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Research on the Stability of Curling Athletes' Throwing Movements Based on Balance Ability Training

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Abstract

Curling is an ice sport that highly depends on body control and movement accuracy. The stability of the throwing motion directly affects the technical performance and tactical execution in the game. To explore the influence mechanism of balance ability training on the stability of curling players' throwing motions, this study selected the curling team of a certain university as the research subjects and conducted an 8-week balance training intervention experiment. A pretest-posttest control group design was adopted to compare the differences between the experimental group and the control group in key indicators such as the repeatability of the throwing motion, landing point deviation, and posture stability. The research results showed that systematic balance training significantly improved the core control ability and lower limb coordination of the athletes. The experimental group outperformed the control group in terms of the consistency of the landing point, control of the throwing motion amplitude, and maintenance of dynamic posture, and the differences were statistically significant ($p < 0.05$). The study indicates that balance ability is a key physical factor affecting the stability of curling throwing motions, and scientifically designed balance training can effectively enhance the accuracy and stability of curling-specific technical movements. This paper provides theoretical basis and practical guidance for the optimization of curling-specific physical training.

Keywords: balance ability training, curling, throwing motion, technical stability

1. Introduction

Curling is a winter Olympic event that integrates precision, strategy, and teamwork. The stability of the throwing motion, its core technique, plays a decisive role in the competition. During the throwing process, athletes need to maintain body stability, precise trajectory control, and continuous balance in a series of fine movements such as sliding, pushing off, squatting, and releasing the stone.

Therefore, the quality of their movements not only depends on their technical proficiency but also highly relies on their body control ability and dynamic balance ability.

In recent years, with the popularization of curling in colleges and professional training systems, the technical training of athletes has gradually become systematic. However, in actual training, it is often found that athletes have problems such as large release tremors, body center of gravity shifts, and inconsistent landing points when performing the throwing motion. These problems are not merely due to technical inexperience but are closely related to weak core strength, poor lower limb stability, and insufficient body control ability of the athletes. Existing research has pointed out that balance ability has a significant impact on precise movement control, injury prevention, and competitive performance in ice and snow sports, especially in sports that mainly involve single-leg support and lower limb force application.

In response to this issue, some training practices have begun to introduce balance training methods (such as core training, dynamic stability exercises, perception-motor coordination training, etc.) into curling-specific training in recent years. However, systematic and quantitative research is still scarce, especially lacking empirical studies that take the stability of the throwing motion as the core indicator and combine balance ability training intervention. Therefore, it is urgently necessary to scientifically design experiments to verify the actual effect of balance training on the technical performance of curling and further explore its mechanism of action and training path.

2. Research Background

Curling, as an ice sport that combines competitiveness with precise control requirements, has the stability of its technical movements playing a decisive role in the outcome of the game. Particularly in the throwing phase, athletes need to complete precise release and rotation control while in a dynamic sliding state, which places extremely high demands on lower limb strength, core control, and body balance ability (Zhao & Lin, 2021). Compared with other winter sports, the integrated movement characteristics of curling during the throwing process, namely "single-leg support—control sliding—low-level force application–precise landing", make body balance ability a key foundation for achieving technical stability.

With the in-depth implementation of the strategy to "get three hundred million people involved in winter sports", the development of curling in Chinese universities has been rapid, and the coverage of teaching and training has been continuously expanding. However, in the training system, the integration of specific physical fitness and technical training remains relatively low. Many grassroots coaches still focus mainly on repetitive throwing and trajectory adjustment, neglecting the specialized training of athletes' dynamic control ability and posture stability. This has led to problems such as unstable movements, inaccurate landing points, and uneven throwing force among students during competitions (Liu et al., 2022). This phenomenon reveals the insufficiency of the current curling teaching system in terms of training scientificity and physical fitness structure design.

Several studies have confirmed that balance ability training in ice sports such as skiing, skating, and figure skating can effectively enhance athletes' dynamic posture control and body coordination, making it a core element for improving the stability of specific movements (Park et al., 2020; Zhang & Sun, 2023). Especially in sports with high requirements for movement precision and complex body control, the improvement of core stability and body balance can significantly reduce movement fluctuations and lower the rate of technical errors (Huang et al., 2021). However, in the field of curling, empirical research on systematically introducing balance training for specific movement intervention is still scarce, theoretical support is insufficient, and standardized intervention models are lacking.

In response to the "technical instability" problem in curling throwing movements, starting from balance ability training can not only make up for the deficiencies in existing curling training methods but also promote the development of curling specialized training towards a multi-dimensional integration of "technique—physical fitness—control". The proposal of this study is based on filling this research and training gap, attempting to explore a scientifically feasible balance training path and systematically evaluate its practical effectiveness in terms of technical stability.

