Functional movement patterns and bilateral asymmetry in badminton athletes: A Functional Movement Screen analysis at the Malang Regional Training Center

Avi Kholifatuz Zahro'[1*,A-F], Muhammad Atiq Noviudin Pritama[1,A,C,E,F]

[1] Department of Sports Coaching Education, Faculty of Sports Science, Universitas Negeri Malang, Malang, East Jawa Province, 65145, Indonesia

***Corresponding author:** Avi Kholifatuz Zahro'; Universitas Negeri Malang, Malang, East Jawa Province, 65145, Indonesia; email: avi.kholifatuz.2206316@students.um.ac.id

Received: 2026-06-15
Accepted: 2026-08-11
Published: 2026-08-17

A – Research concept and design
B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

ABSTRACT

Background: Badminton involves repetitive unilateral overhead movements, rapid changes of direction, and explosive actions that may contribute to side-to-side differences in functional movement patterns.

Objectives: This study aimed to describe functional movement patterns and bilateral asymmetry among badminton athletes at the Malang Regional Training Center using the Functional Movement Screen (FMS).

Methods: This cross-sectional study involved 16 sub-elite badminton athletes aged 15–20 years selected through purposive sampling. Functional movement was assessed using the seven-component FMS. Total scores were classified as high (≤14), moderate (15–17), or low (18–21) injury risk. Bilateral asymmetry was identified from differences between right- and left-side scores in five bilateral FMS components. Data were analyzed descriptively using means, standard deviations, frequencies, and percentages.

Results: Most athletes (62.5%, n = 10) were classified as having moderate injury risk, while 18.75% (n = 3) were classified as high risk and 18.75% (n = 3) as low risk. Shoulder Mobility showed the highest prevalence of bilateral asymmetry (100%, n = 16), followed by the In-Line Lunge and Rotary Stability (62.5%, n = 10 each), Hurdle Step (50.0%, n = 8), and Active Straight Leg Raise (43.75%, n = 7).

Conclusions: Bilateral functional movement asymmetry was common among badminton athletes, particularly in shoulder mobility, while most athletes were classified within the moderate injury-risk category. These findings support functional movement screening to identify movement limitations and inform individualized corrective exercise strategies.

Keywords: badminton, bilateral asymmetry, functional movement, Functional Movement Screen, movement screening.

How to cite this article: Zahro', A. K. & Pritama, M. A. N. (2026). Functional movement patterns and bilateral asymmetry in badminton athletes: A Functional Movement Screen analysis at the Malang Regional Training Center. *Physical Education and Sports: Studies and Research*, *5*(2), 196-207. https://doi.org/10.56003/pessr.v5i2.756

INTRODUCTION

Physical activity involves various body structures, such as muscles, ligaments, and joints. The body can move optimally when supported by adequate strength, elasticity, and tissue mobility. However, increased mobility without corresponding stability can increase the risk of injury. Sports injuries remain a major challenge in athlete development, particularly in high-intensity sports such as badminton, as they can impair performance, disrupt training programs, prolong recovery periods, and adversely affect long-term athletic development (Sudirman et al., 2021). Injuries can result from both internal and external factors (Bahr & Krosshaug, 2005). One important internal factor is muscle imbalance, which is associated with the athlete's physiological and biomechanical characteristics. Muscle imbalance can impair movement efficiency, disrupt force distribution throughout the body, and increase the risk of injury.

This issue is particularly relevant in badminton because the sport involves rapid changes in direction, jumping, and repetitive movements performed predominantly on the dominant side of the body (Efendi & Rochmania, 2019). Although a certain degree of asymmetry is naturally present in humans, excessive asymmetry may reduce physical performance and increase the risk of injury (Wiriawan et al., 2024). In addition, muscle weakness has been identified as a factor contributing to injuries in young athletes (Ribeiro & Costa, 2006). Uneven loading of joints and soft tissues caused by imbalances between agonist and antagonist muscles may lead to acute or chronic injuries. Shoulder and lower-extremity injuries, including anterior cruciate ligament (ACL) injuries caused by single-leg landings, are among the most common injuries experienced by badminton athletes (Efendi & Rochmania, 2019; Zein & Sudarko, 2020).

