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Original Article

Differential effects of strength training volumes on Functional Movement Screen™ performance in elite soccer players

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Abstract:
This study examined the effects of varying volumes of strength training on Functional Movement Screen™ (FMS™) outcomes in 12 elite soccer players. Participants were divided into two groups, ES1 and ES2, based on training frequency, age (over 18), and the exclusion of goalkeepers owing to differing training protocols. The ES1 group had a mean age of 23.06 ± 2.60 years, a weight of 76.35 ± 7.88 kg, and a height of 178 ± 6.06 cm, while the ES2 group had a mean age of 21.08 ± 2.18 years, a weight of 74.93 ± 3.13 kg, and a height of 179.92 ± 5.62 cm. Over the 9-week period, ES1 completed two strength training sessions per week, while ES2 completed four. The initial average FMS™ score for both groups was 12.92 ± 2.57 points, which improved to 15.42 ± 1.83 points by the program's conclusion. ES1's score increased from 13.50 ± 1.38 to 14.67 ± 1.37 (Cohen's d = 0.85), indicating a medium effect. ES2's score improved from 12.33 ± 3.44 to 16.17 ± 2.04 (Cohen's d = 1.35), indicating a large effect. These findings suggest that both training frequencies effectively improved FMS™ scores, with higher frequency leading to more substantial gains. These results indicate that both training frequencies effectively improved FMS™ scores, with the higher frequency group (ES2) showing more pronounced gains. The effect sizes in both groups demonstrate that the changes were not only statistically significant but also practically meaningful. The improvements in FMS™ scores highlight the positive influence of systematic strength training on players' functional movement abilities. The ES2 group, which completed four sessions per week, achieved greater progress, suggesting that a higher training frequency may lead to better outcomes in the FMS™ test. However, the potential risk of overtraining should also be considered. Based on these findings, we recommend that coaches tailor training frequency to the individual needs and capacities of athletes. While increasing training frequency can yield more significant improvements, it is crucial to ensure proper management and monitoring to avoid the risk of overtraining.
Key Words*:* Asymmetry, corrective exercise, injury prevention, movement adaptation, physical performance.

Introduction

In the modern sports, optimizing performance and preventing injuries are crucial for athletes and coaches. One of the most recognized tools for assessing movement patterns and identifying injury risk is the Functional Movement Screen™ (FMS™). The FMS™ has a critical role in this functional approach by providing a standardized method for assessing fundamental movements that require a balance of mobility and stability. The FMS™ consists of seven key movement patterns designed to reveal weaknesses and imbalances that may contribute to injury or hinder performance. By testing these fundamental movements, the FMS™ offers insights into an athlete's overall movement quality, helping sports professionals to tailored rehabilitation and training protocols to the specific needs of the individual. This screening tool fills the gap between pre-participation evaluations and performance testing, making it a valuable resource in both injury prevention and performance enhancement (Cook et al., 2006a, 2006b, 2014a, 2014b, 2014c). While FMS™ has been widely used to identify injury risks in professional sports, studies like Kolodziej and Jaitner (2018) show that lower FMS™ scores, particularly in core stability and strength tests, are also associated with a higher risk of injury in amateur soccer players.

Although FMS™ has become widely recognized as a tool for identifying injury risks, its relationship to different volumes of strength training remains unclear. Most research, such as studies by Kiesel et al. (2007), Garrison et al. (2015), and Lisman et al. (2013), has shown that low FMS™ scores are associated with an increased risk of injury. Rusling et al. (2015) found that only certain components of FMS™, such as the deep squat and trunk stability, were significant predictors of injury, while the overall FMS™ score did not have a strong relationship with injury risk. This view was also supported by Mokha et al. (2016), who emphasized that individual FMS™ scores of asymmetry are a more accurate indicator of potential musculoskeletal injuries than the composite score. Garrison et al. (2015) confirmed that low FMS™ scores are linked to a higher risk of injury, suggesting that improving these scores could reduce that risk. However, Miyamori et al. (2020) indicated that FMS™ might lack sufficient sensitivity and specificity for predicting injuries, which requires for further

