

THE EFFECTIVENESS OF A VIRTUAL REALITY-BASED FOREHAND SMASH TRAINING MODEL IN ENHANCING TECHNICAL SKILLS OF JUNIOR TABLE TENNIS ATHLETES

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Abstract

This study aims to develop and test the effectiveness of the Virtual Reality (VR) based forehand smash training model in improving forehand smash technique skills in table tennis athletes aged 12-16 years. In this study, the VR training model is designed to provide more immersive, flexible, and interactive training, which is expected to accelerate the learning process of forehand smash techniques without space and time limitations. This study used a research and development (R&D) approach involving 30 table tennis athletes who underwent trials of VR-based training models. The results showed that the use of VR had a significant impact on improving forehand smash skills, with an increase in scores between 15% to 30% in the pretest and posttest trials. Statistical analysis using t-test showed a significant difference between pretest and posttest scores (p -value = 0.000), indicating that VR is effective in improving speed, accuracy, and consistency of forehand smash technique. VR technology was also shown to increase athletes' motivation and engagement in training, which are important factors in technique mastery. However, although VR is effective for athletes who are still in the beginner or intermediate stages, this study also showed that highly skilled athletes experienced smaller improvements, which suggests that VR may be more effective for basic technique development. This study suggests continuing to develop VR technology by adjusting the difficulty level of the exercises according to athletes' abilities, as well as improving the comfort and user interface of VR devices. Overall, this study provides strong evidence that VR can be an effective training tool.

Keywords: Virtual Reality, forehand smash training, table tennis, technical skills, athletes aged 12-16 years, technical improvement, motivation, talent development, VR-based training

INTRODUCTION

Along with rapid technological advances, various innovations have opened up new opportunities in the world of sports, especially in terms of training and developing athlete skills. One technology that is experiencing rapid and promising development is Virtual Reality (VR). VR technology has shown great potential in various sectors, including the sports sector. With its ability to create an immersive environment, VR has become an effective tool to improve athletes' performance without relying on external factors such as weather or training space limitations (Putranto et al., 2022; Zhou, 2020). This technology allows athletes to practice their skills in a safe and controlled environment, reducing the risk of injury and improving training efficiency (Düking et al., 2018; Stone et al., 2018). One sport that benefits from the application of VR technology is table tennis. Table tennis is a sport that relies on technical skills, one of which is forehand stroke skills. Effective forehand strokes require good mastery of technique and repeated practice so that athletes can execute them precisely in real matches (Wu et al., 2021). However, monotonous traditional training and limited variety in training can cause boredom for athletes, especially young athletes who have high curiosity and get bored quickly (Pane et al., 2021).

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To address these challenges, the use of VR technology offers an innovative solution in improving the technical skills of table tennis athletes, particularly in forehand stroke training. VR can change the way athletes train by creating more engaging and effective simulations, as well as allowing athletes to train in a more flexible range of conditions without being affected by physical or weather restrictions (Ferrer et al., 2020; Tsai et al., 2022). In addition, VR also allows for more specific and focused training on improving certain techniques, such as forehand stroke technique, in a more interactive and enjoyable way (Michalski et al., 2019).

Therefore, this study aims to develop and evaluate a VR-based forehand smash training model for table tennis athletes aged 13–17 years, in the hope that it can fill the existing gaps and make a significant contribution in table tennis training at the junior level. This study aims to explore the effectiveness of a forehand smash training model using VR technology in improving the technical skills of junior level table tennis athletes. The main focus of this study was to determine the extent to which the use of VR can improve forehand stroke technique and assist athletes in overcoming the challenges faced during traditional training. By incorporating advanced technology such as VR in the training process, it is hoped that this research can make a significant contribution in the development of more innovative and efficient table tennis training methods.

LITERATURE REVIEW

Advances in Virtual Reality (VR) technology have supported the creation, application, evaluation, and delivery of interactive VR applications at a lower cost. The VR research community is increasingly active, with a significant increase in contributions to the IEEE Virtual Reality conference in 2020, which recorded a growth of about 10% over the previous year (Lang, 2021). Oculus Quest 2, the best-selling VR headset released in 2020, showed the fastest sales pace, signalling the increasing popularity of VR, including in the field of training (Lang, 2021). In the business world, VR-based training has become the most commonly used method, reaching 62% according to Ostrowski's (2018) survey, illustrating the success and potential of VR in various fields, including education (Lorenzo et al., 2020; McGarr, 2020; Radianti et al., 2020), medicine (Bhattacharjee et al., 2020; Felipe et al., 2020; Maier et al., 2020a; Xin et al., 2020), computer games (Bapka et al., 2018; Yang et al., 2018; Allspaw et al., 2019), and the acquisition of new motor skills (Prasertsakul et al., 2018; Ricca et al., 2018; de Moraes et al., 2020).

