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PHYSICAL ACTIVITY/SPORTS PERFORMANCE AND THE BENEFITS OF VIRTUAL
REALITY – A SYSTEMATIC REVIEW

by

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B.S., Fairmont State University, 2020

A Research Paper

Submitted in Partial Fulfillment of the Requirements for the
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Southern Illinois University Carbondale
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RESEARCH PAPER APPROVAL
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In the field of Kinesiology

Approved by:

Juliane P. Wallace, PhD, Chair

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Southern Illinois University Carbondale

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CHAPTER 1

INTRODUCTION

Physical activity and exercise is an important activity that helps reduce diseases such as cardiovascular disease, obesity, diabetes, and many other health problems (Gebauer, Salas, Scherrer, & Callahan, 2020). The American College of Sports Medicine recommends for adults to reach an average of 150 minutes per week of moderate to vigorous physical activity to help reduce the risk of developing these diseases. Unfortunately, many Americans do not meet this physical activity recommendation, and live a very sedentary life (Gebauer, Salas, Scherrer, & Callahan, 2020). Individuals tend to participate in physical activity more when they live in an environment with places to walk and relax, such as sidewalks or parks (Gebauer, Salas, Scherrer, & Callahan, 2020). It is a great accomplishment that these individuals can reach their physical activities due to their living environment. However, it is important to figure out how individuals without these opportunities provided by their environment, such as no sidewalks available, can reach the physical activity recommendations at home.

Virtual reality is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside, or gloves fitted with sensors (Virtual Reality Definition & Meaning). This is a somewhat new invention that is slowly gaining popularity. According to a 2021 report, virtual reality's economic benefits are expected to be felt worldwide (Alsop, 2021). This invention can be used for many things, such as video games, watching videos, and taking up time when one is bored. Not only is it used for entertainment, but it can also be used for physical activity. Bringing virtual reality into one's home will be beneficial for all ages.

Investigators in the field of exercise science have researched how virtual reality affects the human body, primarily regarding its influence on physical activity and exercise. This research can provide insight on how virtual reality can affect one's physical fitness, and how it can be used to achieve the physical activity recommendations or enhance physical performance. Unfortunately, due to virtual reality being so new, there are no studies that have focused on long term benefits, but in many recent studies, there are findings that indicate that virtual reality is a beneficial tool. When looking at batting tests/sports related improvement, it has shown to significantly improve pre-post training. (Gray, 2017).

Enhancing physical activity in sedentary populations is a potentially important application of virtual reality. For example, virtual reality may help older adults find the motivation to exercise where traditional exercise is not feasible. Matsangidou and colleagues (2019) found that virtual reality during exercise can reduce negative sensations associated with exercise. The findings from this study indicate that virtual reality could be a very appealing form of exercise, that is more enjoyable and feels better, which ultimately could drive individuals of all ages to engage in more physical activity weekly.

Studying virtual reality and its impacts on physical activity and sport performance is very important because it can help athletes find alternative and effective ways to enhance their athletic performance. Virtual reality has been found to play a major role in competitive athletes' training (Akbas, et al., 2019), indicating that virtual reality can be an effective and beneficial training method for athletes. When working with ball sports, virtual reality can be an interesting tool to assess or train team ball sports skill/situations as it allows the researchers to control and standardize situations and focus on specific skills/subskills (Faure, Limballe, Bideau, & Kulpa, 2020).

Physical activity is a very overlooked everyday activity, and it is important to attempt to find different ways to help people of all ages reach the recommended daily activity levels in their own homes. Some individuals prefer to engage in physical activity and sports training the traditional way instead of virtual reality, and do not understand what the point is in using virtual reality to replace traditional training. Virtual reality enhances sports performance (Reneker, et al. 2020), improves physical fitness (Debska, Polechonski, Mynarski, & Polechonski, 2019) and increases enjoyment while lowering RPE/the feeling of difficulty while exercising (Zeng, Liu, Pope, McDonough, & Gao, 2021). The objective of this systematic review of the research was to assess how virtual reality improves physical activity and performance. To this end, our review attempted to address the following questions:

- Can virtual reality be used to enhance sports performance?
- Does physical activity achieved through virtual reality improve fitness more than traditional exercise and be more enjoyable to engage in?
- Is virtual reality a good form of physical activity for all ages?

