ORIGINAL ARTICLE

Functional movement test performance improves in youth ice speed skaters after 8-week FMS training

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ABSTRACT

In sports competitions worldwide, the scheduling of tournaments is tightly packed, imposing strict demands on athletes' physical fitness. In high-intensity environments, the risk of sports-related injuries significantly escalates. The Functional Movement Screen (FMS) test has gained recognition among coaches in multiple countries and has been employed within sports teams. To more effectively and rapidly identify issues among athletes and devise corresponding intervention training plans, this study combined interview methods to understand the training situation of a speed skating team. It conducted FMS screenings on 16-speed skaters, exploring their overall body control stability, joint flexibility, and potential issues in overall proprioception. Specific intervention plans were developed based on identified problems. Results: Before intervention training, the average score of FMS tests for speed skaters was (15.38 ± 0.92) points, which increased to (19.13 ± 0.64) points after training. Conclusion: Through the intervention training devised in this study, athletes exhibited significant improvements in various scores and overall FMS scores, thereby enhancing their athletic performance.

Keywords: Physical education, Motor skill, Physical training, Athletes performance, Adolescent.

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INTRODUCTION

In today's speed skating competitions, athletes need to continually improve their overall physical fitness to effectively showcase their techniques and tactics. Only by enhancing these qualities can they adapt to the constant innovation and evolution of skills and strategies in competitions. Against this backdrop, elevating the quality of training becomes imperative. However, training with incorrect movement patterns can lead to sports-related injuries during practice or competitions, significantly increasing the risk of athletes getting injured (Ruotong, Jiahe, & Shibo, 2022). Numerous scholars have found that implementing well-designed and targeted physical conditioning training programs can significantly reduce the likelihood of sports injuries. Therefore, it's evident that physical conditioning training holds immense importance in the daily training regimen of athletes (Boyle, 2016; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Lily, 2011; Santana, 2015; Xiaolin & Chitian, 2015).

In speed skating, whether coaches or researchers serving the team, the primary attitude towards athlete injuries is generally prevention, followed by treatment. To reduce the occurrence of sports injuries, early prevention is essential (Rahimi, Samadi, Abbasi, & Rahnama, 2023). Scientific and reasonable physical fitness training is one of the important means to reduce the occurrence of sports injuries. When athletes engage in physical fitness training, the first thing to consider is their basic movement abilities (Zarei, Soltanirad, Kazemi, Hoogenboom, & Hosseinzadeh, 2022). FMS (Functional Movement Screen) uses simple means to collect information and data on three aspects of subjects: basic movements, neuromuscular control of movement patterns, and the subjects' foundational movement abilities (Xiaolin & Chitian, 2015). Combining results and data helps identify and pinpoint serious deficiencies in subjects' movements, determining where their movement abilities are restricted or asymmetrical. In other words, FMS is an organized evaluation system for normal movement patterns. In 2003, Gray Cook further introduced the concept of the "*Movement Competency Pyramid*." Through FMS screenings, assessments can swiftly, conveniently, and accurately identify weaknesses, asymmetries, and restricted movements within an individual's body (Cook, 2010). Subsequent training can then be tailored based on these test results, employing more scientific and targeted methods to address and improve the obstacles and deficiencies found in the subject.

This study, in conjunction with the specialized characteristics of speed skating, utilized FMS screening to identify functional issues among 16-speed skaters. Based on the FMS results, corresponding intervention training was devised, laying theoretical and practical foundations to enhance athletes' performance, reduce speed skating injuries, and provide a basis for intervention training. We hypothesize that training plans devised through FMS testing can improve athletes' FMS test scores while enhancing their performance.

METHODOLOGY

Participants

This study focuses on the application of the Functional Movement Screen (FMS) in speed skating physical training. Sixteen athletes from the speed skating team were selected as participants, all of whom are active members of the team and possess a skating level at or above level one. Written informed consent was obtained from each participant before the experiment. Before participating in the study, all participants completed a brief questionnaire regarding personal information such as height, weight, and any disabilities.