This study selected badminton players affiliated with the Malang Regional Training Center (Puslatkab) as the research sample. The primary factors in selecting this sample were the high intensity of their daily training routines and their participation in various regional and national championships. Since the athletes at the Malang Regional Training Center (Puslatkab) are currently in a performance-enhancement phase, conducting a biomechanical study at this stage is crucial for assessing injury risk. The FMS consists of seven functional movements that assess balance, mobility, stability, and neuromuscular control, thereby identifying movement limitations and compensations that are not apparent during routine exercise. The FMS also places the body in specific positions to reveal stability and mobility deficits that can lead to inefficient movement patterns (Cook et al., 2006). Although injury prediction based on FMS scores is not always accurate when used as the sole indicator, the FMS remains relevant as a screening tool for assessing movement quality and asymmetry associated with injury risk (Dorrel et al., 2018). Research by Triplett et al. (2021) also indicates that athletes with asymmetry in their FMS scores tend to have a higher risk of musculoskeletal injury compared to athletes without such asymmetry. Therefore, the FMS is useful as a basis for designing more specific corrective exercises, particularly to improve mobility and stability, reduce imbalances between the dominant and non-dominant sides, and monitor the athlete's profile.

The Functional Movement Screen (FMS) was selected because it provides a practical assessment of fundamental movement quality by examining mobility,

stability, and movement control across a series of standardized tasks (Cook et al., 2006). Several FMS components are assessed bilaterally, allowing side-to-side differences in movement performance to be identified. Such differences may provide useful information regarding functional movement asymmetry; however, they should not be interpreted as direct measures of muscular strength imbalance because the FMS does not quantify muscle force or neuromuscular activation. Therefore, in badminton athletes, the FMS may be useful as an initial screening tool for identifying movement limitations and bilateral asymmetries that warrant further assessment.

Although the Functional Movement Screen (FMS) has been widely used to assess movement quality and injury risk across various sports, evidence on its application in badminton athletes remains limited. This is particularly relevant for athletes involved in intensive training programs, such as those at the Malang Regional Training Center (Puslatkab), who are in a critical phase of athletic development. Therefore, this study aimed to describe functional movement patterns and bilateral asymmetry among badminton athletes at the Malang Regional Training Center using the Functional Movement Screen. The findings are expected to provide empirical information on functional movement patterns and to support the development of appropriate injury-prevention strategies for badminton athletes.

METHODS

Study Design and Participants

This study employed a quantitative, descriptive, cross-sectional design with an observational approach to evaluate functional movement profiles, injury risk, and bilateral movement asymmetry among badminton athletes (Zein & Sudarko, 2020).

The participants in this study were 16 sub-elite badminton athletes aged 15–20 years who were members of the Malang Regional Training Center (Puslatkab). Participants were selected using a purposive sampling technique based on predetermined inclusion and exclusion criteria. The inclusion criteria consisted of athletes who actively participated in regular training sessions, agreed to participate in the study, and completed all assessment procedures. The exclusion criteria included athletes who had experienced severe musculoskeletal injuries within the previous six months, reported pain during the assessment, or were unable to complete the Functional Movement Screen (FMS) protocol.

Ethical approval statement

Ethical approval for this study was obtained from the Research Ethics Committee of Universitas Negeri Malang under Ethical Exemption Number 02.09.01/UN32.14.2.8/LT/2025. The study was declared ethically appropriate in accordance with the seven WHO 2011 standards and the 2016 CIOMS Guidelines. Written informed consent was obtained from all participants before data collection

Research Instrument

Functional movement quality was assessed using the Functional Movement Screen (FMS), which consists of seven movement patterns scored on a scale ranging from 0 to 3, where 3 indicates correct movement execution, 2 indicates movement completion with compensation, 1 indicates an inability to complete the movement, and 0 indicates pain during movement (Cook et al., 2006). For bilateral tests, the

right and left sides were scored separately, and the lower score was used to determine the final score for each movement.

The total FMS score was used to classify injury risk. Scores of 14 or lower were classified as high risk, scores of 15–17 as moderate risk, and scores of 18–21 as low risk. Bilateral functional movement asymmetry was identified based on differences between right- and left-side scores in the Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, and Rotary Stability tests. The validity and reliability of the FMS have been demonstrated in previous studies, supporting its use for assessing functional movement patterns and identifying movement-related risk factors (Cook et al., 2006).