CHAPTER 2

METHODOLOGY

We used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) to identify and select articles for review. We researched articles under SportDiscus, MEDLINE (EBSCO), PsycInfo, ERIC (EBSCO), and PubMed using the terms *Virtual Reality* in ANY FIELD and *Physical Activity/Exercise/Sports Performance/Perceived Exertion* in ANY FIELD. Each term was searched under an advanced search. Inclusion criteria for articles consisted of: (1) published in English; (2) identified in peer-reviewed science outlets; and (3) examined the correlation between virtual reality and physical activity/sports performance. Abstracts were reviewed to determine eligibility based on inclusion criteria. We obtained full reports for all articles that appeared to meet the inclusion criteria or where there was no certainty about the relevance of the article. We reviewed the included articles' reference lists for additional published works not otherwise identified. For each included article, referring to the specific questions under study, we recorded the study participants, variables measured, the type of study design, and notable outcomes or findings.

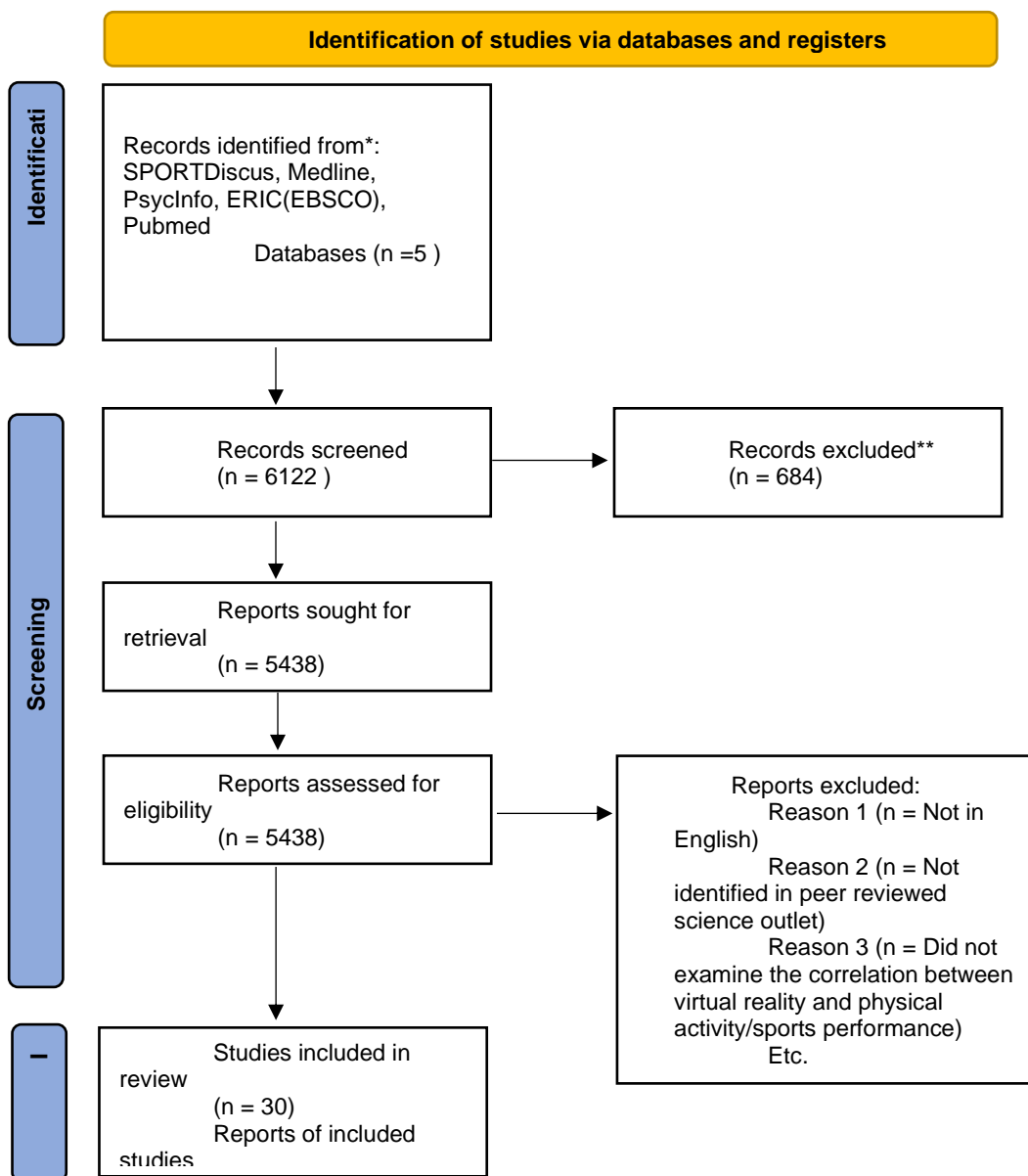


Figure 1 – PRISMA Flow Diagram

CHAPTER 3

RESULTS

The initial search criteria returned 5438 articles (609 SPOTDiscus, 1524 Medline, 701 PsycInfo, 90 ERIC(EBSCO), and 3198 Pubmed). The search term *virtual reality/physical activity* contributed more to the number of returned articles. We reviewed relevant abstracts for inclusion based upon the stated criteria and the 3 research questions. From the returned articles, 30 met the inclusion criteria and review objectives and were separated into 3 main categories. There were 10 studies on physical activity and sports performance (Table 1), 10 studies on physical activity and enjoyability (Table 2), and 10 studies on physical activity and all ages (Table 3).

Virtual reality was shown to be a great tool in assessing and training team ball sports skills (Faure, Limballe, Bideau, & Kulps, 2020), aiding in whole-body visualization which led to higher accuracy (Pastel, Chen, Petri, & Witte, 2020), and even helped reduce pain more than isokinetic training and conventional training (Nambi, et al. 2020). It has also shown to improve motor control, and influence reaction time and decision-making in sports (Balko, Heidler, & EDL, 2018). These newly learned skills are not only great for using in sports/competitive competitions, but also transfer to real life everyday situations.