Table 1. Basic information for athletes (n = 16).

Age (years)	Weight (kg)	Height (cm)	Training years (years)	Level
15.13 ± 1.46	60.70 ± 4.31	168.4 ± 5.57	6.50 ± 1.07	China National Level

Experimental design

As needed, FMS testing was conducted on 16-speed skaters, encompassing seven components: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability tests. The test outcomes serve as essential data sources for this study.

The FMS testing took place at the Jilin Institute of Physical Education training centre. The first test, before intervention training, occurred on July 30, 2022, while the second test, following the completion of intervention training, took place on September 31, 2022.

(1) Identifying research subjects, selecting them based on preliminary tests, and collecting basic information such as name, gender, age, athletic level, and other indicators.
(2) Athletes must perform movements according to the experimenter's instructions during FMS testing. Each test is conducted three times, and the scores are recorded.
(3) During the Functional Movement Screen (FMS), record the individual scores for each test item. If bilateral movements are tested, record the scores for each side.
(4) Perform phased data processing and analysis on the acquired data.
(5) Through data analysis, discuss and analyse various evaluation indicators. Based on the athletes' scoring results, propose reasonably scientific intervention training methods to effectively reduce the risk of athlete injuries and improve their athletic performance.

FMS Test

As required, FMS testing was conducted on 16 athletes, comprising seven components: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability tests. The test outcomes serve as essential data sources for this study.

Measurement equipment includes a ruler, Functional Movement Screen Test Kit, FMS test evaluation form, mini bands, Swiss balls, dumbbells, barbells, yoga mats, foam rollers, massage sticks, balance pads, and others.

Intervention

(1) Experimental Period: August 2022 to September 2022, lasting for 2 months, equivalent to 8 weeks.
(2) Experimental Arrangement: Conducting intervention training three times a week, carried out after regular training sessions, and ensuring it does not disrupt the coaches' training plans. Each training session lasts between 45 to 50 minutes.
(3) Design of intervention Training: Aimed at enhancing athletes' performance based on the FMS test scores of active speed skating athletes, the intervention training was designed considering both the test outcomes and the characteristics of speed skating. The FMS intervention training includes: ① Flexibility training, focusing on joint mobility and muscle flexibility; ② Stability training, emphasizing the sequence of basic movement patterns to demonstrate excellent posture control ability; ③ Movement pattern reconstruction, integrating fundamental flexibility and stability into specific movement patterns to enhance overall body coordination.

Unlike traditional physical training, when devising intervention training plans (Carlos, 2019), numerous factors are considered in addition to the scores of each test action. The sequence should follow from basic flexibility → basic stability → construction of movement patterns, and adhere to the following principles:

(1) When scores are equal, symmetry consistency is prioritized. FMS test actions are designed based on fundamental human movements, thus having a certain sequence.
(2) Principle of Action Hierarchy: Some athletes may exhibit multiple incorrect movement patterns, where some issues arise from poor flexibility while others stem from inadequate stability. In such cases, addressing the athlete's flexibility issues should take precedence before correcting their stability.
(3) Principle of Progression from Difficult to Easy: Training should gradually increase the difficulty of movement patterns only under conditions the individual can control. For instance, reducing the athlete's base of support, changing or combining exercise equipment, or altering the posture during movements.

Based on the athletes' screening results, an intervention training spanning 8 weeks (3 sessions per week, totalling 24 sessions) has been established. To better intervene in the athletes' training, this program will be divided into three phases. Phase One: Weeks 1-3, focuses on rectifying improper body and movement postures, improving athletes' kinaesthetic awareness, and enhancing muscle coordination and flexibility. Phase Two: Weeks 4-6, aims to improve core stability while intensifying flexibility training. The final phase spans Weeks 7-8, emphasizing reconstruction of athletes' movement patterns. A second FMS test will be conducted after the 8-week training program concludes.