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investigation. Moreover, Newton et al. (2017) found no significant relationship between FMS™ scores and non-contact injury rates among elite Premier League youth players, suggesting that while FMS™ may not predict injuries in certain age groups, it can still offer valuable insights for practitioners when designing strength-training programs, especially at the start of a new season with unfamiliar players. Similarly, Smith and Hanlon (2017) found no significant difference in injury incidence between players scoring above or below 14 on the FMS™ when normalized against match exposure in semi-professional soccer players, suggesting that FMS™ composite scores alone may not be reliable predictors of non-contact injury risk. In competitive sports, injuries not only disrupt training and competition but can also have long-term consequences for an athlete's career. Marques et al. (2017) highlighted functional deficits and asymmetry in young athletes and emphasized the need for targeted interventions to improve movement patterns and reduce the risk of injury. Exercises aimed at improving symmetry, balance, and correcting deficits can significantly help minimize injury risks. Such exercises, aimed at achieving better symmetry and balance between mobility and stability, as noted by Kiesel et al. (2011) can significantly contribute to reducing injury likelihood. Portas et al. (2016) also emphasized the influence of maturity on FMS™ scores in young soccer players, underscoring the need for tailored training according to individual athlete development. Sawczyn (2020) demonstrated that periodized functional strength training significantly improves FMS™ scores in students with a higher risk of injury. Similar results were observed by Siamaki et al. (2017), who found significant improvements in FMS™ scores in young soccer players after 10 weeks of functional training program.

Regarding training volumes, no direct studies were found examining the impact of different strength training volumes on FMS™ improvement. However, Otero-Esquina et al. (2017) showed that higher frequency strength training (twice per week) resulted in better performance in strength and speed capabilities, suggesting that greater training volume may lead to better physical performance. Conversely, Yanci et al. (2017) found that even one plyometric training session per week could be as effective as two sessions in improving physical performance, indicating that lower training volumes might be sufficient for achieving similar results. However, it remains to be seen how different training volumes will affect FMS™ improvements. At the same time, Lockie et al. (2015) and Venter et al. (2017) found minimal relationships between FMS™ scores and performance metrics such as speed and agility, indicating that FMS™ may not always be a sensitive enough tool to predict performance in team sports. However a study on elite collegiate soccer players found that higher FMS™ total scores were significantly associated with better performance in 10-m and 30-m sprints and the agility test, suggesting that improved movement patterns could enhance physical performance (Lee et al., 2019). Kiesel et al. (2011) demonstrated that off-season corrective exercises can significantly improve FMS™ scores and functional symmetry, making them suitable for implementation during this phase of the season. Bryson et al. (2021) further pointed out that educating and raising awareness about FMS™ criteria could positively impact FMS™ results, which is important to consider when implementing the tool.

Although training volumes clearly influence physical capabilities, further research is needed to determine how these volumes affect improvements in movement patterns evaluated by FMS™. Given the mixed results in the literature, more research is required to determine whether higher volumes of strength training lead to greater functional movement improvements, or whether similar benefits can be achieved with lower volumes without the risk of overtraining. To better understand the effects of different strength training volumes on FMS™ improvements, we conducted a 9-week period involving 12 elite soccer players from the 2nd Slovak soccer league during the 2021/2022 season. The players were divided into two groups: ES1, which completed two strength training sessions per week, and ES2, which completed four sessions per week. The training sessions focused on corrective exercises based on FMS™ results, aiming to improve the weakest areas identified in the initial tests of each athlete. Assessments using the full FMS™ battery were conducted before and after the intervention. Statistical analyses compared the FMS™ results before and after the intervention in both groups, and effect sizes were calculated to assess the extent of improvements in functional movement and to optimize training volumes without increasing the risk of overtraining.

Material & methods

Participants

In the preseason phase, more than 20 soccer players actively participated in the training process. These players were members of a team competing in the 2nd Slovak soccer league during the 2021/2022 season. However, only 12 players (Table 1) met the specific criteria required for inclusion in the study. These criteria included regular attendance at training sessions, being over 18 years of age, and the exclusion of goalkeepers due to their unique training programs. Upon completion of the training plan, and after applying these selection criteria, the players were divided into two groups for further analysis.

