International Journal of Education and Training (InjET)
Volume 11, Issue (2), 2025
eISSN: 2462-2079
http://doi.org/10.47836/injet.11.2.01

Effects of Virtual Reality Intervention on Psychological Resilience of Professional Basketball Players in Shandong, China: A Pilot Study

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Received : 13 June 2025
Accepted : 20 July 2025
Published : 29 August 2025

ABSTRACT

In team sports, athletes' psychological resilience can influence teammates through a "psychological contagion" mechanism, which has significant effects on enhancing cooperation between athletes and improving overall team performance. The traditional training method is primarily used to enhance the psychological resilience of team sports athletes, which neglects the individual needs of athletes in favour of the team's collaborative capabilities. This has resulted in some team athletes failing to improve their psychological resilience effectively, and may even have counterproductive effects on certain athletes. Therefore, exploring training methods that can effectively enhance the psychological resilience of team sports athletes is a critical research gap. This study employed a cluster randomised controlled trial (CRCT) design to investigate the effects of virtual reality training (VRT) on psychological resilience among Chinese professional basketball players. Participants from the Shandong Basketball Management Centre were recruited and randomly assigned to either the experimental group (VRTG) or the control group (CTG, traditional training), with an additional two weeks of intervention. The psychological resilience level was evaluated before and after the intervention. The results indicated that two weeks of virtual reality training can significantly improve the psychological resilience of professional basketball players. The findings of this study provide support for the notion that virtual reality training can substantially enhance psychological resilience among professional basketball players.

Keywords: Virtual Reality, VR Training, Psychological Resilience, Professional Basketball Player

INTRODUCTION

In competitive sports, psychological resilience is essential for athletes to maintain stable performance under pressure and to recover effectively from setbacks. Athletes with higher psychological resilience tend to better manage emotional responses during training and competition, allowing them to stay focused and perform at their peak levels. However, a lack of psychological resilience often results in reduced performance under high-pressure situations, leading to an increased risk of errors in critical moments of a game (Gucciardi et al., 2019). Recent studies have highlighted the importance of psychological resilience for athletes, particularly in situations that require rapid decision-making and the ability to stay composed despite external stressors (Frolova et al., 2019).

In team sports like basketball, psychological resilience not only enhances an athlete’s performance but also positively impacts team dynamics. Resilient athletes are better able to handle collective pressure, thus improving their communication and coordination with teammates (Vasser et al., 2020). Moreover, psychological resilience contributes to a team's overall mental toughness, which can significantly influence the outcome of high-stakes games (Stinson et al., 2014). While traditional training methods focus primarily on physical and technical skill development, the need for psychological resilience training is increasingly recognised as essential for achieving sustained success (Li, 2021).

One promising approach to developing psychological resilience in athletes is the use of Virtual Reality (VR) training (Chen et al., 2023). VR technology provides immersive environments that

eISSN: 2462-2079
http://doi.org/10.47836/injet.11.2.01

simulate real-world pressure scenarios, enabling athletes to practice their psychological coping mechanisms in a controlled setting. Studies have shown that VR training can significantly improve athletes' ability to manage stress and anxiety, enhancing their mental toughness and overall performance (Harris et al., 2020). For example, VR scenarios can simulate high-pressure game situations, helping athletes rehearse their responses to competitive stressors such as audience noise, time pressure, or critical decision-making moments (Cossich et al., 2023).

In recent years, VR training has been increasingly integrated into sports programs to address psychological resilience issues. For instance, NBA teams have begun incorporating VR into their training regimens to help athletes enhance their psychological resilience, resulting in significant improvements in decision-making ability under pressure and stress tolerance (NBA Technology Report, 2023). Similarly, VR has been shown to improve psychological resilience in soccer and hockey players by creating realistic scenarios that challenge players' mental fortitude and ability to stay focused under stress (Emmelkamp et al., 2022). However, despite the widespread use of VR in other sports, the application of VR training to enhance psychological resilience in basketball athletes, especially in China, remains in its early stages, with few studies evaluating its effectiveness.

Given the potential benefits, further research is needed to fully understand how VR training can be optimised to improve psychological resilience in basketball players. Under this background, this study aims to investigate the effect of virtual reality training on psychological resilience among Chinese professional basketball players. This study seeks to provide scientific evidence and practical guidance for enhancing the psychological resilience of Chinese basketball players. The research results are expected to provide more effective psychological resilience training options for Chinese basketball players.

