KARYA ILHAM PUBLISHING
CONNECTING MINDS, BRIDGING IDEAS, INSPIRING READERS

Journal of Advanced Research in Social and Behavioural Sciences

Journal homepage:
https://karyailham.com.my/index.php/jarsbs/index
ISSN: 2462-1951

Effects of Digital Simulation Training and Balance Training on Technical Stability of University Curling Athletes

Guo Baoyu[1], Hamdan Mohd Ali[1,*]

[2] lFaculty of Education and Liberal Studies, City University Malaysia, Petaling Jaya, 46100, Malaysia

ARTICLE INFO

Article history:
Received 1 May 2026
Received in revised form 6 Jun 2026
Accepted 20 July 2026
Available online 12 August 2026

Keywords:

Digital simulation training; balance training; curling athletes; technical stability; sports training

ABSTRACT

Curling is a technically demanding Winter Olympic sport that requires solid teamwork, balance and standardized movements, with technical stability crucial to competition performance. Traditional on-ice training is limited by venues, seasons and high costs, making repeated practice and timely error correction difficult, and may even fix faulty movement habits. Separate balance training can improve physical control but cannot target sport-specific skills.This study adopted multiple research methods and conducted a 12-week intervention on 40 university curling athletes divided into four groups. The results revealed that single virtual simulation or balance training both effectively boosted athletes' technical stability. Combined training achieved far better outcomes than single and traditional training. Balance ability positively moderated the conversion of virtual training effects to real-game performance and narrowed the gap between virtual and on-ice movements. The two training approaches complement each other. This research finally establishes a targeted integrated training plan, offering references for optimizing curling training and enhancing athletes' competitiveness.Keywords: virtual simulation training; balance training; university curling athletes; technical stability; sports intervention experiment.

1. Introduction

With the vigorous development of ice and snow sports worldwide, curling has gained growing popularity among college students and become a key event in campus sports programs. Different from high-intensity winter sports, curling relies heavily on stable postures, accurate movements and consistent techniques [2]. Slight body shaking or center-of-gravity deviation will change the trajectory of curling stones and lead to competition failures. Therefore, technical stability is the core competency for all curling athletes [13].

* *Corresponding author.*
E-mail address: hamdan.mhdali@city.edu.my

https://doi.org/10.37934/arsbs.45.1.202207

Traditional on-ice curling training faces prominent restrictions including high venue costs, seasonal limits and uncontrollable ice conditions. Athletes have insufficient chances to repeat movements and receive timely error correction, which easily results in fixed incorrect motor patterns [4]. Meanwhile, many university curling teams focus merely on technical drills and ignore systematic balance training. Deficient static and dynamic balance is a major cause of movement distortion during long competitions [14,15].

In recent years, digital simulation technology represented by virtual reality and motion capture has been widely applied in precision sports training. It can build immersive virtual ice rinks, collect real-time movement data and realize visualized error correction [9]. Foreign curling teams have combined virtual simulation and balance training to improve training efficiency, while most domestic universities use the two methods separately [10]. Based on experimental data, this paper discusses the synergistic mechanism of the two training modes and proposes feasible training plans for university curling teams.

2. Research Method

2.1 Literature Research Method

The author retrieved domestic and foreign journals, dissertations and research reports about curling training, virtual simulation, balance ability and technical stability from multiple academic databases. Relevant theories, experimental schemes and research conclusions were sorted out. This method clarified the theoretical basis of the research and defined testing indicators and intervention standards [12].

2.2 Experimental Method

This study adopted a controlled experimental design. A total of 40 university curling athletes aged 18 to 22 with 1 to 3 years of training experience were selected. They were randomly divided into four groups with 10 members in each group: Group A (digital simulation group), Group B (balance training group), Group C (combined training group) and Group D (traditional control group). The experiment lasted for 12 weeks, with four 90-minute training sessions per week.

Group A received 60 minutes of digital simulation training plus stretching. Group B took 60 minutes of specialized balance training plus stretching. Group C conducted 35 minutes of simulation training and 25 minutes of balance training. Group D maintained regular on-ice training. Tests were implemented before the experiment, in the 6th week and the 12th week respectively.

2.3 Testing Method

Two categories of indicators were tested. Balance indicators included single-leg static balance duration and multi-axis dynamic balance score. Technical stability indicators contained average trajectory deviation of 10 deliveries, delivery error times and sweeping movement consistency score [7].Three professional curling coaches completed all tests and scoring to guarantee data reliability.

2.4 Mathematical Statistics Method

Excel was used to organize raw data. SPSS 26.0 was adopted for descriptive statistics, paired-samples t-test and one-way ANOVA. The significance level was set at $P < 0.05$, and the extremely significant level was set at $P < 0.01$.

3.Results and Discussion

3.1 Pre-Experiment Data Analysis

Before the intervention, there was no significant difference among the four groups in age, training experience, static balance, dynamic balance, delivery deviation and sweeping performance ($P > 0.05$). The grouping was reasonable and the experimental conditions were consistent, which ensured the validity of follow-up comparative analysis.