The ES1 group had an average age of 23.06 ± 2.60 years, an average weight of 76.35 ± 7.88 kg, and an average height of 178 ± 6.06 cm. In comparison, the ES2 group had an average age of 21.08 ± 2.18 years, an average weight of 74.93 ± 3.13 kg, and an average height of 179.92 ± 5.62 cm, highlighting slight differences between the two groups in terms of age, weight, and height.

Table 1. Description of the participants integrating each of the studied groups.

Group	Number of participants	Average age (years)	Average weight (kg)	Average height	Group
ES1	6	23.06 ± 2.60	76.35 ± 7.88	178 ± 6.06	ES1
ES2	6	21.08 ± 2.18	74.93 ± 3.13	179.92 ± 5.62	ES2

The aim of the study was to evaluate the effects of different volumes of strength training on movement abilities measured using the FMS™. In 9 weeks, ES1 completed two training sessions per week, while ES2 had four training sessions per week, for a total of 16 sessions for ES1 and 32 sessions for ES2 (the fifth week had no strength training).

Training units:

Main trainings (A): They lasted up to 75 minutes and were aimed at the development of myofibrillar hypertrophy, maximal strength, speed strength and strength speed. These exercises included basic pushing and pulling movements for both the upper and lower body in bilateral and unilateral ways, including exercises suchas squats, bench presses, deadlifts and other (Figure 2 and 3).

Secondary trainings (B): They lasted up to 45 minutes and complemented the main program with a focus on plyometric exercises, medicine ball exercises and in some phases- circuit training. These sessions were aimed at improving explosive power, explosiveness and endurance (Figure 2 and 3).

Table 2. Overview of training weeks and their characteristics

Block	TW	Character	Repx sets	Vol.	Int.	Character	Repx sets	Vol.	Int.
EXT I	-3, -2, -1	AA	8-10 x 4	128 – 160	65 – 75 %	-	-	-	-
INT I	1-2	MS	3 x 4	48	+ 85 %	SP	< 5 x 4	< 80	Exp
EXT II	3-4	MH	6 x 4	96	75 – 85 %	CT	30 s x 10	1200 s	30 – 45 %
-	5	-	-	-	-	-	-	-	-
INT II	6-7	SpS	< 5 x 4	< 60	45 – 65 %	FP	< 5 x 4	< 60	Exp
INT III	8	SSp	< 5 x 4	< 60	25 – 45 %	FP	< 5 x 4	< 60	Exp

TW= training week; Vol.= training volume; Int.= intensity

AA= anatomic adaptation; MS= maximal strength; MH= myofibril hypertrophy; SpS= speed strength; SSp= strength speed

SP= slow plyometrics; CT= circle training; FP= fast plyometrics, Exp= explosive

Table 3. Overview of weekly training units in ES1 and ES2 groups

Training week	ES1 Group TS	ES2 Group TS	**Character of training**	ES1 Group TS	ES2 Group TS	**Character of training**
1-2	A1	A1, A2	Maximal strength	B1	B1, B2	Slow plyometrics
3-4	A3	A3, A4	Myofibrillar hypertrophy	B3	B3, B4	Circle training
5	-	-	-	-	-	-
6-7	A5	A5, A6	Speed strength	B5	B5, B6	Fast plyometrics
8	A7	A7, A8	Strength speed	B7	B7, B8	Fast plyometrics

TU= training session; A1 - A8= main training units; B1 - B8= secondary training units

Before the start of the experiment, participants completed a three-week individual preparatory phase focused on muscle adaptation and improving aerobic capacity. This phase included six strength training sessions over three weeks, gradually increasing intensity while reducing volume. The final week emphasized intensive work on myofibrillar hypertrophy to conclude the phase.

Each training session starts with a specific warm-up routine, including myofascial massage, core activation, joint mobilization, and dynamic stretching. These exercises prepared participants for the main strength training, which incorporated exercises targeting weaknesses identified through FMS™ diagnostics.