Data Collection

Data collection was conducted through structured observation and direct measurement during a single testing session. Before the assessment, all participants completed a standardized warm-up lasting approximately 10 minutes. Each FMS movement was performed three times, with short rest periods provided between movements to minimize the potential effects of fatigue.

The assessments were conducted by a five-member research team. Two trained evaluators independently observed and scored the participants' movement patterns, after which any differences in scoring were discussed to reach a consensus on the final score. Simultaneously, three team members recorded the movements from the frontal, posterior, and lateral views to facilitate subsequent review and improve scoring accuracy. The final scores were subsequently reviewed and discussed with a licensed physical therapist to enhance consistency in the assessment process. Formal inter-rater reliability analysis was not performed.

Data Analysis

Descriptive statistical analysis was performed using Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA, USA). The data were analyzed to determine functional movement profiles, injury risk levels, and indicators of bilateral movement asymmetry among badminton athletes. The results were presented as means, standard deviations, frequencies, and percentages.

RESULTS

This study involved 16 badminton athletes aged 15–20 from the Malang Regional Training Center (Puslatkab). Functional movement patterns were evaluated using the Functional Movement Screen (FMS) to describe total FMS score profiles and bilateral functional movement asymmetry. According to Table 1, the participants had a mean age of 15.81 ± 1.26 years, a mean height of 162.75 ± 9.84 cm, a mean body weight of 55.44 ± 6.57 kg, and a mean body mass index (BMI) of 20.94 ± 1.54 kg/m².

Table 2 shows that the majority of badminton athletes (62.5%, n = 10) were classified as having a moderate injury risk based on their total FMS scores. Meanwhile, three athletes (18.75%) were classified as high risk and three athletes (18.75%) as low risk. These findings indicate that most athletes exhibited FMS scores within the moderate-risk category, while a smaller proportion demonstrated either higher or lower risk profiles. Overall, the distribution suggests that functional

movement limitations were relatively common among the athletes and may warrant further assessment and targeted preventive interventions.

Table 1. Description of Research Subjects

Characteristics	Mean ± Standard Deviation (n = 16)
Age (years)	15.81 ± 1.26
Height (cm)	162.75 ± 9.84
Weight (kg)	55.44 ± 6.57
BMI (kg/m²)	20.94 ± 1.54

Table 2. Distribution of Injury Risk Categories Among Badminton Athletes at the Malang Regional Training Center (Puslatkab) Based on FMS Scores

Injury Risk Category	Number of Athletes	Percentage (%)
High Risk (≤14)	3	18.75%
Moderate Risk (15 – 17)	10	62.5%
Low Risk (18 – 21)	3	18.75%
Total	16	100%

Table 3. Distribution of Athletes with Differences Between Right- and Left-Side Scores for Each FMS Movement

FMS Movement	Number of Athletes with Differences Between Both Sides	Percentage (%)
Hurdle Step	8	50%
In-Line Lunge	10	62.5%
Shoulder Mobility	16	100%
Active Straight Leg Raise	7	43.75%
Rotary Stability	10	62.5%

Table 3 shows that bilateral asymmetry was observed across all five FMS movements assessed. Shoulder Mobility demonstrated the highest prevalence of asymmetry, with all 16 athletes (100%) exhibiting differences between the right and left sides. This was followed by the In-Line Lunge and Rotary Stability, each showing asymmetry in 10 athletes (62.5%), and the Hurdle Step in eight athletes (50.0%). The lowest prevalence of asymmetry was observed in the Active Straight Leg Raise, affecting seven athletes (43.75%). Overall, these findings indicate that bilateral movement asymmetry was common among the badminton athletes, particularly in shoulder mobility, suggesting side-to-side differences in functional movement patterns that may warrant further assessment and targeted corrective interventions.

DISCUSSION

The present study revealed two main findings regarding functional movement patterns among badminton athletes at the Malang Regional Training Center. First, most athletes were classified within the moderate injury-risk category based on the predefined FMS score classification, with 10 of 16 athletes (62.5%) scoring between 15 and 17, while three athletes (18.75%) were classified as high risk and three (18.75%) as low risk. Second, bilateral movement asymmetries were evident across the five bilateral FMS components. Shoulder Mobility showed the highest prevalence of asymmetry, occurring in all athletes (100%), followed by the In-Line Lunge and Rotary Stability (62.5% each), Hurdle Step (50.0%), and Active Straight Leg Raise (43.75%). Collectively, these findings indicate that side-to-side differences in functional movement were common in this group, with upper-extremity asymmetry being particularly prominent.