LITERATURE REVIEW

Psychological resilience refers to an athlete's ability to effectively adapt and recover from adversity, maintain focus under pressure, and continue to perform at high levels despite challenges (Triberti et al., 2014). Virtual Reality (VR) has emerged as a promising tool in psychological interventions, particularly for enhancing psychological resilience in athletes. VR intervention involves the use of immersive virtual environments to simulate real-life stressors and pressure scenarios that athletes may encounter in competitive sports (Wilson et al., 2015; Gryaznova et al., 2020).

VR technology simulates real-world game or training environments, offering athletes a highly controlled yet dynamically changing space. In this environment, athletes can engage in high-intensity training, face complex tactics or pressure situations, while avoiding the exposure risks associated with real-world exposure (Roberts et al., 2019). For example, athletes can face virtual failures without real-world consequences, allowing them to reflect and recover. Through repeated training to cope with failure or setbacks, they can strengthen their psychological resilience (Fendrian et al., 2024).

The VR technology enables athletes to be exposed to various high-stress situations in a safe and manageable way, allowing them to practice adaptive coping strategies and refine their psychological adaptability (Turner et al., 2014). In VR, athletes can experience both internal (e.g., anxiety, fear, self-doubt) and external (e.g., crowd noise, referee decisions, opponents' pressure) stressors, which can help them develop greater emotional regulation, enhanced focus, and quicker recovery from setbacks (Vasser et al., 2020). These simulated scenarios aim to promote long-term psychological resilience by allowing athletes to learn from virtual failures and successes, relying on their enhanced psychological adaptability (Rizzo et al., 2019). Moreover, VR interventions for psychological resilience are based on several psychological theories, including cognitive-behavioural theory, exposure therapy, and mindfulness, all of which contribute to building stronger coping mechanisms (Lanier et al., 2019). By providing athletes with real-time feedback, VR allows them to become aware of their emotional reactions, make necessary adjustments, and enhance their psychological fortitude through repetition and exposure (Shoshani et al., 2024).

According to present research on the impact of virtual reality training on athletes' psychological resilience, Gaggioli et al. (2014) utilised VR simulations to help athletes manage stress. Their findings showed that VR training effectively enhanced emotional stability and stress management, as athletes who practised in virtual environments demonstrated improved performance in high-stress situations

eISSN: 2462-2079 © Universiti Putra Malaysia Press
http://doi.org/10.47836/injet.11.2.01

compared to those who did not undergo VR training. Meanwhile, Levin et al. (2015) also examined the role of VR in psychological intervention. They found that athletes who trained with VR simulations had higher levels of psychological resilience, particularly in their ability to manage anxiety and improve self-confidence under competition pressure. This study also concluded that VR offers a more effective tool for enhancing resilience compared to traditional psychological training methods.

Zhang et al. (2019) described the effects of VR on emotional regulation and psychological resilience in basketball players. Their research showed that athletes who engaged in VR training demonstrated better emotional control and coping strategies under pressure, with improvements in psychological resilience as measured by standard psychological scales such as the Connor-Davidson Resilience Scale (CD-RISC). In addition, Hussain et al. (2022) conducted a study involving professional basketball and football players. They found that VR training significantly improved psychological resilience by reducing stress responses and improving emotional control during high-pressure game situations. They also noted the applicability of VR in creating controlled stress environments that helped athletes better prepare for real competition. Moreover, the diversity of athletes' experiences and individual differences in baseline resilience levels suggest that VR interventions should be tailored to the needs of each athlete. Future research should focus on optimising VR training protocols based on the athlete's psychological characteristics, including training duration, frequency, and intensity.

METHODOLOGY

Participants

The study involved 19 professional basketball players as participants, recruited from four basketball training centres in Jinan, Qingdao, Yantai, and Weihai, Shandong Province, China. They were randomly assigned to the experimental group (n = 9) and the control group (n = 10).

The inclusion criteria were:

a) Professional basketball players;
b) Participants must have at least one year of training background at the
c) Shandong Basketball Training Centre and have signed a legal professional athlete contract with the Shandong Provincial Sports Bureau;
d) Participants must have participated in the Chinese basketball national team selection competition in Shandong Province

Exclusion criteria included:

a) History of sports injuries within the past year and continuous treatment;
b) Participants who cannot complete the entire experimental training due to participating in the professional competition schedule;
c) For electronic devices with primary Electromagnetic Hypersensitivity (EHS) symptoms (Johnson et al., 2021).