Through investigation and understanding of the athletes, combined with the principles of intervention training formulation, this intervention training plan will focus on several aspects: flexibility, including shoulder joint flexibility and flexibility in the primary injury-prone joints; stability, involving stability of muscles around the primary injury-prone joints and core control ability; athletes' balance; functional strength training for various joints; and finally, reconstruction of athletes' movement patterns. The selection of training plans will primarily reference three books: "*Body Function Training Manual*,"(Xiong & Zhaoche, 2014) "*Body Movement Function Diagnosis*,"(Jun, 2015) and "*Training and Movement - Functional Movement Training System*."(Cook;, Zhang Yingbo, Liang Lin, & Hongbo (Translated), 2011) Addressing these aspects will lead to the proposal of targeted and rational intervention training programs for the athletes.

The formulation of this intervention training program is primarily based on the common issues observed among the athletes. However, in the specific implementation process, the selection and arrangement will be based on the specific physical conditions of each athlete (Savinykh, Stoliarova, Stovba, Khomenko, & Kurchenkov, 2022).

First Stage Training - Flexibility-focused Training

In the first stage of training, our primary focus was on enhancing the athletes' flexibility. This phase involved exercises to improve muscle coordination, kinaesthetic awareness, stretching, and relaxation training. It aimed to rectify issues in athletes' flexibility and establish a strong foundation for the subsequent second-stage training. During the intervention training period of 1 to 3 weeks, our main emphasis was on rectifying improper body and movement postures among the athletes, enhancing their kinaesthetic awareness, and improving muscle coordination and flexibility. Through this phase of training, we observed a significant improvement in athletes' performance regarding movement postures. There was also an enhancement in muscle coordination and kinaesthetic awareness.

Second Stage Training - Stability-focused Training

This stage of training primarily emphasizes the stability of the athletes. Building upon the improvement in athletes' flexibility and muscle coordination, this phase incorporates instability factors into exercises, targeting stability in athletes' spines, cores, various joints, and smaller muscle groups. Compared to the first stage of training, the difficulty level in the second stage has increased. It introduces instability factors atop the foundational exercises. For instance, progressing from a basic hip bridge to a hip bridge with a military march movement, incorporating balance training devices into squat exercises, etc.

Third Stage Training - Movement Pattern Reconstruction
The final stage of training spans 2 weeks, primarily focusing on reconstructing the athletes' movement patterns and providing targeted training for the tested actions.

Figure 1. Shoulder flexibility exclusion test.

To rule out functional issues among athletes, an exclusion test was concurrently conducted during the assessment. This was to see whether the test movements would induce pain, further examining potential risks not covered by the test movements. If pain occurred during the test, it was marked as a positive result "+". If the exclusion test showed a positive result "+", the corresponding test movement's score was recorded as 0, without scoring the exclusion test itself. Through the assessments, none of the athletes showed any signs of pain.

Statistical analyses
FMS testing was scored using a scale, obtaining scores for athletes before and after intervention training. The collected data underwent differential analysis using SPSS 20.0, with results presented as mean ± standard deviation (Mean ± SD). Paired-sample t-tests were employed to see changes in FMS test scores before and after intervention training, with a significance level set at .05.

RESULTS

After conducting FMS tests on 16 athletes and organizing the results, for bilateral scoring items, the lower score was recorded. Finally, the scores of the seven individual items were summed to obtain the total FMS test score for each athlete, as shown in the Table 2.

Table 2. Correlation test of test results for male and female athletes.

