Bayati *et al. Journal of Orthopaedic Surgery and Research* (2025) 20:486
https://doi.org/10.1186/s13018-025-05911-z

Journal of Orthopaedic Surgery and Research

RESEARCH **Open Access**

Effects of the wrestling + injury prevention program in freestyle wrestlers: a two-arm randomized controlled trial

Rasoul Bayati[1], Ali Shamsi Majelan[1*] and Hamed Zarei[1]

Abstract

Background To assess the effectiveness of the Wrestling + injury prevention program on incidence of injuries, neuromuscular mechanisms and dynamic balance of freestyle (FS) wrestler.

Methods The participants of this study consisted of FS wrestling players in Qom province (Iran). A total of 80 participants were assigned to this study and using simple and random method with computer divided into experimental (EXP, $n = 40$) and control (CON, $n = 40$) groups. The groups were blinded against each other. The follow-up period was one season (6 months). EXP replaced their warm-up by Wrestling + program. CON performed a standard warm-up program. The primary outcome was the injury incidence density (injuries per 1000 h of wrestling exposure), compared between groups by incidence rate ratios (RR). Also, the secondary outcome was neuromuscular mechanisms and dynamic balance.

Results The per-protocol analysis showed a reduction of the overall injury incidence density in the EXP group by 58% compared to the CON group. Additionally, within-group analyses revealed significant improvements in neuromuscular mechanisms and dynamic balance for both the EXP and CON groups following 24 weeks of warm-up programs ($p < 0.05$). Furthermore, between-group comparisons indicated significant differences favoring the EXP group relative to the CON group ($p < 0.05$).

Conclusion The Wrestling + program is effective in reducing injuries among FS wrestlers with overall injuries reduced by 58%. Moreover, the results indicate that the Wrestling + program is more effective than traditional warm-up routines in improving neuromuscular mechanisms and dynamic balance among FS wrestlers. Therefore, it is recommended that coaches use a Wrestling + program to reduce the incidence of injury in FS wrestlers.

Keywords Primary prevention, Athletic injures, Dynamic warm-up, Neuromuscular mechanisms

*Correspondence:
Ali Shamsi Majelan
shamsi@guilan.ac.ir
[1]Corrective Exercises and Sports Injury Department, Faculty of Physical Education & sport sciences, University of Guilan, kilometers 10 Rasht-Ghazvin Road, Rasht, Iran

Introduction

Wrestling stands out as one of the most physically demanding sports in high school and college athletics [1]. It involves a series of rapid, repetitive offensive and defensive maneuvers [2, 3]. Currently, two primary styles—Greco-Roman (GR) and freestyle (FS)—are featured in the modern Olympics [4, 5]. FS wrestling has its roots in catch-as-catch-can wrestling, where the main objective is for the wrestler to secure victory by throwing or pinning their opponent to the mat [6].

In FS wrestling, the execution of various functional movements relies heavily on key factors such as muscular strength, flexibility, neuromuscular coordination, and both static and dynamic balance [7, 8]. Achieving optimal performance in FS wrestling competitions hinges on the development of proper muscular capabilities in both the upper and lower body [9]. Wrestlers must produce significant levels of anaerobic and aerobic energy to generate the muscle power and force necessary for competition, which places considerable stress on both their skeletal and muscular systems [10]. Additionally, maximal dynamic strength is crucial for executing effective offensive and defensive techniques, including lifting and throwing opponents while countering their attacks [11]. However, as is common in contact sports, these athletes are at risk for occasional injuries.

Wrestling injuries rank as the second most common type of sports injuries, following football [12]. The injuries typically encountered in wrestling are closely linked to factors such as musculoskeletal strength, flexibility, and the athlete's skill level [13, 14]. A study [15] analyzed data from the National Collegiate Athletic Association Injury Surveillance System over a 16-year span, revealing an injury rate of 9.6 per 1,000 athlete exposures in collegiate wrestling. Notably, the injury rate during competitions was significantly higher than during practice; however, the injury profiles in both settings were found to be equally critical [15]. According to additional research on injury prevalence in wrestling, the data reveals a concerning trend. Head, spine, and trunk injuries account for 24.5–48% of all wrestling-related injuries. Upper limb injuries range from 9.3 to 42%, while lower limb injuries fall between 7.5% and 15% [16]. Furthermore, injuries specifically affecting the skull make up 5–21.6% of the total injuries sustained by these athletes [17]. These statistics clearly demonstrate the high incidence of injuries in the sport of wrestling, which can result in significant financial burdens for both teams and individual athletes [18]. Therefore, it is imperative that scientific studies be conducted to identify the key factors contributing to these injuries and develop effective prevention strategies.

In 2015, the researchers of the World Wrestling Federation (UWW) developed a specialized program called Wrestling + with the aim of addressing the issue of injury prevention in the sport [19]. To design an effective injury prevention program, it is crucial to carefully analyze various parameters, including the characteristics of injuries, the mechanisms underlying these injuries, and the specific physical demands of the sport [19]. The Wrestling + program is a targeted warm-up regimen consisting of three distinct parts, encompassing a total of 14 exercises to be performed in a designated sequence. A key emphasis of this program is on using proper technique throughout all the exercises, as well as maintaining correct posture and body control [19].

Despite previous research has indicated that the Wrestling + program can enhance various physical attributes among participants, such as dynamic balance [20], static balance, lower limb strength [21], and functional movement screening (FMS) test scores [22], significant gaps remain in the literature. Notably, there is a lack of studies specifically examining the program's impact on injury incidence among wrestlers, which is crucial for assessing its effectiveness in promoting athlete safety. Additionally, while improvements in lower limb strength have been documented, there is insufficient evidence regarding the program's influence on overall upper and lower limb function, including coordination and flexibility, which are vital for wrestling performance and injury prevention. Furthermore, the neuromuscular mechanisms underlying the benefits of the Wrestling + program have not been thoroughly explored, leaving a gap in understanding how it affects muscle activation patterns and motor control. The term "neuromuscular mechanisms" encompasses various physiological and biomechanical factors that contribute to muscle performance and coordination, making it essential to define this concept in the context of our study. By testing maximal isometric strength, power, force sense, range of motion (ROM) of ankle plantarflexion and shoulder flexion, as well as proprioception of the ankle and shoulder, we aim to gain a comprehensive understanding of how these variables interact to influence overall neuromuscular function. These assessments provide insights into the participants' muscular capabilities, joint mobility, and sensory feedback mechanisms, which are critical for effective movement and injury prevention. Understanding these relationships is vital for evaluating the effectiveness of the intervention being studied, as improvements in these neuromuscular parameters may correlate with enhanced athletic performance and reduced injury risk. Therefore, the present study seeks to address these gaps by examining the effects of the Wrestling + injury prevention program on injury incidence, neuromuscular mechanisms, and dynamic balance specifically in FS wrestler.

Methods

Participants

The participants of this study consisted of FS wrestling players in Qom province (Iran). The participants were selected according to the available samples from a province. Participants were required to complete all the training sessions and attend all assessment sessions. As a result of these requirements, a total of 80 participants were assigned to this study and using simple and random method with computer-generated random numbers divided into experimental (EXP, $n = 40$) and control (CON, $n = 40$) groups. (see Fig. 1). A power analysis was conducted to determine the sufficient sample size of each group. The sample size was calculated based on a previous study by Tatlici, Lima [23] with an alpha level of 0.05, effect size of 0.5 and an actual power (1-beta) of 0.80. The analysis (G × Power, Version 3.1.9.2, University of Kiel, Germany) revealed that a sample size of $n = 35$ would be sufficient for each group to find significant effects between variables. With the possibility of participants dropping out, the number of participants was considered 10% more for each group.

