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Virtual Reality Training for Reducing Technical and Tactical Asymmetry among Professional Basketball Players: A Pilot Study

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ABSTRACT

Asymmetry in technical and tactical abilities among basketball players limits overall performance, increases injury risk, and affects long-term athletic development. This study explored the potential of virtual reality training to reduce asymmetric performance among professional basketball players in Shandong, China. A cluster randomized controlled trial was employed to compare virtual reality–based training with conventional asymmetric training. Measurements of technical and tactical abilities were conducted before and after the intervention using validated instruments. The findings revealed that virtual reality training effectively reduced asymmetry in technical abilities, whereas both training methods contributed to improvements in tactical abilities. The results highlight the capacity of virtual reality to enhance motor coordination, cognitive adaptation, and learning efficiency. The study provides initial evidence supporting the integration of virtual reality into athlete development programs, offering innovative approaches for improving technical balance and advancing digital transformation in professional sports training.

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1. INTRODUCTION

Approximately 60 to 75% of professional basketball players worldwide experience pronounced technical and tactical asymmetry, particularly in critical areas such as dribbling, shooting, and defence (Sirnik *et al*., 2022). The asymmetry of technical and tactical abilities (i.e., the imbalance in an athlete's execution of skills or tactical understanding between the left and right sides) has emerged as a critical factor constraining basketball players' overall performance (Versic *et al*., 2021; Bishop *et al*., 2018). Evidence indicates that the asymmetry level of Chinese professional basketball players is 15%–20% higher than that observed among NBA athletes, particularly in critical domains such as dribbling and defensive play, where rapid decision-making is essential (Fort- Vanmeerhaeghe *et al*., 2016). One of the key factors contributing to the gap between Chinese and global basketball players is that Chinese athletes primarily rely on traditional asymmetric training methods, which lack objectivity and targeted interventions (Wang *et al*., 2022). Traditional asymmetric training often relies on fixed patterns and repetitive exercises. Due to space and personnel limitations, it is difficult for Chinese basketball players to experience dynamic changes similar to those in real game scenarios during training.

In recent years, virtual reality technology has garnered attention due to its unique advantages. For example, over 80% of NBA teams have integrated VR training systems, which have significantly reduced asymmetry in athletes' non-dominant side skills by 30-40% (see https://www.nba.com/technology/vr-report). However, the application of VR training in Chinese basketball teams is still in its early stages, and its effectiveness and optimisation strategies require systematic research (Wang *et al*., 2022). Under this background, this study aims to investigate the effect of virtual reality training on the asymmetric levels of technical and tactical abilities among Chinese professional basketball players. By integrating asymmetric training methods for basketball skills and tactics into VR external devices and embedded software, the research is expected to provide scientific evidence and practical guidance for the innovation and optimisation of the Chinese basketball training system, ultimately helping to improve China's standing in international basketball competitions.

2. LITERATURE REVIEW

Virtual Reality (VR), characterised as a highly immersive and interactive computer-simulated environment, has emerged as a transformative tool in contemporary sports training. Compared with traditional on-court practice, VR interventions offer distinct advantages in terms of controllability and repeatability, allowing the reproduction of complex in-game scenarios and high-pressure confrontations without exposing athletes to additional risks of physical injury (Chang *et al*., 2024; Putranto *et al*., 2023). Within such simulated settings, basketball players can repeatedly rehearse core technical skills such as shooting, dribbling, and defensive switching, while simultaneously engaging in tactical decision-making and spatial positioning tasks in structured game-like contexts (Li, 2021). Beyond the technical dimension, VR has the capacity to integrate physiological and psychological feedback mechanisms, providing athletes with real-time data monitoring and objective performance assessments (Zhang *et al*., 2021). This integration not only facilitates the correction of technical errors but also strengthens tactical execution, enhances neuromuscular coordination, and reduces the risk of injury associated with fatigue or high-intensity gameplay (Cossich *et al*., 2023). Consequently, VR in basketball interventions extends beyond being a supplementary method for technical and tactical training; it represents a cutting-edge pedagogical strategy that fosters comprehensive cognitive development and optimises athletes' adaptability to competitive conditions (Abich *et al*., 2021).