Exercises were selected based on FMS™ results and aimed at improving ankle mobility, hip flexors, core activation, and rotational stability. Progressions and regressions were applied as needed, with examples of exercises provided in Table 4 and Table 5.

Table 4. Pillar preparation in A trainings

Pillar preparation	Exercise	Sets	Reps/ time	Rest
Soft tissue	Foam rolling- quadriceps, hamstring, calf, upperback		30 sec/ each	
Mobility	Dorsiflexion from half kneeling	2	8/ each	30 s
	Open half kneeling mobility	2	8/ each	
	Bent knee hamstring stretch/ with rope	2	8/ each	
	Thoracic rotation with rig grab	2	8/ each	
Activation	Dead bug ipsi/ contralateral	3	8/ each	30 s

Table 5. Pillar preparation in B trainings

Pillar preparation	Exercise	Sers	Reps/ time	Rest
Soft tissue	Foam rolling- quadriceps, hamstring, calf, upperback		30 sec/ each	
Mobility	Open half kneeling mobility	2	8/ each	30 s
	Hip flexor stretch from half kneeling	2	8/ each	
	Quadruped thoracic rotation	2	8/ each	
Activation	Plank/ plank with hip flexion	3	8/ each	30 s

Data collection and analysis

Testing took place under the supervision of certified FMS™ specialists. Testing included exercises: Deep Squat, Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-up, and Rotational Stability. Each test was evaluated on a three-point scale with a maximum score of 21 points. During FMS™ testing, each participant was assigned a score from 0 to 3 for each test according to standard FMS™ criteria (Cook et al., 2006a, 2006b, 2014a, 2014b, 2014c; Teyhan, 2012).

Tests such as the Hurdle Step, Inline Lunge, Shoulder Mobility, Active Straight Leg Raise, and Rotational Stability were assessed separately for each side of the body, allowing for the identification of asymmetries in movement patterns. In these tests, the lower score for both sides was included in the overall scoreof the corresponding movement test.

Statistical analysis

Statistical tests, including paired t-tests, were used to compare initial and final FMS™ scores in both groups. Effect size (Cohen's d) was calculated to assess the magnitude of changes in scores between the two groups. Results were considered statistically significant at $p < 0.05$.

Results

As part of monitoring the results of the FMS™ diagnostics, we noted that the total average score before the start of the training program was 12.92 ± 2.57 points. After the end of the program, we noticed an increase to an average score of 15.42 ± 1.83 points. A detailed comparison of the results between individual groups showed improvement in all monitored groups.

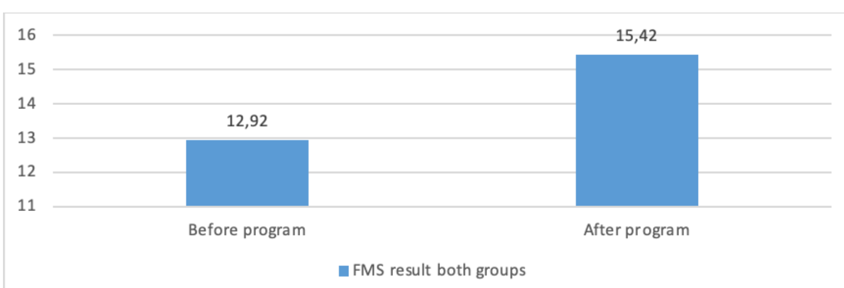

Figure 1. Initial and final FMS™ scores for all participants

ES1 showed an increase from the initial 13.50 ± 1.38 points to 14.67 ± 1.37 points, with an effect size (Cohen's d) for ES1 of 0.85, represents a large effect. This improvement suggests that the training program witha frequency of two training units per week was effective in increasing the functional movement abilities of the players in this group.

ES2 showed an increase from the initial 12.33 ± 3.44 points to 16.17 ± 2.04 points, with an effect size (Cohen's d) for ES2 of 1.35, represents a very large effect. The results indicate that a higher frequency of trainingunits, namely four training units per week, resulted in a more significant improvement in functional movement abilities compared to a lower frequency.