The inclusion criteria for the study included: 1) participant' gender: male [20]; 2) sports field: wrestling [20]; 3) participants: cadet FS wrestlers [20]; 4) cadet wrestler: according to the definition of the UWW, the age range is (16–17) years for a cadet wrestler [20]; 5) the training experience of the subjects is at least 2 years (According to the McKay, Stellingwerff [24] McKaya qualification criteria, the subjects of our study were classified in Tier 3, which includes individuals categorized as Highly Trained or at the National Level); 6) all subjects will be healthy

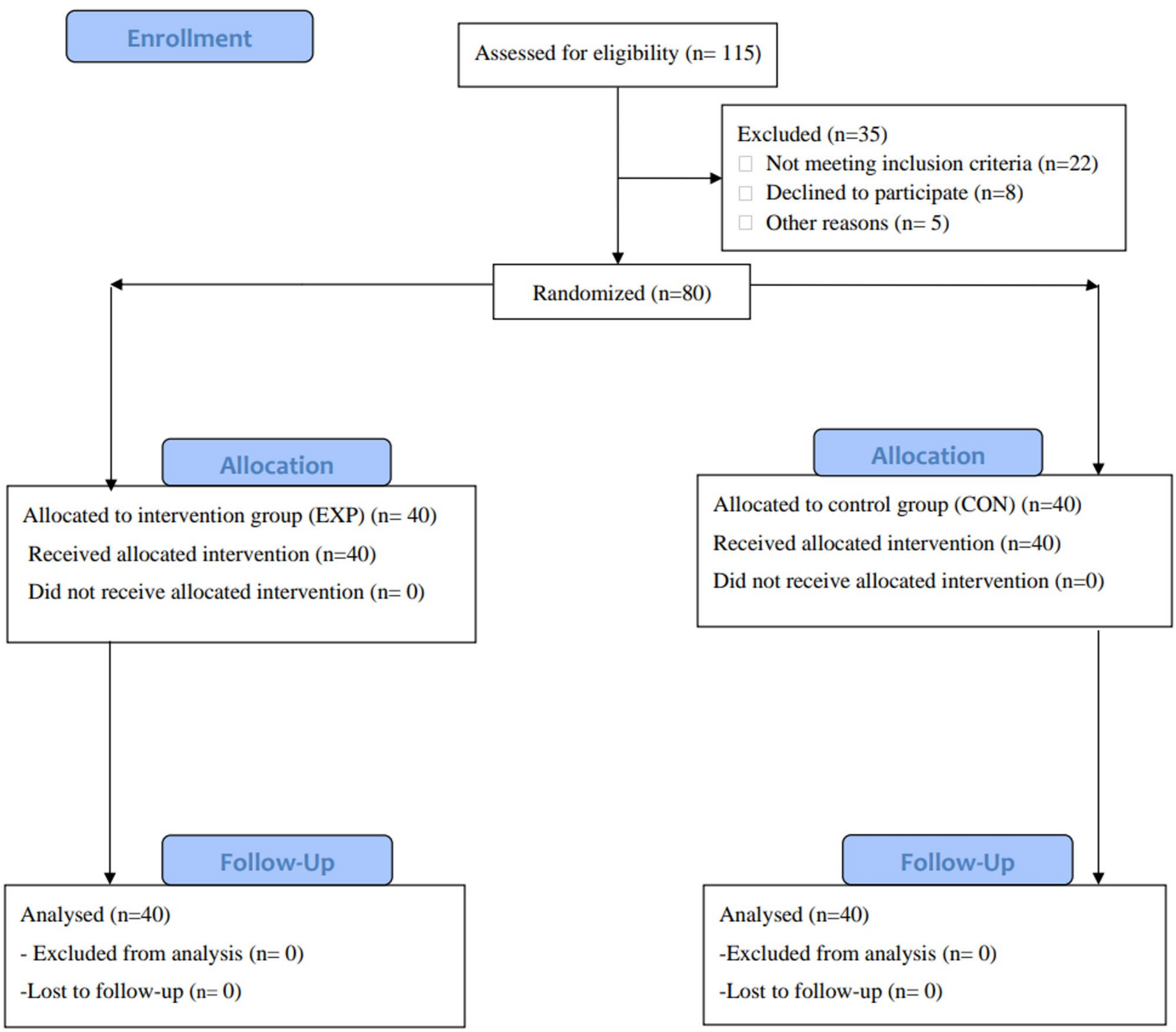

Fig. 1 Flowchart of eligibility, inclusion and exclusion criteria, and analysis

and without any injuries [20]. The exclusion criteria for the study were as follows: (1) use of neurological drugs that influence function [4]; (2) History of lower or upper extremity injuries within the last 6 months [4]; (3) history of muscular or neural ailments, such as myopathy, myositis, peripheral neuropathy, or muscular dystrophy [25]; (4) surgery or fracture within a year before the study; (5) insulin-dependent diabetes [25]; (6) joint rheumatoid arthritis [25]; (7) diagnosed cerebrovascular disease or any other disease that interferes with sensory input [25]; (8) lower extremity rotational deformities, such as increased anteversion or tibial torsion, or pes planovalgus [26]. Before the initiation of the study, the participants (cadet individuals) and their parents were informed about the research procedures, and their written consent was obtained (Fig. 1).

Study design

The start and end of the recruitment period for this study was 2/7/2024 and 2/2/2025 respectively. This study employed a two-armed cluster-randomized controlled trial design with convenience sampling. The study followed the CONSORT 2010 guidelines for reporting randomized trials [27]. The participants were pair-matched based on their sports experience and then randomly divided into two groups: an experimental group and a control group. The randomization was performed using a computer-generated block randomization table, with a blinded member of the study team responsible for the allocation. The experimental group replaced their warm-up by Wrestling + program. The experimental group participated in the Wrestling + program, which involved 20-minute sessions, 3 days per week, for a duration of 6 months. The control group performed their regular season training programs, which involved 20-minute sessions, 3 days per week, for a duration of 6 months. The study period spanned 27 weeks, with the following timeline: Week 1 - Familiarization period; Week 2 - Pre-test period; Weeks 3 to 26 - Training period; Week 27 - Post-test period. Two weeks before the training period, a researcher communicated with the participants and standardized the training procedures. The weekly training sessions were co-created between the trainer and the participants, who were instructed to properly execute the prescribed exercises.

The study was registered and allocated by the Clinical Trials (IRCT20241123063808N1) 29/11/2024, and was approved by the University of Guilan (Iran) IR.GUILAN.REC.1403.138. All experiments were conducted in accordance with the relevant guidelines and regulations.

Procedures

The participants underwent a total of 2 weeks of testing, which included both pre-tests and post-tests. To minimize the potential impact of circadian variations on the test results, the participants were tested at the exact same time of day (between 2 PM and 5 PM) and on the same day of the week as the pre-test session. Additionally, the testing was conducted during the same training hour as the pre-test, ensuring consistency in the testing conditions at the gym.