3.2 Changes in Balance Ability after Intervention

After 12 weeks of training, Group D showed slight improvement in balance indicators without statistical significance ($P > 0.05$). Traditional on-ice training had limited effects on enhancing sport-specific balance. Group A's balance indicators increased mildly ($P > 0.05$), proving that pure digital simulation could not effectively improve physical balance control [3,11].

Group B achieved significant growth in static and dynamic balance ($P < 0.05$). Specialized balance training was the most direct way to improve athletes' body control. Group C obtained the largest improvement with extremely significant differences ($P < 0.01$). Standard movements practiced in virtual training helped athletes maintain correct postures during balance drills, thus generating auxiliary reinforcement effects.

3.3 Changes in Technical Stability after Intervention

3.31 Delivery performance

Delivery is the core technique of curling. After the experiment, Group D's delivery deviation and error times had no obvious changes ($P > 0.05$). Group A witnessed a significant drop in errors and trajectory deviation ($P < 0.05$). Digital simulation helped athletes consolidate standard delivery movements and reduce random mistakes [8]. Group B also had remarkable improvements ($P < 0.05$), which verified that good balance was the basic guarantee of accurate delivery.

Group C showed an extremely significant decrease in delivery errors and deviation ($P < 0.01$). Its performance was far better than other groups, which fully reflected the prominent synergistic effect of combined training.

3.3.2 Sweeping performance

Sweeping is a typical dynamic movement requiring continuous balance during movement. Group A's sweeping consistency score improved slightly ($P > 0.05$). The virtual environment lacked real ice friction and dynamic load, leading to movement distortion in real practice [6]. Group B's score increased significantly ($P < 0.05$), but the improvement was restricted by inherent incorrect movements. Group C achieved the most outstanding results ($P < 0.01$). Virtual training standardized movements and balance training ensured dynamic stability, so the two defects were well solved.

3.4 Comprehensive Analysis of Training Modes

3.4.1 Advantages and limitations of single digital simulation training

Digital simulation training breaks venue and seasonal limits. It uses motion capture and big data to record movement details, conduct repeated drills and realize instant error correction [5]. Its core

advantage lies in standardizing technical movements and strengthening motor memory. However, the virtual scene cannot simulate real ice conditions and dynamic center-of-gravity changes. Long-term separate use will cause disconnection between virtual practice and on-ice performance, especially for dynamic sweeping movements.

3.4.2 Advantages and limitations of single balance training

Balance is the fundamental physical quality for all curling techniques. Static balance supports stable delivery, while dynamic balance ensures the completion of continuous sweeping and variable-angle delivery [14]. Specialized balance training strengthens core muscle groups and center-of-gravity shifting ability. Nevertheless, it cannot correct athletes' formed incorrect movements. Even with improved balance, technical stability will reach a bottleneck.

3.4.3 Synergistic mechanism of combined training

Digital simulation solves the problem of non-standard movements, and balance training solves the problem of unstable postures. The two modes form a complementary system. Improved balance enables athletes to better replicate standard virtual movements on real ice and raise the conversion rate of virtual training. Standard movements also reduce extra physical burden caused by distorted postures and consolidate balance training effects. The combined training promotes technical stability from both technical and physical dimensions.

3.5 Practical Problems in Current Curling Training

Most university curling teams still rely on traditional on-ice training. They are faced with high costs and insufficient training time. The separation between technical training and physical training is common. Coaches either overemphasize on-ice drills while ignoring balance ability, or carry out physical training without targeted technical correction. In addition, many colleges have introduced digital training equipment but failed to match it with supporting physical training, resulting in low utilization of new technologies.

4. Conclusion

This 12-week intervention experiment drew the following main conclusions. First, single digital simulation training and single balance training can both significantly improve university curling athletes' technical stability ($P < 0.05$). The former focuses on movement standardization, and the latter focuses on posture control. Second, the combined training mode has an extremely significant synergistic effect ($P < 0.01$), which is superior to all single training and traditional training modes. Third, balance ability plays a positive moderating role. It is the key link to realize the transformation of virtual training effects. Fourth, traditional on-ice training has limited effects on improving athletes' balance and technical stability, and the training mode needs urgent optimization.

Based on the conclusions, targeted suggestions are proposed. Firstly, universities should establish the regular combined training mode of digital simulation plus balance training, and adopt the 35-minute simulation plus 25-minute training ratio for daily courses. Secondly, design hierarchical balance training content according to athletes' levels and genders. Beginners focus on static balance, while advanced students strengthen dynamic balance drills [1]. Third, optimize the application of digital equipment. Adopt the alternating mode of virtual practice and on-ice replication to narrow

the gap between virtual and real scenes. Fourth, reposition traditional on-ice training and take it as the carrier of tactical practice and team cooperation. Fifth, increase investment in digital sports equipment and organize professional training for coaches.

This research only selected athletes from a single university, and the sample size is limited. Follow-up studies can expand the research scope, extend the experimental cycle and explore differentiated training plans for male and female athletes.

