercise paired with SDT-based counseling. The secondary aim was to assess participants' attitudes, interest, and enjoyment regarding each exercise modality, as well as the acceptance, usability, and overall enjoyment of the VR exercise platform. The results demonstrated significant improvements in physical, psychological, and behavioral factors for the intervention group compared to the control group. It was also observed increased engagement in physical activity, attitudes towards exercise, and interest/enjoyment in the intervention group compared to the control group. Finally, high scores of perceived enjoyment, intention for future use, usability and VR equipment satisfaction were reported. The results of the semi-structured interview about their experience were also encouraging.

Physical aspects

The study's findings indicate that the intervention significantly impacted BMI, body fat mass and hip circumference. Participants in the intervention group showed a

notable reduction in BMI, body fat mass and hip circumference from pre-intervention to post-intervention measurements. While the control group also experienced decreases in these measurements, the changes were limited and not statistically significant. Many studies have examined the effects of exercise on weight loss in individuals with obesity. However, only recent studies examine the effects of VR exercise on the BMI of this population. A recent study, after an 8-week intervention with VR-based exercise, showed that the BMI was significantly decreased compared with the baseline measures and compared with traditional exercise (Seo et al., 2023). Additionally, other studies have demonstrated similar positive outcomes with innovative exercise methods. For instance, Smith et al. (2020) found that combining traditional exercise with technology-based interventions, such as mobile apps and wearable devices, significantly enhanced weight loss and adherence to exercise programs compared to traditional methods alone.

Psychological Aspects

For the BPN in general, the results revealed no statistically significant interaction between measurements and the two groups, suggesting that the overall trend in BPN in general scores did not differ significantly between the intervention and control groups across the study period. However, a closer examination showed that post-intervention, the intervention group scored significantly higher on BPN in general than the control group. Additionally, within the intervention group, there were significant increases in BPN in general scores from pre- to post-intervention, highlighting that the intervention enhanced the participants' psychological well-being. Moreover, the analysis showed a large effect size indicating that the VR-based intervention had a substantial impact on participants' BPN in general, and more specifically in competence. These results are consistent with previous studies that have shown the positive impact of structured physical activity on psychological well-being (Deci & Ryan, 2000). Regarding the BPN components -Autonomy, Competence, and Relatedness- the results provided further insights. For autonomy, there were no statistically significant changes, neither between nor within groups, suggesting that the intervention did not have a significant impact on participants' sense of autonomy. This could imply that while the intervention was beneficial overall, it did not specifically address or enhance the participants' feelings of autonomy. The autonomy support techniques used in this study such as eliciting participants' perspectives and sources of motivation toward participation in exercise, non-controlling language, free choice of exercise intensity and duration, experimenting,

and self-initiation of the behavior may not have been sufficient to bring about changes in the satisfaction of this need, even though they were effective in previous studies. For instance, in another study, it was observed that autonomy levels were higher in self-selected exercise conditions (Rose & Parfitt, 2012). In terms of competence, the intervention group showed significant improvements post-intervention compared to the control group, and within the intervention group itself, pre- to post-intervention scores also increased. This suggests that the intervention was particularly effective in enhancing participants' sense of competence, likely by addressing potential barriers to behavior change, setting realistic expectations, providing education on goal-setting and adjustments during counseling sessions, as well as through the use of self-monitoring forms and the educational booklet. These findings align with studies by Ntoumanis and Standage (2009), who found that competence is a key predictor of motivation and engagement in physical activities. Moreover, according to Vlachopoulos & Neikou (2007), the need for competence is the main predictor of exercise adherence/dropout and levels of exercise attendance and according to Banerski et al. (2024) a sense of competence enhances well-being during VR exercise. The increased sense of competence may be influenced by the self-selected intensity and duration of exercise, while according to Rose and Parfitt (2012), self-selected intensity and duration of exercise may positively influence the sense of autonomy and competence. For relatedness, similar to competence, the intervention group reported significantly higher post-intervention scores compared to pre-intervention, indicating that the relatedness support techniques such as expressing interest in participants' thoughts, offering empathy, support, and motivation, allowing them to ask questions and express themselves freely, and providing positive reinforcement regardless of the outcome, were highly effective. Following our results, Reer et al. (2022) revealed that VR technology can increase the satisfaction of BPN, and more specifically the needs of autonomy and competence, compared with non-VR intervention. Overall, it is clear that the intervention group showed better outcomes in two of the three components of the BPN compared to the control group. Given that the type of exercise was the only distinguishing factor between the two groups, it can be assumed that this may have contributed to the observed differences.

In this study, within the intervention group, participants exhibited significant improvements in both self-efficacy and self-esteem from pre- to post-intervention measurements. The importance of self-efficacy and self-esteem in obesity is

particularly evident in the context of physical activity. Studies have shown that higher levels of self-efficacy are associated with greater participation in physical activities, which is critical for weight management and overall health (Warziski et al., 2008). Additionally, improvements in self-esteem can help individuals with obesity overcome psychological barriers to engaging in physical activity, leading to more sustainable lifestyle changes (Palmeira et al., 2007). It was supported that regular exercise can lead to improved levels of self-efficacy, self-esteem, and body awareness (Tikac et al., 2022). More specifically, according to a meta-analysis, interventions that provide feedback on participants' performance, or vicarious experience can lead to the highest increases in self-efficacy (Ashford et al., 2010). Additionally, McAuley et al. (2011) demonstrated that physical activity interventions could significantly improve self-esteem, further supporting the findings of our study. Aerobic exercise has been shown to significantly enhance body self-esteem among college students, and particularly in students with overweight or obesity (Shu et al., 2023). Similar positive effects from VR exercise have been observed in both stroke patients, where self-efficacy was enhanced (Long et al., 2020), and older adults, where self-esteem showed significant improvements (Fan et al., 2022). Additionally, college students reported higher levels of self-efficacy and enjoyment after VR biking compared to traditional biking (Zeng et al., 2017; McDonough et al., 2020). Furthermore, according to the present results, there was a strong positive correlation between personal innovativeness and self-efficacy. Similarly, a study conducted on employees found that personal innovativeness was significantly correlated with participants' self-efficacy (Nohut & Balaban, 2022). This finding means that individuals who were more innovative and open to new technology tended to have greater levels of self-efficacy. The self-esteem and self-efficacy of participants in both groups were positively affected, with the intervention group showing statistically significant differences. This indicates that VR exercise played a key role in this change, compared with traditional exercise.

There is also a small positive correlation between general mental distress and body image suggesting that individuals experiencing higher levels of health-related distress might also report concerns or dissatisfaction with their body image. As body image is closely related to psychological well-being, negative body image can affect negatively psychological well-being (Yazdani et al., 2018). Additionally, body image dissatisfaction is related with poor quality of life and self-esteem, depression and psychological distress (Lo Coco et al., 2014).

Behavioral aspects

The results of the present study revealed changes in attitudes toward the program between the intervention and control groups post-intervention. The findings indicate that participants in the intervention group exhibited higher scores in attitudes toward the program compared to those in the control group. Moreover, the analysis showed a large effect size indicating that the VR-based intervention had a substantial impact on participants' attitudes towards the program. These results suggest that engaging in VR exercise, as it was the only difference between the two groups, can enhance participants' attitudes toward the program. Interestingly, while the attitudes toward the program were significantly improved within the intervention group from pre- to post-intervention, it did not have the same effect on perceived control, intentions to exercise, and subjective norms. This aligns with research by Hardeman et al. (2002), who found that interventions often need to address multiple components of TPB to achieve comprehensive behavior change. Further, research by Rhodes et al. (2009) supports the idea that perceived behavioral control is a crucial determinant of behavior change and may require targeted strategies to enhance an individual's confidence in their ability to perform the desired behavior. Moreover, studies such as those by Plotnikoff et al. (2013) highlight the importance of social support and environmental factors in shaping behavioral intentions and actions, indicating that future interventions might benefit from incorporating these elements more robustly. Our study underscores the complexity of behavior change and the necessity for multifaceted interventions that address attitudes toward the program, and other psychological and social factors. The significant improvements in attitudes toward the program and intentions to exercise within the intervention group suggest that VR-based exercise interventions have promising potential but also highlight the need for longer-term and more comprehensive strategies to translate these changes into sustained behavior.

Physical activity, attitudes toward exercise and interest/enjoyment

According to our results, the intervention group demonstrated significantly higher physical activity levels post-intervention and in follow-up comparing to the control group. This suggests that engaging in VR exercise effectively increased physical activity levels immediately after the intervention and maintained these levels one month later, highlighting its lasting effect. In contrast, the control group did not exhibit any significant changes in physical activity levels throughout the study period,

suggesting that the VR-based exercise option was crucial for promoting and maintaining increased physical activity. It is important to mention that the analysis showed a large effect size, which indicates a substantial difference between the physical activity levels of the intervention and control groups and not only statistical significance but also practical relevance in real-world applications. These findings are consistent with previous research indicating the effectiveness of technology-based interventions in promoting physical activity. For instance, a study by Larsen et al. (2019) found that digital interventions, including VR, significantly increased physical activity levels and maintained these changes over time. Similarly, Maturo and Cunningham (2013) highlighted that interactive and engaging interventions like VR can be more effective in sustaining long-term physical activity compared to traditional methods. Research suggests that VR-based exercise has the potential to enhance adherence and motivation by creating engaging and enjoyable environments (Liu et al., 2019). The ability to provide pleasurable and performance-enhancing virtual spaces makes exercise more attractive. It is also supported that while a relaxing VR environment may not promote high-intensity activity, it maximizes enjoyment, which could encourage prolonged engagement (Lemments et al., 2023). Additionally, researchers highlight that active VR games can elicit various levels of physical activity intensity, with those perceived as the most enjoyable and least effortful further supporting long-term participation in physical activity (Evans et al., 2021). Moreover, there was also found a moderate positive correlation between the follow-up physical activity levels and personal innovativeness. This relationship could suggest who are more open to new technology, may also be more likely to maintain participating in VR exercise programs. There was a small positive correlation between the follow-up physical activity levels and body image. This may indicate that individuals with a more positive body image are slightly more likely to maintain or increase levels of physical activity. Following our results, Sabiston et al. (2019) support that individuals with a negative perception of their body image were less likely to engage in physical activity and sports, as it was often seen as an obstacle to participation. In contrast, those with a positive body image were more inclined to be active and involved in sports.