Measurements

The participants' height was measured using a wall-mounted stadiometer (Seca 222, Terre Haute, IN) and recorded to the nearest 0.5 cm. Their body mass was measured to the nearest 0.1 kg using a digital scale (Tanita, BC-418MA, Tokyo, Japan) [28]. To measure the actual leg length, the distance between the anterior superior iliac spine (ASIS) and the medial malleolus was recorded using a strip meter in centimeters [29]. Participants were instructed to remove their shoes and maintain identical lower limb positions with their pelvis aligned squarely while in a supine position. Similarly, to measure the actual hand length, the participants were instructed to stand with their arms flexed at 90 degrees [30]. The distance between the acromion process and the middle fingertip was then measured using a strip meter in centimeters. The lever arm lengths of the ankle and shoulder were also determined using a strip meter in centimeters, following the methods described in detail by Casadei and Kiel [31]. To determine the participants' dominant hand and leg, they were asked to perform tasks such as throwing and hitting a ball.

To assess lower body balance performance, the Y-Balance Test (YBT) was administered, following the detailed methodology described by Ko, Wikstrom [32]. To normalize the YBT scores, the distance reached was divided by the participant's leg length and then multiplied by 100. Leg length was quantified as the distance (in centimeters) from the anterior superior iliac spine to the center of the ipsilateral medial malleolus, with the participants in a supine position (Fig. 2). In addition, upper body balance performance was measured using Upper Quarter YBT (YBT-UQ) according to described method in details by Schwiertz, Beurskens and Muehlbauer [33] (Fig. 3).

Maximal isometric strength of the ankle plantar flexors and shoulder flexors was assessed using a manual dynamometer (Mechanical dynamometer, 8983, Hausmann, NJ, USA), following the guidelines presented by Leijendekkers, Hinte [34]. To assess power force sense, a target force reproduction test was used, as described in detail by Bock and Thomas [35].

To measure the range of motion in ankle plantar flexion and shoulder flexion, an goniometer (Biometrics Ltd, VA, USA) was utilized, based on the methods described by Norkin and White [36]. For the ankle plantar flexion range of motion, the participant was seated with the

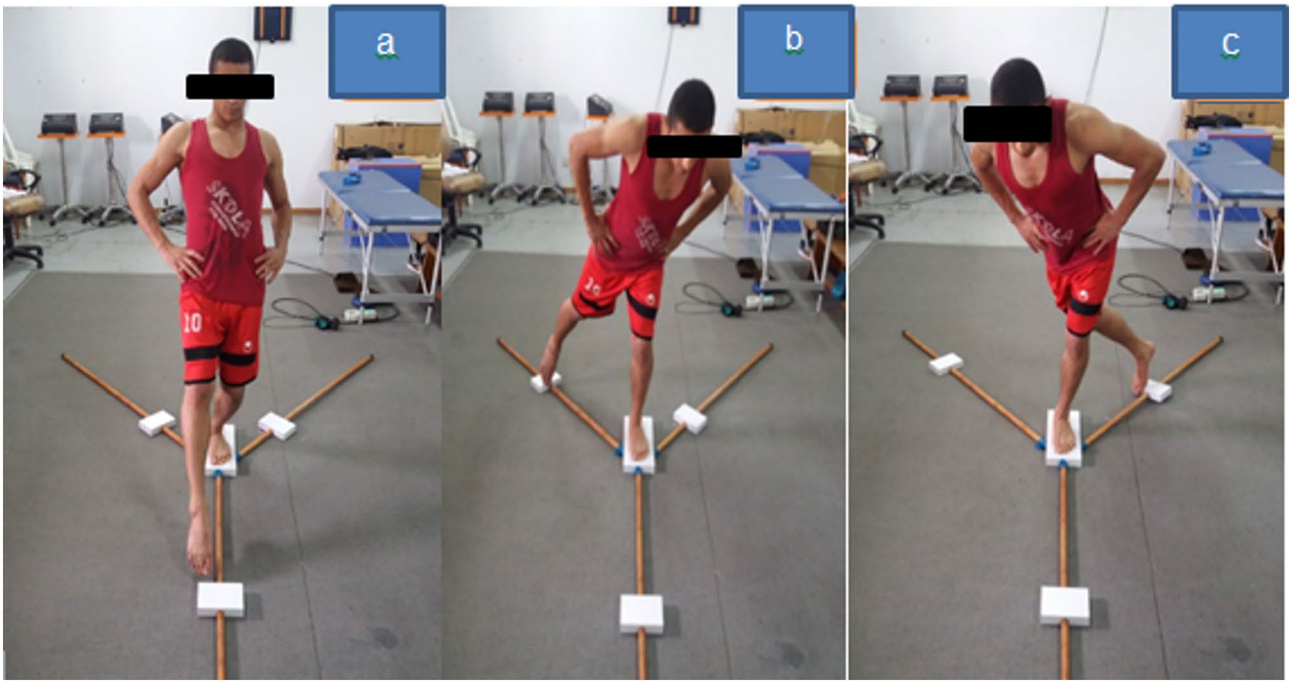

Fig. 2 Performance of the Y Balance Test with a dominant leg stance reaching into (**a**) anterior, (**b**) posteromedial, and (**c**) posterolateral direction

knee flexed to 90 degrees. The foot was positioned in 0 degrees of inversion and eversion. The fulcrum of the goniometer was centered over the lateral aspect of the lateral malleolus. The proximal arm was aligned with the lateral midline of the fibula, using the head of the fibula as a reference. The distal arm was aligned parallel to the lateral aspect of the fifth metatarsal. At the end of the plantar flexion range of motion, the examiner used one hand to maintain the plantar flexion and align the distal goniometer arm, while the other hand stabilized the tibia and aligned the proximal arm of the goniometer. For the shoulder flexion range of motion, the participant was placed in a supine position with the knees flexed to flatten the lumbar spine. The shoulder was positioned in 0 degrees of abduction, adduction, and rotation, with the elbow in extension. The forearm was in 0 degrees of supination and pronation, with the palm facing the body. The fulcrum of the goniometer was centered over the lateral aspect of the greater tubercle. The proximal arm was aligned parallel to the midaxillary line of the thorax, and the distal arm was aligned with the lateral midline of the humerus. Ankle and shoulder proprioception were assessed using the ankle angle-reproduction test [37] and the shoulder flexion reproduction test [38], respectively.

Intervention

The Wrestling + Warm-up Program consists of 3 parts and 14 exercises that must be performed in a specific order. The key to this program is to use the correct technique throughout all exercises and maintain proper posture and optimal body control. Part 1 involves slow-moving exercises with active shoulder stretches, grips, and bridges. Part 2 includes 5 exercises focused on core muscle strength, shoulder and leg strength, and balance. These exercises have 3 levels of increasing difficulty. Part 3 consists of wrestling-simulated exercises. Wrestlers begin with Level 1 exercises and progress to the next level based on their performance in the previous stage. The duration and number of repetitions are specified for each level [19].

In this research, the wrestlers performed the first, second, and third levels of exercises for 8 weeks each, totaling 24 weeks and 72 sessions, with 3 sessions per week. Given the importance of proper exercise execution and correcting any technique issues, the presence and supervision of an instructor were essential during the training sessions. For more details, see Fig. 4.

Statistical analysis

All values are presented as mean ± standard deviation (SD). The pre- and post-values for the dependent variables were analyzed to determine if the distributions were normal using the Shapiro-Wilk Normality test. Differences in all variables were analyzed using a 2 (group) x 2 (time) repeated measures ANOVA. When a significant F-value was achieved across time or groups, Bonferroni post-hoc procedures were performed to identify the specific pairwise differences. Additionally, the effects of training (effect size [ESs]) were calculated using Cohen's d [39].

