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Enhancing Balance Skills in Secondary School Sports Students through VR Simulation Training: An Experimental Study

Feng Miao[1], Jun Yan[2]

[1,2]Cangzhou Normal University, Cangzhou, Hebei, China
[1]272807467@qq.com, [2]502893875@qq.com

Abstract: ***Virtual reality (VR) simulation training has emerged as a promising approach to enhance balance skills in sports students. VR simulations offer a safe and controlled environment that replicates real-life situations, allowing students to practice and refine their balance skills in an immersive and interactive manner. This experimental study aims to investigate the effectiveness of VR simulation training in improving balance skills among secondary school sports students.***

Keywords: Balance; VR; School Sports Students.

1. INTRODUCTION

Sports play a vital role in the physical and mental development of secondary school students. In particular, balance skills are crucial for athletes participating in various sports activities. The ability to maintain stability and control body movements is essential for performance optimization and injury prevention[1]. Traditional training methods, such as drills and exercises, have limitations in providing dynamic and realistic scenarios to enhance balance skills.

To address this challenge, virtual reality (VR) simulation training has emerged as a promising approach to enhance balance skills in sports students. VR simulations offer a safe and controlled environment that replicates real-life situations, allowing students to practice and refine their balance skills in an immersive and interactive manner. This experimental study aims to investigate the effectiveness of VR simulation training in improving balance skills among secondary school sports students.

The primary research question guiding this study is: Does VR simulation training enhance balance skills in secondary school sports students?

To answer this question, the study aims to achieve the following objectives:

1) Assess the baseline level of balance skills among secondary school sports students.

2) Design and implement a VR simulation training program to enhance balance skills.

3) Evaluate the effectiveness of VR simulation training in improving balance skills.

This experimental study will adopt a pretest-posttest control group design. A sample of secondary school sports students will be randomly assigned to either the experimental group receiving VR simulation training or the control group receiving traditional training methods. The study will use validated measures of balance skills to assess participants' baseline levels and evaluate the impact of the training intervention.

The VR simulation training program will involve various balance tasks and scenarios, including single-leg balance, dynamic movements, and simulated sports-specific scenarios. Participants in the experimental group will receive several training sessions over a specific period, while the control group will follow their usual training regimen.

Data analysis will involve comparing pre- and post-training balance skill scores between the experimental and control groups. Additionally, potential gender and age differences in the effectiveness of VR simulation training will be explored.

The key findings of this study will provide insights into the effectiveness of VR simulation training for enhancing balance skills among secondary school sports students. The results will contribute to the existing body of knowledge on innovative training methods and inform educators, coaches, and policymakers about the potential benefits of integrating VR technology into sports training programs.

2. LITERATURE REVIEW

2.1 Balance ability

Balance ability is a crucial physiological function within the human body that plays a significant role in maintaining overall stability[2]. Extensive clinical studies have defined balance ability as the capacity of the human body to automatically adjust and sustain postural equilibrium during movement or when encountering external forces. Research findings suggest that balance ability encompasses the skill to uphold stability comprehensively, particularly by maintaining specific postures or regulating body balance under external influences. Undeniably, balance ability represents a pivotal physiological function within the human body.

The National Strength and Conditioning Association (NSCA) has specifically defined balance as the aptitude to sustain static or dynamic equilibrium of the body, including the ability to surpass the supporting surface spanned by the body's center of gravity. Conversely, stability denotes the body's capacity to regain a fixed posture after engaging in non-static movements. Collectively, these two facets constitute the fundamental concept of "balance ability" within human motor function[3].

Rehabilitation medicine perceives balance as the intrinsic ability of the body to adaptively regulate and maintain posture during movement or exposure to external forces. Researchers have categorized human balance abilities into static balance and dynamic balance. Static balance denotes the body's ability to control its center of gravity, regulate posture, and sustain relative immobility when in a stationary position. Remarkably, even during stationary periods, the body's center of gravity experiences physiological postural oscillations that exceed conscious control, commonly referred to as postural sway. Dynamic balance refers to the capacity of the body to autonomously adjust its stability while in motion by actively responding to external stimuli and controlling balance. This study underscores the importance of considering various facets of static and dynamic balance within the comprehensive assessment of balance ability, revealing the human body's ability to govern its center of gravity in both static and dynamic movements[4].