The Ethics Review Committee of Yantai Ruichen Medical Equipment Company provided ethical approval (Approval No. LURCYL20230712336972). Throughout the intervention period, participants were advised to refrain from engaging in any additional training and to maintain their regular dietary routines, which were carefully observed and documented by the researchers. Continuous assessments were carried out during the intervention to evaluate its effectiveness and practicality.

Participant Characteristics

Essential demographic information was collected, including age, height, weight, and training background. Height and weight are measured using an electronic measuring instrument with an infrared sensor. The mean age in the VRTG was 21.65 ± 3.120 years, and for the CTG was 21.57 ± 3.203 years. The mean height in the VRTG was 189.104 ± 9.233 cm, and for CTG was 189.176 ± 9.311 cm. The average weight in the VRTG was 81.376 ± 10.118 kg, and for the CTG, it was 81.643 ± 10.368 kg. The

eISSN: 2462-2079
http://doi.org/10.47836/injet.11.2.01

respective mean training background was as follows: VRTG, 20.700 ± 3.100 months; CTG, 21.100 ± 2.800 months.

Training Program

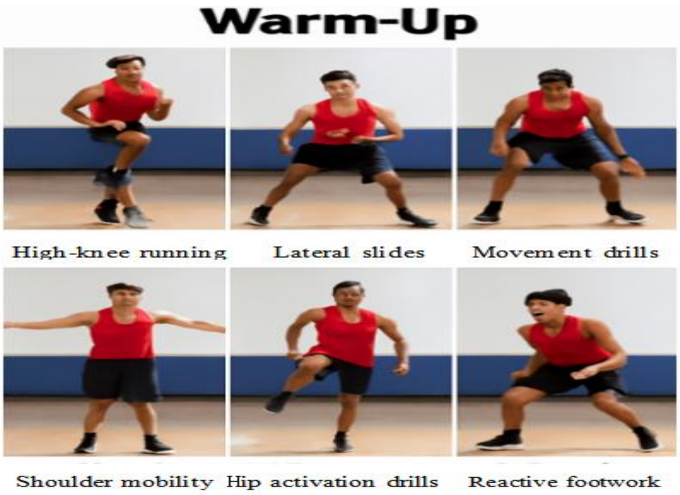
To determine the optimal virtual reality training program for evaluating psychological resilience among professional basketball players, the FITT (frequency, intensity, time, and type) principle was incorporated to maximise performance outcomes during the virtual reality training intervention (Baye et al., 2023).

The precision and systematisation of training interventions play a decisive role in enhancing athletes' psychological resilience (Smith et al., 2021). VR training involves the integration of complex cognitive and motor processes (Rokooei et al., 2023). The professional coaches and technicians of the experimental team in this study monitor the standardised execution of the training program to ensure consistency and effectiveness of the intervention. Before the experiment began, all participants received a detailed explanation of the training protocol and completed baseline assessments, including tests on asymmetric technical and tactical levels, as well as assessments of psychological resilience. All baseline data were collected and analysed before the intervention began.

Participants were divided into two groups: the VRTG and the CTG, both of which followed the same intervention schedule. The intervention lasted for two weeks, with training sessions occurring three times per week, each lasting up to 35 minutes. The total training time per week was 105 minutes. The exercise intensity was moderate, progressively adjusted based on the participants' adaptation, and sufficient rest and feedback time were incorporated to maintain the integrity of the intervention.

Each training session consisted of three components: routine warm-up, asymmetric training of basketball technical abilities, and asymmetric training of basketball tactical abilities. Both the VRTG and the CTG were supervised throughout the intervention by a national-level basketball coach, a researcher proficient in virtual reality equipment, and a psychologist. Additionally, VRTG requires users to wear the appropriate equipment and stand on a fixed training platform throughout the training process. After the training, all participants in the VRTG must undergo monitoring for side effects.

i. **Warm-up (15 minutes):** This session began with a dynamic stretching protocol designed to prepare participants for the subsequent intervention training. Both groups followed an identical warm-up routine, which included high-knee running, lateral slides, basic basketball movement drills, shoulder mobility exercises tailored for basketball, hip activation drills, reactive footwork exercises, and visual tracking training.