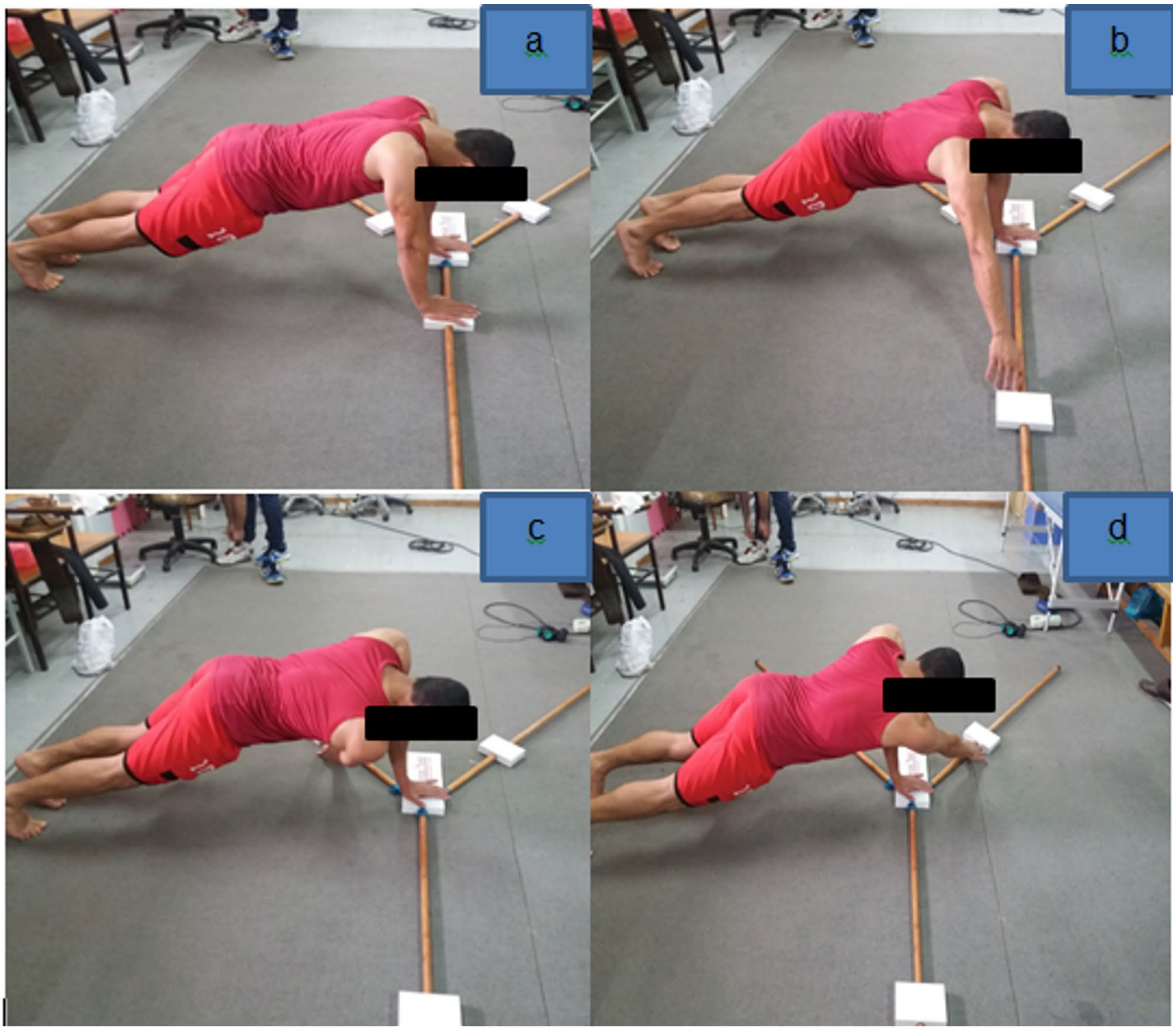

Fig. 3 Performance of the YBT-UQ Test with a dominant hand stance (**a**) Start position, (**b**) medial YBT-UQ reach, (**c**) Inferolateral YBT-UQ reach, and (**d**) Superolateral YBT-UQ reach

Injury incidence densities were calculated as the number of injuries per 1,000 h of exposure. The injury characteristics were described descriptively, reporting the absolute numbers and percentages for overall, match, and training injuries, as well as for specific body regions (knee, ankle, shoulder, and spine). Severe injuries, defined as those leading to an absence longer than 28 days, were also reported separately [40]. The injury incidence densities, expressed as the number of injuries per 1,000 h of wrestling exposure, were presented with 95% confidence intervals. To compare the injury incidence densities between groups, rate ratios (RRs) were calculated using Comprehensive Meta-Analysis (CMA) software.

Results

There were no significant differences in participant characteristics (age, height, weight, body mass index and training experience) between the EXP and CON groups ($p > 0.05$). Further baseline data are presented in Table 1 ($p \leq 0.05$).

There was no significant difference between groups at baseline in all measures ($p > 0.05$). The EXP and CON groups showed a significant change in YBT, YBT-UQ, muscular strength of ankle plantar flexor, muscular strength of shoulder flexors, error sense of force in ankle plantar flexors, error sense of force in shoulder flexors, range of motion in ankle plantar flexion, range of motion in shoulder flexion, error joint reposition of ankle plantar flexion, and error joint reposition of shoulder flexion,