Furthermore, results indicated that participants in the intervention group reported significantly higher levels of interest/enjoyment in exercise compared to the control group. As happened in Seo's et al. (2023) study in which the levels of exercise enjoyment and immersion were significantly higher in the virtual reality exercise group

compared with the other groups. This heightened interest/enjoyment could be a key factor contributing to the sustained increase in physical activity levels observed in the intervention group. According to Granero-Jiménez et al., 2022, this is an important determinant for higher levels of physical activity. Moreover, research by Johnson et al. (2021) suggested that interactive and immersive VR exercises could increase motivation and engagement, leading to more consistent and prolonged exercise habits among participants. There was also a moderate positive correlation between personal innovativeness and interest/enjoyment, indicating that individuals with high levels of personal innovativeness may experience more interest/enjoyment during exercise in VR environment.

Additionally, the intervention group demonstrated more positive attitudes toward exercise than the control group, further supporting the notion that engaging in VR exercise not only enhanced physical activity levels but also positively influenced participants' perceptions and attitudes toward exercise. That is also supported by other researchers, that VR training can improve participants' positive feelings and attitudes toward physical effort (Banerski et al., 2024).

Exercise and counseling perceptions

According to our results, the participants of the intervention group scored highly in perceived enjoyment, intention for future use, and usability, and expressed positive perceptions of using the VR system. Following our results, VR-based physical activities can reduce anxiety and improve overall mental health, which can be particularly beneficial for individuals struggling with obesity. These findings suggest that incorporating VR technology in exercise regimens could address both physical and psychological barriers to weight loss (Garcia et al. 2022).

The results from the semi-structured interviews indicated distinct differences and similarities emerged between the groups. Participants in the intervention group, who engaged in both counseling and VR exercise, consistently described the intervention as innovative and highly motivating. Significant improvements were reported in psychological well-being, consistency in their exercise regimen, and positive changes in mood and body image. The VR exercise was particularly praised for its entertainment value and ease of use, contributing to increased self-efficacy and sustained physical activity. Despite facing challenges like time constraints, the Intervention group participants expressed a strong intention to continue using the VR

system and behavior change techniques, underscoring the importance of support and goal-setting in their progress. Regarding control group, which received only counseling, found the sessions positive and effective, helping them set and achieve goals related to exercise and nutrition. While most participants reported improved self-efficacy and mood, the degree of these improvements varied, with some not experiencing significant changes. Similar to the Intervention group, time constraints were a notable challenge. The digital booklet and goal-setting process were also valued in control group, aiding in progress tracking and behavioral changes. Both groups appreciated the support and guidance provided, particularly through online communication, which helped maintain focus and motivation. Overall, while both interventions were deemed effective, the addition of VR exercise in the Intervention group provided an extra layer of engagement and motivation, leading to more pronounced improvements in psychological well-being and self-efficacy compared to counseling alone in control group.

Limitations

Despite the encouraging results, this study has several limitations that should be mentioned. Although we conducted a power analysis to determine the appropriate sample size, and the 40 participants meet this requirement, the findings should be generalized with caution. A larger sample size could enhance the generalizability of the results. Additionally, the novelty effect of VR could have temporarily enhanced participants' motivation and adherence to exercise. Initial enthusiasm for VR-based interventions may diminish over time as users become more familiar with this technology. Future studies could explore the long-term sustainability of VR-based exercise beyond the four-week period and assess whether the observed benefits persist over time. Investigating its effectiveness in different populations and examining the psychological mechanisms that contribute to increased enjoyment and motivation would provide deeper insights. Additionally, research should focus on the impact of VR exercise on psychological factors such as anxiety, stress, and mental well-being. Furthermore, future research could examine the cost-effectiveness of VR interventions to determine their feasibility for widespread implementation in clinical and real-world settings. Comparative studies with other emerging exercise technologies, such as AI-powered fitness platforms, could help identify the most effective tools for enhancing exercise adherence and outcomes.

Practical implications

Integrating VR-based exercise into obesity interventions offers a promising approach for enhancing engagement and adherence to physical activity. Fitness professionals can use VR technology to create immersive, interactive workouts tailored to individual needs and preferences. Structured VR exercise programs, such as guided virtual training sessions, can be implemented in gyms, rehabilitation centers, or even home-based settings to provide accessible and enjoyable exercise experiences. Additionally, VR can be used to simulate real-world environments that may not be feasible due to cost, safety concerns, or weather conditions, enabling individuals with obesity to engage in diverse activities within a controlled and motivating setting. Personalization features, such as adaptive difficulty levels and real-time feedback, can further enhance motivation by ensuring that workouts remain both challenging and achievable. Finally, combining VR-based exercise with behavioral counseling and SDT-based strategies may maximize long-term adherence and support sustainable lifestyle changes.

Conclusion

The present study highlights the potential physical, psychological, and behavioral benefits of VR-based exercise combined with SDT-based counseling for individuals with overweight and obesity, compared to traditional exercise with SDT-based counseling. Significant improvements were observed in BMI and body fat mass, alongside enhanced psychological outcomes including increased competence, relatedness, self-efficacy, and self-esteem. These positive changes were not observed to the same extent in the control group. Additionally, VR-based exercise proved to be effective in sustaining physical activity levels, likely due to high levels of enjoyment, positive attitudes toward exercise, great psychological needs satisfaction, usability, and satisfaction with the VR equipment.

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CHAPTER VI– GENERAL DISCUSSION

Overview and discussion of findings

Acceptance, usability, interest/enjoyment & VR equipment

In all studies conducted, the acceptance, usability, interest/enjoyment, and satisfaction from the VR exercise system equipment were evaluated. According to the results, participants in all four studies achieved high scores in all the above variables. In the comparisons made in the studies with exercise performed without the VR exercise system, it was evident that participants scored lower on these variables after typical exercise. More specifically, the acceptance of the system was evaluated through questions regarding perceived enjoyment, intention for future use, and participants' attitudes toward exercising in a virtual environment. Recent studies highlight the positive impact of combining VR technology with exercise on the aforementioned variables. According to one study, participants who exercised in VR scored higher on enjoyment compared to exercise without VR, indicating that the immersive nature of VR can make exercise feel more like a game rather than a "chore" (Mouatt et al., 2020; Tang et al., 2016). Another study suggests that exercising in a virtual environment positively influenced participants' attitudes compared to exercising on a flat screen (Banerski et al., 2025). The intention for future use is influenced by perceived enjoyment and attitudes, particularly by perceived effectiveness (Ekpezu et al., 2024). For this reason, high scores were also recorded for this variable in all our studies. Usability is also a factor that enhances the intention for future use, which can also be influenced by satisfaction with the VR equipment. In our studies, satisfaction with the VR equipment was high. According to a study conducted across various age groups, younger adults scored higher in the usability of a VR exercise system. However, all age groups achieved higher scores in immersion and motivation for exercise compared to the non-VR-based exercise condition (Fang & Huang, 2021). According to other researchers, the intention for future use of a VR system is positively influenced by perceived usefulness and negatively affected by the feeling of cybersickness. Additionally, personal innovativeness positively impacts perceived usefulness (Sagnier et al., 2020). Personal innovativeness was examined in 3 out of the 4 studies, and the scores recorded were moderate to high. Therefore, this factor contributes to the positive results found in the acceptance of the VR exercise system. Finally, participants in all studies reported high scores on interest/enjoyment from VR-based exercise, with

significantly higher scores compared to traditional exercise in the studies where a comparison between the two types of exercise was made. In agreement with our results, those of another study also reported higher scores on interest/enjoyment after high-intensity VR-based exercise compared to exercise without the VR exercise system (Farrow et al., 2019).

Qualitative data

According to the interviews conducted regarding the participants' feelings, expectations, and perceptions of the usability and tolerability of the VR exercise system, the results were very encouraging. Most participants from all the studies stated that they would like to use this VR system for exercise, although a small percentage mentioned that they would not want to use it for regular exercise. The difficulties and technical issues that arose were minimal, and very few participants reported problems with using the equipment, such as poor fitting of the VR headset or difficulties with the use of the controllers. None of the participants required additional assistance or time to understand the operation and use of the VR exercise system, which consequently enhanced the system's usability. Most participants reported a sense of presence and control, although a large percentage mentioned that the virtual environment seemed artificial and unrealistic. Only a few participants expressed negative emotions, such as discomfort, dizziness, or distraction during the trial. Overall, participants found the VR exercise system enjoyable, fun, relaxing, comfortable, easy to use, accessible, attractive, motivating, inspiring, innovative, interesting, challenging, and capable of eliciting positive emotions. They also mentioned that the system gave them a sense of escape from reality, was user-friendly, served as a good motivator for exercise, and helped make the exercise time pass more quickly.

Negative findings

Despite the positive findings from all four studies, a small percentage of participants expressed dissatisfaction with exercising in the virtual environment and indicated that they would not prefer using the VR exercise system to exercise regularly. They explained their perspective by emphasizing that VR technologies cannot fully replace the natural environment and noted that the virtual setting felt overly artificial to them. Other participants reported feeling uncomfortable with the VR equipment due to its weight or motion sickness or they reported that they couldn't use the joysticks

effectively. In addition, some found that their exercise experience was lacking a connection to the real world. Furthermore, some individuals expressed concern about screen time and the lack of social interaction compared with traditional exercise environments. Personal preferences or lack of familiarity with VR technology may have contributed to their reluctance.

Exercise self-efficacy, self-efficacy expectations, self-esteem & mood

Self-efficacy and self-efficacy expectations were assessed in the three studies, and significant improvements were found in two of them after the VR-based exercise.

Patients with T1DM did not show statistically significant improvements after VR-based exercise, but this may be due to the small sample size. Enhanced self-efficacy can lead individuals to set challenging goals and remain committed to them even when difficulties arise. Furthermore, it can lead to the successful adoption of healthy behaviors, such as participation in exercise programs (Pekmezi et al., 2009). Conversely, participation in physical activity can improve individuals' self-efficacy levels. According to a recent systematic review and meta-analysis, participation in physical activity can have a positive impact on self-efficacy and motivation in adults (Ghayour Baghbani et al., 2023). Additionally, the use of VR can lead to increased levels of self-efficacy and satisfaction (Chiang et al., 2022). Positive outcomes in enhancing self-efficacy have emerged from exercise in VR, both in stroke patients (Long et al., 2020) and in elderly individuals, where self-esteem showed significant improvements (Fan et al., 2022). Additionally, students reported higher levels of self-efficacy and enjoyment after cycling in VR environment compared to traditional cycling (Zeng et al., 2017; McDonough et al., 2020). Furthermore, McAuley et al. (2011) demonstrated that interventions involving physical activity can significantly improve self-esteem, further supporting our findings. According to a meta-analysis, interventions that provide feedback on participants' performance or experiences through others can lead to improvements in self-efficacy (Ashford et al., 2010). Finally, based on our results, there was a strong positive correlation between personal innovation and self-efficacy. A study conducted on employees found that personal innovation is significantly correlated with the participants' self-efficacy (Nohut & Balaban, 2022). This finding means that individuals who were more innovative and open to new technology tend to have higher levels of self-efficacy.