In the context of sports, VR has been widely applied for performance analysis, simulation development, and virtual training (Adamovich et al., 2009; Calabro et al., 2017; Akbas et al., 2019). VR provides personalised training for technical, tactical and motor skills without being limited by time and place, allowing players to practice against selected opponents or situations (Akbas et al., 2019). By reducing distractions in complex sports experiments, VR provides accurate control and synchronisation in repeatable experiments to compare the results of different trials (Pereira et al., 2018). In addition, the immersive experience offered by VR increases users' motivation and participation in exercise (Slater, 2009).

One sport that can greatly benefit from the application of VR is table tennis. This sport involves very complex movements, and basic techniques such as the forehand stroke have a great influence on game performance (Hodges, 1996). In table tennis, the skill level of the forehand shot differs between athletes, and the ability to master this technique is crucial for success in a match. VR has great relevance in developing forehand smash technique, especially for young players aged 13 to 17. VR technology provides a realistic and immersive virtual environment, allowing young players to practice forehand smash technique as if they were in a real match. This provides a valuable experience that helps them develop muscle memory and improve correct hitting mechanics (Riva et al., 2019; Errichiello et al., 2019).

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By using VR, training can be personalised according to each player's strengths and weaknesses. VR allows young players to practice forehand smash techniques anytime and anywhere, without the need for a physical table or playing partner. This allows flexibility in training schedules and helps them develop skills without being limited by location or physical condition. Repetitive practice performed in a VR environment can improve the consistency and power of forehand shots, by giving players the opportunity to practice without physical fatigue or the need to pick up the ball (Trunfio et al., 2019; Pereira et al., 2018).

In addition, VR provides instant feedback regarding players' forehand smash technique, allowing them to make adjustments and improvements in real time. This is especially beneficial for young players who are prone to injury or have physical limitations, as VR provides a safe environment to practice without adding stress to their bodies. The immersive and interactive features of VR also increase young players' motivation by incorporating game elements and challenges in training, making it more fun and fulfilling (Trunfio and Campana, 2019; Akbas et al., 2019). The experience gained from VR training can be directly applied in real-world table tennis matches. Young players who practice forehand smash techniques in a VR environment will feel more prepared and confident in applying these skills in actual matches. Thus, VR not only serves as an effective training tool but can also accelerate the process of technique mastery and improve athletes' overall performance (Riva et al., 2019; McGarr, 2020).

Research regarding the use of Virtual Reality (VR) technology in sports training, particularly table tennis, has shown promising results in improving athletes' skills. Michalski et al. (2019) showed that VR training significantly improved participants' table tennis performance, with effective transfer of skills from VR to the real world. The study involved participants from different age groups and underlined the potential of VR in sports training. Another study by Y. Zhang (2021) examined the comparison between VR training and traditional training in table tennis, showing that VR training was more effective in improving athletes' technical skills and internal motivation. Meanwhile, Le Noury et al. (2021) revealed the importance of creating a realistic VR environment to train perceptual-cognitive skills, which are relevant in improving technical abilities in table tennis.

Research by Bedir & Erhan (2021) also shows the effectiveness of VR in improving mental skills, such as athletes' mental images, which can be applied to various sports, including table tennis. S. Wang et al. (2022) developed a VR training system for volleyball, demonstrating that VR can improve athlete training outcomes and reduce training costs, the relevance of which can be applied to table tennis training. Prasertsakul et al. (2018) examined the impact of VR-based training on motor balance in healthy adults, providing insight into the benefits of VR in the development of basic motor skills that are also important in table tennis training.

Although there are differences in the subjects and types of sports studied, all of these studies emphasise the great potential of VR in improving athletes' skills and providing a more engaging and effective training experience. However, most of these studies involved participants with diverse backgrounds and did not focus on specific techniques in table tennis, such as forehand smash technique.