Test	Male	Female	*p*-Value
Deep squat	2.10 ± 0.316	2.20 ± 0.568	1.00
Hurdle step	2.10 ± 0.568	1.90 ± 0.316	.343
Inline lunge	2.20 ± 0.422	2.10 ± 0.568	.660
Shoulder mobility	2.20 ± 0.422	2.40 ± 0.516	.355
Active straight-leg raise	2.70 ± 0.316	2.90 ± 0.483	.288
Trunk stability push-up	2.30 ± 0.422	2.10 ± 0.422	1.000
Rotary stability	1.80 ± 0.316	1.60 ± 0.422	.556
Total screen score	15.60 ± 0.843	15.40 ± 1.350	1.000

From Table 2, it's evident that based on the FMS test scores, male athletes scored higher than female athletes. However, upon statistical analysis, there wasn't a significant difference ($p > .05$) between the scores of male and female athletes, indicating that gender will not have an impact on the subsequent training results.

Table 3. Athletes' test scores for each screening movement (persons).

Score	Test						
	Deep Squat	Hurdle Step	Inline Lunge	Shoulder Mobility	Active Straight-Leg Raise	Trunk Stability Push-Up	Rotary Stability
3	3	2	4	6	14	3	0
2	12	11	11	10	2	13	14
1	1	2	1	0	0	0	2

In the overall scoring of athletes, scores mainly concentrated around 2 points, with no athletes scoring 1 point in the Shoulder Mobility, Active Straight-Leg Raise, and Trunk Stability Push-Up tests. However, 14 athletes did not score 3 points in the Rotary Stability test.

Table 4. Comparison of athletes' FMS test scores before and after training.

Test	Before intervention training	After intervention training
Deep squat	2.25 ± 0.46	2.75 ± 0.46*
Hurdle step	1.88 ± 0.35	2.50 ± 0.54*
Inline lunge	2.00 ± 0.00	2.75 ± 0.46**
Shoulder mobility	2.25 ± 0.46	2.88 ± 0.35**
Active straight-leg raise	2.75 ± 0.46	3.00 ± 0.00
Trunk stability push-up	2.25 ± 0.46	2.87 ± 0.35 **
Rotary stability	2.00 ± 0.00	2.38 ± 0.52
Total screen score	15.38 ± 0.92	19.13 ± 0.64 **

*Note. *p < .05 significant difference before and after intervention training; **p < .01 highly significant difference before and after intervention training.*

Paired sample t-tests were conducted on before and after training FMS test scores using SPSS. The results indicated significant differences after intervention in the deep squat test ($p = .049$), hurdle step test ($p = .009$), and shoulder mobility test ($p = .049$); whereas highly significant differences were observed in the in-line lunge test ($p < .001$), trunk stability push-up test ($p = .009$), and overall score ($p < .001$) post-intervention. The straight leg raise and rotary stability test yielded non-significant results ($p > .05$), yet there was an improvement in the quality of movement execution by the athletes.

DISCUSSION

Through 8 weeks of targeted intervention training, athletes demonstrated an improvement in FMS test scores. The training enhanced the flexibility of the muscles in the lower leg, strengthened the muscles in the lower back, increased flexibility in the thoracic spine, and enhanced stability in the ankle and hip joints. Consequently, significant improvements were observed in the scores of the deep squat test, hurdle step test, and shoulder flexibility test, particularly notable improvements in the in-line lunge, trunk stability, and overall FMS score, alongside enhanced performance during the testing process. Following the training, male athletes exhibited noticeable improvements in shoulder joint flexibility, reduction in shoulder movement restrictions, and a clear enhancement in athletic performance. Over the 8 weeks of intervention training, athletes experienced fewer instances of injuries during routine training compared to other athletes, indicating that intervention training plays a preventive role in sports injuries.

Speed skating is a sport that involves lower limb exertion; hence, it requires balanced and good flexibility in areas such as the waist, knees, and ankles of the athletes to reduce the occurrence of injuries. Combining the technical characteristics of speed skating, investigations into injuries related to this sport, and surveys of athletes, it is found that the most common injuries among speed skaters occur in the knee and ankle joints (Dubravcic-Simunjak, Pecina, Kuipers, Moran, & Haspl, 2003; Quinn, Lun, McCall, & Overend, 2003). Analysing the characteristics of speed skating, the knee and ankle joints are identified as the main joints involved in completing the movements. Instability in these two joints can directly lead to poor performance, hindering athletes from completing technical actions and affecting competition results. If functional movement patterns are affected, the athlete is likely to experience sports injuries. Muscle capability surpassing joint integrity, force pressing on stability, flexibility issues damaging body posture control, and muscle imbalances leading to premature fatigue and undesirable muscle engagement are potential consequences (Cook, Burton, Hoogenboom, & Voight, 2014b). For instance, when an athlete's joint muscles are excessively tense, restricted movement may occur.