Table 1. highlights the benefits of virtual reality in enhancing performance in a variety of sport settings.. From throwing tasks to real world table tennis skills, virtual reality has shown to improve many different skills.

Table 1

Studies of Virtual Reality and Sports Performance

Authors	Type of Study	Major Findings
Faure, C., Limballe, A., Bideau, B., & Kulpa, R. (2020)	Review	<ul style="list-style-type: none"> VR is an interesting tool to help train or assess team ball sports skills/situations
Pastel, S., Chen, C.-H., Petri, K., & Witte, K. (2020)	Experimental	<ul style="list-style-type: none"> VR led to significantly greater accuracy throwing task, and the whole-body visualization led to a higher accuracy
Michalski, S. C., Szpak, A., Saredakis, D., Ross, T.J., Billinghamurst, M., & Loetscher, T. (2019)	Intervention	<ul style="list-style-type: none"> VR training significantly improved participants' real-world table tennis performance compared to a no-training control group
Bedir, D., & Erhan S. E., (2021)	Experimental	<ul style="list-style-type: none"> Significant differences between the groups in shot performance and imagery skills VR led to faster development in shot performance
Nambi, G., Abdelbasset, W. K., Elsayed, S. H., Alrqawaili, S. M., Abodonya, A. M., Saleh, A. K., & Elnegamy, T. E. (2020)	Intervention	<ul style="list-style-type: none"> Virtual reality protocol improves pain and sports performances more than isokinetic training and conventional training in university football players with chronic low back pain
Akbas, A., Marszalek, W., Kamieniarz, A., Polechonski, J., Slomka, K. J., & Juras, G. (2019)	Review	<ul style="list-style-type: none"> Virtual reality seems to play a big role in competitive athletes' training VR interventions bring significant improvements in clinical research
Balko, S., Heidler, J., & EDL, T. (2018)	Review	<ul style="list-style-type: none"> The environment of virtual reality can be beneficial for improvements in sports performance and motor control VR can be used to improve reaction times and decision making in sports
Hoffmann, C. P., et al. (2014)	Intervention	<ul style="list-style-type: none"> There was an improvement in performance in VR group when participants were instructed to track a virtual boat on a screen, whereas the control group did not