METHOD

This study adopts a research and development (R&D) approach that aims to develop and test the effectiveness of a Virtual Reality (VR)-based forehand smash training model in improving the technical skills of junior table tennis athletes aged 12-16 years. The focus of this research is to create a VR-based training model that can help improve the forehand smash technique of young athletes, as well as provide solutions to the limitations of time, space, and monotony in traditional training. Using qualitative and

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quantitative approaches, this research aims to develop effective and practical training products that can be implemented by coaches and athletes.

This research was conducted in South Sulawesi Province, with research locations in PTM Pinrang Regency, PTM Pare-pare City, and PTM Makassar City. This research is planned to take a minimum of 6 months, following the systematic Research and Development from Borg and Gall (1983) which includes the stages of planning, product development, trials, evaluation, and model implementation. The population of this study was table tennis athletes aged 12-16 years registered at PTM in South Sulawesi, with a sample involving 30 table tennis athletes. In addition to athletes, coaches and table tennis experts will also be involved in the evaluation to provide input on the design and effectiveness of the VR-based training model developed.

The data collection method in this study uses test and non-test instruments. The test instrument used is a forehand smash skill test that has been validated by measurement experts, which will be used to measure changes in athletes' forehand smash skills before and after the application of the VR-based training model. Non-test instruments include questionnaires for coach and athlete needs analysis and expert evaluation questionnaires to get input on the quality and effectiveness of VR-based training models. The steps of this research began with a preliminary study involving literature analysis, field observations, and identification of problems faced by coaches and athletes in forehand smash training. The data obtained from this stage was used to design a training model that suits the needs of athletes and coaches. Based on the findings from the preliminary study, the researcher designed a VR-based forehand smash training model that includes a variety of exercises to develop technical skills thoroughly. This model allows exercises that can be done anytime and anywhere by athletes, without space or time limitations. After designing the model, it was validated by table tennis experts and coaches to ensure the quality and effectiveness of the model. Expert feedback was used to improve and refine the training model to better suit practical needs in the field.

Product trials were conducted in two stages: small group trials and large group trials. In the small group trial stage, the training model was tested by 8 athletes, while in the large group trial, 30 athletes were involved in field testing. The results of the small and large group trials will be used to revise and refine the training model. After revision, the refined training model will be tested more widely in the field to see its acceptance and effectiveness. Data collected from the trials and evaluations will be analysed using quantitative and qualitative approaches. In the quantitative analysis, data from the pretest and posttest tests will be analysed using the t-test statistical test to see if there is a significant difference in forehand smash skills before and after the application of the VR-based training model. In addition, descriptive statistical techniques will also be used to analyse data obtained from evaluation questionnaires and questionnaires to identify aspects that need to be improved in the training model. A qualitative evaluation was also conducted to gain further insight into the experiences of athletes and coaches in using the VR training model. This research is expected to produce an effective and practical VR-based forehand smash training model for athletes aged 12-16 years. By using VR technology, forehand smash technique training is expected to be more interesting, flexible, and safe for young athletes who want to improve their forehand smash ability. Through the evaluation and trials conducted, this research will make an important contribution to the development of innovative table tennis training methods that can be applied in various contexts.

RESULTS AND DISCUSSION

The results of this study indicate that the Virtual Reality (VR) based forehand smash training model has a significant impact on improving forehand smash technique skills in table tennis athletes aged 12-16 years. Based on the results of trials involving 30 table tennis athletes, pretest scores ranging from 50 to 64

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increased to 60 to 80 in the posttest. This increase shows that VR has a positive impact in improving the speed, accuracy, and consistency of forehand smash techniques. The average increase in scores on the pretest and posttest ranged from 15% to 30%, with some athletes experiencing greater improvements, up to 40%. This study is consistent with previous findings indicating that VR technology can significantly improve athletes' technical skills. Michalski et al. (2019) found that VR-based training can significantly improve table tennis skills under real-world conditions, suggesting that VR has potential in improving the technique of sports involving complex motor skills, such as table tennis. In addition, Zhang (2021) also noted that VR can increase athletes' motivation and engagement in training, factors that are crucial in technique mastery at the elite level, which is also reflected in the results of this study.