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ii. **Basketball technical asymmetric training (15 minutes):** Asymmetric correction training for basic technical abilities, and non-dominant side technique reinforcement training for implementing composite techniques under defensive pressure.

iii. **Basketball tactical asymmetric training (20 minutes):** Including tactical spatial positioning training, left and right balance tactical coordination training, and randomly generated tactical variation training.

iv. **Side effect monitoring:** Participants in VRTG were guided by accompanying doctors, coaches, and researchers to complete the Simplified Virtual Reality Discomfort Self-Assessment Scale (Ames et al., 2009).

v. **Training environment control:** VRTG underwent all training procedures in a closed, temperature-controlled indoor environment with minimal light and auditory distractions. This stable setting minimised external sensory interference and ensured the consistent operation of VR equipment. At the same time, CTG completed their training in an indoor basketball facility that was as closely matched in dimensions and layout as possible to the VRTG environment to minimise spatial perception and movement flow differences.

Test Instrument

For the testing of psychological resilience variables, this study used Hu Yueqin's Psychological Resilience Scale (HYPRC). Previous research has extensively validated and established the reliability of these tools, ensuring their credibility for use in the study (Tannoubi et al., 2023; Emmelkamp et al., 2021).

Statistical Analysis

Statistical analyses were performed using SPSS version 23 (IBM Corp., USA), with a significance threshold set at $p < 0.05$ for two-tailed tests. To verify the data quality, descriptive statistics were computed, with continuous and categorical variables presented as means ± standard deviations and frequencies. Before conducting inferential tests, the assumptions of normality and variance homogeneity were examined using ANOVA, the Shapiro-Wilk test, and Levene's test. To assess the effects of the VR training intervention on psychological resilience, a longitudinal analysis was conducted using a generalised estimating equation (GEE) model.

RESULTS

Primary Outcomes

The Content Validity Index (CVI) is a commonly employed approach for assessing the content validity of a measurement (Almanasreh et al., 2019). To guarantee the accuracy and consistency of the items in this study, a group of eight experts with expertise in relevant research fields was assembled to evaluate the content validity of the intervention components. The content validity indices (CVI) for all items in this study fell within the acceptable range (CVI = 1.000 and Kappa = 1.000), confirming that the intervention programme exhibited high content validity. Table 1 provides the detailed data.

Table 1. Correlation and consistency of psychological resilience

Variables	Measurement Method	Number in Agreement	Clarity	
			I-CVI	KAPPA
Psychological resilience	HYPRC	8	1.000	1.000

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale.

Reliability

The literature review on athlete training and sports psychology has highlighted that reliability is often

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eISSN: 2462-2079 © Universiti Putra Malaysia Press
http://doi.org/10.47836/injet.11.2.01

assessed through three distinct approaches: test-retest reliability, alternate-form reliability, and internal consistency, which examines how well the items within a tool hold together as a unified construct (Bolarinwa, 2015). Since the test-retest method is a simple and low-risk approach **(**Kimberlin et al., 2008**)**, this study employed it as a practical strategy to evaluate the reliability of the measurement tools across repeated measurements. According to Fleiss' guidelines, when the Intraclass Correlation Coefficient (ICC) is above 0.40, it suggests that the reliability hovers in a fair to good range (Koo et al., 2016). The results showed that the ICC values of all testing methods exceeded 0.800, suggesting all testing methods had high reliability. The detailed data are shown in Table 2.

Table 2. Results of the reliability of HYPRC

Variables	Items	Intra-class Correlation Coefficient
HYPRC	IA	0.891
	FS	0.967
	GF	0.965
	EC	0.929
	PC	0.955

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale; IA, interpersonal assistance; FS, family support; GF, goal focus; EC, emotional control; PC, positive cognition.

This study employed the Generalised Estimating Equation (GEE) approach to evaluate the effects of VR training on psychological resilience among professional basketball players in China. GEE analysis was conducted on pre-test and post-test psychological resilience to identify differences between and within the groups. Table 3 provides the descriptive data for psychological resilience.

Table 3. Descriptive statistics of the HYPRC of each group in different periods

Variables	Time	VRTG Mean (Standard)	CTG Mean (Standard)
HYPRC	**Pre-test**	13.510 (0.351)	13.433 (0.373)
	Post-test	12.911 (0.379)	13.203 (0.386)

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale; VRTG, virtual reality training group; CTG, traditional training group

In this study, the GEE model stepped in as a statistical companion to examine group and time effects. The results of the GEE analysis indicated that the main effects of the group on psychological resilience (Wald $\chi^2 = 5.420$, $p < 0.001$) were statistically significant. The findings of this study also showed that psychological resilience (Wald $\chi^2 = 1873.271$, $p < 0.001$) was a significant predictor over time. Additionally, the statistical analysis revealed a significant interaction effect of the psychological resilience (Wald $\chi^2 = 169.312$, $p < 0.001$) between group and time. Results indicated significant improvements across all groups from pre-test to post-test. Table 4 provides the details.