According to our results, a significant improvement in participants' mood was found after a VR-based exercise session compared to regular cycling. These results are also supported by other researchers who have concluded that this type of exercise can enhance the well-being and mood of different populations compared to typical exercise (Ochi et al., 2024). Immersive exercise in VR environment is said to facilitate the reduction of negative emotions such as anger, fatigue, and depression, while improving positive emotions like vigor in students. It serves as a means of motivation for them to engage in physical activity, holistically improving their mood (Liu et al., 2024). The combination of VR and exercise enhances enjoyment and energy and reduces feelings of fatigue compared to the use of VR without exercise, which led to increased tension and reduced energy levels (Plante et al., 2003). However, another study that compared a VR cycling session with outdoor cycling, while presenting the positive effects of VR-based exercise on engagement and physiological responses, concluded that outdoor cycling had greater benefits in motivation, enjoyment, and intention to adhere to exercise (Poli et al., 2024).

Cognitive effects

According to our results, a VR-based exercise session had positive effects on the attention of individuals in the process of drug addiction recovery. Generally, the literature supports that VR-based exercise can positively affect cognitive factors, as the rapid development of technology has enabled researchers to create interventions for rehabilitation and cognitive training. These interventions can have a significant impact on functional ability, attention, and memory. Additionally, participation in VR games can improve cognitive functions such as memory due to their immersive and interactive nature. For example, a study comparing participation in games involving exercise and static VR games supported that the former led to better cognitive outcomes and that VR can improve both physical and cognitive health (Sousa et al., 2021). According to other researchers, the processing of information and performance of the functional brain network in individuals addicted to methamphetamine were enhanced after a VR-based exercise session (Qi et al., 2021). The combination of VR-based exercise and cognitive training has been studied, particularly in patients with cognitive impairment or those with dementia or Alzheimer's, and significant improvements were found in gait performance along with other skills (Liao et al., 2019), improvements in cognitive ability (Bamidis et al., 2015), functional memory, and verbal fluency (Mrakic-Sposta

et al., 2018). According to a recent systematic review, VR-based exercise is an effective approach for improving overall cognitive performance and executive function in older adults with or without cognitive impairment (Sakaki et al., 2021). Therefore, VR is a promising tool for enhancing cognitive factors, particularly when combined with exercise and positive outcomes may even be observed after the first session.

Physical effects

The results from our studies were encouraging for the measurements taken on variables related to obesity and diabetes. Specifically, BMI, body fat mass, and hip circumference significantly decreased after one month of VR-based exercise combined with counseling. In agreement with our results, those of Seo et al. (2023) showed that BMI decreased after 8 weeks of VR-based exercise compared to baseline measurements and compared to traditional exercise (Seo et al., 2023). In general, according to a systematic review, individuals who participated in VR-based exercise programs showed greater engagement in physical activity and a reduction in BMI compared to control groups, leading to the conclusion that the use of VR can be effective for managing obesity.

A small decrease in blood glucose levels was observed in T1DM patients after the VR-based exercise trial. It is known that glucose uptake by muscles is increased during aerobic exercise (Colberg et al., 2016). Previous research support that increased stress levels can lead to poor glucose control (Surwit et al., 1992). VR-based exercise has been shown to offer a stress-reducing, enjoyable activity, contributing to greater glucose reduction compared to traditional exercise. Lee et al. (2023) highlighted the positive impact of VR-based exercise on glucose control in T2DM patients. Similarly, de Brito Gomes et al. (2023) demonstrated that a two-week VR-based exercise program with 30-minute sessions at 65-70% maximum heart rate achieved comparable effects to running, with fewer hypoglycemic episodes in T1DM patients. However, a systematic review by Yim and Hur (2023) found that longer VR interventions did not significantly improve glycated hemoglobin in diabetic patients. Few studies have examined the immediate effects of VR-based exercise on biometric parameters. Gomes et al. (2021) found similar biological responses between VR and non-VR-based exercises when matched for duration and intensity, though glucose reduction was lower in non-VR conditions.

Cost-Benefit of VR in exercise and therapy

Integrating VR systems in exercise programs can be a compelling cost-benefit scenario. The cost of VR equipment may appear high, but its long-term benefits can offset these costs. For instance, VR systems enable personalized and adaptive exercise programs, reducing the need for continuous close one-on-one supervision by experts and potentially lowering operational costs in therapy settings. Additionally, VR can increase adherence to exercise programs by making activities more engaging and enjoyable, thus improving health outcomes and reducing the costs associated with chronic disease management (Valenzuela et al., 2018). Moreover, the ability to conduct telerehabilitation through VR eliminates geographical barriers, decreasing travel-related costs for patients and providers alike (Lloréns et al., 2015). When implemented effectively, VR not only enhances therapeutic and exercise experiences but also offers a cost-effective solution for promoting physical and mental health.

Clarifications and additional notes

In study 2, “Exploring the acute effects of immersive virtual reality biking on self-efficacy and attention of individuals in the treatment of substance use disorders: A feasibility study”, upon further consideration, while the study was initially described as employing a quasi-experimental research design, a more accurate characterization would be that of a one-group experimental study.

Moreover, to enhance transparency, it may be helpful to include a brief description of the Stroop test procedure, ensuring a more comprehensive understanding of its implementation in this study. The Stroop test was conducted using 3 tabs (naming, reading and interference). In the naming condition, participants named the colors of squares. In the reading condition, they read color words written in black ink. In the interference condition, they named the ink color of color words that conflict with the word's meaning (e.g., the word “red” written in blue ink). The time taken and errors were recorded.

Practical Implications

Exercise plays a significant role in many aspects of health for both healthy and clinical populations. According to the World Health Organization, large percentages of adults and adolescents worldwide do not meet the WHO recommendations for weekly

participation in physical activity or exercise (WHO, 2020). Therefore, one factor that has led to an increase in researchers' interest in VR is the fact that nowadays, a sedentary lifestyle is one of the most significant global health concerns and is associated with many chronic diseases, including mental health disorders, hypertension, metabolic syndrome, and cancer. Although health organizations recommend participation in physical activities, a large percentage of individuals lead a sedentary lifestyle, even though they are aware of the health benefits that exercise provides. One of the main factors driving these behaviors is the lack of motivation. Thus, technology has contributed to finding new alternatives for exercises that can help people adopt a healthier lifestyle. One of these is virtual reality games (exergames), which have many advantages, are easy to acquire, and are user-friendly. These video games not only represent a potential strategy for reducing sedentary behavior but also serve as an effective method for improving health and rehabilitation in populations with various conditions. A review aimed to demonstrate that the use of such games for health promotion is supported by the literature. According to the results, it is concluded that since exercise is considered to have therapeutic effects on chronic conditions, a combination of exercise with virtual reality could enhance therapeutic outcomes. Particularly in certain cases, such as improving cognitive functions in the elderly, increasing balance and functionality (Silva et al., 2018).

The findings of this dissertation underscore the clinical and public health potential of VR exercise systems. The findings of the present studies suggest that VR-based exercise systems may be adaptable to different populations and show promise in supporting physical, psychological, or cognitive aspects of health, while also enhancing motivation for exercise participation. Moreover, VR-based exercise emerges as not merely a technological innovation but a transformative intervention with the capacity to improve health outcomes and promote physical activity.

Office Workers

- *Integration of short exercise breaks:* VR applications can be used for short exercise or stretching sessions during work breaks, reducing the prolonged sedentary posture of employees.
- *Improvement of posture and mobility:* VR applications with core strengthening, stretching, and mobility exercises can be used to help employees to reduce

musculoskeletal tension and decrease absenteeism due to musculoskeletal issues.

- o *Relief from psychological discomfort:* VR applications that simulate activities in natural landscapes or gentle, relaxing activities like yoga can be used to help reduce stress and psychological tension among workers

Patients in SUD treatment

- o *Integration of VR-based exercise in rehabilitation programs:* VR applications can increase motivation for participation in exercise programs, which are beneficial in addressing substance use disorders (SUDs), as they can further engage individuals, particularly within this population, and stimulate their interest.
- o *Improvement of mood and self-confidence:* The use of VR during exercise can provide stimuli that contribute to enhancing positive psychology and self-efficacy regarding exercise, reducing symptoms of anxiety and depression, and improving mood. It can also incorporate mild relaxation exercises for stress management.
- o *Social support:* The use of interactive VR applications that allow multiple users to participate in exercise programs enhances the need for connection and socialization, fostering a sense of community and mutual support among participants.

T1DM patients

- o *Integration of VR-based exercise in T1DM management:* VR-based exercise applications can be incorporated into T1DM management programs with controlled, gradual intensity increases and monitoring of blood glucose levels to prevent hypoglycemic episodes. Low intensity exercises within VR are less likely to trigger hypoglycemia, making them a safer option for individuals with diabetes.
- o *Enhancement of exercise adherence and education:* The immersive and enjoyable nature of VR applications increases interest and motivation for continued participation in physical activity. Additionally, patients can be playfully educated in managing their condition and use applications that

simulate different scenarios for experiential learning, promoting long-term engagement in health management.

- o *Anxiety and psychological distress management:* VR-based exercise can help improve mood, reduce anxiety, and enhance positive psychology in patients, benefiting their mental health, which is closely linked to their condition. By engaging in immersive environments, patients may experience relief from stress and emotional strain, fostering better overall well-being.

Overweight/Obese

- o *Integration of VR-based exercise in obesity management:* VR applications can serve as a motivating tool for active participation in exercise by making it more enjoyable. They offer the ability to adjust the duration and intensity of the exercise based on the individual's fitness level. VR-based exercise can be incorporated into obesity management programs to enhance their effectiveness, promoting sustainable engagement and better physical outcomes.
- o *Psychological support and self-monitoring:* VR-based exercise applications incorporating psychological techniques can enhance individuals' mental health and self-esteem through positive reinforcement and motivational messages. These applications allow users to track their progress and achievements, boosting their sense of accomplishment. Additionally, by utilizing avatars, they can contribute to improving body image, encouraging users to remain physically active and stay committed to their goals.