The predominance of athletes within the moderate-risk category indicates the presence of functional movement limitations that may warrant further assessment. The FMS was developed to identify limitations and asymmetries in fundamental movement patterns involving mobility, stability, and neuromuscular control (Cook et al., 2006). Previous badminton-specific studies have similarly demonstrated that functional movement characteristics assessed using the FMS can be responsive to training. For example, Zhao et al. (2021) reported improvements in total FMS score and specific components, including the In-Line Lunge and Rotary Stability, following integrative neuromuscular training in female badminton players. Similarly, functional training has been reported to improve movement quality and reduce side-to-side differences in FMS components among young badminton players (Chen, 2023). These findings suggest that the functional movement limitations identified in the present sample are potentially modifiable characteristics rather than fixed deficits. Nevertheless, the injury-risk classifications should be interpreted cautiously. The present study did not prospectively record injury incidence, and FMS-derived classifications therefore represent screening-based profiles rather than direct estimates of future injury probability.

The most prominent finding was the 100% prevalence of asymmetry in the Shoulder Mobility test. This finding is particularly relevant to the biomechanical characteristics of badminton, which requires frequent unilateral overhead strokes. During badminton play, overhead actions account for a substantial proportion of strokes and repeatedly expose the shoulder complex to combinations of internal and external rotation under considerable mechanical loading (Fernandez-Fernandez et al., 2019). Consequently, repeated exposure to these asymmetric demands may promote sport-specific adaptations between the dominant and non-dominant shoulders. This interpretation is supported by Couppé et al. (2014), who examined adolescent national-level badminton players and found significantly lower total rotational range of motion (TROM) in the dominant shoulder than in the non-dominant shoulder in both male and female players. More specifically, their data showed lower dominant-side internal rotation in male athletes and side-to-side differences in external rotation among female athletes.

Further badminton-specific evidence supports this interpretation. Fernandez-Fernandez et al. (2019) found significant baseline side-to-side differences in shoulder rotational profiles among elite junior badminton players, characterized by greater external rotation on the dominant side and greater internal rotation and total arc of motion on the non-dominant side. The prevalence of side-to-side differences reached 35.4% for internal rotation, 22.5% for external rotation, and 77.4% for total arc of motion. The same study demonstrated that two competitive badminton matches performed on the same day produced additional changes in shoulder ROM and strength, indicating that shoulder function may also respond acutely to competitive loading. Taken together, these findings provide a plausible explanation for the high prevalence of Shoulder Mobility asymmetry observed in the present study: repeated unilateral overhead loading over training and competition may contribute to systematic dominant-to-nondominant adaptations in shoulder function.

Similar adaptations have also been reported in other racquet sports. Moreno-Pérez et al. (2015) observed that professional tennis players demonstrated reduced internal rotation and total rotational ROM and increased external rotation ROM in the

dominant shoulder compared with the non-dominant shoulder. These dominant-to-nondominant differences are consistent with adaptations frequently observed in athletes exposed to repetitive unilateral overhead loading. Importantly, however, side-to-side ROM asymmetry in the tennis players was not significantly different between athletes with and without a history of shoulder pain (Moreno-Pérez et al., 2015). Thus, the Shoulder Mobility asymmetry observed in the present study should not automatically be interpreted as pathological impairment or evidence of future shoulder injury. Moreover, because the FMS Shoulder Mobility test does not directly quantify glenohumeral internal and external rotation, the present findings cannot establish the specific anatomical or biomechanical source of the observed asymmetry.

Substantial asymmetry was also identified in the In-Line Lunge and Rotary Stability components, each affecting 62.5% of the athletes, while asymmetry was observed in the Hurdle Step and Active Straight Leg Raise in 50.0% and 43.75% of the sample, respectively. These findings indicate that side-to-side differences in the present athletes were not limited to the upper extremities but were also evident in movement patterns involving lower-extremity mobility, trunk control, and multisegmental coordination. Previous badminton-specific research has shown that the In-Line Lunge and Rotary Stability components are responsive to neuromuscular and functional training (Zhao et al., 2021; Chen, 2023), suggesting that these movement characteristics may represent modifiable functional attributes.