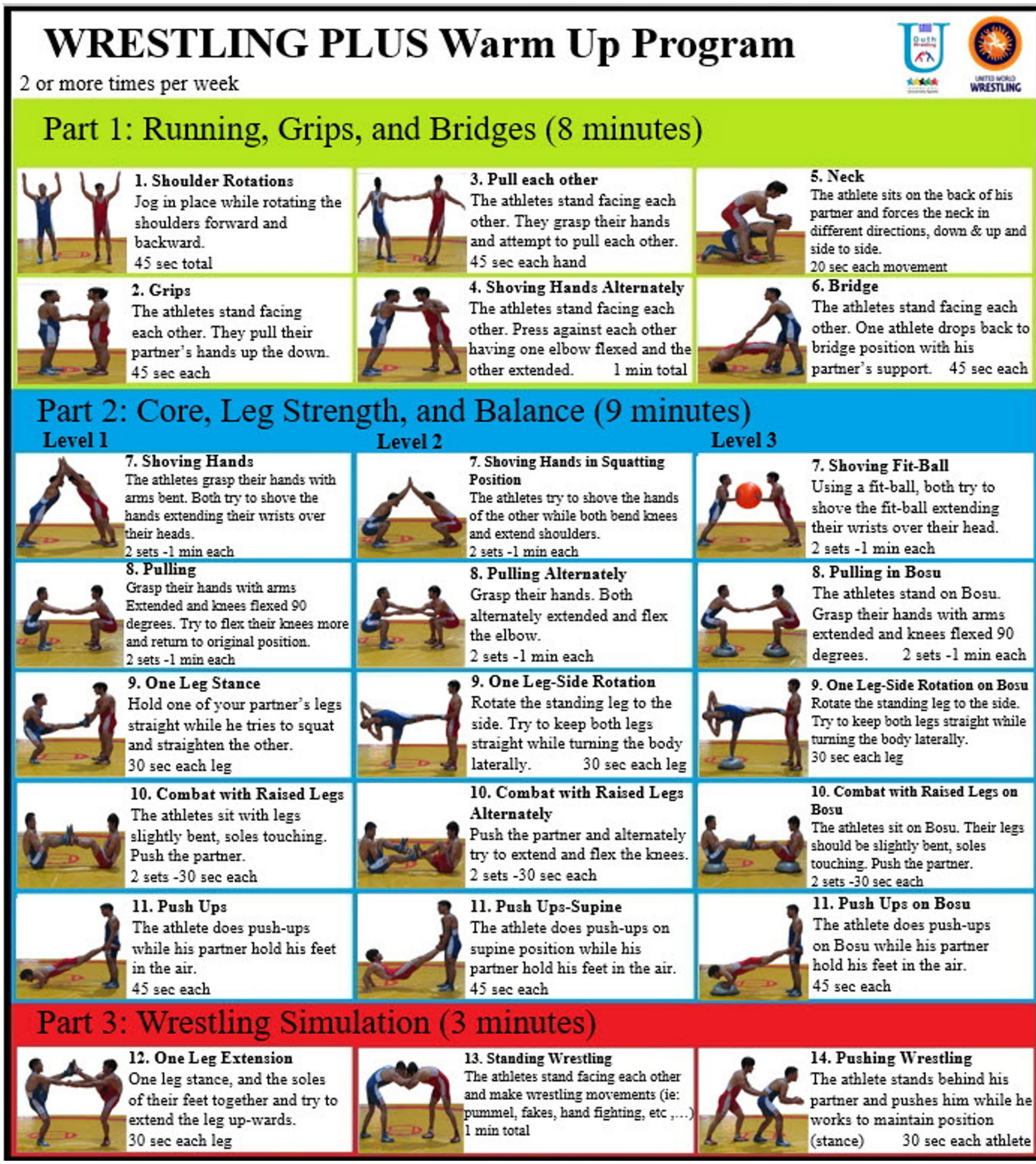

Fig. 4 Wrestling + warm-up program

after 24 weeks Wrestling + injury prevention program ($p < 0.05$). Furthermore, the EXP group indicated significant differences in comparison to CON ($p < 0.05$) (Table 2).

The per-protocol analysis showed a reduction of the overall injury incidence density in the EXP group by 58% compared to the CON group (Table 3). The total number of days lost due to injury was lower in the EXP group compared to the CON group (Table 1). Injury burden (lay-off days per 1000 h) was 63% lower in the EXP group compared to the CON group (RR 0.71 95%-CI 0.21, 1.28). Overall (66% reduction), Knee (60% reduction), Ankle (71% reduction), Spine (71% reduction), and shoulder (63% reduction) were reduced in the EXP group

Table 1 Participants and injury characteristics (Mean ± SD)

Variables	EXP (n = 40)	CON (n = 40)	p-value
Age (year)	17.1 ± 1.1	17.3 ± 0.9	0.23
Height (cm)	171.1 ± 10.2	170.2 ± 8.2	0.46
Weight (kg)	56.7 ± 7.3	57.1 ± 6.86	0.46
Body mass index (kg / m^2)	22.1 ± 2.1	23.2 ± 2.4	0.86
Training experience (year)	4.3 ± 1.2	4.6 ± 1.6	0.96
Total exposure (h)	10,053	9963	
Match exposure (h)	96	96	
Training exposure (h)	9957	9867	
Number of injuries during the study period by time loss			
Total number of injuries (*N*) (%)	20	30	
> 28 d (*N*) (%)	4 (20)	10 (33.33)	
Sum of days lost to injury (d)	236	369	
Injury burden (d/1000 h) (95%-CI)	15.52 (12.36–18.69)	25.52 (22.36–28.69)	
Types of injuries			
Bursitis (*N*)	3	4	
Sprains (*N*)	1	5	
Strains (*N*)	5	8	
Dislocation (*N*)	2	3	
Contusions (*N*)	3	6	
Tendinitis (*N*)	6	4	

EXP: Experimental group; CON: Control group; h = hour; d = days; 95%-CI = 95% confidence interval

compared to the CON group. The according point estimates of the rate ratios do indicate a beneficial effect of the Wrestling + injury prevention program. However, the respective confidence intervals were too large to draw firm conclusions for the latter injury subcategories (Table 3).

Dissection

The aim of the present study was the effects of Wrestling + injury prevention program on incidence of injuries, neuromuscular mechanisms and dynamic balance of the FS wrestler. The findings indicated that a 24-week Wrestling + injury prevention program was more effective than traditional routine warm-up in enhancing the neuromuscular mechanisms and dynamic balance of FS wrestlers. Also, the per-protocol analysis showed a reduction of the overall injury incidence density in the Wrestling + injury prevention program group by 58% compared to the traditional routine warm-up group. Moreover, the according point estimates of the rate ratios do indicate a beneficial effect of the Wrestling + injury prevention program.

The reductions in overall injuries observed in this study align with findings from other researches [41–43]. Furthermore, a recent literature review on injury prevention strategies indicated that sport-related injuries can be reduced by engaging in dynamic warm-up programs that incorporate preventive exercises, as well as strength, balance, and mobility exercises during training sessions [44]. The Wrestling + program is a comprehensive training approach that addresses strength, balance, neuromuscular function, and core stability, making it an effective dynamic warm-up program for reducing injuries among wrestlers.

Studies have emphasized that injury prevention efforts should particularly target severe injuries [45, 46]. While this study was not specifically designed to investigate severe injuries, the point estimates suggest a notable reduction in their occurrence. Depending on the injury's severity, players may need to decrease their training intensity or rest completely until they have adequately recovered [47]. Additionally, injuries are a significant factor contributing to dropout from sports participation [48]. Reducing dropout rates from sports can also decrease societal costs by promoting higher long-term physical activity levels. When cadet stay active, they are more likely to become active adults, which in turn lowers their risk of lifestyle-related diseases [49].

The observed reduction in injuries is significant from both health and performance perspectives. The Wrestling + program group experienced a reduction of more than half in the number of days lost to injury, resulting in fewer interruptions to training and match participation. While reduced training load can negatively impact player performance, time-loss injuries inherently decrease participation in training and competition, which can further diminish performance [50]. Exercise-based injury prevention programs, such as the Wrestling + program, have been shown to directly enhance athletes' performance compared to traditional warm-up routines [51–53]. Thus, these injury prevention programs may effectively meet

Table 2 Changes in neuromuscular mechanisms and dynamic balance performance (mean ± SD)