Table 4. Results of GEE on HYPRC Score

Variables	Source	Wald-Chi Square	df	p-value
HYPRC	Group	5.420*	1	<0.001
	Time	1873.271*	2	<0.001
	Group*Time	169.312*	2	<0.001

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale; df: degree of freedom; *p<0.05 level of significance

The data analysis of the HYPRC revealed significant differences between the pre-test and post-test ($p < 0.001$) in the measurement of VRTG. However, there were no significant differences between the pre-test and post-test ($p = 0.158$) in CTG. The findings of this study indicated that two weeks of VR training can significantly improve the psychological resilience level of professional basketball players. Still, traditional training (CTG) had no effect after a two-week intervention. See Table 5 for more details.

eISSN: 2462-2079
http://doi.org/10.47836/injet.11.2.01

Table 5. Within Groups Comparison of HYPRC Scores Across Time for Both Groups

Group	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CI for Difference	
						Lower	Upper
VRTG	Pre-test	Post-test	0.599*	0.128	＜0.001	0.346	0.850
CTG	Pre-test	Post-test	0.230*	0.121	0.158	0.147	0.467

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale; * Mean difference is significant at the 0.05 level.

The results obtained from the Post Hoc test (Bonferroni) exploring the differences in HYPRC between the two groups over time (pre-test and post-test) show that HYPRC scores did not differ between VRTG and CTG at the pre-test (p = 0.652). However, there were significant differences between VRTG and CTG at post-test (p = 0.011) in the test of HYPRC. The findings of this study indicated that compared to traditional training, 2 weeks of VR training had more significant effects on improving the HYPRC scores among Chinese professional basketball players. Table 6 provides the details.

Table 6. Between-Groups Comparison of Mean Score for HYPRC at Two Times

Variable	Time	Mean Difference (VRTG-CTG)	SE	p-value	95% CI for Difference	
					Lower	Upper
HYPRC	Pre-test	0.077	0.172	0.652	-0.260	0.414
	Post-test	-0.292*	0.183	0.011	-0.651	0.067

Note: HYPRC, Hu Yueqin's Psychological Resilience Scale; * Mean difference is significant at the 0.05 level.

DISCUSSION

The findings of this study indicate that after 2 weeks of training intervention, both the VRTG and CTG groups showed significant improvements in psychological resilience. However, compared to traditional training, the effect of virtual reality training on enhancing psychological resilience among professional basketball players was more substantial.

VR training creates highly immersive environments that simulate real game situations, helping athletes better adapt to high-pressure scenarios. This virtual environment effectively enhances athletes' ability to perform under actual competition conditions, thereby improving their psychological performance under stress (Harris et al., 2020). Timely physiological and emotional feedback plays a crucial role in psychological regulation and behavioural change (Bolarinwa et al., 2015). VR training provides immediate feedback mechanisms that enable athletes to quickly recognise and adjust their emotional responses, helping them manage pressure and emotions more effectively (Koo et al., 2016). This highly immersive and personalised training approach enables athletes to repeatedly practice without external distractions, thereby enhancing their psychological regulation skills for real-world competition (Wu et al., 2021). Therefore, these findings support the conclusions of this study.

According to current research findings, VR training utilises controlled psychological stress to help athletes gradually build psychological resilience in simulated high-pressure game environments (Cariati et al., 2023). Levin et al. (2015) demonstrated in their study that VR training can reduce cortisol stress responses by 35%, whereas traditional training only results in a 12% reduction. This difference suggests that VR training can precisely regulate the intensity of stress and is more effective than conventional training in simulating the psychological stressors present in actual competitive settings. Additionally, research has indicated that VR training integrates attention control techniques, guiding athletes to adopt the "Quiet Eye" gaze pattern, which significantly reduces anxiety interference and enhances decision-making ability (Warnier et al., 2020).