2.2 Virtual Reality technology

Virtual Reality (VR) technology is an acronym derived from "Virtual Reality" in English. It is a cutting-edge technology centered around computer simulation techniques that facilitate the creation of virtual environments closely resembling reality. Through a range of sensory modalities, simulated interactions can be achieved [10]. VR technology encompasses several key aspects, including image rendering, information processing, and sensor technology. Moreover, human-computer interaction is an integral part of advanced virtual reality applications. By utilizing devices such as headsets, mice, and controllers, users are able to engage in interactive experiences with objects within the virtual world. The integration of immersive virtual environments further amplifies the users' sense of presence and delivers a heightened visual experience.

Google Cardboard represents a prototype device that effectively transforms smartphones into virtual reality platforms. By leveraging VR panoramic video applications available on smartphones, users have access to a diverse array of virtual scenarios that closely replicate real-world settings. In this study, we strategically employ the Cardboard platform and pre-edit a 3-minute panoramic video capturing the experience of a surfer paddling. By employing a smartphone, Cardboard, headphones, a BOSU ball, and a VR panoramic video application, we aim to enhance participants' sense of balance, allowing them to immerse themselves in an authentic representation of the challenges encountered by surfers from a first-person perspective.

2.3 Scenario simulation training

Scenario simulation training in sports training practice involves creating or selecting scenarios that closely resemble actual competition conditions using simulated images and voice. This approach enables athletes to engage in systematic and adaptive training. The scope of scenario simulation encompasses various elements such as competition format, schedule, opponent tactics, audience behavior, referee judgments, and environmental

conditions. Scenario simulation teaching entails the creation of lifelike work scenarios within educational content, whereby students assume roles and comprehensively reenact every aspect of the event. Throughout this process, teachers provide guidance, analysis, and a conclusive summary, thereby rendering it an effective virtual practical teaching method. Widely employed during the acquisition of novel clinical skills by medical personnel, this methodology contributes to the enhancement of professional aptitude and competencies. Moreover, emerging experimental research indicates that scenario simulation training not only significantly improves the aforementioned aspects for clinical medical staff but also effectively alleviates preoperative patients' anxiety, irritability, and depression. Additionally, it enhances postoperative patients' pain management and fosters the development of self-directed patient care abilities.

STRIVR, an acclaimed American sports technology company, has gained recognition for its athlete virtual reality simulation training. The company introduced its inaugural product, QBSIM, in collaboration with a team back in 2014. QBSIM stood out as the sole solution at the time, enabling quarterbacks to engage in simulated training involving real football within a mixed reality environment. By harnessing artificial intelligence derived from over a decade of game data and statistics, this innovative approach facilitates comprehensive athlete training. The platform effectively employs big data and VR technology to expedite skill acquisition while emphasizing neural recognition patterns and mitigating injury risks, thereby optimizing overall performance. In preparation for the 2018 Winter Olympics, the U.S. Ski Team partnered with the U.S. Ski Association to seamlessly integrate virtual reality technology with immersive 360° panoramic videos. This cutting-edge technique empowered U.S. team athletes to quickly immerse themselves in specific training scenarios during routine sessions, enabling efficient exploration of diverse snow-related technical aspects like terrain, gates, and turns without the requirement of their physical presence at the actual competition venue.

Dr. Lindsay Ross-Stewart, an esteemed sports medicine specialist, has dedicated her research at Southern Illinois University Edwardsville to the field of image-assisted virtual reality. Her recent collaboration with the American Lion Baseball Team delved into the potential of image-assisted simulated reality in augmenting athletes' confidence and performance[5]. The study entailed athletes utilizing a smartphone application integrated with virtual reality glasses to engage in daily practice sessions by watching personalized videos and following guided imagery scripts. Notably, the findings demonstrated a remarkable enhancement in athletes' psychological training skills after the training period, showcasing significant progress in relaxation techniques, self-suggestion, visualization, and overall mental performance. These outcomes hold great promise in advancing athletic training methods and warrant further exploration in the realm of sports science.

Balance training is crucial for achieving complex movements in the human body, especially activities that require posture control and coordination of limb movements. Good balance ability is a fundamental requirement for athletes to perform skillful movements and demonstrate competitive abilities. Therefore, balance training is highly valued in athletes' physical training. Research has shown that balance training significantly improves participants' static balance ability when standing on one foot [6]. Empirical studies have been conducted on the effects of balance training on dynamic balance ability, and the results indicate that balance training can significantly improve dynamic balance ability when standing on one foot [7].

Furthermore, researchers have attempted to demonstrate the supplementary effect of incorporating balance training into daily sports training by integrating it with other sports training methods and comparing different training methods. Some studies suggest that balance training can significantly increase the electromyographic activity of the triceps surae muscles during maximum voluntary contraction, but its impact on the rate of strength development is not significant [8]. Another study supports this view and found that balance training did not improve the rate of strength development in the plantar flexor muscles or lead to significant changes in triceps surae electromyographic activity when compared to strength training [9].