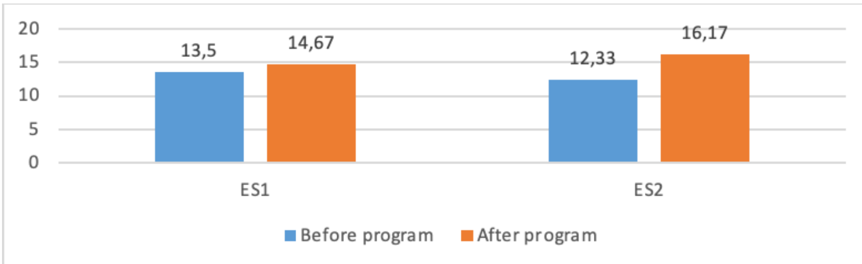

Figure 2. Initial and final FMS™ scores by group

Both training frequencies improved FMS™ scores, with ES2 showing greater enhancement, suggesting higher training frequency might yield better results. However, caution should be taken to avoid the risk of overtraining. Despite the improvement in FMS™ scores, ES2 did not show consistent improvements across all performance tests, indicating potential overtraining effects. In some strength and speed tests, ES1 showed better improvements compared to ES2, suggesting that excessive strength training frequency may not always yield optimal performance outcomes and could lead to overtraining.

For example, in the some tests what are not subject of this article such as single-leg long jump, ES1 showed a moderate effect size (Cohen's d = -0.622) compared to ES2's low effect size (Cohen's d = -0.052). Inthe double-leg long jump, ES1 had a moderate effect size (Cohen's d = 0.465) compared to ES2's low effect size (Cohen's d = 0.022). Similarly, for the non-countermovement vertical jump, ES1's moderate effect size (Cohen's d = 0.465) outperformed ES2's low effect size (Cohen's d = 0.022).

In agility, both groups showed high effect sizes (Cohen's d = 1.087) in the Pro agility test (5-10-5), indicating significant improvements. However, for speed tests over 5 and 10 meters, neither group showed significant improvements, with ES1 even showing a moderate decline in performance over 5 meters (Cohen's d = -0.493).

Individual Tests

Detailed analysis of individual FMS™ tests provides insight into specific performance strengths and weaknesses.

Table 6. Summary of initial and final FMS™ test scores for ES1 and ES2 groups for each test

Test	Initial score ES1	Final score ES1	Initial score ES2	Final score ES2
Rotatory Stability	1.33	1.67	1.33	2.00
Trunk Stability Push-up	3.00	3.00	2.00	3.00
Active Straight Leg Raise	2.17	2.67	2.17	2.67
Shoulder Mobility	2.50	2.50	2.17	2.67
Inline Lunge	1.33	1.50	1.00	1.83
Hurdle Step	1.83	2.00	2.00	2.17
Deep Squat	1.33	1.33	1.67	1.83

These results clearly show that both training frequencies (two and four training sessions per week) were effective in improving FMS™ scores. However, more significant improvements were achieved by the group with a higher training frequency (ES2). This suggests that a higher frequency of training may lead to better results, although caution is needed to avoid the risk of overtraining that we might see in performance tests.
For example, in the Inline Lunge test, the initial score was 1.33 in ES1, improving to final 1.50. In ES2, the initial score was 1.00, improving significantly to 1.83. In the Deep Squat test, the average initial score in ES1 was 1.33 and did not change, while in ES2, it improved from 1.67 to 1.83.

In the Hurdle Step test, the final average scores improved to 2.00 in ES1 and 2.17 in ES2, from initial scores of 1.83 (ES1) and 2.00 (ES2). In the Active Straight Leg Raise test, both groups improved to 2.67, showing enhanced flexibility and mobility of the lower limbs. In the Shoulder Mobility tests, the score in ES1 remained at 2.50, while in ES2, it increased from 2.17 to 2.67.

