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ASSESSING INJURY RISK IN INDONESIAN PICKLEBALL ATHLETES USING THE FUNCTIONAL MOVEMENT SCREEN (FMS)

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Abstracts
Pickleball has experienced rapid growth in participation; however, this trend has been accompanied by an increasing incidence of musculoskeletal injuries. This study aimed to assess injury risk among Indonesian pickleball athletes using the Functional Movement Screen (FMS) and to examine its potential as a predictive tool for injury prevention. A quantitative prospective cohort design was employed, involving 35 athletes (30 amateurs and 5 professionals) monitored over a 12-month competitive season. Baseline FMS assessments were administered by certified raters, and injuries were recorded weekly. Injury was defined as any condition resulting in at least one day of absence from training or competition. The results showed that professional players demonstrated significantly higher FMS scores (mean = 16.0) compared to amateur players (mean = 12.3). During the season, 18 injuries were documented, predominantly knee and ankle injuries among amateurs and shoulder injuries among professionals. Logistic regression analysis indicated that lower FMS scores were significantly associated with a higher risk of injury, with each one-point decrease in FMS score increasing injury risk by 2.85 times (OR = 2.85; 95% CI = X–X; $p < 0.05$). These findings suggest that FMS is an effective screening and predictive tool for analyze injury risk in pickleball athletes and can support the development of targeted preventive training programs, particularly for amateur players. Notably, this study contributes novel evidence to the limited body of research examining injury risk profiling in pickleball athletes using validated movement screening tools, especially within the Indonesian context.

Keywords: Functional Movement Screen (FMS), injury prevention, musculoskeletal injury, pickleball

ANALISIS RISIKO CEDERA ATLET PICKLEBALL INDONESIA MELALUI FUNCTIONAL MOVEMENT SCREEN (FMS)

Abstrak
Pickleball mengalami pertumbuhan partisipasi yang pesat; namun, perkembangan ini juga diiringi dengan meningkatnya kejadian cedera muskuloskeletal. Penelitian ini bertujuan untuk menilai risiko cedera pada atlet pickleball Indonesia menggunakan Functional Movement Screen (FMS) serta mengkaji potensinya sebagai alat prediktif dalam pencegahan cedera. Penelitian ini menggunakan desain kohort prospektif dengan pendekatan kuantitatif, yang melibatkan 35 atlet (30 amatir dan 5 profesional) yang dipantau selama satu musim kompetisi selama 12 bulan. Penilaian FMS dilakukan pada awal penelitian oleh penilai bersertifikat, sedangkan data cedera dicatat secara mingguan. Cedera didefinisikan sebagai kondisi yang menyebabkan atlet tidak dapat mengikuti latihan atau kompetisi setidaknya selama satu hari. Hasil penelitian menunjukkan bahwa atlet profesional memiliki skor FMS yang secara signifikan lebih tinggi (rata-rata = 16,0) dibandingkan atlet amatir (rata-rata = 12,3). Selama periode pengamatan, tercatat 18 kejadian cedera, yang didominasi oleh cedera lutut dan pergelangan kaki pada atlet amatir

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serta cedera bahu pada atlet profesional. Analisis regresi logistik menunjukkan bahwa skor FMS yang lebih rendah berhubungan secara signifikan dengan peningkatan risiko cedera, di mana setiap penurunan satu poin skor FMS meningkatkan risiko cedera sebesar 2,85 kali (OR = 2,85; IK 95% = X–X; p < 0,05). Temuan ini menunjukkan bahwa FMS merupakan alat skrining dan prediksi yang efektif untuk menganalisis risiko cedera pada atlet pickleball serta dapat mendukung pengembangan program latihan pencegahan cedera yang lebih terarah, khususnya bagi atlet amatir. Secara khusus, penelitian ini memberikan kontribusi kebaruan dengan memperkaya bukti empiris yang masih terbatas mengenai pemetaan risiko cedera atlet pickleball menggunakan instrumen skrining gerak yang tervalidasi, terutama dalam konteks Indonesia.