		EXP ($n = 40$)		CON ($n = 40$)
		Mean ± SD		Mean ± SD
YBT (cm)	Pre. test	82.15 ± 8.19		82.78 ± 7.11
	Post. test	86.23± 9.32	*,**	84.28 ± 9.19
	Effect size	0.81 (-0.13, 1.22)		0.53 (-0.42, 0.98)
YBT-UQ (cm)	Pre. test	76.23 ± 8.36		75.96 ± 8.29
	Post. test	81.26 ± 9.16	*,**	77.69 ± 7.86
	Effect size	1.26 (0.41, 1.92)		0.64 (-1.08, 0.18)
Muscular strength of ankle plantar flexor (*n*)	Pre. test	2.89 ± 0.39	*,**	3.03 ± 0.71
	Post. test	4.26.16 ± 0.59		4.13 ± 0.64
	Effect size	1.26 (-0.36, 1.6)		0.71 (-0.12, 0.1.25)
Muscular strength of shoulder flexors (*n*)	Pre. test	3.76 ± 0.76	*,**	3.26 ± 0.71
	Post. test	5.16 ± 0.79		4.76 ± 0.54
	Effect size	1.56 (-0.91, 2.16)		0.89 (-1.08, 0.23)
Error sense of force in ankle plantar flexors (*n*)	Pre. test	4.23 ± 0.98	*,**	4.63 ± 0.79
	Post. test	2.1 ± 0.56		3.01 ± 0.46
	Effect size	1.2 (-0.91, 2.12)		0.67 (-1.08, 0.98)
Error sense of force in shoulder flexors (*n*)	Pre. test	4.93 ± 0.79	*,**	4.46 ± 0.49
	Post. test	1.98 ± 0.38		3.01 ± 0.76
	Effect size	1.46 (-0.91, 2.46)		0.86 (-1.08, 0.98)
Range of motion in ankle plantar flexion (^{0})	Pre. test	36.19 ± 5.49	*,**	35.16 ± 5.16
	Post. test	39.16 ± 6.26		36.94 ± 6.54
	Effect size	1.2 (-0.91, 1.85)		0.64 (-1.08, 0.97)
Range of motion in shoulder flexion (^{0})	Pre. test	173.49 ± 10.16	*,**	174.49 ± 10.49
	Post. test	177.19 ± 11.55		175.94 ± 9.51
	Effect size	1.6 (-0.91, 2.49)		0.76 (-1.08, 0.89)
Error joint reposition of ankle plantar flexion (^{0})	Pre. test	5.11 ± 0.98	*,**	5.49 ± 0.71
	Post. test	2.51 ± 0.67		3.86 ± 0.76
	Effect size	1.6 (-0.91, 2.96)		0.66 (-1.08, 0.96)
Error joint reposition of shoulder flexion (^{0})	Pre. test	5.12 ± 0.98	*,**	5.76 ± 0.49
	Post. test	2.46 ± 1.1		3.46 ± 0.67
	Effect size	1.2 (-0.91, 2.15)		0.67 (-1.08, 0.89)

*Significant differences compared with pre-training value ($p \leq 0.05$); **Significant differences compared with control group ($p \leq 0.05$); EXP: Experimental group; CON: Control group; YBT: Y-Balance Test; YBT-UQ: Upper Quarter YBT

Table 3 Number and percentage of injuries, injury incidence density (IID), and rate ratio (RR) between EXP and CON groups

Injury	EXP ($N = 20$ injuries)			CON ($N = 30$ injuries)			RR (95%-CI)
	N	%	IID (95%-CI)	*N*	%	IID (95%-CI)	
Overall	20	100	0.81 (1.23; 2.69)	30	100	1.92 (0.66; 2.34)	0.58 (0.16; 0.81)
Match	14	70	12.36 (5.79; 16.49)	19	63	16.79 (1.49; 17.27)	0.36 (0.16; 0.94)
Training	6	30	2.89 (0.23; 1.94)	11	37	4.79 (0.26; 2.39)	0.46 (0.19; 0.92)
Knee	3	15	0.66 (0.25; 0.84)	5	17	1.26 (0.39; 1.89)	0.59 (0.46; 0.97)
Ankle	5	25	0.54 (0.29; 0.93)	7	23	1.11 (0.37; 1.49)	0.58 (0.05; 1.68)
Spine	5	25	0.61 (0.49; 1.12)	7	23	1.36 (0.47; 1.89)	0.57 (0.08; 0.86)
Shoulder	7	35	0.49 (0.24; 0.97)	11	37	1.11 (0.39; 1.79)	0.75 (0.09; 0.87)
Severe	1	5	0.17 (0.09; 0.21)	4	13	0.89 (0.02; 0.89)	0.68 (0.49; 0.96)

IID: Injury incidence density; 95%-CI = 95%: Confidence interval; RR = Rate ratio; EXP: Experimental group; CON: Control group

the demands of high-level sports, where the primary focus is on maximizing performance.

Exercises are proved to change cellular capacity and structure and improve neuromuscular compatibility of athletes and influence their reflective as well as voluntary activities. In this regard, it seems that specific exercises have a greater impact on neuromuscular mechanisms than other exercises. In the present study, it was found that Wrestling + injury prevention program had a greater impact on neuromuscular mechanisms and dynamic balance of FS wrestlers. The results of the present study are consistent with the results of studies Bayati, Shamsi

Majelan and Mirzaei (20), Bayati, Shamsi Majelan (22), and Barbas, Gioftsidou (21). These researches have indicated that the Wrestling + program can enhance various physical attributes among participants, such as dynamic balance, static balance, lower limb strength, and FMS test scores [20–22].

One reason the Wrestling + program positively affects neuromuscular mechanisms and dynamic balance is its comprehensive nature, incorporating strength, neuromuscular, and stretching exercises. Activities such as squats, grappling, and balancing on one leg on a Bosu ball effectively enhance strength, provide stable support for peripheral movements, and improve reach in the YBT and YBT-UQ tests. Consequently, the observed improvements in the YBT and YBT-UQ tests for both lower and upper limbs can be attributed to increased muscle strength. Additionally, a gradual increase in exercise intensity, difficulty, and repetitions contributes to enhanced neuromuscular control and stability during dynamic balance assessments. However, Thorpe and Ebersole [54] suggested that improvements in dynamic balance may be more closely linked to enhanced neuromuscular control rather than solely muscle strength. Overall, the findings of this study indicate that the Wrestling + program effectively improves both muscle strength and neuromuscular mechanisms, making it a comprehensive training approach that significantly benefits the performance of FS wrestlers.

Furthermore, core strength is a vital component of the Wrestling + program. This program includes seated endurance exercises on a Bosu ball to target the anterior abdominal muscles, as well as lateral abdominal strengthening exercises performed during single-leg stands on the Bosu ball, complemented by lateral trunk flexion. These exercises aim to enhance wrestlers' core stability. Research by Tsukagoshi, Shima [55] indicates that the endurance of core stability muscles is significantly correlated with dynamic balance, as measured by the Y-balance test. Therefore, the improvement in dynamic balance observed in participants can be attributed to increased core muscle endurance.

Additionally, neuromuscular training is a key component of the Wrestling + program. These exercises, performed within a closed kinetic chain and involving simultaneous muscle contractions, enhance the functioning and organization of mechanoreceptors in the skin, joints, and capsules, thereby improving the efficiency of proprioceptive receptors [56]. Neuromuscular exercises contribute to faster nerve conduction, better coordination between opposing muscle groups, and adaptations in both extraspinal and intraspinal fibers, while also reducing Golgi tendon organ activity [57]. In addition to, these exercises can activate neural pathways, increase the number of synapses, and expand the relevant sensory areas, demonstrating neural plasticity [58]. Research has shown that training can lead to increased output from muscle spindles, which may enhance the accuracy of movements by modifying muscle tone [59]. Adaptations in these areas can improve joint position sense, force perception, and range of motion, as evidenced in the current study.