		<ul style="list-style-type: none"> • VR is a means to learn an energy-related skill and improve performance
Reneker, J. C., Pannell, W. C., Babl, R. M., Zhang, Y.m Lirette, S. T., Adah, F., & Reneker, M. R. (2020)	Intervention	<ul style="list-style-type: none"> • There was a positive transfer from virtual to real world environments. In virtual immersive sensorimotor training, which consisted of nine novel exercises in headset virtual reality
Gray, R. (2017)	Intervention	<ul style="list-style-type: none"> • The adaptive Virtual reality training group showed a significantly greater improvement from pre-post training • Players in VR group had superior batting statistics in league play and reached higher levels of competition

When looking at virtual reality and physiological effects/enjoyment levels, it was shown that traditional exercise had higher ratings of perceived exertion when compared to virtual reality based exercising (Table 2., Zeng, Pope, & Gao, 2017; Zeng, Liu, Pope, McDonough & Gao, 2021). Virtual reality training was associated with a longer time to exhaustion when compared to non-virtual reality groups (Matsangidou, et al., 2019). Not only was the RPE lower in virtual reality, but participants expressed more enjoyment during virtual reality exercise than traditional. Virtual reality increased enjoyment during exercise, and that children preferred exercise using virtual environments (Banos, et al., 2016). Virtual exercise environment is an effective way to induce a relaxing effect (Wang, Sit, Tnag, & Tsai, 2020). Virtual reality has ultimately shown to be a great way to lower ratings of perceived exertion, while also eliciting enjoyment while performing physical activity (Deutsch, James-Palmer, Damodaran, & Pug, 2021).

Table 2. outlines the studies that highlight how virtual reality can enhance the positive feelings in physical activity and can ultimately feel easier to perform when compared to traditional exercise. Each study below indicates that virtual reality increases participant's self-

efficacy and overall enjoyment when performing exercise when compared to traditional exercise. Not only is physical activity thought to be more enjoyable through virtual reality, but it also helps participant's ratings of perceived exertion lower when compared to traditional exercise. This is can help individuals that struggle finding motivation to exercise have a new and fun way to reach the recommended physical activity requirements.

Table 2
Studies of Virtual Reality and Physiological effects

Authors	Types of Study	Major Findings
Perrin, T., Faure, C., Nay, K., Cattozzo, G., Sorel, A., Kulpa, R., & Kerherve, H. A. (2019)	Experimental	<ul style="list-style-type: none"> • Adding wrist worn weight (simple constraint) was an effective measure to increase energy expenditure during active gaming
Zeng, N., Pope, Z., & Gao, Z. (2017)	Experimental	<ul style="list-style-type: none"> • Higher ratings of perceived exertion during traditional exercise biking sessions compared with VR-based exercise biking. • VR participants had higher self-efficacy and enjoyment during biking session compared with traditional stationary bike
Wang, T.C., Sit, C. H. -P., Tnag, T. -W., & Tsai, C. -L. (2020)	Intervention	<ul style="list-style-type: none"> • Findings implied that virtual exercise environment is an effective way to induce a relaxing effect in patients with GAD
Evans, E., Naugle, K. E., Kaleth, A. S., Arnold, B., & Naugle, K. M. (2021)	Intervention	<ul style="list-style-type: none"> • The games rated highest in enjoyment required mostly arm movements and a perceived light exertion • Active VR games can elicit varying degrees of PA intensity levels in young healthy adults
Yasukawa, K., Koike, Y., Konno, T., Sudo,	Experimental	<ul style="list-style-type: none"> • VR exercise with faster visual flow induced positive mood states