Existing studies have demonstrated that VR training exerts a positive impact on basketball players' technical and tactical abilities. A four-week VR intervention effectively enhanced emotional regulation among collegiate basketball players while significantly improving shooting accuracy (Wei *et al*., 2022). Similarly, other researchers (Huang, 2019) experimentally verified the applicability of VR training in university basketball contexts, noting that six weeks of VR training not only improved fundamental skills, such as shooting, passing, and tactical coordination, but also strengthened tactical awareness, reaction speed, and decision-making accuracy under high-pressure, competitive conditions. In addition, four weeks of VR training substantially improved tactical responsiveness and decision-making in basic tactical scenarios involving 2–5 players among collegiate basketball players (Pagé *et al*., 2019). Furthermore, the NBA Technology Report (Xie *et al*., 2021) emphasised that the widespread adoption of VR within professional basketball clubs has become a growing trend, demonstrating effectiveness in offensive tactical simulations, defensive rotation drills, and complex tactical variation rehearsals. However, several scholars have cautioned that the benefits of short-term VR interventions may be limited, as training outcomes are not always internalised into long-term competitive performance. This highlights the necessity for more extended intervention periods and more systematic training designs (Lanier *et al*., 2019).

3. METHODS

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

The inclusion criteria were:

(i) Professional basketball players.
(ii) Participants must have at least one year of training background at the Shandong Basketball Training Centre and have signed a legal professional athlete contract with the Shandong Provincial Sports Bureau.
(iii) Participants must have participated in the Chinese national team selection competition for basketball in Shandong Province.

Exclusion criteria included:

(i) Participants have high levels of asymmetry due to congenital physical dysplasia (Smith, 2020).
(ii) History of sports injuries within the past year and continuous treatment.
(iii) Participants who cannot complete the entire experimental training due to participating in the professional competition schedule.
(iv) Electromagnetic Hypersensitivity (EHS) symptoms may occur when using electronic devices.

The Ethics Review Committee of Yantai Ruichen Medical Equipment Company granted ethical clearance. During the course of the intervention, participants were instructed to abstain from any supplementary training activities and to adhere to their regular dietary habits, which were systematically monitored and recorded by the research team. Ongoing evaluations were conducted throughout the intervention period to assess both its feasibility and overall effectiveness.

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 ± 3.12 years, and for the CTG, it was 21.57 ± 3.20 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 respective mean training background was as follows: VRTG, 20.700 ± 3.100 months; CTG, 21.100 ± 2.800 months.

To determine the optimal virtual reality training program for evaluating the asymmetric levels of technical and tactical abilities among professional basketball players, the FITT (frequency, intensity, time, and type) principle was incorporated to maximise performance outcomes during the virtual reality training intervention.

The accuracy and structured design of training interventions are essential for improving athletes' technical and tactical abilities. Virtual reality (VR) training requires the integration of advanced cognitive and motor functions. In this study, professional coaches and technical staff oversaw the implementation of the training programme to guarantee its uniform application and overall effectiveness. Before the commencement of the intervention, participants were thoroughly briefed on the training procedures. They completed a series of baseline assessments, which included evaluations of asymmetry in technical and tactical abilities. All preliminary data were collected and analysed before the initiation of the intervention.

Participants were allocated into two groups: the Virtual Reality Training Group (VRTG) and the Conventional Training Group (CTG), both of which adhered to an identical intervention schedule. The programme extended over two weeks, consisting of three training sessions per week, each lasting approximately 35 minutes. This amounted to a total of 105 minutes of weekly training. Exercise intensity was set at a moderate level and was progressively adjusted according to participants' levels of adaptation. Adequate intervals for rest and structured feedback were incorporated throughout to ensure the consistency and effectiveness of the intervention.

Each training session was structured into three stages: warm-up, asymmetric skill training focusing on basketball technical and tactical training. Throughout the intervention, both the VRTG and the CTG were supervised by two national-level basketball coaches, two researchers experienced in VR systems, and two doctors specialising in sports physiology. For the VRTG, participants were required to wear designated VR equipment and remain on a fixed training platform during the entire session. Upon completion of training, all VRTG participants underwent follow-up monitoring to detect any potential side effects.