In the FMS test scores, we observed that male athletes perform better in stability than female athletes. However, female athletes scored higher than male athletes in areas like shoulder flexibility, straight leg raise, and similar tests measuring muscle flexibility and joint mobility. On the other hand, male athletes exhibited better performance in tests related to strength and core stability such as squatting, trunk stability, and inline lunge. Females showed slightly lower core strength, hip joint, and lower limb strength compared to males, consistent with injury-related reports among speed skating athletes. Due to some female athletes' lower joint stability, muscle strength, control over the pelvis and core, or lower limb and hip joint flexibility, they struggle to execute complete movements effectively (Clark, Rowe, Adnan, Brown, & Mulcahey, 2022).

We also noticed asymmetry between the left and right sides of athletes; some displayed a phenomenon where both knee joints tend to turn inward and were unsynchronized during squatting. This could be due to poor bilateral balance in the athletes' knee and ankle joints, where weaker muscles on one side lead to compensatory movements on the other (Burton, Eisenmann, Cowburn, Lloyd, & Till, 2021). Apart from weak muscle strength, poor flexibility is also a contributing factor. Restricted flexibility in the upper limbs or torso directly impacts an athlete's final performance, fostering incorrect technical movements and potentially causing sports injuries (Fengwu, 2011).

During testing, the most noticeable aspect was the shoulder flexibility test, where male athletes scored lower than female athletes. This could be due to male athletes deliberately developing muscles like the pectoralis minor, rectus abdominis, and latissimus dorsi, causing these muscles to shorten, thereby limiting shoulder flexibility. The adverse consequences of postural changes include ineffective limitations in the range of motion in the glenohumeral joint and scapula (Harper, Bailey, Jones, & Bradley, 2023). Alternatively, poor flexibility in the thoracic spine may result in insufficient stability in the scapula, leading to decreased shoulder flexibility. Therefore, exclusionary tests were conducted on the shoulders.

Based on the investigation and understanding of the athletes, and in conjunction with intervention training principles, this intervention training plan and its formulation will focus on several aspects: flexibility, including shoulder joint flexibility and joint flexibility in injury-prone areas; stability, encompassing the stability of muscles around the injured joints and core control ability (Cook, Burton, Hoogenboom, & Voight, 2014a); athlete's balance capacity; functional strength training for various joints; and finally, reconstruction of the athletes' movement patterns.

Before implementing intervention training, the squat test scores of athletes were primarily concentrated around 2 points, consistent with the characteristics of speed skating and the research findings of numerous scholars (Dubravcic-Simunjak et al., 2003; Okamura et al., 2014). In the long-term and high-intensity training process of speed skaters, knee injuries or risks of injury have been more or less prevalent. Through discussions with coaches, we learned that 80% of athletes had experienced knee injuries. These injuries were mostly attributed to routine training. Coaches find it challenging to promptly observe athletes' tolerance for training load and intensity during training sessions. Additionally, athletes, in their eagerness to rapidly enhance their performance, tend to push their bodies beyond their capacity to withstand training loads, ultimately resulting in injuries.

The intervention training in the first 1-3 weeks primarily focused on improving and addressing athletes' incorrect body postures, enhancing athletes' proprioception abilities, and increasing athletes' muscle coordination and flexibility. In the initial phase of training, the emphasis was on flexibility training, comprising flexibility exercises, stretching sessions, and relaxation exercises in each training session. After 3 weeks of training, athletes showed significant improvements in their posture, with muscle fibres gradually elongating and relaxing, enhancing their elasticity and extensibility. This reduction in muscle tension during movement increased their flexibility and range of motion, heightened neural adaptability, improved signal transmission, and muscle coordination, thereby enabling more effective muscle coordination and movement, ultimately expanding joint mobility.