Long-term challenges

Despite the numerous benefits that VR exercise systems may offer, challenges in long-term adherence and technical limitations must be addressed to maximize their effectiveness. The issue of "cybersickness," which involves symptoms such as nausea, dizziness, and disorientation, is one that can negatively impact user comfort and ability to engage in VR-based activities over time (Chang et al., 2020). Moreover, prolonged use of VR headsets can result in physical discomfort, such as eye strain or neck fatigue and musculoskeletal discomfort, further impacting adherence (Souchet et al., 2023). Other studies highlight common VR-related adverse effects such as fatigue and worsening of symptoms like posttraumatic stress disorder and anxiety, though data limitations hinder accurate prevalence estimates (Lundin et al., 2023). Challenges can

also include reduced interpersonal interaction, cost, user attitudes, design complexities, safety, and validation of the applications (Baniyadi et al., 2020). It is essential to address these challenges through user-centered design, proper onboarding, and technical support in order to ensure a seamless and enjoyable experience. By overcoming these challenges, VR systems can become more viable for sustained use in exercise and therapy programs.

Despite possible challenges after long-term VR use, which can be limited with further development of technology, this dissertation demonstrates that VR exercise systems are safe, user-friendly, and suitable for physical activity in both healthy and studied clinical populations. Moreover, it emphasizes that the effectiveness and safety of these applications are significantly enhanced when used under the guidance of specialized professionals, ensuring the minimization of risks and the maximization of beneficial outcomes.

Limitations and Future Research Directions

The results of our studies were highly encouraging regarding the use of VR-based exercise in the examined populations. However, these findings could be strengthened by conducting research with larger sample sizes that include volunteers of both genders, various age groups, and longer intervention durations. It is also essential to include control groups to compare pre- and post-exercise changes and to evaluate the extent to which such exercise methods can contribute to improvements in various aspects of physical fitness, physical health, mental well-being, and cognitive health. More specifically, since the VR system was tested in only one session in three out of the four studies, longer-duration interventions are necessary to examine whether this form of exercise remains enjoyable and engaging over time, as well as its long-term effects. Consequently, intervention studies are needed to explore the long-term effectiveness of VR-based exercise and the potential benefits it may offer to specific populations. Additionally, in the studies conducted, the exercise intensity was low or self-selected. It would be valuable to conduct studies involving higher-intensity and longer-duration exercise programs to assess their physical and psychological impact. An additional consideration is that the lead researcher also acted as the primary intervention facilitator and data collector during the implementation of all studies. While this ensured consistent protocol delivery and close participant monitoring, it may

also introduce potential bias, which should be considered when interpreting the findings. Based on the findings, there were improvements in cognitive factors, such as attention, following a single session VR-based exercise in individuals with SUD. Future research could further explore and clarify the mechanisms underlying these changes in cognitive factors. Another area worth investigating is the monitoring of biological mechanisms activated during VR-based exercise, comparing them to traditional forms of exercise. This would help determine in which cases VR-based exercise might be more beneficial or applicable. Further research could be conducted across diverse populations to understand the effectiveness of this form of exercise in a broader context. Psychological mechanisms contributing to the increased enjoyment of VR exercise systems could be explored, with a focus on the impact of VR-based exercise on psychological factors such as anxiety and mental well-being. Additionally, comparisons between VR-based exercise and other emerging technologies, such as AI exercise platforms, could help identify the most effective tools for enhancing exercise adherence and outcomes. Furthermore, the incorporation of AI into VR systems could offer personalized exercise experiences by adapting workout intensity, duration, and feedback to individual needs and preferences, enhancing user adherence, effectiveness and make VR-based exercise even more applicable. Studies could be conducted to examine the cost-effectiveness of VR-based exercise or to evaluate factors such as cybersickness and potential contraindications that might arise during a VR intervention. We recommend that future research incorporate the use of the Simulator Sickness Questionnaire (SSQ) to ensure data comparability with other studies. Finally, it is important to note that many of the outcomes reported in this dissertation reflect the acute effects of a single VR-based exercise session.

Conclusion

In conclusion, the findings of this dissertation suggest that VR-based exercise may represent a promising and innovative approach for supporting positive health outcomes in specific populations, such as office workers, individuals with obesity, substance use disorders, and type 1 diabetes. This approach may enhance psychological factors such as self-efficacy, mood, and self-esteem, alongside physical outcomes like BMI and body fat reduction, and cognitive improvements such as memory enhancement. Participants reported that VR-based exercise was applicable, user-

friendly, enjoyable, and preferable to traditional methods, demonstrating its capacity to motivate individuals and sustain their adherence to exercise programs.

Although these findings are encouraging, the generalizability of the results is limited due to small sample sizes and short intervention durations. Therefore, further research is needed to assess the long-term effects, adherence, and effectiveness of VR-based exercise in broader and more diverse populations. Future studies should also aim to optimize personalization and evaluate the integration of such systems into established exercise and health promotion programs.

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Appendices

Appendix 1. Video Demo of VRADA

Video Demo of VRADA can be found here:

<https://drive.google.com/file/d/1s2sL7GvxgHvgAJMOoJwKrrQgxabRsVQp/view?usp=sharing>

Appendix 2. Personal Innovativeness Questionnaire

Κλίμακα προσωπικής καινοτομίας για την αξιολόγηση των πεποιθήσεων των ατόμων σχετικά με τις αποφάσεις υιοθέτησης τεχνολογίας (Agarwal et al., 1998).

Ποια είναι η σχέση σας με τις νέες τεχνολογίες;					
	Διαφωνώ απόλυτα	Διαφωνώ	Δεν είμαι σίγουρος/η	Συμφωνώ	Συμφωνώ απόλυτα
Γενικά, είμαι άτομο που...					
1. ...ανυπομονεί να πειραματιστεί με νέες τεχνολογίες	1	2	3	4	5
2. ...θέλει να πειραματιστεί με νέες τεχνολογίες	1	2	3	4	5
3. ...δεν διστάζει να δοκιμάζει νέες τεχνολογίες	1	2	3	4	5
4. ...συνήθως δοκιμάζει πρώτος τις νέες τεχνολογίες	1	2	3	4	5

Appendix 3. Acceptance Questionnaires

Κλίμακα αντιλαμβανόμενης ευχαρίστησης για την αξιολόγηση της ευχαρίστησης από την άσκηση (Rasimah et al., 2011).

Αντιλαμβανόμενη ικανοποίηση της άσκησης με το σύστημα εικονικής πραγματικότητας					
1. Η άσκηση με το σύστημα εικονικής πραγματικότητας είναι διασκεδαστική στη χρήση	1	2	3	4	5
2. Η άσκηση με το σύστημα εικονικής πραγματικότητας είναι ευχάριστη στη χρήση	1	2	3	4	5
3. Απόλαυσα την άσκηση με το σύστημα εικονικής πραγματικότητας	1	2	3	4	5
4. Θα ήθελα η συνεδρία της άσκησης με το σύστημα εικονικής πραγματικότητας να κρατήσει περισσότερο	1	2	3	4	5
5. Θα ήθελα να επαναλάβω την ίδια εμπειρία άσκησης με το σύστημα εικονικής πραγματικότητας	1	2	3	4	5
6. Βρήκα την άσκηση με το σύστημα εικονικής πραγματικότητας μια ενδιαφέρουσα εμπειρία	1	2	3	4	5

Κλίμακα πρόθεσης για μελλοντική χρήση για την εκτίμηση του βαθμού στον οποίο το άτομο θέλει συνειδητά να χρησιμοποιεί το σύστημα εικονικής πραγματικότητας για να ασκείται (Agarwal et al., 1998).

Πρόθεση άσκησης με τη χρήση του συστήματος εικονικής πραγματικότητας					
1. Σκοπεύω να χρησιμοποιήσω την άσκηση με το σύστημα εικονικής πραγματικότητας όταν είναι διαθέσιμο	1	2	3	4	5
2. Αν είχα πρόσβαση στην άσκηση με το σύστημα εικονικής πραγματικότητας, προβλέπω ότι θα το χρησιμοποιούσα συχνά	1	2	3	4	5
3. Υποθέτοντας ότι είχα πρόσβαση στην άσκηση με το σύστημα εικονικής πραγματικότητας, σκοπεύω να το χρησιμοποιήσω	1	2	3	4	5

Κλίμακα στάσεων για την αξιολόγηση των στάσεων προς την άσκηση εντός ΕΠ (Agarwal et al., 1998).

Βρίσκω την άσκηση με το σύστημα εικονικής πραγματικότητας: (Κυκλώνετε μία λέξη που σας αντιπροσωπεύει περισσότερο)		
Καλή	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Κακή
Ανόητη	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Έξυπνη
Χρήσιμη	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Όχι χρήσιμη
Υγιεινή	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Ανθυγιεινή
Άσχημη	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Όμορφη
Δυσάρεστη	πολύ ----- αρκετά ----- λίγο ----- έτσι και έτσι ----- λίγο ----- αρκετά ----- πολύ	Ευχάριστη

Appendix 4. Usability Questionnaire

Κλίμακα ευχρηστίας (System Usability Scale) για την αξιολόγηση της ευχρηστίας του συστήματος ΕΠ (Brooke, 1996).

Ποια η γνώμη σας για το σύστημα εικονικής πραγματικότητας που μόλις ασκηθήκατε;					
	Διαφωνώ απόλυτα	Διαφωνώ	Δεν είμαι σίγουρος/η	Συμφωνώ	Συμφωνώ απόλυτα
1. Νομίζω ότι θα ήθελα να χρησιμοποιώ αυτό το σύστημα εικονικής πραγματικότητας συχνά	1	2	3	4	5
2. Βρήκα αυτό το σύστημα εικονικής πραγματικότητας περίπλοκο	1	2	3	4	5
3. Σκέφτηκα ότι αυτό το σύστημα εικονικής πραγματικότητας ήταν εύκολο στη χρήση	1	2	3	4	5
4. Νομίζω ότι θα χρειαστώ επιπλέον βοήθεια από κάποιον τεχνικό για να είμαι σε θέση να χρησιμοποιήσω αυτό το σύστημα εικονικής πραγματικότητας	1	2	3	4	5
5. Βρήκα τις διάφορες λειτουργίες σε αυτό το σύστημα εικονικής πραγματικότητας καλά ολοκληρωμένες	1	2	3	4	5
6. Σκέφτηκα ότι υπάρχει μεγάλη ασυνέπεια σε αυτό το σύστημα εικονικής πραγματικότητας	1	2	3	4	5
7. Φαντάζομαι ότι οι περισσότεροι άνθρωποι θα μάθουν να χρησιμοποιούν αυτό το σύστημα εικονικής πραγματικότητας πολύ γρήγορα	1	2	3	4	5
8. Βρήκα αυτό το σύστημα εικονικής πραγματικότητας πολύ περίπλοκο / δύσκολο στην χρήση	1	2	3	4	5
9. Ένωσα πολύ σίγουρος χρησιμοποιώντας αυτό το σύστημα εικονικής πραγματικότητας	1	2	3	4	5
10. Χρειάστηκε να μάθω πολλά πράγματα πριν να μπορέσω να ξεκινήσω με αυτό το σύστημα εικονικής πραγματικότητας	1	2	3	4	5

Appendix 5. Preference between VR or non-VR trial

Σύγκριση της Άσκησης Με και Χωρίς το Σύστημα Εικονικής Πραγματικότητας
Συμπληρώστε με ένα [✓] σε κάθε απάντηση που σας αντιπροσωπεύει.