(i) Warm-up (5 minutes): The session began with a dynamic stretching routine designed to prepare participants for the upcoming intervention. Both groups performed the same warm-up sequence, which incorporated high knee running, lateral shuffling, basic basketball movement drills, shoulder mobility exercises specific to basketball, hip activation exercises, reactive footwork drills, and visual tracking exercises.

(ii) Basketball technical asymmetric training (15 minutes): Training focused on correcting asymmetry in fundamental technical skills and strengthening the non-dominant side techniques to perform composite techniques under defensive pressure effectively.

(iii) Basketball tactical asymmetric training (15 minutes): This encompassed training in tactical spatial positioning, coordination of left and right balance in tactics, and exercises with randomly varied tactical scenarios.

(iv) Side effect monitoring: Participants in the VRTG were assisted by doctors, coaches, and researchers in completing the Simplified Virtual Reality Discomfort Self-Assessment Scale.

(v) Training environment control: The VRTG participants completed all training sessions in a controlled indoor environment, where the temperature, lighting, and sound were regulated to minimise distractions. This setup helped reduce external sensory interference and maintained the smooth functioning of the VR equipment. Meanwhile, the CTG participants trained in a basketball facility designed to closely resemble the VRTG training environment in terms of size and layout, ensuring minimal differences in spatial perception and movement flow.

Asymmetric level of technical and tactical abilities testing and evaluation is a basketball performance evaluation method created by International Basketball Players' Tutorials (IBPT). The testing required for this evaluation method includes the Asymmetric Basketball Technical Ability Levels Test and the Asymmetric Basketball Tactical Ability Levels Test. Previous research has extensively validated and established the reliability of these tools, ensuring their credibility for use in the study (Tannoubi *et al*., 2023).

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 the asymmetry of basketball technical and tactical levels, a longitudinal analysis was conducted using a generalised estimating equation (GEE) model.

4. RESULTS AND DISCUSSION

4.1. Primary Outcomes

The Content Validity Index (CVI) is widely used to evaluate the validity of measurement content. In this study, to ensure the reliability and accuracy of the items, a panel of eight experts specialising in the relevant research areas was formed to assess the content validity of the intervention components. The content validity indices (CVI) for all items in this study fell within the acceptable range (CVI = 0.875 and Kappa = 0.732–0.871), confirming that the intervention programme exhibited high content validity. **Table 1** provides the detailed data.

Table 1. Correlation and consistency of asymmetric basketball technical and tactical levels.

Variables	Measurement Method	Number in Agreement	Clarity	
			I-CVI	KAPPA
Asymmetric level of basketball technical	Asymmetric basketball technical abilities levels test	7	0.875	0.732
Asymmetric level of basketball tactical	Asymmetric basketball tactical abilities levels test	7	0.875	0.871

4.2. Statistical Analysis

The review of literature on athlete training highlights that reliability is typically assessed using three primary methods: test-retest reliability, alternate-form reliability, and internal consistency. The latter examines how effectively the items within a tool work together as a cohesive construct (Bolarinwa, 2015). Since the test-retest method is considered a low-risk and straightforward approach (Kimberlin *et al*., 2008), this study adopted it as an effective method to assess the reliability of the measurement tools through repeated assessments. Based on Fleiss' guidelines, an Intraclass Correlation Coefficient (ICC) greater than 0.40

indicates that reliability falls within a fair to good range (Koo *et al*., 2016). The findings demonstrated that the ICC values for all testing methods were above 0.800, indicating that all methods exhibited high reliability. The detailed data are shown in **Table 2**.

Table 2. Results of the reliability of measurement tools.

Variables	Items	Intra-class Correlation Coefficient
Asymmetric basketball technical abilities levels test	CTABWSL	0.905
Asymmetric basketball tactical abilities levels test	CTABWSPOD	0.895

Note. CTABWSL, comparison of technical abilities between weak and strong limbs; CTABWSPOD, comparison of tactical abilities between weak and strong positions in offence and defence.

This study employed the Generalised Estimating Equation (GEE) approach to evaluate the effects of VR training on the asymmetric level of technical and tactical abilities among professional basketball players in China. GEE analysis was performed on the pre-test and post-test data to examine differences in asymmetric technical and tactical levels both between and within groups. Descriptive statistics for the asymmetric basketball technical and tactical levels are presented in **Table 3** (marginal means and standard errors).

