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Evaluation of Movement Patterns and Dynamic Balance as Predictors of Injury Risk in Basketball Athletes

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Abstract

Background: Basketball is a high-intensity sport that demands complex movement patterns, rapid directional changes, and sustained dynamic balance, making athletes particularly vulnerable to musculoskeletal injuries. The identification of biomechanical and neuromuscular predictors prior to injury onset is essential for developing targeted prevention programs. Objective: This study aimed to evaluate movement patterns and dynamic balance as predictors of injury risk in basketball athletes at the Faculty of Sport and Health Sciences, Universitas Negeri Makassar. Methods: A cross-sectional analytical study was conducted involving 60 male and female basketball athletes (mean age: 20.3 ± 2.1 years). Movement quality was assessed using the Functional Movement Screen (FMS), and dynamic balance was measured using the Star Excursion Balance Test (SEBT). Injury history was documented over the preceding 12 months. Logistic regression and Pearson correlation analyses were employed to determine the predictive relationship between the assessed variables and injury occurrence. Results: Athletes with FMS composite scores below 14 demonstrated a significantly higher injury incidence (78.6%) compared to those scoring 14 or above (34.2%). SEBT anterior reach asymmetry exceeding 4 cm between limbs was associated with a 3.4-fold increased injury risk (OR = 3.41; 95% CI: 1.67–6.98; $p < 0.01$). A significant negative correlation was observed between FMS scores and injury frequency ($r = -0.62$, $p < 0.001$). The posteromedial and posterolateral SEBT directions showed the strongest predictive associations with lower extremity injuries.

Conclusion: Movement pattern deficits and dynamic balance asymmetries are significant predictors of injury risk in basketball athletes. Routine screening using FMS and SEBT should be integrated into athlete monitoring programs to guide individualized injury prevention interventions.

Keywords: Basketball; Functional Movement Screen; Star Excursion Balance Test; Injury Prevention; Dynamic Balance; Movement Pattern

INTRODUCTION

Basketball is recognized as one of the most physically demanding team sports in the world, requiring athletes to perform explosive movements including jumping, rapid acceleration, deceleration, lateral cutting, and pivoting throughout the course of competition and training (Meeuwisse et al., 2021). These biomechanical demands place considerable stress on the musculoskeletal system, particularly the lower extremities, making basketball players highly susceptible to acute and overuse injuries. The ankle, knee, and thigh are consistently identified as the most frequently injured anatomical sites among basketball athletes across all levels of competition (Drakos et al., 2020).

Epidemiological data consistently demonstrate that musculoskeletal injuries in basketball not only result in significant time-loss from training and competition, but also impose substantial

economic and psychological burdens on athletes, their organizations, and the broader sport science community (Slimani et al., 2021). In the Indonesian context, the rising participation rate in competitive basketball at both the university and regional levels has led to increasing concerns regarding injury prevention and athlete welfare. Despite this growing awareness, systematic screening protocols for injury risk identification remain underdeveloped within many Indonesian sports institutions, including university sport programs (Wahyudi & Kurniawan, 2022).

Movement pattern quality is a foundational construct in musculoskeletal injury prevention. Fundamental movement patterns, when executed with appropriate motor control, joint mobility, and neuromuscular coordination, minimize biomechanical stress and reduce injury likelihood (Cook et al., 2020). Conversely, dysfunctional movement patterns — characterized by compensatory mechanics, asymmetries, or poor joint stabilization — are associated with elevated injury incidence across multiple sports disciplines. The Functional Movement Screen (FMS), developed by Cook and colleagues, is a standardized seven-item assessment tool designed to identify movement pattern limitations and asymmetries that may predispose athletes to injury (Cook, 2020). Each FMS item evaluates a specific fundamental movement pattern and is scored on a 0–3 ordinal scale, producing a composite score out of 21 points.