Consistently high scores in tests such as Trunk Stability Push-Up, where both ES1 and ES2 reached a score of 3.00 after the training interventions, confirm that the maintenance of strong areas was successful during the training period. The ES2 results showed that the more intense training regimen led to better improvement in several tests, especially in Rotatory Stability, where the score increased.

Our detailed analysis of individual FMS™ tests further reveals specific areas where higher frequency training was particularly beneficial. For example, in the Rotary Stability and Inline Lunge tests, the ES2 showed significantly greater improvements compared to the ES1. These findings provide valuable insights for the development of training plans, highlighting the need to focus on areas with lower initial scores and significant potential for improvement. Effective training protocols should combine different intensities and types of exercise to ensure comprehensive improvement in functional movement and minimize the risk of injury.

Dicussion

The results of our study showed that systematic and regular strength training had a positive effect on the functional movement skills of soccer players, as reflected in the improved FMS™ scores across all groups.

Group ES1 increased from 13.50 ± 1.38 to 14.67 ± 1.37 points (Cohen's d = 0.85), indicating that two weekly training sessions were effective. ES2 showed a more significant improvement from 12.33 ± 3.44 to 16.17 ± 2.04 points (Cohen's d = 1.35), indicating that four weekly training sessions had a greater impact.

These results emphasize the importance of higher training volumes. Research by Kiesel et al. (2007), Garrison et al. (2015), and Lisman et al. (2013) supports the connection between low FMS™ scores and a higher risk of injury. While Garrison et al. (2015) state that FMS™ can predict future injuries, Smith and Hanlon (2017) found that FMS™ scores did not significantly predict non-contact injury rates when adjusted for match exposure. This suggests that while FMS™ is useful, it might not always provide accurate injury predictions on its own. Marques et al. (2017) highlighted the common functional deficits and asymmetry in young athletes, stressing the importance of targeted exercises to correct these imbalances and reduce injury risk. Exercises focused on improving balance between mobility and stability, as Kiesel et al. (2007) noted, can significantly decrease the likelihood of injury. Corrective exercises during the off-season, as demonstrated by Kiesel et al. (2011), are particularly effective in improving FMS™ scores and functional symmetry. Our findings support that strength training can help address functional movement deficits and asymmetries, especially with an increased training volume, though overtraining must be carefully avoided.

The positive relationship between increased training volume and improvements in functional movement aligns with findings by Otero-Esquina et al. (2017), who showed that higher frequency strength training resulted in better performance outcomes. Similarly, Yanci et al. (2017) found that even lower training volumes could lead to significant physical performance improvements, although higher frequencies tend to yield superior results.

In tests such as Trunk Stability Push-Up, both ES1 and ES2 achieved a score of 3.00, indicating that strong areas were maintained successfully during the training period. Additionally, the more intense training regimen led to greater improvements in several tests, particularly in Rotary Stability (increased from 1.33 to 2.00 on average) and Inline Lunge (increased from 1.00 to 1.83 on average), where ES2 saw greater improvements compared to ES1. However, in the Hurdle Step test, ES2 did not show a significant improvement over ES1.

To prevent injuries, monitoring individual FMS™ tests and focusing on raw scores is crucial. This can help identify asymmetries that may increase injury risk. Rusling et al. (2015) and Mokha et al. (2016) found that individual FMS™ scores are better indicators of potential musculoskeletal injuries than aggregate scores, stressing the importance of detailed evaluation. Kolodziej and Jaitner (2018) further reinforced this by linking lower FMS™ scores, especially in core stability, to a higher risk of injury in amateur soccer players.

In terms of training volume, there is limited research specifically focused on its effect on FMS™ improvement. Otero-Esquina et al. (2017) found that strength training twice per week improved strength and speed performance, while Yanci et al. (2017) showed that even a single plyometric session per week could achieve similar results as two sessions, suggesting that lower training volumes may still be effective. Meanwhile, Lockie et al. (2015) and Venter et al. (2017) reported weak correlations between FMS™ scores and performance metrics like speed and agility, implying that FMS™ may not reliably predict performance in team sports. However, Lee et al. (2019) found that higher FMS™ scores were linked to improved sprint and agility performance in elite collegiate soccer players.