In conclusion, balance training is undoubtedly a key training method to improve balance ability. However, further exploration and research are needed to identify diverse training methods. While balance ability does affect athletes' performance to some extent, according to relevant research, the direct impact of balance training as a singular training method on athletes' performance has yet to be confirmed. Therefore, the mechanisms of how balance training benefits athletes' performance still require further research and verification.

Balance skills play a crucial role in the physical and mental development of secondary school students, particularly those involved in various sports activities. Achieving stability and controlling body movement are essential for

optimizing performance and preventing injuries. Traditional training methods, such as drills and exercises, fail to provide dynamic and realistic scenarios to enhance balance skills.

To address this challenge, virtual reality (VR) simulation training has emerged as a promising approach to improve balance skills in secondary school students. VR simulations create a safe and controlled environment that replicates real-life situations, allowing students to practice and refine their balance skills in immersive and interactive ways. Previous studies have explored the effectiveness of VR simulation training in various domains, such as medical education, aviation, and rehabilitation. However, its application and impact on balance skills in secondary school sports students are relatively unexplored.

Theoretical frameworks and models that inform the study: This study draws upon several theoretical frameworks and models to inform the investigation into the effectiveness of VR simulation training in enhancing balance skills. One key framework is the Ecological Systems Theory, which emphasizes the interaction between individuals and their environment. According to this theory, VR simulations provide a dynamic and ecologically valid environment where students can develop their balance skills through active engagement.

Another relevant framework is the Cognitive Load Theory, which suggests that learning is influenced by the cognitive load imposed on learners. VR simulations have the potential to optimize the balance training experience by manipulating the cognitive load and providing immediate feedback, thus facilitating skill acquisition and transfer.

Furthermore, the Self-Efficacy Theory, proposed by Albert Bandura, posits that individuals' beliefs about their own abilities influence their motivation and performance. By exposing students to challenging yet achievable balance tasks in the VR environment, this study aims to foster self-efficacy beliefs, leading to improved balance skills.

3. METHODOLOGY

3.1 Research Design:

This experimental study aims to investigate the effectiveness of VR simulation training in enhancing balance skills among secondary school sports students. A pretest-posttest control group design will be employed. Participants will be randomly assigned to either the experimental group, which will receive VR simulation training, or the control group, which will not receive any additional training.

3.2 Sample Size and Selection Criteria:

The study recruited a total of 40 middle school students majoring in physical education who had not undergone systematic balance training. Among the participants, there were 26 boys and 14 girls, with an average age of 14 years. Exclusion criteria included no history of lower limb injuries within the past 6 months. The observation method was employed to evaluate the participants' ability to maintain balance in various scenarios, including sitting, standing, stepping reactions, and active movements. This approach served as a preliminary assessment for identifying potential balance impairments and ensuring that individuals with existing balance impairments were excluded from the study. Following the initial assessment, the participants were randomly assigned into two groups: an experimental group and a control group, each consisting of 20 individuals. The gender distribution was equivalent between the two groups. Prior to the start of the experiment, no significant differences were observed between the control group (receiving conventional training) and the experimental group (undergoing VR simulation training) in terms of static and dynamic balance test results. Throughout the experiment, every step was carried out with full informed consent from all participating students.

3.3 Data Collection Methods and Instruments:

The experimental and control groups underwent a four-week training period in the same location and for the same duration. Throughout the training, the experimental group utilized virtual reality technology devices while training on an unstable virtual environment using a Bosu ball for balance exercises, while the control group received traditional Bosu ball balance training. The training content was standardized for both groups. Pre- and post-training data were analyzed and conclusions drawn using SPSS 27.0, using closed-eye single-leg standing and Y-balance tests as indicators.

4. RESEARCH FINDINGS

Following 4 weeks of balance training, notable disparities were observed in the closed-eye static balance test for secondary school physical education students in the experimental group when comparing their pretest and post-test scores. The left foot support indicator ($p<0.01$) and right foot support indicator ($p<0.01$) exhibited significant differences. Conversely, the control group displayed enhancements in various static balance ability indicators before and after the experiment; however, these alterations did not reach statistical significance.

After 4 weeks of balance training, considerable discrepancies were identified in the post-test scores of the lower left composite value ($p<0.05$) and lower right composite value ($p<0.05$) in the Y Balance Test among secondary school physical education students in the experimental group when comparing their pretest and post-test scores. The control group also demonstrated substantial contrasts in these indicators. It is noteworthy that the experimental group showcased more pronounced advancements in the Y Balance Test compared to the control group.