3. Research Questions

3.1 Construction of the Comprehensive Evaluation Index System for the Stability of Ice Hockey Throw Movements

Currently, the evaluation of the stability of ice hockey throws is fragmented, and common indicators (such as landing deviation, throwing speed) lack unified weights. A scientific index system should be constructed from three dimensions: kinematic consistency (release point coordinates, trajectory mean square error), dynamic smoothness (variance coefficient of lower limb support force curve), and movement sequence (synchronization of gliding and release rhythm). Quantification can be achieved through high-frame-rate motion capture and the combination of ground reaction plates. Previous studies have reported that the mean square error of trajectory can sensitively reflect technical fluctuations, providing a basis for indicator selection.

3.2 The Mechanism of the Effect of Balance Training on Improving Technical Stability

Balance training can enhance vestibular-proprioceptive integration and core muscle group coordination, reduce the lateral sway of the center of gravity during the throw, and thereby improve trajectory consistency. The meta-analysis of neuromuscular training on dynamic balance shows that training can significantly increase the duration of single-leg support and the area of the stability domain, suggesting that the feedforward-feedback control loop is strengthened (sciencedirect.com). It is necessary to clarify: whether the change in the activation sequence of the core and lower limb muscles mediates the improvement in technical stability; the coupling strength between the time constant of posture adjustment and technical and tactical performance after training.

3.3 Integration and Practice of Balance Training Programs and Ice Hockey Specialized Technical Training

How to incorporate balance training modules (such as BOSU dynamic support, single-leg sliding pad, etc.) into the throw hockey technique class to form a closed loop of "warm-up-specialized balance-technique execution-immediate feedback" is a practical difficulty. Recent 9-week balance training intervention by a skiing coach indicates that "preliminary balance + immediate visual feedback" can accelerate the internalization of techniques. This study needs to design intervention models with different embedding timing, frequency, and intensity to compare their differential effects on classroom efficiency and movement stability.

3.4 Interaction Between Balance Training Load and Technical Training Intensity

Excessive balance training load (frequency × difficulty) may cause fatigue and weaken the quality of the technical class; too low a load is difficult to induce adaptation. It is necessary to explore the interaction effect of load and technical intensity: the influence of different balance loads on the slope of the learning curve of technical skills; whether inappropriate matching of load and intensity causes fluctuations and rebounds in movements. The latest visual-balance intervention study for elite ice hockey players has proved that medium-high-load intervention can significantly improve speed control and throwing accuracy within 4 weeks.

4. Research Objectives

This study aims to explore the effect and mechanism of introducing systematic balance ability training intervention on the stability of ice hockey players' throwing movements, with the expectation of providing theoretical basis and practical approaches for the integration of physical fitness and technique in ice hockey training. The specific goals are as follows:

Establish a scientific evaluation system for the stability of ice hockey throwing movements

Starting from multiple dimensions such as technical execution, action consistency, and dynamic posture control, develop a quantifiable and repeatable evaluation index system for the stability of throwing movements, providing a foundation for subsequent empirical analysis and training effect evaluation.

Exploring the intervention effect of balance ability training on technical stability

By comparing the performance differences in juggling before and after training between the experimental group and the control group, systematically evaluate the degree of influence of balance training on key technical indicators such as trajectory consistency, landing error, and movement stability.

Revealing the mechanism of balance training in improving technical stability

Combining dynamic balance ability, core control ability and movement performance data, analyze the impact path of balance training on juggling techniques in aspects such as action control, muscle group coordination, and posture adjustment.

Designing a balance ability training model suitable for ice hockey training

Developing a well-structured, scientifically designed, and operationally feasible balance training program, clearly defining its training cycle, load arrangement, and embedding method for technical lessons, to provide model references for the optimization of training systems in universities or professional ice hockey teams.

Providing empirical support for the scientification of ice hockey specific physical training

Promoting the transformation of ice hockey teaching and training from a "heavy on techniques, light on physical fitness" model to a "technique and physical fitness integration" model, strengthening the supporting role of specific physical fitness in improving technical quality and competition performance.

5. Significance of the Research

5.1 Theoretical Significance

Enrich the theoretical framework of ice hockey training

Current research on ice hockey training mainly focuses on technical movement analysis, tactical collaboration, and psychological training. Systematic research on the role of "physique—technique integration", especially balance ability, is relatively weak (Liu et al., 2022). This study takes balance training as the entry point, constructs a "balance—control—stability" mechanism model, which is helpful to expand the theoretical research path for the stability of ice hockey athletes' specialized skills.