Η άσκηση ήταν πιο ευχάριστη όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Η άσκηση ήταν πιο εύκολη όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Ο χρόνος που ασκήθηκα μου φάνηκε πιο σύντομος όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Με κούρασε περισσότερο όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Η άσκηση ήταν πιο βαρετή όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Οι νοητικές ασκήσεις μου φάνηκαν πιο ευχάριστες όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Οι νοητικές ασκήσεις μου φάνηκαν πιο εύκολες όταν...

...ασκήθηκα χωρίς τη μάσκα [] [] ...ασκήθηκα με τη μάσκα

Αν μου δινόταν η ευκαιρία ξανά να ασκηθώ στο στατικό ποδήλατο θα επέλεγα...

...να ασκηθώ χωρίς τη μάσκα [] [] ...να ασκηθώ με τη μάσκα

Appendix 6. Interest/Enjoyment

Κλίμακα Intrinsic Motivation Inventory (IMI) για την αξιολόγηση του ενδιαφέροντος/ευχαρίστησης των συμμετεχόντων για την άσκηση με ή χωρίς το σύστημα εικονικής πραγματικότητας (Goudas et al., 1994; Goudas et al., 2000).

Απάντησε βάζοντας σε κύκλο την επιλογή που σε εκφράζει περισσότερο		Διαφωνώ απόλυτα	Διαφωνώ	Ούτε συμφωνώ ούτε διαφωνώ	Συμφωνώ	Συμφωνώ απόλυτα
Για κάθε μια από τις παρακάτω ερωτήσεις, παρακαλώ δήλωσε πόσο συμφωνείς ή διαφωνείς. Καθώς θα απαντάς στις ερωτήσεις, φέρε στο μυαλό σου <u>πώς αισθάνθηκες καθώς έκανες την άσκηση αυτή.</u>						
1.	Η άσκηση αυτή μου άρεσε πάρα πολύ	1	2	3	4	5
2.	Η άσκηση αυτή ήταν ευχάριστη	1	2	3	4	5
3.	Η άσκηση αυτή ήταν πολύ ενδιαφέρουσα	1	2	3	4	5
4.	Η άσκηση αυτή ήταν απολαυστική	1	2	3	4	5
5.	Η άσκηση αυτή ήταν πολύ διασκεδαστική	1	2	3	4	5
6.	Ο χρόνος περνούσε πολύ γρήγορα καθώς έκανα την άσκηση	1	2	3	4	5

Appendix 7. Satisfaction of VR equipment

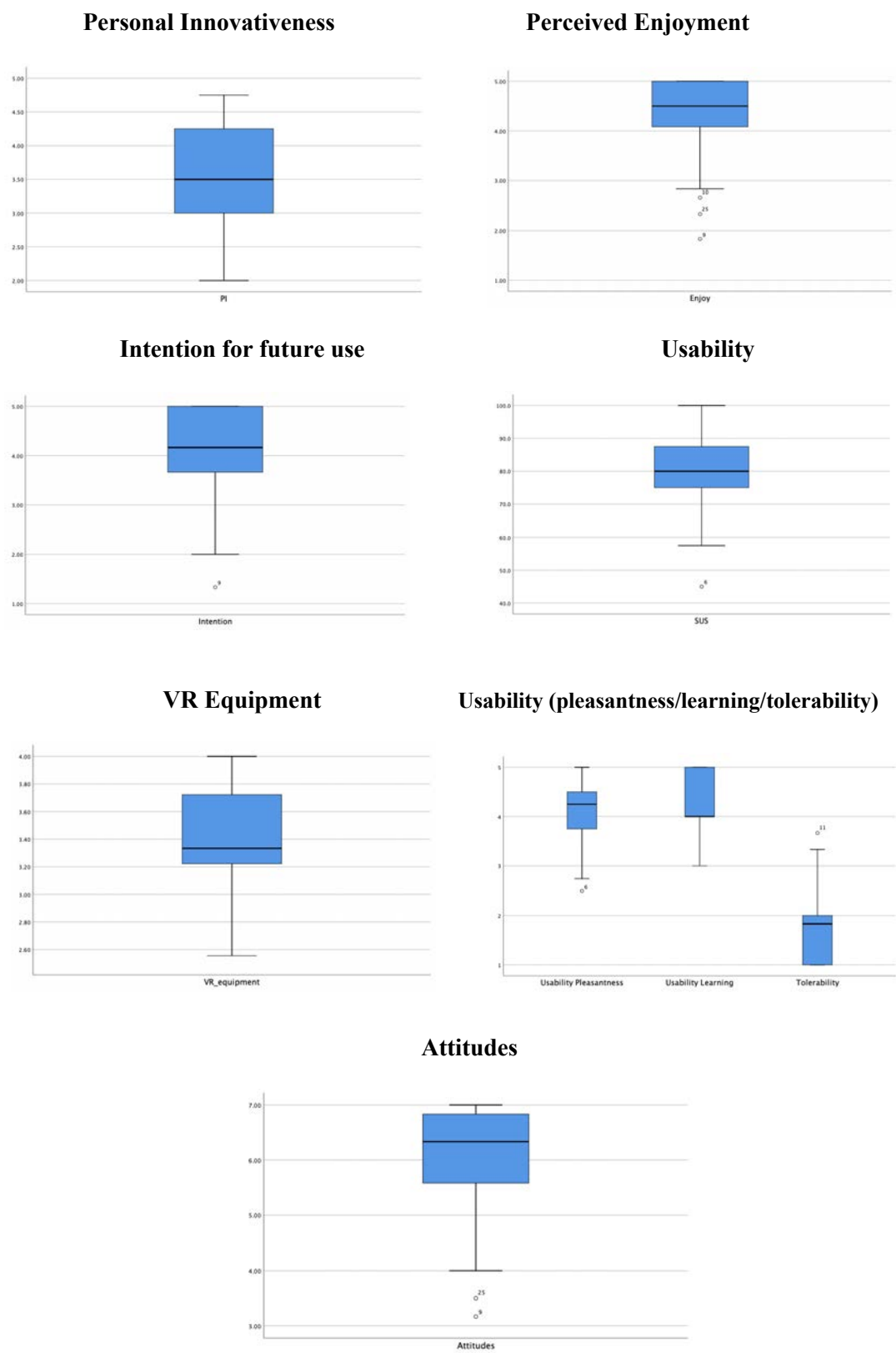
Κλίμακα αξιολόγησης του εξοπλισμού ΕΠ (Mrakic-Sposta et al., 2018).

Εξοπλισμός και εικονικό περιβάλλον					
1. Ένιωθα άνετα με τη χρήση της μάσκας	1	2	3	4	5
2. Ένιωθα άνετα με τη χρήση του τηλεχειριστηρίου	1	2	3	4	5
3. Άκουγα καλά/καθαρά τη μουσική	1	2	3	4	5
4. Ήταν εύκολο να διαβάζω της νοητικές ασκήσεις κατά τη διάρκεια της άσκησης	1	2	3	4	5
5. Ήταν εύκολο να κάνω τις αριθμητικές πράξεις κατά τη διάρκεια της άσκησης	1	2	3	4	5
6. Απολάμβανα να κοιτάζω το πάρκο καθώς έκανα ποδήλατο	1	2	3	4	5
7. Αισθάνθηκα κάποια ζάλη κατά τη διάρκεια της άσκησης	1	2	3	4	5
8. Βαρέθηκα κατά τη διάρκεια της άσκησης	1	2	3	4	5
9. Ένιωσα άγχος κατά τη διάρκεια της άσκησης	1	2	3	4	5

Appendix 8. Semi-structured Interview (Chapter II & IV) (Pedroli et al., 2018)

1. Γιατί θα θέλατε να χρησιμοποιείτε αυτό το σύστημα εικονικής πραγματικότητας για να ασκείστε;
2. Τι δυσκολίες αντιμετωπίσατε κατά τη διάρκεια της άσκησης με το σύστημα εικονικής πραγματικότητας;
3. Τι τεχνικά προβλήματα αντιμετωπίσατε κατά τη διάρκεια της άσκησης με το σύστημα εικονικής πραγματικότητας;
4. Χρειάστηκε να ζητήσετε βοήθεια για το πώς να χρησιμοποιήσετε το σύστημα εικονικής πραγματικότητας; Σε πιο σημείο χρειαστήκατε περισσότερη βοήθεια; Νομίζετε ότι χρειάζεστε περισσότερες οδηγίες;
5. Χρειάστηκε πολύ χρόνο για να κατανοήσετε πώς λειτουργεί το σύστημα εικονικής πραγματικότητας; Σε πιο σημείο χρειαστήκατε περισσότερο χρόνο για να κατανοήσετε το σύστημα εικονικής πραγματικότητας; Το δοκιμαστικό ήταν αρκετό για να κατανοήσετε το σύστημα εικονικής πραγματικότητας;
6. Η χρήση του τηλεχειριστηρίου ήταν δύσκολη/περίπλοκη (π.χ. κουμπιά); Τι σας δυσκόλεψε περισσότερο με τη χρήση του τηλεχειριστηρίου;
7. Τι σας άρεσε περισσότερο και τι λιγότερο στο σύστημα εικονικής πραγματικότητας;
8. Υπήρχε κάποιο σημείο στο σύστημα εικονικής πραγματικότητας στο οποίο νιώσατε άβολα;
9. Τι προβλήματα είχατε κατά τη διάρκεια της άσκησης με το στατικό ποδήλατο σε σχέση με τη χρήση της μάσκας;
10. Νοιώσατε ότι γίνετε ένα με το εικονικό περιβάλλον;
11. Νοιώσατε ότι έχετε τον έλεγχο τους συστήματος εικονικής πραγματικότητας;
12. Τι γνώμη έχετε για τη διάρκεια της εμπειρίας;
13. Είχατε διάσπαση προσοχής κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας; Σε ποια φάση διασπάστηκε η προσοχή σας.. που ακριβώς;
14. Νοιώσατε ότι το εικονικό περιβάλλον ήταν ρεαλιστικό ή τεχνητό;
15. Υπήρχε κάποιο σημείο κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας που αισθανθήκατε άσχημα;;
16. Νοιώσατε ναυτία, ζάλη ή άλλα φυσικά συμπτώματα κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας;
17. Εσείς προσωπικά θα χρησιμοποιούσατε αυτό το σύστημα εικονικής πραγματικότητας για να κάνετε άσκηση συστηματικά;
18. Ποιοι νομίζετε ότι θα έβρισκαν αυτό το σύστημα εικονικής πραγματικότητας χρήσιμο;
19. Τι πλεονεκτήματα πιστεύετε ότι θα είχε η συστηματική χρήση του ποδηλάτου ΕΠ από τους/τις εργαζόμενους/ες στον δικό σας εργασιακό χώρο;
20. Με ποιο τρόπο νομίζετε ότι η χρήση του ποδηλάτου ΕΠ μπορεί να σας βοηθήσει να είστε πιο παραγωγικός/ή στη δουλειά σας;
21. Πόσο ρεαλιστικό το βλέπετε να ασκείστε συστηματικά κάνοντας ποδήλατο ΕΠ που βρίσκεται μέσα στον εργασιακό σας χώρο;
22. Αν υπήρχε μόνιμα στη διάθεση σας ένα ποδήλατο ΕΠ στο χώρο εργασίας σας πιστεύετε ότι θα το χρησιμοποιούσατε συστηματικά; Πότε; Γιατί; κλπ.