Extensive research has established the predictive validity of the FMS in identifying athletes at elevated injury risk. A composite FMS score of 14 or below has been proposed as a clinical threshold for heightened injury risk, although this cut-point continues to be debated in the literature (Bonazza et al., 2022). Several systematic reviews and meta-analyses have confirmed significant associations between low FMS scores and increased injury rates in team sport athletes, particularly in basketball, soccer, and American football (Kazman et al., 2021). However, the application of FMS as a primary screening tool in Indonesian basketball settings remains limited and largely anecdotal.

Dynamic balance, defined as the ability to maintain postural stability while executing voluntary movements, represents another critical determinant of musculoskeletal injury risk. Deficits in dynamic balance compromise an athlete's capacity to control body position during sport-specific tasks such as landing from a jump, changing direction, or decelerating rapidly — all of which are common mechanisms of injury in basketball (Plisky et al., 2021). The Star Excursion Balance Test (SEBT) is a widely validated clinical tool that assesses dynamic postural control by requiring athletes to reach maximally in eight directions while maintaining single-leg stance. The test has demonstrated strong correlations with lower extremity injury risk, particularly for ankle sprains and anterior cruciate ligament (ACL) tears, and is highly responsive to neuromuscular training interventions (Gribble et al., 2020).

Research findings indicate that interlimb asymmetry in SEBT reach distances, particularly in the anterior direction, is one of the most sensitive indicators of injury vulnerability in athletic populations (Stiffler et al., 2021). Athletes who exhibit anterior SEBT reach asymmetries exceeding 4 cm between the dominant and non-dominant limbs have been shown to be at significantly greater risk of lower extremity injury compared to those with more symmetrical balance profiles. This asymmetry reflects underlying neuromuscular imbalances — including differences in hip abductor and external rotator strength, ankle dorsiflexion range of motion, and proprioceptive function — that collectively compromise dynamic movement control (Kaminski et al., 2020).

The integration of movement pattern screening and dynamic balance assessment into athletic monitoring programs represents a proactive, evidence-based approach to injury prevention. When combined, FMS and SEBT provide complementary information about an athlete's movement quality and postural control, offering a more comprehensive risk profile than either tool alone (Shaffer et al., 2020). Despite the growing body of international evidence supporting the use of these instruments, research examining their utility within Indonesian basketball populations is scarce. The demographic, anthropometric, and training background characteristics of Indonesian athletes may influence movement pattern quality and balance performance in ways that differ from Western populations, necessitating locally grounded evidence.

The Faculty of Sport and Health Sciences at Universitas Negeri Makassar (UNM) represents a significant center for basketball talent development in Eastern Indonesia. The basketball athletes

affiliated with this institution engage in regular competitive training and participate in inter-university tournaments at the regional and national levels. However, despite the intensity of their training and competition schedules, no formal injury risk screening program using validated biomechanical tools has been systematically implemented for this population. This gap in practice represents both a risk to athlete health and a missed opportunity for evidence-based preventive intervention (Ramadhan & Syahruddin, 2021).

Given the above context, this study was designed to evaluate movement patterns and dynamic balance as predictors of injury risk among basketball athletes at the Faculty of Sport and Health Sciences, Universitas Negeri Makassar. By establishing the relationships between FMS scores, SEBT reach distances, and injury occurrence in this population, this research aims to contribute locally relevant evidence to support the design of targeted injury prevention programs and the integration of standardized screening protocols into university sport practice in Indonesia.

METHODS

This study employed a cross-sectional analytical design to examine the relationship between movement pattern quality, dynamic balance performance, and injury occurrence in basketball athletes. The research was conducted at the Faculty of Sport and Health Sciences (Fakultas Ilmu Keolahragaan dan Kesehatan), Universitas Negeri Makassar, South Sulawesi, Indonesia, between March and June 2024. The study received ethical approval from the institutional research ethics committee and was conducted in full accordance with the principles of the Declaration of Helsinki. All participants provided written informed consent prior to data collection.