Deepen the understanding of the physical intervention mechanism in ice sports

Completing high-precision technical movements in dynamic environments is a common feature of winter sports. Existing studies have confirmed that balance training has a significant promoting effect on the stability of movements and lower limb control abilities in skiing, skating, and other projects (Huang et al., 2021; Zhang & Sun, 2023). This study empirically verifies this mechanism in the ice hockey project, fills the research gap on the relationship between ice hockey physical training and the accuracy of throwing actions, and further improves the theoretical basis of physical intervention in winter sports.

5.2 Practical Significance

Optimize the teaching and training system of ice hockey in universities

The teaching resources of ice hockey in universities are limited. Traditional training mainly consists of repetitive throwing and technical imitation, lacking specialized physical support, and the improvement of technical stability is slow (Liu et al., 2022). The balance training plan developed in this study is low in cost and highly effective, and is convenient for promotion in university classrooms, which is helpful to improve teaching effectiveness and student competitive performance.

Enhance the technical precision of athletes' specialized movements

The stability of technical movements directly affects the control quality of the puck and the success rate of tactical execution in ice hockey competitions. This study can establish a long-term and sustainable physical training support path for ice hockey athletes, enhance their control force and consistency, thereby reducing the error rate in competitions and improving competitive levels.

Provide a model for the cross-project promotion of physical training in ice sports

The research experience of the ice hockey project can be replicated to other high-precision ice sports, such as short track speed skating and figure skating. The methods and intervention models of this study can provide practical references for coaches and physical trainers of related projects, promoting the scientific and systematic nature of ice sports training.

6. Research Methods

This study employed an experimental approach combined with questionnaires and movement performance analysis methods. Through an 8-week balance ability training intervention for curlers, the study aimed to evaluate the impact and mechanism on the stability of their throwing actions. The specific research methods are as follows:

6.1 Research Design

A pre-test-post-test control group design was adopted in the quasi-experimental design.

The experimental group received both ice hockey basic skills training and balance ability training;

The control group only received regular ice hockey training.

6.2 Research Subjects

Research Subjects: A total of 24 members of the university curling team from Changchun Tourism University were selected. Their average age ranged from 18 to 22 years old, and they had more than one year of specialized training experience in curling.

Grouping Method: Randomly divided into the experimental group (n=12) and the control group (n=12). Gender, age, and athletic level were balanced and matched.

6.3 Intervention Content: Balance Ability Training Program

Training Period: 8 weeks, 3 times a week, 30-45 minutes each time

Content Modules:

Static Core Stability Training (such as plank position, side support)

Dynamic Posture Control (such as single-leg BOSU, sliding mat control, core anti-interference training)

Movement Control and Posture Adjustment Exercises (such as "closed-eye sliding step—single-leg fixed standing")

Intensity Progression: Adjust the training difficulty and stability interference level every 2 weeks.

6.4 Measurement Indicators and Tools

Table 1.

Dimension	Indicator Name	Measurement Tool/Method
Stability of the throwing motion	Bowling trajectory deviation	High-speed camera + kinematic video analysis system
	Throwing landing point error	Center target coordinate measurement (manual + video assistance)
	Consistency of movements score	Coach's expert rating + Comparison of movement trajectories (RMS error)
Balance ability	Total score of Y balance test	Y-Balance testing device
	Time spent standing on one leg	Timer + video review
Subjective feedback	Learning engagement and technical confidence	Self-compiled Likert scale questionnaire

6.5 Data Analysis Methods

Descriptive statistical analysis: basic distribution analysis such as mean and standard deviation.

Paired sample t-test: comparison of changes in pre- and post-tests within the same group.

Independent sample t-test: comparison of the significance of differences between the experimental group and the control group after intervention.

Multivariate analysis of variance (MANOVA): comparison of overall differences in multiple throwing action indicators.

Correlation analysis: linear relationship between balance ability indicators and action stability indicators.

Qualitative analysis: analysis of interview text to determine the main content of students' feedback on training.

Software used: SPSS 27.0 (quantitative analysis), Excel 365 (charts), NVivo 12 (qualitative analysis).

7. Research Results and Analysis

7.1 Analysis of Changes in Throwing Action Stability Indicators

Bowing trajectory deviation (unit: °/cm)

The experimental group decreased from an average of 6.3° to 3.8°, a decrease of 39.7%;

The control group decreased from 6.5° to 5.9°, a decrease of only 9.2%.

Statistical results: Paired sample t-test showed

significant differences between the experimental group before and after ($p < 0.01$), and significant differences between groups ($p < 0.05$).

Explanation: Balance training significantly improved the control ability of the bowing trajectory.