Appendix 9. Boxplots of the examined variables



Appendix 10. Self-Efficacy expectations scale

Μπορώ να αντέξω στο ίδιο τεστ για 15 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Μπορώ να αντέξω στο ίδιο τεστ για 20 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Μπορώ να αντέξω στο ίδιο τεστ για 25 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Μπορώ να αντέξω στο ίδιο τεστ για 30 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Μπορώ να αντέξω στο ίδιο τεστ για 35 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Μπορώ να αντέξω στο ίδιο τεστ για 40 λεπτά: (βάλε σε κύκλο) ΝΑΙ ΟΧΙ
Πόσο σίγουρη/ος είσαι γι' αυτό;

ΚΑΘΟΛΟΥ ΑΠΟΛΥΤΑ
ΣΙΓΟΥΡΗ/ΟΣ: 1 2 3 4 5 6 7 8 9 10 : ΣΙΓΟΥΡΗ/ΟΣ

Appendix 11. Semi-structured Interview (Chapter III) (Pedroli et al., 2018)

1. Γιατί θα θέλατε να χρησιμοποιείτε αυτό το σύστημα εικονικής πραγματικότητας για να ασκείστε;
2. Τι δυσκολίες αντιμετωπίσατε κατά τη διάρκεια της άσκησης με το σύστημα εικονικής πραγματικότητας;
3. Τι τεχνικά προβλήματα αντιμετωπίσατε κατά τη διάρκεια της άσκησης με το σύστημα εικονικής πραγματικότητας;
4. Χρειάστηκε πολύ χρόνο για να κατανοήσετε πως λειτουργεί το σύστημα εικονικής πραγματικότητας; Σε πιο σημείο χρειαστήκατε περισσότερο χρόνο για να κατανοήσετε το σύστημα εικονικής πραγματικότητας; Το δοκιμαστικό ήταν αρκετό για να κατανοήσετε το σύστημα εικονικής πραγματικότητας;
5. Η χρήση του τηλεχειριστηρίου ήταν δύσκολη/περίπλοκη (π.χ. κουμπιά); Τι σας δυσκόλεψε περισσότερο με τη χρήση του τηλεχειριστηρίου;
6. Τι σας άρεσε περισσότερο και τι λιγότερο στο σύστημα εικονικής πραγματικότητας;
7. Υπήρχε κάποιο σημείο στο σύστημα εικονικής πραγματικότητας στο οποίο νιώσατε άβολα;
8. Τι προβλήματα είχατε κατά τη διάρκεια της άσκησης με το στατικό ποδήλατο σε σχέση με τη χρήση της μάσκας;
9. Τι γνώμη έχετε για τη διάρκεια της εμπειρίας;
10. Είχατε διάσπαση προσοχής κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας; Σε ποια φάση διασπάστηκε η προσοχή σας; Που ακριβώς;
11. Νιώσατε ότι το εικονικό περιβάλλον ήταν ρεαλιστικό ή τεχνητό;
12. Υπήρχε κάποιο σημείο κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας που αισθανθήκατε άσχημα;
13. Υπήρχε κάποιο σημείο κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας που σε έκανε να σκεφτείς περίεργα πράγματα; Αν ναι, τι ήταν αυτά;
14. Νιώσατε ναυτία, ζάλη ή άλλα φυσικά συμπτώματα κατά τη διάρκεια της άσκησης στο σύστημα εικονικής πραγματικότητας;

Appendix 12. Informational Brochure

ΕΞΕΡΕΥΝΗΣΕ ΤΗΝ ΑΣΚΗΣΗ ΣΕ
ΠΕΡΙΒΑΛΛΟΝ ΕΙΚΟΝΙΚΗΣ
ΠΡΑΓΜΑΤΙΚΟΤΗΤΑΣ
Virtual Reality Exercise Program

Είσαι 18-65 ετών;
Έχεις βάρος πάνω από το ενδεικνυόμενο;

**ΕΝΑΣ
ΜΗΝΑΣ
ΔΩΡΕΑΝ!**


ΚΑΝΕ ΑΣΚΗΣΗ ΣΕ
ΕΙΚΟΝΙΚΟ ΠΕΡΙΒΑΛΛΟΝ


ΕΝΤΑΞΟΥ ΣΕ ΠΡΟΓΡΑΜΜΑ
ΑΣΚΗΣΗΣ


ΣΥΜΒΟΥΛΕΥΤΙΚΗ
ΥΠΟΣΤΗΡΙΞΗ

Συμπλήρωσε τη φόρμα για να λάβεις μέρος
στο πιλοτικό πρόγραμμα άσκησης σε
περιβάλλον εικονικής πραγματικότητας σε
συνεργασία με το Πανεπιστήμιο
Θεσσαλίας.

**ΔΗΛΩΣΕ ΣΥΜΜΕΤΟΧΗ
ΣΚΑΝΑΡΕ ΚΑΙ ΣΥΜΠΛΗΡΩΣΕ**

QR code

Η κάλεσε στο  για περισσότερες πληροφορίες



Appendix 13. SDT behavior change techniques according to Teixeira et al., 2019, used and applied in the intervention

<i>Behavior change technique</i>	<i>Applied in the intervention</i>
Autonomy support	
Elicit perspectives on condition or behavior	Using the TPB questionnaire and the first session of counseling to investigate the participants' perspectives toward participation in exercise.
Prompt identification of sources of pressure for behavior change	During the first counseling session, a discussion was held to explore the participants' motivations for engaging in exercise as well as any sources of pressure they may be experiencing.
Use non-controlling, informational language	During the counseling sessions, non-controlling language was employed. For example, words like "might" or "could" were used to suggest potential strategies for overcoming obstacles and engaging in exercise and diet programs.
Provide choice	All participants could freely choose their preferred form of exercise, including the frequency, duration, and intensity level. They could also tailor the exercise program to fit seamlessly into their daily routines.
Encourage the person to experiment and self-initiate the behavior	Experiment and self-initiate were facilitated through participation in the VR-exercise program, but also in traditional exercise as they could manage their exercise program
Relatedness support	
Acknowledge and respect perspectives and feelings	Statements of empathy, support and motivation were provided through Viber chat and counseling sessions to create a warm and accepting environment
Encourage asking of questions	They were free to ask questions anytime through Viber chat and during counseling sessions
Show unconditional regard	Positive support was provided during counseling sessions, regardless of participants' outcomes in the exercise or diet program.
Demonstrate/show interest in the person	Statements of interest about the participants' thoughts and perceptions were provided in counseling sessions
Use empathic listening	Participants had time to express themselves without pressure in counseling sessions
Competence support	
Address obstacles for change	Discussion of likely barriers in behavior change in the counseling session. The booklet given was designed to provide relevant information and help participants to deal with most common barriers.
Clarify expectations	Discussion of their expectations and goal-setting during counseling sessions
Assist in setting optimal challenge	Education about SMART goal-setting was provided through first counseling session
Offer constructive, clear, and relevant feedback	Counseling sessions included discussions on whether goals were achieved or not, with adjustments made to the goals as needed.
Help develop a clear and concrete plan of action	Discussion about the changes they need to make in order to reach the goals they have yet to achieve and goal adjustments
Promote self-monitoring	Self-monitoring forms were used as a tool to help self-monitoring
Explore ways of dealing with pressure	The booklet provided to participants was designed to support them in overcoming barriers and managing pressures related to maintaining a healthy lifestyle. It offered practical advice on how to navigate challenges such as adhering to a balanced diet and staying consistent with exercise routines. Additionally, it included strategies for coping with stress, anxiety, and other pressures that may interfere with their health goals.

Appendix 14. Booklet

Informational booklet can be found here:

<https://drive.google.com/file/d/1WB1KWseyZX2ZfGQBmJkbjbQTjBFMDCD6/view?usp=sharing>

Appendix 15. Goal-Setting Form

Πάμε να θέσουμε στόχους με βάση το σύστημα **SMART**. Θα μας βοηθήσει να θέσουμε σαφείς, μετρήσιμους, εφικτούς, ρεαλιστικούς και χρονικά προσδιορισμένους στόχους. Συνεπώς, πιο αποτελεσματικούς.

Συγκεκριμένος :

Ο στόχος πρέπει να είναι σαφής και προσδιορισμένος. Πρέπει να είναι ξεκάθαρο τι ακριβώς θέλουμε να επιτύχουμε.

Μετρήσιμος :

Πρέπει να είναι δυνατό να μετρήσουμε την πρόοδο προς την επίτευξη του στόχου. Αυτό συμβάλλει στην παρακολούθηση και αξιολόγηση των αποτελεσμάτων.

Εφικτός :

Ο στόχος πρέπει να είναι ρεαλιστικός και εφικτός. Πρέπει να είναι κάτι που μπορούμε να πραγματοποιήσουμε με τους διαθέσιμους πόρους.

Ρεαλιστικός :

Πρέπει να είναι αντίστοιχος με τους στόχους και τις δυνατότητές μας. Πρέπει να είναι κάτι που είναι εφικτό με την προσπάθειά μας.