A possible explanation for these asymmetries is the repetitive asymmetric loading inherent in sport-specific movements. Badminton involves frequent multidirectional lunges, rapid acceleration and deceleration, changes of direction, and repeated use of preferred movement strategies, which may expose the two lower limbs to different mechanical and neuromuscular demands. Evidence from other sports involving substantial unilateral lower-extremity demands supports this interpretation. Sanjaya et al. (2025) suggested that limb dominance, preferential use of one leg during jumping and changing direction, uneven training loads, and insufficient unilateral strengthening may contribute to inter-limb strength asymmetry in athletes. Similarly, Dewi et al. (2025) reported inter-limb differences in eccentric hamstring strength among sub-elite taekwondo athletes and noted that repeated preferential use of one side, together with differences in training exposure and neuromuscular adaptation, may contribute to asymmetrical lower-extremity characteristics. However, these studies assessed muscular strength asymmetry rather than FMS movement asymmetry. Therefore, they provide a plausible mechanistic context rather than direct evidence explaining the present FMS findings.

Importantly, the lower-extremity asymmetries identified in the present study should not be interpreted as direct evidence of muscular imbalance or weakness. The FMS evaluates the quality and symmetry of movement patterns but does not directly quantify muscle strength, joint kinetics, or neuromuscular activation. Consequently, athletes presenting with asymmetry in the In-Line Lunge, Hurdle Step, or Rotary Stability tests may warrant further assessment using more specific measures of unilateral strength, dynamic balance, hip function, and lower-extremity neuromuscular control. Such an approach would help determine whether the observed movement asymmetry represents sport-specific adaptation or an underlying functional deficit requiring targeted intervention.

The asymmetry observed in the Hurdle Step (50.0%) and Active Straight Leg Raise (43.75%) further indicates that side-to-side differences were not restricted to the shoulder or to a single movement domain. Rather, the findings suggest a broader pattern of individual variability in mobility and movement control across the athletes. Importantly, not all asymmetry should necessarily be considered maladaptive. In a unilateral sport such as badminton, some degree of functional asymmetry may represent sport-specific adaptation to repeated technical and tactical demands. Therefore, screening results should be interpreted at the individual athlete level and, where necessary, followed by more specific assessments to distinguish potentially relevant functional limitations from normal sport-related adaptations.

From a practical perspective, the present findings support the use of FMS primarily as an initial functional screening and monitoring tool rather than as a stand-alone diagnostic or injury-prediction instrument. Athletes presenting with Shoulder Mobility asymmetry may benefit from more specific assessment of glenohumeral ROM, thoracic mobility, scapular control, and internal- and external-rotator strength. This recommendation is particularly relevant because badminton-specific research has demonstrated measurable dominant-to-nondominant differences in both shoulder ROM and rotational strength (Couppé et al., 2014; Fernandez-Fernandez et al., 2019). For athletes presenting with In-Line Lunge or Rotary Stability asymmetry, subsequent assessment could focus on hip function, trunk control, dynamic balance, and unilateral lower-extremity movement quality. Corrective or conditioning interventions should then be individualized according to the deficits confirmed through these additional assessments rather than prescribed solely on the basis of FMS scores.

The available intervention evidence also suggests that these movement characteristics may be modifiable through targeted training. Integrative neuromuscular and functional training approaches have been associated with improvements in FMS scores and selected movement patterns among badminton players (Zhao et al., 2021; Chen, 2023). Accordingly, mobility exercises, trunk stabilization, unilateral strength training, dynamic balance, and neuromuscular control exercises may be incorporated where corresponding deficits are confirmed. Periodic screening may subsequently be used to monitor changes in movement quality across the training cycle. However, the primary objective should not necessarily be to eliminate all asymmetry, because some side-to-side differences may represent functional adaptations to the unilateral demands of badminton. Instead, the emphasis should be placed on identifying substantial or clinically relevant limitations and determining whether they coexist with pain, reduced ROM, strength deficits, impaired performance, or previous injury.