These findings provide valuable insights for the development of training plans, highlighting the need to focus on areas with lower entry scores and significant potential for improvement. Effective training protocols should combine different intensities and types of exercises to ensure comprehensive improvement in functional movement and minimize the risk of injury.

Conclusions

Based on our findings, we recommend:

Integration of specific warm-up exercises: Incorporate stabilization and mobilization exercises tailored to individual deficits identified through FMS™ assessments.

Targeted strength training: Implement appropriate volumes of strength training according to individual player needs, with a focus on more intensive regimens for those with greater deficits.

Regular monitoring and testing: Systematically assess players' functional movement abilities throughout the season to identify and address new or ongoing issues.

Individual training approach: Apply a personalized training plan that considers the player's age, training experience, and specific needs.

Monitoring player fatigue and performance: Prevent overtraining by closely tracking player fatigue and adjusting training loads accordingly.

Caution with high-volume strength training: Be mindful of the potential ineffectiveness of high-volume strength training for overall development. For FMS™ improvements, it may be sufficient to include compensatory and corrective exercises at the start of training sessions.

The aim of these recommendations is to assist coaches and sports professionals in creating effective training programs that enhance functional movement skills, minimize injury risks, and support overall athletic performance.

Conflict of interests
The authors declare no conflict of interest.

References:

Bryson, A., Arthur, R., & Easton, C. (2021). Prior knowledge of the grading criteria increases functional movement screen scores in youth soccer players. Journal of Strength and Conditioning Research, 35(3), 762–768. https://journals.lww.com/nsca-jscr/abstract/2021/03000/prior_knowledge_of_the_grading_criteria_increases.25.aspx

Cook, G., Burton, L., & Hoogenboom, B. (2006a). Pre-participation screening: The use of fundamental movements as an assessment of function - part 1. North American Journal of Sports Physical Therapy: NAJSPT, 1(2), 62–72.

Cook, G., Burton, L., & Hoogenboom, B. (2006b). Pre-participation screening: The use of fundamental movements as an assessment of function - part 2. North American Journal of Sports Physical Therapy: NAJSPT, 1(3), 132–139.

Cook, G., Burton, L., Hoogenboom, B., & Voight, M. L. (2014a). Functional movement screening: The use of fundamental movements as an assessment of function – part 1. International Journal of Sports Physical Therapy, 9(3), 396–409.

Cook, G., Burton, L., Hoogenboom, B., & Voight, M. L. (2014b). Functional movement screening: The use of fundamental movements as an assessment of function – part 2. International Journal of Sports Physical Therapy, 9(4), 549–563.

Cook, G., Burton, L., Hoogenboom, B., & Voight, M. L. (2014c). Movement: Functional movement systems: Screening, assessment, corrective strategies. On Target Publications.

Garrison, M., Westrick, R., Johnson, M. R., & Benenson, J. (2015). A functional movement screen and injury development in college journal of sports physical therapy. International Journal of Sports Physical Therapy, 10(1), 21–28. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4325284/

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? North American Journal of Sports Physical Therapy: NAJSPT, 2(3),
147. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953296/

Kiesel, K., Plisky, P., & Butler, R. (2011). Functional movement test scores improve following a standardized off-season intervention program in professional football players. Scandinavian Journal of Medicine & Science in Sports, 21(2), 287–292. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0838.2009.01038.x

Kolodziej, M., & Jaitner, T. (2018). Single functional movement screen items as main predictors of injury risk in amateur male soccer players. German Journal of Exercise and Sport Research, 48(3), 349–357.