Table 1. Differential Test Results

Variables	Independent Samples Test	Levene's Test for Equality of Variances	t-test for Equality of Means
	F	Sig.	t
Pretest vs Posttest	0.002	0.967	-26.83

Source of Processed Data, 2025

Table 1 shows a significant difference between the pretest and posttest scores with a p-value of 0.000, indicating that the application of the VR-based training model had a significant impact on improving the athletes' forehand smash technique. The mean difference between the pretest and posttest was -21.88, indicating that the posttest score was higher than the pretest, reflecting a marked improvement in the athletes' smash technique. The standard error of difference of 0.816 indicates that this mean difference is quite stable and consistent. This statistical test also shows that the results of the difference between posttest and pretest scores are reliable and have considerable significance, supporting that the application of VR in training can effectively improve skills.

The results of this study indicate that the VR-based forehand smash training model is proven effective in improving forehand smash technique skills in table tennis athletes aged 12-16 years. The use of VR technology in training provides a more interesting and immersive training experience, which is very important to improve the quality of technique training. Previous research by Pereira et al. (2018) and Akbas et al. (2019) showed that VR provides personalised training for technical and motor skills, without being limited by time and place, which is very similar to the findings in this study. Given VR's ability to reduce distractions in complex sports experiments and provide accurate control in training, this technology can create a more realistic and effective simulation for table tennis training.

VR technology is also effective in improving techniques by providing real-time feedback. Slater (2009) revealed that immersion and presence in virtual environments can increase user participation and motivation. This is very relevant to the findings of this study, where VR increases athletes' motivation, which encourages them to practice harder and hone their forehand smash technique more effectively. However, although the VR-based training model showed significant improvements, some athletes who already had higher forehand smash skills before the VR-based training experienced smaller improvements than other athletes. This leads to questions regarding the effectiveness of VR for technique development in athletes who are already at a higher skill level. Research by Michalski et al. (2019) also showed that the use of VR is more effective for athletes who are at the basic technique mastery stage, which is consistent with these findings. Nonetheless, VR can still serve to improve overall technique and provide more structured training.

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The results of this study provide strong evidence that VR can significantly improve table tennis athletes' forehand smash skills. The improvements recorded in the pretest and posttest indicate that VR provides an opportunity for athletes to practice forehand smash techniques intensively and repeatedly in conditions close to real matches. Previous research by Zhang (2021) showed that VR can increase athletes' internal motivation and accelerate the process of technique mastery at the elite level, which is also reflected in the results of this study, where athletes who practised using VR showed significant skill improvement.

However, VR technology may be more effective for athletes who are still in the beginner or intermediate stage, as indicated by the difference in results between athletes who already have high skills and athletes who are still in the learning stage. Research by Le Noury et al. (2021) showed that VR is effective in training perceptual-cognitive skills and can improve technique mastery at a basic level, but this study also showed that more complex techniques in advanced athletes may require more specialised training.

Nonetheless, the results of this study support the application of VR as an effective training tool in improving technical skills in young athletes. This is in line with the findings conducted by Michalski et al. (2019), which showed that VR has the potential to improve performance in sports by providing more controlled and interactive training. This study confirms that VR-based training not only improves forehand smash technique, but also provides a more engaging training experience, increases motivation, and allows athletes to train anytime and anywhere, without physical restrictions.

As explained by Pereira et al. (2018), VR allows for more specific and intensive training, which is key in mastering complex technical skills such as forehand smashes. VR technology allows athletes to train in a simulation that closely resembles a real match situation, but without the physical limitations often faced in traditional training. Using VR, athletes can repeat forehand smash technique movements many times in a safe and controlled environment, which helps accelerate the process of mastering the technique without the risk of injury.

One of the particularly interesting findings in this study is how VR not only improves forehand smash technique skills, but can also serve to identify and develop talent in young athletes. Based on data analysis, VR allows coaches to more quickly detect athletes' technical strengths and weaknesses, which accelerates the talent identification process. Previous research by Michalski et al. (2019) also showed that VR can be used to train technical skills in various sports and improve athletes' skills in a shorter time. By providing structured and more repetitive training, VR allows coaches to work more efficiently in identifying athletes who have the potential to develop further in the sport.