Limitations of the study

Several limitations should be considered when interpreting the findings. First, the relatively small sample of 16 athletes from a single regional training center limits the generalizability of the results to other badminton populations, competitive levels, and age groups. Second, the cross-sectional design prevents determination of whether the observed movement asymmetries developed as a consequence of badminton participation or preceded participation in the sport. Third, injury incidence was not prospectively monitored; consequently, the present study cannot determine whether athletes classified into different FMS risk categories subsequently experienced

different injury rates. Fourth, FMS identifies observable movement limitations and asymmetries but does not determine their underlying physiological or biomechanical mechanisms. Direct measurements of shoulder and hip ROM, muscle strength, trunk function, joint kinetics, and neuromuscular activation were not performed. Fifth, although two trained evaluators reached consensus on the final FMS scores and recordings from multiple views were used to support scoring, inter-rater reliability was not quantified. This should be considered when interpreting the consistency of the assessments. Finally, the use of purposive sampling may have introduced selection bias and further limits the representativeness of the sample.

Future research should therefore include larger and more diverse samples of badminton athletes, objective assessments of strength and joint ROM, and prospective injury surveillance. Longitudinal studies are particularly needed to determine whether specific FMS asymmetries or combinations of movement limitations are associated with subsequent musculoskeletal injury or changes in badminton performance. Combining functional screening with sport-specific biomechanical, strength, and workload assessments may provide a more comprehensive understanding of the clinical and performance relevance of bilateral movement asymmetries in badminton athletes.

CONCLUSION

This study identified a high prevalence of bilateral functional movement asymmetry among badminton athletes at the Malang Regional Training Center. Shoulder Mobility demonstrated the highest prevalence of asymmetry, affecting all athletes, followed by the In-Line Lunge and Rotary Stability, whereas most athletes were classified within the moderate injury-risk category based on the predefined FMS score classification. These findings indicate that side-to-side differences in functional movement are common in this group, particularly in movement patterns involving the shoulder. However, the observed asymmetries should not be interpreted as direct evidence of muscular imbalance or future injury because the FMS is a functional screening tool rather than a direct measure of muscle strength or a stand-alone predictor of injury. Functional movement screening may therefore be useful for identifying athletes who require further individualized assessment of mobility, strength, stability, and neuromuscular control. Prospective studies incorporating objective biomechanical and neuromuscular assessments and injury surveillance are needed to determine the clinical and performance relevance of these asymmetries in badminton athletes.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the athletes, coaches, and staff of the Malang Regional Training Center (Puslatkab) for their participation, cooperation, and support during the data collection process.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used DeepL Translate to assist with language translation and Grammarly to improve grammar, spelling,

punctuation, and language clarity. All outputs were carefully reviewed, revised, and verified by the authors to ensure the accuracy, originality, and integrity of the manuscript. The authors assume full responsibility for the content of this manuscript.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FUNDING

This research does not receive external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

PUBLISHER'S NOTE

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or a claim its manufacturer may make, is not guaranteed or endorsed by the publisher.

REFERENCES

Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: A key component of preventing injuries in sport. British Journal of Sports Medicine, 39(6), 324–329. https://doi.org/10.1136/bjsm.2005.018341

Chen, C. (2023). Effect of functional training on hitting quality in badminton players. *Revista Brasileira de Medicina do Esporte, 29*, e2022_0616. https://doi.org/10.1590/1517-8692202329012022_0616

Cook, G., Burton, L., & Fields, K. (2011). *The Functional Movement Screen and Exercise Progressions Manual.* On Target Publications.

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

Couppé, C., Thorborg, K., Hansen, M., Fahlström, M., Bjordal, J. M., Nielsen, D., ... & Magnusson, S. P. (2014). Shoulder rotational profiles in young healthy elite female and male badminton players. *Scandinavian Journal of Medicine & Science in Sports, 24*(1), 122-128. https://doi.org/10.1111/j.1600-0838.2012.01480.x

Daffa, M. A., Anam, K., Setiowati, A., & Indardi, N. (2025). Prediksi cedera pesepakbola muda: Penggunaan functional movement screening. *Journal of Sport Science and Fitness, 5*(1), 29–37. https://doi.org/10.33292/sepakbola.v5i1.379

Dewi, C. S., Pudjijuniarto, Firmansyah, A., & Irawan, R. J. (2025). Eccentric hamstring strength profile and limb asymmetry in sub-elite female taekwondo athletes: Implications for injury prevention. *Sport, Exercise, and Injury, 1*(1), 70–