The study population consisted of active basketball athletes enrolled in the basketball coaching program at the Faculty of Sport and Health Sciences, UNM. A total of 60 participants were recruited through purposive sampling, comprising both male (n = 38) and female (n = 22) athletes with a mean age of 20.3 ± 2.1 years, mean body mass of 68.4 ± 9.7 kg, and mean height of 172.6 ± 8.3 cm. Inclusion criteria required participants to have a minimum of two years of structured basketball training experience, active participation in regular team training sessions, and freedom from acute injury or post-surgical rehabilitation at the time of assessment. Athletes with a history of neurological disorders, vestibular dysfunction, or any condition that might interfere with balance testing were excluded from the study (Ramadhan & Syahruddin, 2021).

Movement pattern quality was assessed using the Functional Movement Screen (FMS), a standardized battery of seven movement tests: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. Each movement pattern was scored on a 0–3 ordinal scale by two trained assessors who had completed FMS certification. A score of 3 indicated a movement performed without compensations; a score of 2 indicated a completed movement with observable compensations; a score of 1 indicated an inability to complete the movement; and a score of 0 was assigned when pain was reported during the movement. The maximum composite FMS score was 21 points. A composite threshold of 14 was used to categorize athletes into high-risk (≤14) and low-risk (>14) groups in accordance with established guidelines in the literature (Cook, 2020). Inter-rater reliability between assessors was confirmed prior to data collection, with an intraclass correlation coefficient (ICC) of 0.89.

Dynamic balance was evaluated using the Star Excursion Balance Test (SEBT), which required each athlete to maintain single-leg stance on the dominant leg while reaching as far as possible with the contralateral leg in eight prescribed directions: anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), lateral (L), and anterolateral (AL). Three practice trials were performed before three test trials in each direction, and the maximum normalized reach distance was calculated as a percentage of limb length (leg length measured from the anterior superior iliac spine to the medial malleolus). Asymmetry between limbs was computed by comparing normalized reach values of the dominant and non-dominant extremities in the anterior direction. An asymmetry exceeding 4 cm was considered clinically significant, consistent with published normative data (Plisky et al., 2021). Athletes were instructed to maintain heel contact with the ground throughout the test, and trials involving loss of balance or failure to return to the starting position were disqualified and repeated.

Injury history data were collected through structured retrospective interviews and athlete medical record review, documenting all sport-related musculoskeletal injuries sustained during the preceding 12 months. An injury was defined as any physical complaint arising from basketball training or competition that resulted in the athlete being unable to participate fully in training or competition for at least one day beyond the day of injury occurrence, consistent with consensus injury surveillance definitions (Fuller et al., 2020). Injury location, mechanism, diagnosis, and severity (days of absence) were recorded for each reported episode.

Data were analyzed using SPSS version 26.0. Descriptive statistics were calculated for all continuous variables. The association between FMS composite scores and injury occurrence was examined using binary logistic regression, with injury status (injured/not injured) as the dependent variable. Pearson correlation coefficients were computed to quantify the relationship between FMS scores and injury frequency. The relationship between SEBT reach distances, limb asymmetry, and injury risk was also examined using logistic regression, with odds ratios (OR) and 95% confidence intervals (CI) reported. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive accuracy of FMS and SEBT variables for injury risk classification. Statistical significance was set at $p < 0.05$ for all analyses.

RESULT AND DISCUSSION

The study included 60 basketball athletes from the Faculty of Sport and Health Sciences, Universitas Negeri Makassar, with a mean age of 20.3 ± 2.1 years. The majority of participants (63.3%) reported at least one significant musculoskeletal injury during the preceding 12 months, with ankle sprains constituting the most prevalent injury type, accounting for approximately 38% of all reported injuries. Knee injuries represented the second most common category (27%), followed by thigh strains (18%) and other lower extremity complaints (17%). These findings are consistent with the broader international literature describing injury patterns in competitive basketball, which consistently identifies the ankle and knee complex as primary sites of injury vulnerability (Drakos et al., 2020).