Limitations and future scope

This study was not adequately powered to analyze the impact of compliance, which is a crucial factor in the effectiveness of an injury prevention program. Future research should explore the intrinsic motivation of coaches to implement these programs and the factors that contribute to compliance. Also, while this study did not specifically investigate severe injuries, future studies should include a detailed analysis of severe injuries. Subsequent research could also assess the effectiveness of the Wrestling + program in real-world settings and examine its long-term effects on injury risk and performance. Additionally, this study focused solely on cadet FS wrestlers aged 16 to 17. Therefore, the effects of this program should be evaluated in GR wrestlers and across different age groups. It is also important to compare the Wrestling + program with other injury prevention programs to determine which dynamic warm-up approach is most effective. Furthermore, future studies should consider gender differences and individual training levels, as the program's effectiveness may vary based on age, skill level, and specific physical characteristics. In addition, the incorporation of advanced biomechanical control tools into the analysis is recommended to facilitate a more nuanced assessment of the program's impact.

Conclusion

The Wrestling + injury prevention program is effective in reducing injuries among FS wrestlers aged 16 to 17, with overall injuries reduced by 58%. In addition to its positive impact on players' health, the Wrestling + program enables athletes to train and compete more frequently, as it significantly decreases the number of days lost to injury. This can enhance individual performance, potentially supporting long-term athlete development. These findings underscore the importance and necessity of injury prevention for cadet athletes. Moreover, the results indicate that the Wrestling + program is more effective than traditional warm-up routines in improving neuromuscular mechanisms and dynamic balance among FS wrestlers. Therefore, it is recommended that coaches use a Wrestling + program to reduce the incidence of injury in FS wrestlers.

Acknowledgements

The researcher would like to express gratitude towards all the participants that contributed to conducting the study.

Author contributions
R.B. & HZ.: data acquisition and analysis. R.B.& A.SM. & H.Z.: data interpretation. R.B.& A.SM. & H.Z.: wrote the main manuscript text and prepared the figures. R.B.& A.SM. & H.Z.: conception/design of the work. All authors reviewed and contributed to the manuscript.

Funding
This research received no funding from any agency in the public, commercial, or not-for-profit sector.

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Clinical trial number
IRCT20241123063808N1.

Conflict of interest
The authors have no conflicts of interest to declare.

Informed consent
All participants were informed of the purpose and procedure of this study, and informed consent was obtained from all participants.

Compliance with ethical guidelines
The study was approved by the University of Guilan (Iran) IR.GUILAN.REC.1403.138. All experiments were conducted in accordance with the relevant guidelines and regulations.

Human ethics and consent to participate declarations
Not applicable.

Disclosure statement
No potential conflict of interest was reported by the authors.

Received: 16 April 2025 / Accepted: 11 May 2025
Published online: 19 May 2025

References
1. Wroble* RR. Wrestling. Combat sports medicine. Springer; 2008. pp. 215–45.
2. Shadgan B, Molavi N, Abaeva E, Falahati S, Sikimic S, Konstantinou L, Molnar S. Wrestling injuries during the 2016 Rio and 2020 Tokyo olympic games. Br J Sports Med. 2024.
3. Maffulli N. Making weight: a case study of two elite wrestlers. Br J Sports Med. 1992;26(2):107–10.
4. Tabasi S, Norasteh A, Mirzaei B, Zarei H. Proprioception and dynamic balance performance in wrestlers: freestyle vs. Greco-Roman Sci Sports. 2022;37(5–6):494. e1-. e7.
5. Mirzaei B, Ghahremani Moghaddam M, Alizaee Yousef Abadi H. Analysis of energy systems in Greco-Roman and freestyle wrestlers who participated in the 2015 and 2016 world championships. Int J Wrestling Sci. 2017;7(1–2):35–40.
6. Said K. Physical and physiological profile of wrestler athletes: Short review. 2016.
7. Mykola L, Sergii L, Alexander K. Performance analysis of freestyle wrestling competitions of the last olympic cycle 2013–16. J Phys Educ Sport. 2017;17(2):590.
8. Jlid M, Maffulli N, Elloumi M, Moalla W, Paillard T. Rapid weight loss alters muscular performance and perceived exertion as well as postural control in elite wrestlers. J Sports Med Phys Fit. 2013;53(6):620–7.
9. Ulupınar S, Özbay S, Gençoğlu C, Ince I. Performance differences between Greco-Roman and freestyle wrestlers: A systematic review and meta-analysis. J Strength Conditioning Res. 2021;35(11):3270–9.
10. Demirkan E, Kutlu M, Koz M, Özal M, Favre M. Physical fitness differences between freestyle and Greco-Roman junior wrestlers. J Hum Kinetics. 2014;41:245.
11. Gutiérrez-Santiago A, Vázquez-Estévez C, Paramés-González A, Argibay-González JC, Reguera-López-de-la-Osa X, Vila-Fernández N, et al. The Temporal structure of male freestyle wrestling bouts in 65, 86 and 125 kg categories. PLoS ONE. 2023;18(3):e0282952.
12. Riccio I, Tarulli FR, Maffulli N, Wrestling. Specific Sports-Related Injuries: Springer; 2022:471–85.
13. Molnár S, Hunya Z, Gáspár K, Szerb I, Szabó N, Mensch K, et al. Moderate and severe injuries at five international olympic-style wrestling tournaments during 2016–2019. J Sports Sci Med. 2022;21(1):74.
14. Molnár S, Hunya Z, Pavlik A, Bozsik A, Shadgan B, Maffulli N. SLAP lesion and injury of the proximal portion of long head of biceps tendon in elite amateur wrestlers. Indian J Orthop. 2020;54:310–6.
15. Agel J, Ransone J, Dick R, Oppliger R, Marshall SW. Descriptive epidemiology of collegiate Men's wrestling injuries: National collegiate athletic association injury surveillance system, 1988–1989 through 2003–2004. J Athl Train. 2007;42(2):303.
16. Brzezińska P, Mieszkowski J, Waldziński T, Durzyńska A, Waldzińska E, Mieszkowski D, et al. Musculoskeletal injuries in freestyle wrestling-sport specification. Arch Budo. 2022;18:241–50.
17. Halloran L. Wrestling injuries. Orthop Nurs. 2008;27(3):189–92.
18. Smith D. SA26 the health economics of professional wrestling. Value Health. 2022;25(7):S609.
19. Gioftsidou A, Barbas I, Turlykhanov D, Podlivaev B, Tunnemann H, Sahmouratov Y, et al. Wrestling + and new structures for youth wrestling. Int J Wrestling Sci. 2015;5(2):93–7.
20. Bayati R, Shamsi Majelan A, Mirzaei B. The effect of 12 weeks of Wrestling + Specific Warm-Up program on dynamic balance in cadet wrestlers. J Sport Biomech. 2018;4(1):63–73.
21. Barbas I, Gioftsidou A, Gkrekidis T, Makri E, Malliou P, Beneka A. The Effects of Wrestling + Injury Prevention Program on Lower Limbs Strength and Balance. Экстрабилити как феномен инклюзивной культуры: формирование инклюзивной культуры в организациях—Екатеринбург, 2020. 2020:34–9.
22. Bayati R, Shamsi Majelan A, Mirzaei B, Barbas I. The effect of 12 weeks of wrestling + warm-up program on functional movement screen scores in cadet wrestlers. Annals Appl Sport Sci. 2019;7(1):39–47.
23. Tatlici A, Lima Y, Çiftçi B, Aktas S, Badak T. The effect of 8-weeks wrestling training on unilateral muscle imbalances. Phys Educ Students. 2021;25(4):205–11.
24. McKay AKA, Stellingwerff T, Smith ES, Martin DT, Mujika I, Goosey-Tolfrey VL, et al. Defining training and performance caliber: A participant classification framework. Int J Sports Physiol Perform. 2022;17(2):317–31.
25. Morrison BM, editor. Editor neuromuscular diseases. Seminars in neurology. Thieme Medical; 2016.
26. Rerucha CM, Dickison C, Baird DC. Lower extremity abnormalities in children. Am Family Phys. 2017;96(4):226–33.
27. Schulz KF, Altman DG, Moher D, Group* C. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. Ann Intern Med. 2010;152(11):726–32.
28. Tipton PH, Aigner MJ, Finto D, Haislet JA, Pehl L, Sanford P, Williams M. Consider the accuracy of height and weight measurements. Nursing2023. 2012;42(5):50–2.
29. Vella SP. The relationship between leg length inequality and pelvic kinematics. Macquarie University; 2020.
30. Norton KI. Standards for anthropometry assessment. Kinanthropometry and exercise physiology: Routledge; 2018. pp. 68–137.
31. Casadei K, Kiel J. Anthropometric measurement. 2019.
32. Ko J, Wikstrom E, Li Y, Weber M, Brown CN. Performance differences between the modified star excursion balance test and the Y-balance test in individuals with chronic ankle instability. J Sport Rehabilitation. 2019;29(6):748–53.
33. Schwiertz G, Beurskens R, Muehlbauer T. Discriminative validity of the lower and upper quarter Y balance test performance: a comparison between healthy trained and untrained youth. BMC Sports Sci Med Rehabilitation. 2020;12:1–8.
34. Leijendekkers RA, Hinte Gv, Sman AD, Staal JB, Nijhuis-Van Der Sanden MW, Hoogeboom TJ. Clinimetric properties of hip abduction strength measurements obtained using a handheld dynamometer in individuals with a lower extremity amputation. PLoS ONE. 2017;12(6):e0179887.
35. Bock O, Thomas M. Proprioception plays a different role for sensorimotor adaptation to different distortions. Hum Mov Sci. 2011;30(3):415–23.
36. Norkin CC, White DJ. Measurement of joint motion: a guide to goniometry. FA Davis; 2016.