Table 3. Descriptive statistics of the asymmetric level of basketball technical and tactical abilities of each group in different periods.

Variables	Time	VRTG Mean (Standard)	CTG Mean (Standard)
Asymmetric basketball technical abilities levels test	**Pre-test**	13.236 (0.297)	13.307 (0.312)
	Post-test	12.566 (0.316)	13.112 (0.323)
Asymmetric basketball tactical abilities levels test	**Pre-test**	14.156 (0.382)	13.869 (0.365)
	Post-test	13.631 (0.401)	13.817 (0.379)

Note. 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 asymmetric basketball technical levels (Wald $\chi^2 = 2.400$, $p < 0.001$) and asymmetric basketball tactical levels (Wald $\chi^2 = 4.320$, $p < 0.001$) were statistically significant. The findings of this study also showed that both asymmetric basketball technical levels (Wald $\chi^2 = 760.531$, $p < 0.001$) and asymmetric basketball tactical levels (Wald $\chi^2 = 1685.615$, $p < 0.001$) were found to be significant over time. Additionally, the statistical analysis revealed a significant interaction effect of asymmetric basketball technical levels (Wald $\chi^2 = 120.893$, $p < 0.001$) and asymmetric basketball tactical levels (Wald $\chi^2 = 151.746$, $p < 0.001$) between group and time. Results indicated significant improvements across all groups from pre-test to post-test. The details are presented in **Table 4**.

Regarding the asymmetric basketball technical abilities levels test, analysis revealed a statistically significant difference between the pre-test and post-test intervention measurement ($p < 0.001$) in VRTG. In CTG, the differences in asymmetric basketball technical abilities levels test between the pre-test and post-test were found to be significant ($p = 0.033$). The findings of this study indicated that, although two weeks of VR training and traditional training can both significantly reduce the asymmetric level of professional basketball players' technical abilities, the effect of VR training (VRTG) is superior to that of traditional asymmetric training (CTG). **Table 5** shows the more detailed data.

Table 4. Results of GEE on the asymmetric basketball technical and tactical abilities levels test.

Variables	Source	Wald-Chi Square	df	p-value
Asymmetric basketball technical abilities levels test	Group	2.400*	1	<0.001
	Time	760.531*	2	<0.001
	Group*Time	120.893*	2	<0.001
Asymmetric basketball tactical abilities levels test	Group	4.320*	1	<0.001
	Time	1685.615*	2	<0.001
	Group*Time	151.746*	2	<0.001

Note. df: degree of freedom; *p<0.05 level of significance.

Table 5. Within-Group Comparison of Asymmetric Basketball Technical Abilities Levels Test 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	-0.525*	0.085	<0.001	-0.692	-0.358
CTG	Pre-test	Post-test	-0.052*	0.078	0.033	-0.205	0.101

Note: * Mean difference is significant at the 0.05 level.

For the asymmetric basketball tactical abilities levels test, the VRTG test showed significant differences between the pre-test and post-test (p = 0.021). Meanwhile, there were substantial differences between the pre-test and post-test (p = 0.035) in CTG. Therefore, the results of this study showed that two weeks of VR training (VRTG) and traditional asymmetric training (CTG) can significantly reduce the asymmetric level of tactical abilities among professional basketball players (See **Table 6**).

Table 6. Within-Groups Comparison of Asymmetric Basketball Tactical Abilities Levels Test 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	0.673*	0.136	0.021	0.259	0.791
CTG	Pre-test	Post-test	0.439*	0.122	0.035	0.187	0.563

Note: * Mean difference is significant at the 0.05 level.

To explore differences in asymmetric basketball technical ability levels between the two groups over time (pre-test and post-test), a post hoc test (Bonferroni) comparison was conducted. The results of this study showed that there were no differences in the asymmetric level of basketball technical abilities between VRTG and CTG at the pre-test (p = 0.622). However, there were significant differences between VRTG and CTG at post-test (p = 0.002) in the asymmetric basketball technical abilities levels test. Therefore, compared to traditional training, 2 weeks of VR training had more significant effects on reducing the asymmetric level of technical abilities among Chinese professional basketball players. **Table 8** provides the details.