Χρονικά Προσδιορισμένος :

Πρέπει να έχει καθορισμένο χρονικό πλαίσιο. Πρέπει να ξέρουμε πότε πρόκειται να επιτύχουμε τον στόχο.

Παράδειγμα:

"Θέλω να χάσω 5 κιλά (συγκεκριμένος), μετρήσιμα μέσω της ζυγαριάς, τους επόμενους 2 μήνες (χρονικά προσδιορισμένος), και θα το πετύχω με την καθημερινή άσκηση και υγιεινή διατροφή (εφικτός και ρεαλιστικός)."

Θέσε έναν στόχο για φυσική δραστηριότητα/άσκηση, έναν στόχο για διατροφή και έναν για νερό για τις επόμενες 2 εβδομάδες.

Καθορισμός στόχων SMART						
Ημ/νια	Στόχος	Πως θα μετρηθεί;	Πότε	Τι θέλω να πετύχω με αυτό;	Επιβράβευση στον εαυτό μου	Πραγματοποιήθηκε;

Σχέδιο πρόθεσης εφαρμογής

Παράδειγμα

"Την επόμενη εβδομάδα (πότε), στις 7:00 π.μ. (πώς), θα πηγαίνω στο γυμναστήριο και θα ασκώμαι για 30 λεπτά τρεις φορές την εβδομάδα (τι) για να βελτιώσω τη φυσική μου κατάσταση."

Ημερομηνία :

Δήλωση :

Για να καταφέρω να (στόχος).....,

θα (πράξη/δραστηριότητα)

(πότε),

(πώς)

Ημερομηνία :

Δήλωση :

Για να καταφέρω να (στόχος).....,

θα (πράξη/δραστηριότητα)

(πότε),

(πώς)

Ημερομηνία :

Δήλωση :

Για να καταφέρω να (στόχος).....,

θα (πράξη/δραστηριότητα)

(πότε),

(πώς)

Appendix 16. Daily Self-Monitoring Form

Φόρμα καθημερινής αυτό-παρακολούθησης
(συμπλήρωσε για 7 συνεχόμενες ημέρες)

	Ημέρα 1η	Ημέρα 2η	Ημέρα 3η	Ημέρα 4η	Ημέρα 5η	Ημέρα 6η	Ημέρα 7η
Πόσα βήματα έκανες σήμερα; (δες το κινητό σου)							
Πόσο νερό ήπιες σήμερα; (σε ποτήρια)							
Πόσα λεπτά φυσικής δραστηριότητας έκανες σήμερα; (π.χ. περπάτημα, ποδήλατο κλπ.)							
Πόσα φρούτα έφαγες σήμερα;							
Πόσα λαχανικά έφαγες σήμερα;							
Πόσα τρόφιμα ή ποτά κατανάλωσες σήμερα που είχαν μεγάλη ποσότητα ζάχαρης; (αναψυκτικά, γλυκά κλπ)							

Appendix 17. PowerBeats Video

Video Demo of Powerbeats app can be found here:

<https://www.youtube.com/watch?v=ATXOTp7NaQM>

Appendix 18. Self-efficacy questionnaire

Συμπλήρωσε το ερωτηματολόγιο γρήγορα, αυθόρμητα, ελεύθερα, χωρίς να προβληματίζεσαι ιδιαίτερα. Δεν υπάρχουν σωστές και λάθος απαντήσεις.

Σημείωσε πόσο σίγουρος/η είσαι ότι μπορείς να κάνεις την άσκηση στο ποδήλατο εικονικής πραγματικότητας, ακόμα και αν βρίσκεσαι σε κάθε μια από τις ακόλουθες καταστάσεις:

Θα κάνω άσκηση στο ποδήλατο εικονικής πραγματικότητας, ακόμα και ...	Καθόλου σίγουρος/η	Λίγο σίγουρος/η	Μέτρια σίγουρος/η	Αρκετά σίγουρος/η	Πάρα πολύ σίγουρος/η
1.Όταν νιώθω κουρασμένος/η	1	2	3	4	5
2.Όταν είμαι σε κακή διάθεση	1	2	3	4	5
3.Όταν νιώθω άρρωστος/η	1	2	3	4	5
4.Όταν νιώθω πόνο στο σώμα μου	1	2	3	4	5
5.Όταν νιώθω ότι δυσκολεύομαι να αναπνεύσω	1	2	3	4	5
6.Όταν νιώθω ότι είμαι πολύ στεναχωρημένος/η	1	2	3	4	5
7.Όταν αισθάνομαι σωματική δυσφορία	1	2	3	4	5
8.Όταν δεν έχω υποστήριξη από κάποιον ειδικό	1	2	3	4	5
9.Όταν νιώθω ότι δεν θα πετύχω τον στόχο της άσκησης	1	2	3	4	5
10.Όταν νιώθω άγχος	1	2	3	4	5

Appendix 19. TPB questionnaire

Να απαντάς σε όλες τις ερωτήσεις καθώς δεν υπάρχουν σωστές ή λάθος απαντήσεις.

Απάντησε γρήγορα ότι έρχεται στο μυαλό σου αυτή τη στιγμή χωρίς να προβληματίζεσαι ιδιαίτερα. Περισσότερο να το βλέπεις σαν ένα παιγνίδι λέξεων.

Κύκλωσε τη λέξη που ταιριάζει περισσότερο στην άποψή σου.

Το να γυμνάζομαι στο πρόγραμμα αυτό περίπου 3 φορές την εβδομάδα για τις επόμενες 4 εβδομάδες, είναι:

καλό :-----:-----:-----:-----:-----:-----:-----: κακό
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

ανόητο :-----:-----:-----:-----:-----:-----:-----: έξυπνο
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

υγιεινό :-----:-----:-----:-----:-----:-----:-----: ανθυγιεινό
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

απωθητικό:-----:-----:-----:-----:-----:-----:-----: ελκυστικό
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

άσχημο :-----:-----:-----:-----:-----:-----:-----: όμορφο
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

δυσάρεστο :-----:-----:-----:-----:-----:-----:-----: ευχάριστο
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

Σκοπεύω να γυμνάζομαι περίπου 3 φορές την εβδομάδα για τις επόμενες 4 εβδομάδες:

πιθανό :-----:-----:-----:-----:-----:-----:-----: απίθανο
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

Είμαι αποφασισμένος/η να γυμνάζομαι περίπου 3 φορές τη βδομάδα για τις επόμενες 4 εβδομάδες

Οχι :-----:-----:-----:-----:-----:-----:-----: Ναι
απόλυτα αρκετά κάπως έτσι κι έτσι κάπως αρκετά απόλυτα

Θα προσπαθήσω να γυμνάζομαι 3 φορές τη βδομάδα τους επόμενους 2 μήνες

Οχι :-----:-----:-----:-----:-----:-----:-----: Ναι
απόλυτα αρκετά κάπως έτσι κι έτσι κάπως αρκετά απόλυτα

Για εμένα, το να γυμνάζομαι περίπου 3 φορές τη βδομάδα για τις επόμενες 4 εβδομάδες είναι:

Δύσκολο :-----:-----:-----:-----:-----:-----:-----: εύκολο
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

καθόλου :-----:-----:-----:-----:-----:-----: απόλυτα
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

καθόλου πολύ λίγο λίγο έτσι κι έτσι λίγο αρκετά πολύ

Θα
διαφωνήσουν:-----:-----:-----:-----:-----:-----:-----: συμφωνήσουν
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

Θα διαφωνήσουν:-----:-----:-----:-----:-----:-----:-----: Θα συμφωνήσουν
πολύ αρκετά λίγο έτσι κι έτσι λίγο αρκετά πολύ

Appendix 20. Semi-structured Interview (Pedroli et al., 2018)

1. Μπορείς να μοιραστείς τη συνολική σου εμπειρία από τη συμμετοχή στη μελέτη;
2. Πως πιστεύεις ότι σε βοήθησε η συμμετοχή σου στο πρόγραμμα να αλλάξεις τη συμπεριφορά σου ως προς την άσκηση και τη διατροφή;
3. Πώς θα περιέγραφες την πεποίθησή σου ότι μπορείς να τα καταφέρεις (αυτοαποτελεσματικότητα) σχετικά με την άσκηση πριν και μετά την παρέμβαση;
4. Πως διαχειρίστηκες τις προκλήσεις, τις ανησυχίες ή τα εμπόδια που προέκυψαν κατά τη διάρκεια του προγράμματος;
5. Τι νομίζεις ότι θα σε βοηθούσε περισσότερο να τα καταφέρεις καλύτερα;
6. Τι αλλαγές παρατήρησες στη διάθεσή σου κατά τη διάρκεια αυτής της προσπάθειας;
7. Πως το πρόγραμμα σε βοήθησε να προσέχεις και να φροντίζεις περισσότερο το σώμα σου;
8. Ποιες συμβουλές για άσκηση και διατροφή βρήκες χρήσιμες στο ψηφιακό βιβλιαράκι που έλαβες;
9. Με ποιο τρόπο σε βοήθησε η διαδικασία να βάζεις σωστούς στόχους;
10. Με ποιο τρόπο σε βοήθησε η διαδικασία να προσαρμόζεις τους στόχους σου κάθε εβδομάδα;
11. Με ποιο τρόπο η αυτό-παρακολούθηση της προόδου σου σε βοήθησε να πετύχεις τους στόχους σου;
12. Σε μια κλίμακα από το 1 έως το 10 πόσο πιστεύεις ότι σκοπεύεις να συνεχίσεις να ασκείσαι με την ίδια ή μεγαλύτερη συχνότητα;
13. Τι θα σε έκανε να βάλεις βαθμό μεγαλύτερο από αυτόν που ανέφερες παραπάνω;
14. Σε μια κλίμακα από το 1 έως το 10 πόσο πιστεύεις ότι σκοπεύεις να συνεχίσεις να χρησιμοποιείς τις τεχνικές αλλαγής συμπεριφοράς που εφάρμοσες σε αυτό το πρόγραμμα;
15. Τι θα σε έκανε να βάλεις βαθμό μεγαλύτερο από αυτόν που ανέφερες παραπάνω;
16. Πώς αισθάνεσαι σχετικά με την υποστήριξη και την καθοδήγηση που λαμβάνεις για να διαχειριστείς τις προκλήσεις σχετικά με την υιοθέτηση υγιεινών συνηθειών;
17. Πως η online επικοινωνία σε βοήθησε να ξεπεράσεις τις προκλήσεις ή τα εμπόδια που μπορεί να προέκυψαν;
18. Με ποιο τρόπο ωφελήθηκες από τις συνεδρίες συμβουλευτικής που διεξήχθησαν κατά τη διάρκεια της μελέτης;
19. Έχεις άλλα σχόλια ή παρατηρήσεις που θέλεις να συζητήσουμε σχετικά με την εμπειρία σου;