37. Yang N, Waddington G, Adams R, Han J. Joint position reproduction and joint position discrimination at the ankle are not related. Somatosens Motor Res. 2020;37(2):97–105.
38. Lee H-M, Liau J-J, Cheng C-K, Tan C-M, Shih J-T. Evaluation of shoulder proprioception following muscle fatigue. Clin Biomech Elsevier Ltd. 2003;18(9):843–7.
39. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Front Psychol. 2013;4:863.
40. Zarei M, Abbasi H, Namazi P, Asgari M, Rommers N, Rössler R. The 11 + Kids warm-up programme to prevent injuries in young Iranian male high-level football (soccer) players: A cluster-randomised controlled trial. J Sci Med Sport. 2020;23(5):469–74.
41. Lopes M, Simões D, Costa R, Oliveira J, Ribeiro F. Effects of the FIFA 11 + on injury prevention in amateur futsal players. Scand J Med Sci Sports. 2020;30(8):1434–41.
42. Al Attar WSA, Bizzini M, Alzahrani H, Alarifi S, Ghulam H, Alyami M, et al. The FIFA 11 + kids injury prevention program reduces injury rates among male children soccer players: a clustered randomized controlled trial. Sports Health. 2023;15(3):397–409.
43. Asgari M, Alizadeh MH, Shahrbanian S, Nolte K, Jaitner T. Effects of the FIFA 11 + and a modified warm-up programme on injury prevention and performance improvement among youth male football players. PLoS ONE. 2022;17(10):e0275545.
44. Ding L, Luo J, Smith DM, Mackey M, Fu H, Davis M, Hu Y. Effectiveness of warm-up intervention programs to prevent sports injuries among children and adolescents: A systematic review and meta-analysis. Int J Environ Res Public Health. 2022;19(10):6336.
45. Rössler R, Donath L, Verhagen E, Junge A, Schweizer T, Faude O. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. Sports Med. 2014;44:1733–48.
46. Lystad RP, Alevras A, Rudy I, Soligard T, Engebretsen L. Injury incidence, severity and profile in olympic combat sports: a comparative analysis of 7712 athlete exposures from three consecutive olympic games. Br J Sports Med. 2021;55(19):1077–83.
47. Rössler R, Junge A, Bizzini M, Verhagen E, Chomiak J, Aus der Fünten K, et al. A multinational cluster randomised controlled trial to assess the efficacy of '11 + Kids': a warm-up programme to prevent injuries in children's football. Sports Med. 2018;48:1493–504.
48. Grimmer KA, Jones D, Williams J. Prevalence of adolescent injury from recreational exercise: an Australian perspective. J Adolesc Health. 2000;27(4):266–72.
49. Rössler R, Verhagen E, Rommers N, Dvorak J, Junge A, Lichtenstein E, et al. Comparison of the '11 + Kids' injury prevention programme and a regular warmup in children's football (soccer): a cost effectiveness analysis. Br J Sports Med. 2019;53(5):309–14.
50. Gabbett T. The relationship between workloads, physical perfo. 2014.
51. Faude O, Rössler R, Petushek EJ, Roth R, Zahner L, Donath L. Neuromuscular adaptations to multimodal injury prevention programs in youth sports: a systematic review with meta-analysis of randomized controlled trials. Front Physiol. 2017;8:791.
52. Zarei M, Abbasi H, Daneshjoo A, Barghi TS, Rommers N, Faude O, Rössler R. Long-term effects of the 11 + warm-up injury prevention programme on physical performance in adolescent male football players: a cluster-randomised controlled trial. J Sports Sci. 2018;36(21):2447–54.
53. Rössler R, Donath L, Bizzini M, Faude O. A new injury prevention programme for children's football–FIFA 11 + Kids–can improve motor performance: a cluster-randomised controlled trial. J Sports Sci. 2016;34(6):549–56.
54. Thorpe JL, Ebersole KT. Unilateral balance performance in female collegiate soccer athletes. J Strength Conditioning Res. 2008;22(5):1429–33.
55. Tsukagoshi T, Shima Y, Nakase J, Goshima K, Takahashi R, Aiba T, et al. Relationship between core strength and balance ability in high school female handball and basketball players. Br J Sports Med. 2011;45(4):378.
56. Arumugam A, Björklund M, Mikko S, Häger CK. Effects of neuromuscular training on knee proprioception in individuals with anterior cruciate ligament injury: a systematic review and GRADE evidence synthesis. BMJ Open. 2021;11(5):e049226.
57. Caldemeyer LE, Brown SM, Mulcahey MK. Neuromuscular training for the prevention of ankle sprains in female athletes: a systematic review. Physician Sportsmed. 2020;48(4):363–9.
58. McPherson AL, Zuleger TM, Foss KDB, Warren SM, Hogg JA, Diekfuss JA, Myer GD. Does neuromuscular training reduce the risk of lower-extremity musculoskeletal injury in high school female athletes with a history of sport-related concussion? J Sport Rehabilitation. 2024;1(aop):1–9.
59. Streckmann F, Elter T, Lehmann HC, Baurecht H, Nazarenus T, Oschwald V, et al. Preventive effect of neuromuscular training on chemotherapy-induced neuropathy: a randomized clinical trial. JAMA Intern Med. 2024;184(9):1046–53.

Publisher's note