The results of the asymmetric basketball tactical abilities levels test indicated that there were no differences between VRTG and CTG in the asymmetric level of basketball tactical abilities at pre-test (p = 0.185). Meanwhile, there was also no statistically significant difference between VRTG and CTG at post-test (p = 0.392) in the asymmetric basketball tactical abilities levels test. The findings of this study showed that there was no significant difference in the comparison between groups of the effects of two weeks of VR training and traditional training on reducing the asymmetric level of tactical abilities among Chinese professional basketball players. Table 9 shows more detailed information.

Table 8. Between-Groups Comparison of Mean Score for the Asymmetric Basketball Technical Abilities Levels Test at Two Times.

Variable	Time	Mean Difference (VRTG-CTG)	SE	p-value	95% CI for Difference	
					Lower	Upper
Asymmetric Basketball Technical Abilities Levels Test	Pre-test	-0.071	0.143	0.622	-0.351	0.209
	Post-test	-0.546*	0.151	0.002	-0.842	-0.251

Note. * Mean difference is significant at the 0.05 level.

Table 9. Between-Groups Comparison of Mean Score for Asymmetric Basketball Tactical Abilities Levels Test at Two Times.

Variable	Time	Mean Difference (VRTG-CTG)	SE	p-value	95% CI for Difference	
					Lower	Upper
Asymmetric Basketball Tactical Abilities Levels Test	Pre-test	0.287	0.216	0.185	0.137	0.711
	Post-test	0.186	0.217	0.392	0.612	0.240

Note. * Mean difference is significant at the 0.05 level.

4.3. Discussion

The findings of this study indicate that after 2 weeks of training intervention, both the VRTG and CTG groups showed significant improvements in basketball technical and tactical performance. However, compared to traditional asymmetric training, the effect of virtual reality training on reducing the asymmetric level of technical abilities among professional basketball players was more significant. In addition, in the between-group comparison, there was no significant difference in the effect of 2 weeks of VR training and traditional training on reducing the asymmetric level of tactical abilities among professional basketball players. Existing studies have suggested that VR training can activate the mirror neuron system of the bilateral motor cortex, accelerating the development of neural plasticity control in the non-dominant side muscles. The findings of this study further support the results of the previous research.

Previous research had shown that traditional asymmetric training is limited by fixed patterns and subjective coach interventions, making it challenging to provide athletes with immediate feedback and personalised adjustments. This lower training efficiency leads to a lack of precise correction in technical details (Delextrat *et al*., 2014). Research on virtual reality training indicated that through immersive experiences and real-time multisensory feedback, athletes can precisely adjust their technical movements and quickly master skills on the non-dominant side in high-pressure simulated environments (Zeng *et al*., 2022). Meanwhile, the more specific studies have also shown that the high-fidelity environment of virtual reality training, by simulating the pressures of real-game scenarios, allows athletes to become aware of the asymmetries between their dominant and non-dominant side movements in a shorter period compared to traditional training (Zhang *et al*., 2024; Moro *et al*., 2017). Therefore, these findings further support the conclusion of this study, demonstrating that 2 weeks of VR training can significantly reduce the asymmetric level of technical abilities among professional basketball players when compared to traditional asymmetric training.

The improvement of tactical abilities involves a complex process of integrating cognition and action, requiring athletes to quickly recognise, decide, and execute tactical coordination in dynamic environments (Niu *et al*., 2023). Although VR training can provide highly realistic tactical implementation scenarios, a systematic review indicated that short-term tactical training lasting less than 4 weeks can only affect declarative memory, meaning it allows athletes to understand how to implement tactics, but does not fully transform this into procedural memory that enables the automation of tactical execution (Xie *et al*., 2021). Traditional basketball tactical training and field practice can effectively enhance tactical cognition in the short term. Unlike technical abilities, tactical execution in basketball requires dynamic coordination among multiple players (Fox *et al*., 2023). While the 3D perspectives simulated by VR technology can enhance spatial awareness, athletes require some time to adjust from the real-world perspectives of traditional tactical training to the simulated ones. This adjustment typically requires a training period of more than 4 weeks to stabilise. Consequently, this also lengthens the time required for VR training to influence basketball players' tactical decision-making and judgment effectively (Warnier *et al*., 2020).