M., Ohkawara, K., & Ando, S. (2021)		<ul style="list-style-type: none"> • Speed of visual flow significantly influenced participants ratings of vitality and pleasure
Matsangidou, M., Ang, C. S., Mauger, A. R., Intarasirisawat, J., Otkhmezuri, B., & Avraamides, M. N. (2019)	Intervention	<ul style="list-style-type: none"> • Participants in VR group reported significantly lower pain and effort • VR exhibited longer time to exhaustion compared to the non-VR group • VR can moderate perception of effort during exercise
McDonough, D. J., Pope, Z. C., Zeng, N., Liu, W., & Gao, Z. (2020)	Experimental	<ul style="list-style-type: none"> • Participants had significantly higher enjoyment and self-efficacy and lower RPE during VR cycling compared with other two cycling sessions
Zeng, N., Liu, W., Pope, Z. C., McDonough, D. J., & Gao, Z. (2021)	Experimental	<ul style="list-style-type: none"> • RPE was reported significantly higher at each time point during the tBike session vs. the vBike and eBike sessions
Banos, R.M., Escobar, P., Cebolla, A., Guixeres, J., Alvarez Pitti, J., Lison, J. F., & Botella, C. (2016)	Experimental	<ul style="list-style-type: none"> • VR increased enjoyment during exercise • Children preferred exercise using virtual environments • Overweight children focused on internal information under traditional condition, but they significantly shifted their attention to regard the external environment in the distraction condition
Deutsch, J.E., James-Palmer, A., Damodaran, H., & Pug, U. (2021)	Experimental/Clinical Trial	<ul style="list-style-type: none"> • Enjoyment was greater for the custom active video games and rate of perceived exertion was lower for the custom active video games

When looking at virtual reality and physical activity for all ages, it has shown that children, adults, and older adults enjoy participating in physical activity using virtual reality. Initially being exposed to it, individuals were having a more difficult time accepting it, but after exposure, attitudes positively changed towards virtual reality (Dockx, et al., 2017). In a study with two older adults, it was found that both enjoyed the virtual reality game while playing and

were both able to perform all the required movements with relative ease. (McSeveny, Heller, Light, & Machaczek, 2013). After children were exposed to virtual reality physical activity gaming, the children surveyed that virtual reality gaming is more attractive and appear to be a beneficial alternative to conventional video games played in an unhealthy sitting position (Polechonski, Nierwinska, Kalita, & Wodarski, 2020).

Table 3 discusses what individuals of all different ages think about virtual reality. All studies that looked at older individuals being exposed to virtual reality indicated that the participants ultimately enjoyed exercising with the equipment. Initially, many did not want to give physical activity on virtual reality a chance, but after exposure they ended up greatly enjoying it. Children and younger adults greatly enjoyed exercise with the virtual reality equipment and discussed how they would prefer using virtual reality over traditional video games (Htut, Hiengkaew, Jalayondeja, & Vongsirinavarat, 2018). These findings show how beneficial virtual reality is and can encourage children and younger adults to reach their recommended weekly physical activity.

Table 3

Studies of Virtual Reality and Physical Activity for all ages

Authors	Type of Study	Major Findings
Ulas, K. & Semin, I. (2021)	Intervention	<ul style="list-style-type: none"> • Virtual reality exercise has the potential to increase the enjoyment in exercise sessions. • Virtual reality shows more motivational effects, whereas traditional exercises show more physical improvements.
Polechonski, J., Niervinska, K., Kalita, B., & Wodarski, P. (2020)	Experimental/Clinical Trial	<ul style="list-style-type: none"> • The intensity of PA in obese children playing AVGs in IVR on an omnidirectional treadmill