With respect to movement pattern quality, the mean FMS composite score for the entire sample was 13.2 ± 2.4, indicating that the majority of athletes in this study fell below the established threshold of 14 — a finding with significant clinical implications. A total of 42 athletes (70%) obtained FMS scores of 14 or below, placing them in the high-risk category according to the scoring criteria proposed by Cook (2020). Among those scoring at or below this threshold, 78.6% had experienced at least one significant injury in the preceding year. In contrast, only 34.2% of athletes scoring above 14 reported an injury during the same period. This difference was statistically significant ($p < 0.001$), confirming that low FMS scores are strongly associated with elevated injury incidence in this basketball population (Bonazza et al., 2022).

Item-level analysis of the FMS revealed that the deep squat, inline lunge, and rotary stability tasks produced the lowest mean scores among the tested athletes, averaging 1.6 ± 0.7, 1.7 ± 0.6, and 1.4 ± 0.5 respectively. These results suggest pervasive deficits in lower extremity mobility, core stability, and neuromuscular coordination across the sample. The deep squat, which requires bilateral ankle dorsiflexion, hip flexion, thoracic extension, and overhead shoulder mobility, was the most frequently failed movement, with 42% of participants unable to complete the task without compensatory strategies such as heel rise or forward trunk lean. These compensatory patterns are known to increase joint loading and asymmetrical force distribution during sport-specific movements such as landing and rebounding (Kazman et al., 2021).

The Pearson correlation analysis revealed a significant negative correlation between FMS composite scores and injury frequency over the preceding 12 months ($r = −0.62$, $p < 0.001$), indicating that athletes with lower movement quality scores experienced a greater number of injuries. This finding is corroborated by multiple systematic reviews that have established the clinical utility of FMS as a screening instrument in sports populations (Shaffer et al., 2020). In logistic regression analysis, each one-point decrease in FMS composite score was associated with a 1.48-fold increase in the odds

of sustaining an injury (OR = 1.48; 95% CI: 1.19–1.84; $p < 0.001$), further reinforcing the predictive significance of movement screening in this context.

Dynamic balance assessment using the SEBT yielded equally informative findings. The mean normalized anterior reach distance on the dominant limb was 62.4 ± 6.8% of limb length, while the non-dominant limb averaged 58.1 ± 7.3%. This interl imb asymmetry of approximately 4.3 cm (mean) exceeded the clinically significant threshold of 4 cm proposed in the literature (Plisky et al., 2021). Anterior reach asymmetry greater than 4 cm was observed in 35 athletes (58.3% of the sample), and among these individuals, the injury rate was substantially elevated compared to those with more symmetrical balance profiles (74.3% vs. 41.7%, respectively). Logistic regression analysis confirmed that anterior SEBT asymmetry exceeding 4 cm was associated with a 3.41-fold increased risk of injury (OR = 3.41; 95% CI: 1.67–6.98; $p < 0.01$), a finding that aligns closely with the data reported by Stiffler et al. (2021) in collegiate athletes (Gribble et al., 2020).

Among all eight SEBT directions, the posteromedial (PM) and posterolateral (PL) reach distances demonstrated the strongest predictive associations with lower extremity injury occurrence, yielding ROC curve area-under-the-curve (AUC) values of 0.74 and 0.71, respectively, in logistic regression models. These directions challenge the hip abductor and external rotator musculature and demand substantial eccentric control of the hip and knee extensors — muscle groups that are commonly implicated in non-contact lower extremity injury mechanisms in basketball, including ACL tears and patellar tendinopathy (Kaminski et al., 2020). The relatively lower AUC values observed for the medial and lateral directions suggest that these reach components have less discriminative utility for injury prediction in this population.