However, although the trial results showed significant improvements in most athletes, there was also a group of athletes who already had higher forehand smash skills prior to the VR-based training, who experienced smaller improvements compared to other athletes. This suggests that VR technology may be more effective for athletes who are at a beginner or intermediate stage who are mastering basic techniques, while for advanced athletes, VR-based training may need to be tailored to their skill level. This is in line with research by Zhang (2021), which states that VR technology can increase athlete motivation and engagement, but its effectiveness tends to be greater in athletes who are still in the learning or beginner stage, who have not fully mastered the basic techniques.

In addition, although VR-based training increases athletes' motivation, some athletes who are already at a higher skill level may experience boredom or lack of challenge in using this technology. Therefore, it is important to adjust the level of difficulty in VR-based training to suit the athlete's individual abilities. This adjustment in difficulty can be done by adding variety in the exercises or introducing more difficult challenges, so that VR not only serves to improve basic techniques but can also be used to train advanced or specific techniques.

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However, the use of VR technology in talent development still shows enormous potential. With the advancement of technology, VR offers a more realistic and immersive training environment that helps athletes to learn faster and more effectively. For example, VR provides the opportunity for athletes to practice forehand smash techniques in a variety of varied scenarios, without being affected by physical conditions or facility limitations. This is especially beneficial for young athletes who may not have access to adequate training facilities or have busy schedules. With VR, they can practice their skills anywhere and anytime.

In addition, the use of VR technology can help athletes reduce the fear or stress that sometimes arises during real training or matches. In a study conducted by Slater (2009), it was found that immersive elements in VR-based training can increase athletes' feelings of engagement and motivation, which is also reflected in this study. By providing a more fun and interactive training experience, VR can make the learning process more interesting and reduce the sense of boredom that often occurs in traditional training. However, it is important to note that although VR has many benefits, this technology cannot completely replace physical training in the real world. VR can be an excellent complement to technique training, but athletes still need on-court training with partners to hone their skills in more real-world and dynamic situations. VR is more effective as a tool to refine basic techniques, improve consistency, and identify talent, but hands-on training with a partner and under actual match conditions remains essential to improve an athlete's overall performance.

Overall, this study provides strong evidence that the VR-based forehand smash training model is highly effective in improving technique skills in table tennis athletes. With trial results showing significant improvements in forehand smash skills, as well as support from previous research demonstrating the effectiveness of VR in technique development across a range of sports, this technology shows great potential for use in table tennis training. However, more research is needed to explore how VR can be adapted to advanced athletes and how this technology can be used in long-term athlete development. Overall, this study confirmed that a VR-based training model can be used to improve forehand smash technical skills in table tennis athletes aged 12-16 years. Given the evidence that VR is effective in accelerating technique mastery and increasing motivation, this study can serve as a basis for the future development of VR-based training, which can accelerate athletes' skill development in various sports.

CONCLUSION

Based on the results of this study, it can be concluded that the Virtual Reality (VR) based forehand smash training model is proven effective in improving forehand smash technique skills in table tennis athletes aged 12-16 years. The trial results showed a significant increase in forehand smash technique skills, with an average increase in scores between 15% to 30%. The application of VR has a positive impact on improving the speed, accuracy, and consistency of smash technique, and helps athletes master the technique more quickly and effectively. In addition, VR was also shown to increase athletes' motivation and engagement in training, which are important factors in technique mastery. However, although VR technology is effective for improving the skills of athletes who are still in the beginner or intermediate stages, for athletes who already have high skills, the effectiveness of VR tends to be smaller. Therefore, it is necessary to adjust the difficulty level of the exercises to suit the abilities of more experienced athletes. This adjustment is important to ensure that VR is not only effective for beginners, but can also be used to train advanced athletes with challenges that are more in line with their abilities.

As a suggestion, further development of this VR-based exercise model needs to be done by considering improving the comfort of using VR devices, such as by making a lighter and ergonomic headset. The development of a more intuitive user interface is also very important to accelerate the adaptation of athletes, especially those who are using VR technology for the first time. In addition, it is

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also important to make more personalised adjustments to exercise difficulty levels to target specific areas that require improvement, so that exercises can be more effective in improving athletes' skills.

It is important to continue to examine the long-term effects of VR-based training on athletes' technical development at the professional level and long-term talent development. Further research could also expand the use of VR in long-term athlete development (LTAD) programmes, to explore how this technology can support continuous training and technique mastery over the long term. With proper customisation, VR technology can be a very useful tool in table tennis training, accelerating the process of technique mastery, and improving the quality of future athletes.

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