Compared to the first phase, the second phase of training has increased in difficulty by incorporating unstable elements onto the foundational exercises. For instance, advancing from a basic hip bridge to a hip bridge with a military step, incorporating balance training devices into squat exercises. Athletes, building on the improvements in fundamental movement patterns from the second phase, further enhanced their body stability by introducing tools like resistance bands, Swiss balls, and similar equipment.

The final stage of FMS functional training is action pattern reconstruction. The preceding phases addressed athlete flexibility and stability, while the last phase focuses on reshaping poor movement patterns or postures to enhance athletes' execution and body control. This phase primarily aims to gradually adjust and refine inefficient movement patterns to align with correct biomechanical principles, minimizing injury risks. Exercises like overhead squats, planks, single-leg hip bridges, while enhancing lower body strength and buttocks, also elevate core and lumbar stability, further improving overall strength, stability, flexibility, and control, reducing asymmetry between the athlete's left and right sides.

Moreover, by performing seven simple test movements, we can swiftly and accurately identify the relatively weaker links in an athlete's kinetic chain (Zarei et al., 2022). Based on these findings, we can develop targeted intervention exercise programs to reduce the risk of sports injuries and enhance athletic performance (Silva, Rodrigues, Clemente, Cancela, & Bezerra, 2019). When implementing these intervention exercise programs, close attention to individual differences and responses of athletes is essential to ensure the effectiveness and safety of the plan. Furthermore, regular assessment and adjustments to these plans are necessary to accommodate the athlete's progress and changes.

Under the guidance of coaches, athletes should actively participate in the implementation of intervention exercise programs to cultivate self-monitoring and self-adjustment abilities. Simultaneously, coaches should provide timely guidance and support based on athletes' performances and feedback. Through this approach, we can effectively enhance athletes' athletic performance, reduce sports injuries, and foster their healthy growth and development. This is crucial for both athletes and coaches, so we should take these matters seriously and continue to pay attention to them.

As the intervention training lasted only 8 weeks and the number of athletes involved in the intervention was relatively small, it is recommended to increase the number of test subjects and add a control group in subsequent experiments to further explore the applicability of FMS screening in speed skating. In the future, combining FMS screening with electromyography tests of various muscle groups and epidemiological investigations will be undertaken to develop a more scientific intervention training program suitable for speed skaters.

CONCLUSION

The intervention training intervention designed for athletes in this study led to a significant improvement in the scores of various test items and the total score of the FMS screening, consequently enhancing the athletes' performance. Conducting regular FMS tests allows for an effective, objective, and comprehensive assessment of athletes' functional issues, providing insights into their physical condition for timely intervention training to enhance performance and prevent injuries.

During physical training, it's advisable to integrate the principles of functional and intervention training, arranging sessions sensibly to assist athletes in optimizing their movement patterns for improved performance. There are various methods for intervention training; coaches should align FMS scores with athletes' actual conditions, physiological traits, and sport-specific characteristics when selecting intervention training programs. Adherence to intervention training principles and timely adjustments in training content are essential.

AUTHOR CONTRIBUTIONS

Conceptualization, QQ, CH & SK; methodology, QQ, CH & SK; software, QQ & JZ; validation, CH & XQ; formal analysis, QQ & JZ; investigation, QQ, CH & JZ; resources, QQ & JZ; data curation, CH & XQ; writing—original draft preparation, QQ & CH; writing—review and editing, JZ & SK; visualization, XQ; supervision, SK; project administration, XQ. All authors have read and agreed to the published version of the manuscript. Qingling Qu and Chansol Hurr contributed equally to this work and designated as co-first authors.

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