Ozturk et al. (2024) demonstrated through experimental results that basketball players who underwent VR-based Quiet Eye training exhibited a 22% higher decision-making accuracy in stress tests compared to the traditional group, as well as improved heart rate variability (HRV), indicating

eISSN: 2462-2079 © Universiti Putra Malaysia Press
http://doi.org/10.47836/injet.11.2.01

enhanced autonomic nervous regulation in the athletes. Moreover, the stepwise difficulty design of VR training aligns with Bandura's self-efficacy theory (Mousavi et al., 2023), where real-time biofeedback systems help athletes visually track their progress, thereby enhancing their sense of self-efficacy. fMRI data shows that VR training significantly outperforms traditional training in enhancing the functional connectivity between the prefrontal cortex and the striatum, suggesting that VR training strengthens athletes' confidence in facing challenges (Arede et al., 2018). Consequently, VR training can also improve athletes' psychological resilience level.

LIMITATIONS

The limited sample size constrained the detection of significant training effects when comparing pre-test and post-test intervention measures. Nevertheless, the primary goal of this pilot study was to offer initial data to lay the foundation for a more systematic and standardised approach in future research. Therefore, to fully capitalise on potential training benefits, future studies should aim to lengthen the training duration.

i. Limitations of Sample Size

This experiment recruited only 19 participants (VRTG: n = 9; CTG: n = 10), a relatively small sample size that may have limited the study’s statistical power. The small sample size may limit the broader applicability of the results. The participants of this pilot study are randomly selected from qualified participants who can be used for formal experimental research. While factors such as participant selection criteria and time constraints contributed to this limitation, the sample size is consistent with similar studies in the field of sports science. Nonetheless, future studies should aim for a larger sample to enhance statistical power and minimise potential data inconsistencies.

ii. Length of the Intervention

The VR training intervention in this study lasted only two weeks, primarily due to time constraints and the competitive schedules of professional athletes. Generally, two weeks of intervention may be insufficient to fully capture the long-term effects of training adaptations. Since psychological resilience is a complex trait, an athlete's resilience may be influenced by other external factors, such as prior mental training, personal experiences, and natural variations in stress responses. A short-term training intervention may not provide enough time for the athlete to internalize the training outcomes and reflect them in their actual performance (Kalisch et al., 2021). While virtual reality training helps simulate scenarios, it may not fully replicate the uncertainty and pressure experienced in real-life competition. Athletes may require longer periods of virtual training and real-world competitive experience to develop the psychological resilience needed to cope with high-pressure situations (Qian et al., 2020). Therefor, future research should extend the intervention duration to observe more robust and sustained training effects, particularly in basketball tactical performance.

iii. Limitations of the Study Population

The study population consisted of professional basketball athletes recruited under controlled conditions from Jinan, Qingdao, Yantai, and Weihai in Shandong Province, China. While the homogeneity of the sample helped standardise training variables, it may limit the broader applicability of the results to other athlete populations (e.g., different skill levels, sports disciplines, or age groups). Therefore, the results of this study are not applicable to amateur and non professional athletes. Future studies should expand the participant pool to include a more diverse range of athletes to assess the generalizability of VR training effects across different contexts.

CONCLUSION

The results of this study indicated that after 2 weeks of training intervention, there was a significant improvement in psychological resilience in both VRTG and CTG during the post-test. However, compared to traditional training, VR training had a more substantial effect on improving psychological resilience among professional basketball players.

When designing virtual reality (VR) training programs to enhance athletes' psychological resilience, it is essential to consider the individual psychological profiles and specific stressors that athletes encounter during competition. Compared to traditional training, VR training, with its immersive and controlled environment, offers a unique platform for athletes to experience and manage high-pressure scenarios in a safe and controlled space. Through real-time feedback and scenario simulations, VR training enables athletes to regulate their emotional responses better and enhance their ability to perform under stress. This personalised approach not only avoids the limitations of traditional training methods, which often fail to simulate real-world pressure, but also enhances athletes' self-efficacy and coping mechanisms when faced with adversity. As a result, VR training offers promising new strategies for optimising psychological resilience and boosting athletes' overall performance. However, it is essential to note that while VR training demonstrates significant improvements in psychological resilience, short-term interventions (such as 2 weeks) may still require additional time to achieve long-lasting effects. This finding highlights the importance of extended training periods in fully developing athletes' psychological adaptability. Future research could investigate the impact of longer VR training interventions and explore how different levels of pressure and scenario complexities impact the development of psychological resilience in athletes

ACKNOWLEDGEMENTS
No funding was provided to support this project.

CONFLICT OF INTEREST
The authors declare that there are no conflicts of interest.

AUTHOR CONTRIBUTIONS
All authors contributed equally to the conception and writing of the manuscript.

DATA AVAILABILITY STATEMENT
The datasets used and analysed in this study are available from the corresponding author upon reasonable request.

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