(1) Bowing landing error (unit: cm)

The experimental group decreased from 28.7 cm to 17.4 cm, while the control group decreased from 29.1 cm to 25.2 cm;

The improvement in the experimental group was significantly greater ($p < 0.01$).

Explanation: Subjects could release the ice puck more accurately after improving their dynamic balance ability.

Action consistency score (expert rating, 10-point scale)

The experimental group increased from an average of 6.2 to 8.1 points; the control group showed no significant change;

MANOVA showed a significant main effect of teaching intervention on action consistency.

Explanation: Improving core control ability helps to improve the repeatability and quality of the throwing action.

7.2 Analysis of Changes in Balance Ability Indicators

Y balance test score (total score 300)

The experimental group increased from 215 to 265; the control group showed little change;

t-test results: The experimental group improved significantly ($p < 0.01$), while the control group had no statistical significance ($p > 0.05$).

Explanation: The balance training program effectively improved dynamic balance control ability.

Single-leg eyes-closed standing time.

The experimental group increased from an average of 12.6 seconds to 21.8 seconds, while the control group showed no significant change;

Explanation: The lower limb stability and anti-interference ability of the experimental group significantly improved.

7.3 Correlation Analysis of Technical Performance and Balance Ability

Table 2.

Indicator relationship	Correlation coefficient r	Significance p
Y balance total score ↔ landing error	-0.71	< 0.01
One-leg standing time ↔ Action consistency score	0.65	< 0.01
Core stability level ↔ Archery trajectory deviation	-0.60	< 0.05

Explanation: There is a moderately significant positive correlation between balance ability and the stability of throwing movements, further verifying the research hypothesis.

7.4 Analysis of Subjective Questionnaires and Interview Feedback (Qualitative)

Student feedback: Most of the students in the experimental group believed that the training improved "center of gravity perception", "action confidence", and "body control";

Coach feedback: It was observed that the students in the experimental group had "more stable postures", "more decisive releases", and "more coherent movements".

8. Conclusion and Countermeasure Suggestions

8.1 Research Conclusion

This study focused on the core question of "whether balance training can effectively improve the stability of ice hockey players' throwing movements", using a research method combining experimental intervention and quantitative analysis, and reached the following main conclusions:

Balance training significantly improves the stability of throwing movements.

After an 8-week balance training period, the athletes in the experimental group showed significant improvements in key technical indicators such as throwing trajectory deviation, landing error, and action consistency, with better results than the control group, verifying the positive effect of balance training on technical accuracy.

Dynamic balance ability is highly correlated with technical performance.

The study found that the Y balance test score

was significantly positively correlated with the accuracy of throwing landing, core stability, and action consistency, indicating that good dynamic posture control is the fundamental guarantee for technical stability.

Structured balance training facilitates the transfer and internalization of technical skills.

During the intervention process, athletes' awareness and reinforcement of center of gravity perception, core control, and lower limb support ability effectively improved their autonomous control ability in action execution, providing strong support for the stable transfer and repeated execution of throwing techniques.

The balance training model is applicable to the ice hockey teaching system in universities.

The "core stability—dynamic control—technical integration" three-stage training path constructed in this study has a clear structure, is simple to operate, and has good teaching adaptability and practical promotion value.

8.2 Countermeasure Suggestions

Systematically introduce balance training modules in ice hockey teaching.

Universities should incorporate specialized balance ability training units into the ice hockey course and training system, including static core stability training, dynamic posture control training, and technical action combination practice, achieving the integration of physical fitness and specialty, and the advancement of ability and technique.

Build a "physical fitness—technique" integrated training system.

It is recommended to develop a multi-dimensional training model, with balance ability as a prerequisite for technical training, through pre-class activation, embedded practice in technical classes, and post-class feedback mechanisms, to form a stable training loop and improve training efficiency and technical control.

Strengthen the evaluation and tracking mechanism for technical stability.

It is suggested that university ice hockey coaches regularly assess the stability of athletes' technical movements, including trajectory analysis, action repeatability scoring, and psychological stability feedback, and promptly adjust training strategies to precisely intervene in technical weaknesses.

Promote the construction of intelligent training auxiliary tools.

Combining virtual simulation systems or AI motion capture technology, establish an action analysis database for ice hockey training, assist in judging the trend of stability changes in athletes, and provide data support and dynamic adjustment basis for personalized training.

Strengthen interdisciplinary cooperation between coaches and physical trainers.

It is recommended to establish a "technology + physical fitness" teaching team, jointly formulate training plans by professional coaches and physical trainers from fields such as sports rehabilitation and sports physiology, to achieve scientific and precise development of ice hockey specialized training.

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