Lee, S., Kim, H., & Kim, J. (2019). The functional movement screen total score and physical performance in elite male collegiate soccer players. Journal of Exercise Rehabilitation, 15(5), 657–662. https://doi.org/10.12965/ jer.1938422.211

Lisman, P., O'Connor, F. G., Deuster, P. A., & Knapik, J. J. (2013). Functional movement screen and aerobic fitness predict injuries in military training. Medicine & Science in Sports & Exercise, 45(4), 636–643. https:// chirosolutions.com.au/wp-content/uploads/2018/07/Functional-Movement-Screen-and-Aerobic-Fitness-Predict- Injuries-in-Military-Training.pdf

Lockie, R. G., Schultz, A. B., Jordan, C. A., Callaghan, S. J., Jeffriess, M. D., & Luczo, T. M. (2015). Can selected functional movement screen assessments be used to identify movement deficiencies that could affect multidirectional speed and jump performance? Journal of Strength and Conditioning Research, 29(1), 195–205. https://doi.org/10.1519/JSC.0000000000000613

Marques, V. B., Medeiros, T. M., Souza Stigger, F., Nakamura, F. Y., & Baroni, B. M. (2017). The functional movement screen (FMSTM) in elite young soccer players between 14 and 20 years: Composite score, individual-test scores and asymmetries. International Journal of Sports Physical Therapy, 12(6), 977–985. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5737452/

Miyamori, T., Nishijima, T., Iizuka, S., & Yoshimoto, Y. (2020). Reliability assessment of the functional movement screen for predicting injury risk in Japanese college soccer players. Journal of Physical Therapy Science, 32(12), 850–855. https://www.jstage.jst.go.jp/article/jpts/32/12/32_2020-159/_article

Mokha, M., Sprague, P. A., & Gatens, D. R. (2016). Predicting musculoskeletal injury in National Collegiate Athletic Association Division II athletes from asymmetries and individual-test versus composite functional movement screen scores. Journal of Athletic Training, 51(4), 276–282. https://meridian.allenpress.com/jat/ article/51/4/276/112434/Predicting-Musculoskeletal-Injury-in-National

Newton, F., McCall, A., Ryan, D., Blackburne, C., aus der Fünten, K., Meyer, T., & McCunn, R. (2017). Functional Movement Screen (FMS™) score does not predict injury in English Premier League youth academy football players. Science and Medicine in Football, 1(2), 102–106. https://doi.org/ 10.1080/24733938.2017.1283436

Otero-Esquina, C., de Hoyo Lora, M., Gonzalo-Skok, Ó., Domínguez-Cobo, S., & Sánchez, H. (2017). Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players? European Journal of Sport Science, 17(10), 1241–1251. https://doi.org/10.1080/17461391.2017.1378372 Portas, M. D., Parkin, G., Roberts, J., & Batterham, A. M. (2016). Maturational effect on functional movement screen™ score in adolescent soccer players. Journal of Science and Medicine in Sport, 19(10), 854–858. https:// doi.org/10.1016/j.jsams.2015.12.001

Rusling, C., Edwards, K., Bhattacharya, A., Reed, A., Irwin, S., Boles, A., ... & Hodgson, L. (2015). The functional movement screening tool does not predict injury in football. Progress in Orthopedic Science, 1(2), 41– 46.

Sawczyn, M. (2020). Effects of a periodized functional strength training program (FST) on Functional Movement Screen (FMS) in physical education students. Physical Education of Students, 24(3), 162-167. Siamaki, R., Minoonejad, H., Alizadeh, M. H., & Soori, R. (2017). Are fundamental movement patterns affected by functional training in youth male soccer players? Journal Of Research In Rehabilitation Sciences, 13(1), 7–13. Smith, P. D., & Hanlon, D. (2017). Assessing the effectiveness of the Functional Movement Screen in predicting noncontact injury rates in soccer players. Journal of Strength and Conditioning Research, 31(12), 3327–3332. https://doi.org/10.1519/JSC.0000000000001757

Venter, R., Masterson, C., van Baalen, G., & Krkeljas, Z. (2017). The relationship between functional movement screening and performance tests in high-level university female netball players. South African Journal for Research in Sport, Physical Education and Recreation, 39(2), 147–159.

Yanci, J., Castillo, D., Iturricastillo, A., Ayarra, R., & Nakamura, F. Y. (2017). Effects of two different volume-equated weekly distributed short-term plyometric training programs on futsal players' physical performance. Journal of Strength and Conditioning Research, 31(7), 1787–1794. https://doi.org/10.1519/ JSC.0000000000001644