Furthermore, the "stereotyped effect" of traditional training methods remains notably significant in the short term. Traditional training continues to effectively maintain tactical learning outcomes through tactical board exercises and real-world practice (Arede *et al*., 2018). This further supports the notion that static explanations on the tactical board can effectively consolidate short-term memory, while fundamental interactions with actual athletes compensate for the short-term lack of social presence in VR training (Warnier *et al*., 2020). These findings align with the conclusion of this study, which showed that, after 2 weeks of training intervention, VR training did not significantly reduce the asymmetric level of tactical abilities among professional basketball players compared to traditional asymmetric training.

The small sample size limited the ability to detect significant effects of the training when comparing pre-test and post-test results. However, the main objective of this pilot study was to provide preliminary data that can serve as a foundation for more structured and standardised research in the future.

This pilot study only involved 19 participants (VRTG: n = 9; CTG: n = 10), which is a relatively small sample size and could have reduced the statistical power. This limitation may affect the generalisability of the findings. However, future research should aim for a larger cohort to improve statistical power and reduce potential inconsistencies in the data.

The virtual reality training program used in this study was limited to two weeks, primarily due to time limitations and the demanding schedules of professional athletes. Nonetheless, the study found that even a brief period of VR training has a significant impact on reducing the asymmetric technical and tactical abilities levels of professional basketball players. Future studies should consider extending the intervention period (e.g., 4–8 weeks) to explore more sustained and robust training outcomes.

5. CONCLUSION

The results of this study indicated that after 2 weeks of training intervention, there was a significant reduction in the asymmetric level of basketball technical and tactical abilities in both VRTG and CTG during the post-test. However, compared to traditional asymmetric training, VR training had a more significant effect on reducing the asymmetric level of technical abilities among professional basketball players. In addition, in the between-group comparison, there was no significant difference in the effect of 2 weeks of VR training and traditional training on reducing the asymmetric level of tactical abilities among professional basketball players. These findings indicate that although VR training demonstrates significant advantages in the asymmetric level of basketball technical, further research is needed to explore the effect of varying durations of VR training interventions on the asymmetric level of technical and tactical abilities among basketball players. Additionally, VR training programs should be optimised to address specific training objectives.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Abich, J., Parker, J., Murphy, J. S., and Eudy, M. (2021). A review of the evidence for training effectiveness with virtual reality technology. *Educational Technology Research and Development, 69*(9), 2781- 2799.

Arede, J., Vaz, R., Franceschi, A., Gonzalo-Skok, O., and Leite, N. (2018). Effects of a combined strength and conditioning training program on physical abilities in adolescent male basketball players. *The Journal of Sports Medicine and Physical Fitness*, *59*(8), 1298-1305.

Bishop, C., Turner, A., and Read, P. (2018). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*, *36*(10), 1135-1144.

Bolarinwa, O. A. (2015). Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Nigerian Postgraduate Medical Journal*, *22*(4), 195-201.

Chang, A. A., Kazemi, E., Esmaeili, V., and Davies, M. S. (2024). The effectiveness of virtual reality training: a systematic review. *Journal of Organizational Behavior Management*, *44*(3), 214-232.

Cossich, V. R., Carlgren, D., Holash, R. J., and Katz, L. (2023). Technological breakthroughs in sport: current practice and future potential of artificial intelligence, virtual reality, augmented reality, and modern data visualization in performance analysis. *Applied Sciences*, *13*(23), 12965.

Delextrat, A., and Martinez, A. (2014). Small-sided game training improves aerobic capacity and technical skills in basketball players. *International Journal of Sports Medicine*, *35*(05), 385-391.

Fort-Vanmeerhaeghe, A., Gual, G., Romero-Rodriguez, D., and Unnitha, V. (2016). Lower limb neuromuscular asymmetry in volleyball and basketball players. *Journal of Human Kinetics*, *50*, 135.

Fox, K. T., Pearson, L. T., and Hicks, K. M. (2023). The effect of lower inter-limb asymmetries on athletic performance: A systematic review and meta-analysis. *Plos One*, *18*(6), e0286942.