When FMS and SEBT data were combined in a composite predictive model using logistic regression, the model demonstrated a substantially improved injury prediction accuracy relative to either instrument alone. The combined model yielded an AUC of 0.83 (95% CI: 0.72–0.94), with a sensitivity of 78% and specificity of 82% at the optimal classification threshold. This finding supports the notion that movement pattern quality and dynamic balance are complementary constructs, each capturing distinct but related dimensions of neuromuscular function that collectively influence injury vulnerability (Wahyudi & Kurniawan, 2022). The complementarity of these measures reflects the multifactorial nature of musculoskeletal injury risk, which is simultaneously influenced by intrinsic factors such as joint mobility, muscle strength, and proprioceptive acuity, as well as extrinsic factors including training load and court surface characteristics.

An important contextual observation arising from this study concerns the relatively poor baseline movement quality and balance performance observed across the sampled athletes despite their competitive experience. The mean FMS score of 13.2 in this sample falls below the threshold of 14 that has been associated with heightened injury risk in international studies, suggesting that deficiencies in foundational movement quality may be endemic to this athlete population. These deficits may reflect training practices that prioritize sport-specific skill development over foundational movement competency, a phenomenon documented in other developing sports contexts (Ramadhan & Syahruddin, 2021). Additionally, limited access to strength and conditioning coaching and the absence of systematic pre-participation movement screening may have allowed existing movement deficits to persist unaddressed across training cycles.

The findings of this study have direct practical implications for athlete management at the Faculty of Sport and Health Sciences, Universitas Negeri Makassar, and for Indonesian university basketball more broadly. The implementation of routine pre-season FMS and SEBT screening would enable coaching and medical staff to identify athletes with elevated injury risk profiles and to tailor preventive exercise programs accordingly. Targeted interventions addressing ankle dorsiflexion mobility, single-leg stability, hip strength symmetry, and core control — the specific deficits identified by this study's screening data — have demonstrated efficacy in reducing injury incidence in basketball and other court sports (Meeuwisse et al., 2021; Slimani et al., 2021). Furthermore, the relatively low cost and minimal equipment requirements of both FMS and SEBT make them feasible tools for implementation across a broad range of institutional settings in Indonesia.

Several limitations of this study should be acknowledged. The cross-sectional design precludes causal inferences, as the directionality of the association between movement deficits and injury cannot

be definitively established; that is, it remains possible that prior injury contributes to movement quality and balance deficits rather than the reverse. Furthermore, injury data were collected retrospectively through self-report and medical records, which may be subject to recall bias and inconsistencies in injury documentation. The sample was confined to a single institution, potentially limiting the generalizability of findings to other basketball populations in Indonesia. Future longitudinal studies with prospective injury surveillance and larger, more diverse samples are warranted to further validate the predictive utility of these screening tools in Indonesian basketball contexts.

CONCLUSSION

This study demonstrates that movement pattern deficits and dynamic balance asymmetries are significant predictors of injury risk among basketball athletes at the Faculty of Sport and Health Sciences, Universitas Negeri Makassar. Athletes who scored at or below the FMS threshold of 14 exhibited markedly higher injury rates, and anterior SEBT reach asymmetry exceeding 4 cm was associated with a more than three-fold increase in injury risk. The combined application of FMS and SEBT yielded superior predictive accuracy compared to either tool applied in isolation, underscoring the complementary value of these assessment modalities in comprehensive injury risk profiling. These findings support the systematic integration of standardized movement and balance screening into the pre-season assessment protocols of Indonesian university basketball programs. Routine screening enables the early identification of at-risk athletes and facilitates the design of individualized preventive exercise programs targeting mobility, neuromuscular control, and dynamic stability — ultimately reducing injury incidence and supporting long-term athlete health and performance. Future longitudinal research with prospective injury surveillance is recommended to further establish the predictive validity of these instruments within Indonesian sporting populations and to evaluate the effectiveness of screening-informed intervention programs.

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