		<p>is high and depends on the plot of the game.</p> <ul style="list-style-type: none"> • ABGs in the IBR are attractive and appear to be a beneficial alternative to conventional video games in the opinions of the children surveyed.
<p>Debska M., Polechonski, J., Mynarski, A., & Polechonski, P. (2019)</p>	<p>Experimental</p>	<ul style="list-style-type: none"> • Average enjoyment level during physical activity in VR on the tested training devices was high. • Both OMNI and Icaros was recommended to obtain pro-health benefits.
<p>McSeveny, K., Heller, B., Light, A., & Machaczek, K. (2013)</p>	<p>Experimental</p>	<ul style="list-style-type: none"> • Both seemed to enjoy the virtual reality game while playing. • Both participants were able to perform all the required movements with relative ease and found that it required some physical effort.
<p>Dockx K., Alcock, L., Bekkers, E., Ginis, P., Reelick, M., Pelosin, E., Lagravinese, G., Hausdorff, J. M., Mirelman, A., Rochester, L., & Nieuwboer (2017)</p>	<p>Experimental Clinical Trial</p>	<ul style="list-style-type: none"> • Attitudes toward VR positively changed following exposure to it.
<p>Evans E. Naugle, K., Ovispo, A., Kaleth, A., Arnold, B., & Naugle, K. (2021)</p>	<p>Experimental</p>	<ul style="list-style-type: none"> • Active VR games could be an alternative and enjoyable mode of obtaining physical activity. • Active VR games can elicit varying degrees of physical activity intensity levels in young healthy adults, with Hot Squat eliciting moderate intensity activity.
<p>Foley, L. & Maddison R. (2010)</p>	<p>Intervention</p>	<ul style="list-style-type: none"> • Compared to traditional nonactive video games, active video games elicited greater energy expenditure, which was similar in intensity to mild to moderate intensity physical activity.

<p>Htut, T. Z. C., Hiengkaew, V., Jalayondeja, C., & Vongsirinavarat, M. (2018)</p>	<p>Experimental Intervention</p>	<ul style="list-style-type: none"> • VRE produced measurable improvements in physical and cognition scores • Both exercises are suggested to older persons to improve physical and cognitive conditions.
<p>Phu, S., Vogrin, S., Al Saedi, A., & Duque, G. (2019)</p>	<p>Intervention</p>	<ul style="list-style-type: none"> • Both groups improved in balance and physical performance measures. • Both showed better improvement than the non-intervention group of TUG, gait speed, limits of stability I posturography assessment, FES-I score and handgrip strength.
<p>D. Majumdar, P. Koch, H. Lee, I. Contento, A. Islas, D. Fu (2012)</p>	<p>Cross-sectional</p>	<ul style="list-style-type: none"> • Virtual reality games may improve dietary and physical activity behaviors among middle school aged youths.

CHAPTER 4

DISCUSSION AND CONCLUSION

We identified 30 studies examining how virtual reality can enhance sports performance, improve physical fitness, improve physiological effects more than traditional exercise, and increases enjoyment during physical activity. It has been determined that using virtual reality is enjoyable and a good form of exercise for all ages (Debska, Polechonski, Mynarski, & Polechonski, 2019; Polechonski, Niervinska, Kalita, & Wodarski, 2020). Elderly individuals may struggle initially to be open to using virtual reality, but following exposure, find virtual reality quite enjoyable and effective (Dockx, et al. 2017). Virtual reality has also been shown to be more enjoyable and easier to execute than traditional exercise (Zeng, Pope, Gao, 2017). Lastly, virtual reality enhances sports performance in many different settings (Faure, Limballe, Bideau, & Kulpa (2020).

Effects of virtual reality on sports performance. Research has shown that virtual reality is a great way to improve sports performance in football, baseball, and tennis (Nambi, et al., 2020, Faure, Lijmballe, Bideau, & Kulpa, 2020, Michalski, et al., 2019). Virtual reality can be a different tool to train or assess team ball sports skills and situations. This is because it allows researchers to control and standardize situations and focus on specific skills or subskills (Faure, Limballe, Bideau, & Kulpa, 2020). Some may think that virtual reality is different than real life situations, but there was a positive transfer from virtual reality to real-world environments (Reneker, et al., 2020). Akbas and colleagues (2019) reviewed 18 articles that met their inclusion criteria, and found that virtual reality played a major role in competitive athletes' training and should be incorporated in a variety of different sports. The variety of different sports included baseball, table tennis, etc.