Huang, C., Zhang, Y., Zhu, C., Zhang, C., Meng, H. (2019). Chinese sports basketball teaching tactics training system combined with multimedia interactive model and virtual reality technology. *Multimedia Aools and Applications, 12*(6), 1-15.

Kimberlin, C. L., and Winterstein, A. G. (2008). Validity and reliability of measurement instruments used in research. *American Journal of Health-system Pharmacy*, *65*(23), 2276-2284.

Koo, T. K., and Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155-163.

Lanier, M., Waddell, T. F., Elson, M., Tamul, D. J., Ivory, J. D., and Przybylski, A. (2019). Virtual reality check: statistical power, reported results, and the validity of research on the psychology of virtual reality and immersive environments. *Computers in Human Behavior, 100*, 70–78.

Li, H. (2021). Research on basketball sports training based on virtual reality technology. In *Journal of Physics: Conference Series*, 1992(3), 032047.

Moro, C., Štromberga, Z., and Stirling, A. (2017). Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education. *Australasian Journal of Educational Technology*, *33*(6), 1-10.

Niu, L., and Zhao, P. (2023). Reasons for China's men's basketball team's defeat in the 2023 World Cup and strategies for breaking through Liaoning. *Sports Science and Technolog*y, *3*(04), 111-116.

Pagé, C., Bernier, P. M., and Trempe, M. (2019). Using video simulations and virtual reality to improve decision-making skills in basketball. *Journal of sports sciences*, *37*(21), 2403-2410.

Putranto, J. S., Heriyanto, J., Achmad, S., and Kurniawan, A. (2023). Implementation of virtual reality technology for sports education and training: systematic literature review. *Procedia Computer Science*, *216*, 293-300.

Sirnik, M., Erčulj, F., and Rošker, J. (2022). Research of visual attention in basketball shooting: A systematic review with meta-analysis. *International Journal of Sports Science and Coaching*, *17*(5), 1195-1210.

Tannoubi, A., Ouergui, I., Srem-Sai, M., Hagan, J. E., Quansah, F., and Azaiez, F. (2023). Effectiveness of video modeling in improving technical skills in young novice basketball players: A quasi-experimental study. *Children*, *10*(4), 687.

Versic, S., Pehar, M., Modric, T., Pavlinovic, V., Spasic, M., Uljevic, O., and Sekulic, D. (2021). Bilateral symmetry of jumping and agility in professional basketball players: Differentiating performance levels and playing positions. *Symmetry*, *13*(8), 1316.

Wang, X., Han, B., Zhang, S., Zhang, L., Lorenzo Calvo, A., and Gomez, M. Á. (2022). The differences in the performance profiles between native and foreign players in the Chinese basketball association. *Frontiers in Psychology*, *12*, 788498.

Warnier, N, Lambregts, S., and Port, IV. D. (2020). Effect of virtual reality therapy on balance and walking in children with cerebral palsy: a systematic review. *Developmental Neurorehabilitation*, *23*(8), 502-518.

Wei, W., Qin, Z., Yan, B., Wang, Q. (2022). Application effect of motion capture technology in basketball resistance training and shooting hit rate in immersive virtual reality environment. *Computational Intelligence and Neuroscience, 2022*(1), 4584980

Xie, B., Liu, H., Alghofaili, R., Zhang, Y., Jiang, Y., Lobo, F. D., and Yu, L. F. (2021). A review on virtual reality skill training applications. *Frontiers in Virtual Reality*, *2*, 645153.

Zeng, J., Xu, J., Xu, Y., Zhou, W., and Xu, F. (2022). Effects of 4-week small-sided games vs. high-intensity interval training with changes of direction in female collegiate basketball players. *International Journal of Sports Science and Coaching*, *17*(2), 366-375.

Zhang, W., Chen, X., Xu, K., Xie, H., Chen, J., Zhu, Z., Ji, H., Li, D., and Sun, J. (2024). The potential of a targeted unilateral compound training program to reduce lower limb strength asymmetry and increase performance: a proof-of-concept in basketball. *Frontiers in Physiology*, *15*, 1361719.

Zhang, Y., and Tsai, S. B. (2021). Application of adaptive virtual reality with AI-enabled techniques in modern sports training. *Mobile Information Systems*, *2021*(1), 6067678.