Στη συνέντευξη της ομάδας παρέμβασης υπήρχαν και οι 3 παρακάτω ερωτήσεις

20. Σε μια κλίμακα από το 1 έως το 10 πόσο η χρήση της εφαρμογής εικονικής πραγματικότητας συνέβαλλε στο να είσαι πιο φυσικά δραστήριος/α αυτό το μήνα;
21. Πως πιστεύεις ότι σε βοήθησε το γεγονός ότι μπορούσες να επιλέξεις τη διάρκεια και την ένταση του προγράμματος άσκησης στο να είσαι πιο φυσικά δραστήριος/α αυτό το μήνα;
22. Πώς προτίθεται να συνεχίσεις με την άσκηση στο μέλλον;

Appendix 21. Thematic analysis from the semi-structured interview for the intervention group

Question	Answer	Frequency
1. Can you share your experience from your participation in this study?	Innovative, highly entertaining, with a positive influence on my psychology and motivation for physical activity	30%
	Extremely fun, interesting and innovative, the support and guidance I received was important	25%
	I am grateful to try this type of exercise and achieve my goals	25%
	Innovative, pleasant, comfortable, easy, accessible and attractive form of exercise	20%
2. In your opinion, how your participation in the program helped you to change your behavior regarding exercise and nutrition?	Enhancing my consistency in the program, understanding the importance of determination and concentration to my goal	30%
	Changed my perspective on exercise and nutrition	30%
	It helped me to improve my psychology and organize myself	15%
	By understanding the value of exercise and creating ways to deal with obstacles	15%
	With the constant support and the very enjoyable type of exercise I felt that I could incorporate exercise into my daily life	15%
3. How would you describe your belief that you can do it (self-efficacy) about exercise before and after the intervention?	The intervention helped me to recognize my potential and my self-efficacy improved	60%
	My self-efficacy levels were high, but it was enhanced until the end of the intervention	30%
	Fear of failure has been decreased	10%
4. How did you manage the challenges, concerns or obstacles that arose during the program?	With great support and communication with the researcher	40%
	With composure and persistence in my goals	30%
	I didn't face any problems	20%
	The digital booklet and online communication helped a lot	20%
5. What do you think would help you do better?	If I had more free time	30%
	If I could practice more in the VR environment and improve my performance	25%
	I believe I have fulfilled the desired objectives to the fullest extent	20%
	If I had more energy	10%
	If there were other VR users to practice with	15%
6. What changes did you notice in your mood during this effort?	I was in a better mood, more optimistic and had a sense of wellness	50%
	I felt joy and motivated regarding exercise	35%
	My mood was improved even on "bad" days	20%
	I felt great self-confidence	20%
	I felt a sense of wellness and relaxation, reduced anxiety and stress	15%
	I felt full of energy and vitality	10%
7. How did the program help you to take care of your body?	My body image was positively affected	45%
	Because I participated in the exercise program, I have decided to follow a diet program to take better care of my body	45%
	I take care of my body as I always did	10%
8. What exercise and diet tips did you find helpful in the digital booklet you received?	All of them were useful and interesting	50%
	Tips for managing stress and anxiety through exercise	20%
	The importance of dedication in the program and patience	20%
	Tips for exercise and active lifestyle through daily choices	15%
	Tips about overeating and emotional eating	10%
	With the SMART method, I learned to set goals in a correct way	80%
9. How did the process of right goal-setting help you?	It helped me to properly assess my needs	40%
	Given goal-setting forms and researcher's guidance helped me	35%
10. How did the process help you adjust your goals each week?	I evaluated my progress and set new, more challenging goals	90%
	With the goal-setting forms given	25%
	The advice from the researcher and constant motivation helped me to adjust my goals	25%

11. How has self-monitoring your progress helped you achieve your goals?	I could better evaluate my progress and my self-confidence was increased	40%
	I avoided "breaking out" of the program because I didn't want to write it	25%
	It helped me focus on my goals	25%
	I could monitor my mistakes and try to correct them	15%
	I felt confident and secure because I felt in control	10%
12. On a scale of 1 to 10, how much do you think you intend to continue exercising with the same or more frequency?	10	35%
	9	25%
	8	20%
	6	10%
	7	5%
13. What would make you score higher than the one you mentioned above?	5	5%
	If I had more free time/ less obligations	35%
	Nothing, I scored 10	35%
	More motivation and rewards	15%
	If I could have access to the VR system whenever I wanted	10%
14. On a scale of 1 to 10, how much do you think you intend to continue using the behavior change techniques you implemented in this program?	If I liked working out and had company while exercising	5%
	10	35%
	8	25%
	9	20%
	7	10%
15. What would make you score higher than the one you mentioned above?	5	5%
	6	5%
	Nothing, I scored 10	35%
	If there was someone to motivate and guide me	30%
	My participation in a community with people with similar goals with me	20%
16. How do you feel about the support and guidance you received to manage challenges relevant to adopting healthy habits?	If I had access to an application which could give me feedback for my progress and encourage me to use such techniques	15%
	Very good, it was very useful	50%
		20%
	It helped me to stay focused on my goals	
	I felt that I wasn't alone and I had guidance	20%
17. How did the online communication help you overcome challenges or obstacles that may have arisen?	It was maybe the most basic thing	10%
	I felt that there was always someone who can guide, motivate and advise me	50%
	It guided me to remember my incentive	25%
	It helped me to adjust my goals	15%
	I didn't need it	10%
18. On a scale of 1 to 10, how much did using the virtual reality app contribute to being more physically active this month?	10	65%
	9	20%
	8	10%
	7	5%
19. How do you think being able to choose the duration and intensity of your exercise program helped you to be more physically active this month?	I could adapt it to my abilities and reduced the stress of failure	40%
	I liked that I could control my exercise program	30%
	It helped me to choose the exercise factors according to the situation I was in that particular day	25%
	It didn't help me; I would like more challenging goals from external source	5%
20. How do you intend to continue with exercise in the future?		
	I would like to continue practicing with the VR	60%
	At the same frequency and intensity	35%
	I will increase exercise frequency and intensity	25%
	I will try to exercise as much as I can	25%

	I will join gym	15%
21. How did you benefit from the counseling sessions conducted during the study?	I have learned to set goals	45%
	I have learned important information about exercise and nutrition	35%
	I realized how important psychological support is for achieving goals	20%
	I found great motivation to exercise and follow a diet plan	15%

Appendix 22. Thematic analysis from the semi-structured interview for the control group

Question	Answer	Frequency
1. Can you share your experience from your participation in this study?	Positive and interesting experience	75%
	Counseling helped me to set goals and achieve them regarding exercise and diet	40%
	Pleasant and efficient	25%
2. In your opinion, how your participation in the program helped you to change your behavior regarding exercise and nutrition?	It helped me to change habits step by step through goal-setting	25%
	It helped me discipline myself through goal-setting	25%
	Helped me improve my diet and increase my exercise participation	20%
	It helped me because I had someone to guide me in the right direction	10%
	It helped me overcome difficulties	10%
	I learned a lot about exercise and nutrition and tried to improve my daily life and health	10%
3. How would you describe your belief that you can do it (self-efficacy) about exercise before and after the intervention?	The intervention helped me to recognize my potential and my self-efficacy improved	80%
	I didn't notice any difference	20%
4. How did you manage the challenges, concerns or obstacles that arose during the program?	Communication with researcher helped me a lot	35%
	With optimism and persistence in my incentive	30%
	With composure, self-restraint and discipline	20%
	I didn't face any problems	15%
5. What do you think would help you do better?	If I had more free time	40%
	Closer monitoring by exercise and nutrition experts	25%
	To be able to access public sports facilities (flexible hours)	20%
	If my health was better (weight, fitness, injuries)	10%
	If I had more appetite and will	5%
6. What changes did you notice in your mood during this effort?	I was in a better mood	40%
	I felt optimistic and a sense of wellness	40%
	I felt full of energy and vitality	15%
	I felt calmer	10%
	I was in a better mood, but I also felt some pressure not to deviate from the program	10%
7. How did the program help you to take care of your body?	My body image was positively affected	50%
	I take care of my body as I always did	35%
	I realized that physical self-care is very important	15%
8. What exercise and diet tips did you find helpful in the digital booklet you received?	All of them were useful and interesting	50%
	Tips for exercise and exercise programs	20%
	Helped me manage overeating and emotional eating	10%
	Tips about diet and usefulness of drinking water	10%
	Ideas about behavior change	5%
9. How did the process of right goal-setting help you?	With the SMART method, I learned to set goals in a correct way	65%
	It helped me to properly assess my needs	20%
	It helped me to prove to myself that it is not difficult to set goals and achieve them	15%
10. How did the process help you adjust your goals each week?	I evaluated my progress and set new, more challenging goals	55%
	With the goal-setting forms given	35%
	The advice from the researcher and constant motivation helped me to adjust my goals	10%
11. How has self-monitoring your progress helped you achieve your goals?	I could better evaluate my progress	40%
	It helped me focus on my goals	25%
	I could monitor my mistakes	25%
	I realized the changes I made in my daily life	10%

12. On a scale of 1 to 10, how much do you think you intend to continue exercising with the same or more frequency?	10	30%
	8	20%
	7	20%
	5	15%
	9	10%
	4	5%
13. What would make you score higher than the one you mentioned above?	If I had more free time	45%
	Nothing, I scored 10	30%
	A bigger challenge	10%
	If I had company while exercising	10%
	If I liked working out	5%
14. On a scale of 1 to 10, how much do you think you intend to continue using the behavior change techniques you implemented in this program?	10	30%
	8	25%
	7	15%
	5	10%
	9	5%
	6	5%
	3	5%
	4	5%
15. What would make you score higher than the one you mentioned above?	If I had fewer obligations in my daily life	35%
	Nothing, I scored 10	30%
	If there was someone to motivate me	25%
	I feel that I still need guidance	10%
16. How do you feel about the support and guidance you received to manage challenges relevant to adopting healthy habits?	Very good, it was very useful	95%
	It helped me to stay focused on my goals	5%
17. How did the online communication help you overcome challenges or obstacles that may have arisen?	It guided me to remember my incentive	35%
	I felt that there was always someone who can guide and advise me	35%
	It helped me because it was immediate and not time consuming	15%
	I didn't need it	15%