Physiological effects in virtual reality compared to traditional exercise. Matsangidou and colleagues (2019) had 80 participants randomly assigned to a virtual reality or a non-virtual reality group that were required to maintain 20% 1 RM isometric bicep curl while reporting ratings of pain intensity and perception of effort. Results show that virtual reality during exercise reduced negative sensations associated with exercise when compared to traditional exercise (Matsangidou, et al., 2019). In addition, the virtual reality group exhibited longer time to exhaustion when compared to the non-virtual reality group. Not only has virtual reality made exercise more enjoyable than traditional exercises, it is associated with feeling less strenuous and difficult at the same intensity of exercise. During virtual reality cycling, participants had significantly higher enjoyment and self-efficacy and lower RPE compared with traditional cycling sessions at the same intensity (McDonough, Pope, Zeng, Liu, & Gao, 2020). RPE has also been shown to be significantly higher during tbike sessions (traditional bike) vs. vbike (virtual bike) sessions (Zeng, Pope, & Gao, 2021).

Enjoyability in virtual reality compared to traditional exercise. When comparing virtual reality with traditional exercise, more people preferred doing virtual reality exercise than traditional exercise. Zeng and colleagues (2017) had 12 healthy college students complete two separate 20-minute exercise sessions on a virtual reality-based exercise bike and traditional stationary exercise bike, there were significantly higher self-efficacy and enjoyment levels for the participants in the VR-based exercise biking session group (Zeng, Pope, & Gao, 2017). Virtual reality exercise has also been shown to induce better mood states (Yasukawa, Koike, Konno, Sudo, Ohkawara, & Ando, 2021), and the environments that virtual reality depicts can enhance relaxation (Wang, Sit, Tang, & Tsai, 2020). Virtual reality is enjoyable, motivating, and effective physical activity tool, and may be an effective addition to traditional exercise.

Impact of virtual reality on children. Research has shown that virtual reality is a great form of physical activity for children of many ages. Certain games were more effective when trying to raise heart rate such as hot squat, which is a virtual reality game that focuses on squats, and turns it into a competition. Games such as Holopoint, Beat Saber, and Relax Walk VR were not able to raise heart rate as high as hot squat did (Evans, et al. 2021). Not only did virtual reality games improve physical activity, but may help improve dietary behaviors in middle school aged children (Majumdar, Koch, Lee, Contento, & Islas, 2020). Many children greatly enjoyed eliciting physical activity through virtual reality, but unfortunately do not have some of the machines accessible to them at home like the OMNI. Many children stated that they would use virtual reality at home as physical activity if accessible to them (Debska, Polechonski, Mynarski, & Polechonski, 2019).

Impact of virtual reality on older adults. Research has shown that older adults had a harder time accepting virtual reality as physical activity than children and younger adults did. Although older adults had a harder time accepting this different option, they became more accepting of it after exposure (Dockx, 2017). Virtual reality was an effective and efficient way to reach everyday physical activity recommendations. In a study that had 9 healthy male participants that had their participants perform three testing components in a randomized order (walking, active gaming, and active gaming with an additional constraint), it was shown that older adults reached a greater amount of physical activity when wearing wrist constraints/ wrist weights while video gaming (Perrin, et al., 2019). With both older and young adults, just about every user of the treadmill and flight simulator on virtual reality recommended physical activity on the tested devices and claimed that if they had this type of training devices, they would practice physical activity in virtual reality (Debska, et al., 2019).

Limitations

We must note certain limitations related to this study. First, we accessed a limited number of databases. There may have been databases that have published with different results that was not available to us as a result. We restricted ourselves only to the search terms *virtual reality/physical activity*, *exercise*, *perceived exertion*, and *sports performance*. Other search terms may have resulted in a broader selection of journal articles, which may have had different results that was found. Another limitation may have been the studies that were looked at did not have a very long assessment of the impacts of virtual reality. We do not know the complete long-term effects of virtual reality and physical activity, which may have ultimately had different findings than the short-term effects noted in this analysis.

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