These findings imply that four weeks of balance training integrated into secondary school physical education classes can result in significant improvements in static balance ability, particularly regarding foot support and lower limb stability during closed-eye conditions. Both the experimental and control groups experienced positive transformations, with the experimental group exhibiting more notable enhancements.

5. CONCLUSION AND IMPLICATIONS

5.1 Conclusion

The balance capability of the human body encompasses the capacity to sustain stability, including the ability to maintain specific postures and make bodily adjustments when exposed to external forces in order to preserve equilibrium. It constitutes a significant physiological function within the realm of human anatomy [10]. According to the classification theory of balance ability, overall balance capacity is comprised of static balance ability and dynamic balance ability.

The ability to maintain stability is known as the balance ability of the human body. It encompasses the capacity to sustain specific positions and make adjustments to maintain balance when subjected to external forces. This is a crucial physiological function of the human body [11]. According to the classification theory of balance ability, overall balance ability consists of static balance ability and dynamic balance ability.

Both the control group and the experimental group utilized BOSU balance training equipment as the support substrate for the participants. This was done to alter the stability of the supporting surface. Furthermore, compared to standing on a flat support surface with both feet, the participants were tasked with standing on a half-round balance ball with one foot while maintaining body balance, which proved to be significantly more challenging. In the training program for the control group, there was no interference with the visual information input of the participants. However, it emphasized maintaining a specific posture (such as single-leg BOSU ball standing) on the half-round balance ball. On the other hand, the experimental group focused on maintaining a specific posture (standing on a BOSU ball with both feet) on the half-round balance ball under VR simulation conditions. Additionally, during a specific phase of the training movement under VR simulation, the experimental group placed emphasis on maintaining a specific posture (resisting yoga ball interference while standing on a BOSU ball). The research results also demonstrated that after approximately 4 weeks of training, both the static and dynamic balance abilities of both the control and experimental groups exhibited significant improvement.

The disparity between the training methods of the experimental group and the control group lies in the utilization of VR simulation and external environmental force interference to impede visual information input and disrupt somatosensory information input of the participants. When the body is on an unstable support surface and the inputs of visual and somatosensory information are obstructed or inaccurate, the body relies more on vestibular sensors and neuromuscular coordination to maintain balance. In situations with minor external force interference (such as the pushing and pulling factors in this study's experimental group), the body tends to employ the ankle joints as an axis for posture adjustment in order to sustain balance. Therefore, in comparison to the balance training program of the control group, the training program of the experimental group can more effectively enhance the proprioception of the ankle joints, thereby expediting body posture adjustments and achieving more precise limb control. This may elucidate why the improvement in closed-eye single-leg standing after training was superior in the experimental group than in the control group. Furthermore, it is also understandable that the improvement in

static and dynamic balance abilities before and after training was more significant in the experimental group compared to the control group.

5.2 Limitations of this study include:

5.2.1. Short intervention period: The four-week intervention period in this study may have limited the extent of skill improvement. Longer interventions could potentially yield more comprehensive and enduring results.

5.2.2. Participant limitations: This study primarily focused on high school physical education students, thereby limiting the generalizability of the findings to other age groups or specific populations. Further research could broaden the sample by including participants from different age groups and sporting backgrounds, enabling more extensive conclusions. Moreover, the imbalance in gender ratio among participants hinders the possibility of conducting correlation analyses pertaining to gender differences in this study.

5.2.3. Unaccounted factors: While this study primarily examined the impact of virtual reality simulation training on balance skills, it did not consider other potential factors that could influence balance improvement, such as individual differences, psychological factors, and external environments. Subsequent research should incorporate these factors and analyze their impact on the results.

5.2.4. Small sample size: With only 40 participants, the sample size in this study was relatively small. Increasing the sample size could enhance the reliability and generalizability of the findings.

In conclusion, despite its limitations, this study provides preliminary evidence regarding the application of virtual reality simulation training to enhance balance skills among high school physical education students. Further research should address these limitations, thereby exploring the potential of virtual reality simulation training across different populations and fields.

5.3 Implications for future research:

Future studies in this field should consider expanding the sample size and extending the duration of the training period, if applicable. Utilizing advanced assessment techniques and VR devices with improved compatibility, researchers can create and develop a wider range of virtual simulation balance training scenarios, thus delving deeper into the mechanisms through which VR simulation training impacts balance abilities. Additionally, further research is warranted to explore the effectiveness of VR simulation training in improving balance abilities among various age groups of healthy individuals. It is particularly important to conduct empirical studies focusing on training and improvement effects of balance abilities among middle-aged and elderly populations.

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