79. https://doi.org/10.56003/sei.v1i1.574

Dorrel, B., Long, T., Shaffer, S., & Myer, G. D. (2018). The Functional Movement Screen as a predictor of injury in National Collegiate Athletic Association Division II athletes. *Journal of Athletic Training, 53*(1), 29–34. https://doi.org/10.4085/1062-6050-528-15

Efendi, C. K., & Rochmania, A. (2019). Cedera olahraga pada cabang olahraga bulutangkis (Studi pada Klub Bulutangkis FIFA BC Sidoarjo). *Jurnal Prestasi Olahraga, 2*(8), 139–147.

Fernandez-Fernandez, J., Lopez-Valenciano, A., Del Coso, J., Gallo-Salazar, C., Barbado, D., Sabido-Solana, R., ... & Cabello-Manrique, D. (2019). The effects of playing two consecutive matches in the shoulder rotational profiles of elite youth badminton players. *Physical Therapy in Sport, 35*, 56-62. https://doi.org/10.1016/j.ptsp.2018.11.004

Moreno-Pérez, V., Moreside, J., Barbado, D., & Vera-Garcia, F. J. (2015). Comparison of shoulder rotation range of motion in professional tennis players with and without history of shoulder pain. *Manual Therapy, 20*(2), 313-318. https://doi.org/10.1016/j.math.2014.10.008

Oktarisa, A., Syafriyanto, D., Indika, P. M., & Andria, Y. (2023). Functional movement screening: Deteksi dini risiko cedera olahraga atlet panjat tebing Kota Padang. *Jurnal Ilmu Keolahragaan, 1*(2), 6–11.

Pristianto, A., Susilo, T. E., & Setiyaningsih, R. (2018). Penerapan Functional Movement Screening (FMS) untuk Pencegahan Cidera Olahraga pada Komunitas Kalistenik Solo. In *The 8th University Research Colloquium* (pp. 267-271).

Ribeiro, R. N., & Costa, L. O. P. (2006). Epidemiologic analysis of injuries occurred during the 15th Brazilian Indoor Soccer (Futsal) Sub-20 Team Selection Championship. *Revista Brasileira de Medicina do Esporte, 12*(1), 1–5. https://doi.org/10.1590/S1517-86922006000100001

Sanjaya, A. D. P., Firmansyah, A., Hakim, A. A., & Bana, P. (2025). Eccentric hamstring strength and asymmetry in female handball athletes: A descriptive study. *Sport, Exercise, and Injury, 1*(1), 60–69. https://doi.org/10.56003/sei.v1i1.553

Sudirman, A., Mahyuddin, R., & Asyhari, H. (2021). Memahami faktor penyebab terjadinya cedera dalam permainan sepak bola. *Jendela Olahraga, 6*(2), 1–9. https://doi.org/10.26877/jo.v6i2.8273

Triplett, C. R., Dorrel, B. S., Symonds, M. L., Selland, C. A., & Daniel, D. (2021). Functional movement screen detected asymmetry and normative values among college-aged students. *International Journal of Sports Physical Therapy, 16*(2), 450–458. https://doi.org/10.26603/001c.19443

Wiriawan, O., Rusdiawan, A., Kusuma, D. A., Firmansyah, A., García-Jiménez, J. V., Zein, M. I., Pavlovic, R., Nowak, A. M., Susanto, N., & Pranoto, A. (2024). Unilateral hamstring muscle strengthening exercises can improve hamstring asymmetry and increase jumping performance in sub-elite badminton athletes. *Retos, 54*, 761–770. https://doi.org/10.47197/RETOS.V54.103783

Zein, M. I., & Sudarko, R. A. (2020). Penilaian muscle imbalance dengan metode functional movement screen pada atlet baseball sub-elite Indonesia. *Jorpres (Jurnal Olahraga Prestasi), 15*(2), 83–87.

https://doi.org/10.21831/jorpres.v15i2.29516

Zhao, W., Wang, C., Bi, Y., & Chen, L. (2021). Effect of integrative neuromuscular training for injury prevention and sports performance of female badminton players. *BioMed research international, 2021*(1), 5555853. https://doi.org/10.1155/2021/5555853