Acknowledgement
The author sincerely thanks all curling athletes and coaches who participated in this experiment. Gratitude is also extended to all experts and peers who provided guidance during the research.

References

[1] Baoyu, Guo, and Mohd Rahimi Bin Che Jusoh. "Research on the Stability of Curling Athletes' Throwing Movements Based on Balance Ability Training." *Studies in Sports Science and Physical Education* 3, no. 2 (2025): 9-15.https://doi.org/10.56397/SSSPE.2025.09.02

[2] Bostancı, Özgür, and Hasan Yılmaz. "The Relationship Between Core Stabilization and Balance in The Curling Athletes." *Pakistan Journal Of Medical & Health Sciences* 15, no. 10 (2021). https://doi.org/10.53350/pjmhs2115103269

[3] Cariati, Ida, Roberto Bonanni, Pierangelo Cifelli, Giovanna D'Arcangelo, Elvira Padua, Giuseppe Annino, and Virginia Tancredi. "Virtual reality and sports performance: a systematic review of randomized controlled trials exploring balance." *Frontiers in Sports and Active Living* 7 (2025): 1497161. https://doi.org/10.3389/fspor.2025.1497161

[4] Daşkesen, Sonay Serpil, Deniz Bedir, Buket Şeran, Hasan Hüseyin Yılmaz, Ferhat Canyurt, Fatih Ağduman, Salih Çabuk, and Süleyman Ulupınar. "Comparison of Performance-Related Parameters of Hearing-Impaired and Non-Hearing-Impaired Curling National Team Athletes." *Journal of Sport Sciences Research* 11, no. 1 (2026): 183-196. https://doi.org/10.25307/jssr.1826758

[5] Friedrich, Mathilde Fogh. "Immersive training in ice hockey: Evaluating the impact of virtual reality on engagement, enjoyment, and motivation." *International Journal of Sports Science & Coaching* 20, no. 6 (2025): 2551-2560. https://doi.org/10.1177/17479541251343272

[6] Le Noury, Peter, Remco Polman, Michael Maloney, and Adam Gorman. "A narrative review of the current state of extended reality technology and how it can be utilised in sport." *Sports Medicine* 52, no. 7 (2022): 1473-1489.https://doi.org/10.1007/s40279-022-01669-0

[7] Li, Tianhe, Xiaoyao Wang, Zhiqiang Wu, and Yapu Liang. "The effect of stroboscopic vision training on the performance of elite curling athletes." *Scientific Reports* 14, no. 1 (2024): 31730.https://doi.org/10.1038/s41598-024-82685-0

[8] Li, Tianhe, Chiyue Zhang, Xiaoyao Wang, Xinai Zhang, Zhiqiang Wu, and Yapu Liang. "The impact of stroboscopic visual conditions on the performance of elite curling athletes." *Life* 14, no. 9 (2024): 1184.https://doi.org/10.3390/life14091184

[9] Michalski, Stefan C., Ancret Szpak, and Tobias Loetscher. "Using virtual environments to improve real-world motor skills in sports: a systematic review." *Frontiers in psychology* 10 (2019): 2159. https://doi.org/10.3389/fpsyg.2019.02159

[10] Richlan, Fabio, Moritz Weiß, Patrick Kastner, and Jeremias Braid. "Virtual training, real effects: a narrative review on sports performance enhancement through interventions in virtual reality." *Frontiers in Psychology* 14 (2023): 1240790. https://doi.org/10.3389/fpsyg.2023.1240790

[11] Witte, Kerstin, Dan Bürger, and Stefan Pastel. "Sports training in virtual reality with a focus on visual perception: a systematic review." *Frontiers in Sports and Active Living* 7 (2025): 1530948. https://doi.org/10.3389/fspor.2025.1530948

[12] Xiao, Wensheng, Te Bu, Junlong Zhang, Haogang Cai, Wuyi Zhu, Xiaorong Bai, Lin Zhang, and Soh Kim Geok. "Effects of functional training on physical and technical performance among the athletic population: a systematic review and narrative synthesis." *BMC Sports Science, Medicine and Rehabilitation* 17, no. 1 (2025): 2. https://doi.org/10.1186/s13102-024-01040-y

[13] Zacharias, Emily, Nicole Robak, and Steven Passmore. "An examination of studies related to the sport of curling: a scoping review." *Frontiers in Sports and Active Living* 6 (2024): 1291241. https://doi.org/10.3389/fspor.2024.1291241

[14] Zemková, Erika, and Ludmila Zapletalová. "The role of neuromuscular control of postural and core stability in functional movement and athlete performance." *Frontiers in physiology* 13 (2022): 796097.https://doi.org/10.3389/fphys.2022.796097

[15] Zhao, Peiting, Gaohui Zhu, Sha Chen, Yu Pan, Kai Chen, Li Huang, and Liya Guo. "Effects of aquatic exercise and floor curling on balance ability and lower limb muscle strength in children with intellectual disabilities: a pilot study in China." *Children* 11, no. 1 (2024): 85. https://doi.org/10.3390/children11010085