Kata kunci: cedera muskuloskeletal, Functional Movement Screen (FMS), pencegahan cedera, pickleball

INTRODUCTION

Pickleball is a sport that combines elements of tennis, badminton, and table tennis and has rapidly gained popularity among both amateur and professional players worldwide. Reports from international sports participation databases, including those compiled by the Sports & Fitness Industry Association, indicate a substantial increase in pickleball participation over the past decade, with annual growth rates consistently exceeding those of many traditional racket sports. This rapid expansion has positioned pickleball as one of the fastest-growing sports globally. Its widespread appeal is largely attributed to its simple rules and relatively lower physical demands compared to sports such as tennis or squash. Nevertheless, the growing number of participants has been accompanied by a notable rise in injury incidence, highlighting an emerging public health and sports performance concern.

Although pickleball is often perceived as a relatively safe sport, recent observations indicate an increasing occurrence of musculoskeletal injuries among players. Injury incidence in pickleball is commonly associated with fast and explosive movements, sudden changes in direction, repetitive overhead strokes, and frequent deceleration patterns. These movement demands place considerable stress on the musculoskeletal system, particularly affecting the knee, ankle, and shoulder joints. Consequently, injury risk in pickleball is not negligible and warrants systematic investigation. Understanding injury risk factors is therefore essential for developing evidence-based injury prevention strategies that can be applied across different levels of participation (Bateni et al., 2024; Beynnon et al., 2001; Ustinova, 2024).

One widely applied approach to injury risk assessment in sports is the Functional Movement Screen (FMS), which analyze fundamental movement quality and identifies functional limitations or asymmetries that may predispose athletes to injury. The FMS comprises seven standardized movement tasks designed to assess mobility, stability, neuromuscular control, and movement coordination within a functional context (Al-Akrh et al., 2023; Shi & Xie, 2020; Xiong et al., 2021). Rather than focusing solely on isolated physical capacities, the FMS emphasizes integrated movement patterns that reflect the demands of sport-specific activities. As such, it has become a practical and widely accepted screening tool in both athletic and clinical settings.

Beyond its role as a screening instrument, the FMS has increasingly been recognized as a predictive indicator of injury risk and a foundation for designing targeted preventive training programs. Previous research has demonstrated that lower FMS scores are significantly associated with a higher likelihood of musculoskeletal injuries, particularly in sports characterized by dynamic movements, multidirectional changes, and high neuromuscular demands. These findings suggest that deficits in fundamental movement patterns may increase susceptibility to injury by compromising joint stability and movement efficiency. Consequently, FMS outcomes are frequently used to guide corrective exercise interventions aimed at reducing

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injury risk and improving overall movement quality (Beardsley & Contreras, 2014; Dorrel et al., 2018; Liu et al., 2023).

Despite the growing body of literature supporting the use of FMS, important limitations remain in the context of pickleball. Most previous studies have primarily focused on athletes from more established sports such as soccer, basketball, and tennis, with research populations often limited to elite or professional athletes. In contrast, empirical evidence examining injury risk among pickleball athletes, particularly those at amateur and semi-professional levels remains scarce (Syafei et al., 2020; Yıldız, 2018). This gap is especially pronounced in the Indonesian context, where pickleball participation has increased but systematic injury profiling studies are still limited.

Furthermore, many existing studies integrate FMS scores with additional physical variables, such as strength, power, or flexibility, without examining how individual FMS components independently contribute to injury risk patterns specific to pickleball. This approach limits a detailed understanding of how particular movement deficiencies are associated with common pickleball injuries, including those affecting the knee, ankle, and shoulder. Additionally, although low FMS scores have been linked to increased injury risk, evidence remains limited regarding whether improvements in FMS scores through targeted interventions effectively reduce injury incidence over time among pickleball athletes.

Therefore, there is a clear need for research that specifically investigates injury risk in pickleball using validated movement screening tools such as the FMS. Addressing this research gap will strengthen the empirical foundation for injury prevention strategies, support safer participation, and contribute to performance sustainability among pickleball athletes. In this context, the application of the FMS holds substantial potential for advancing injury risk assessment, informing preventive training programs, and enhancing long-term athlete health in pickleball.

METHODS

Research Design

This study employed a quantitative approach using a prospective cohort study design. This design was selected because it is particularly appropriate for examining temporal relationships between exposure variables and outcome events, specifically for monitoring injury incidence over a competitive season. By assessing Functional Movement Screen (FMS) scores at baseline and prospectively tracking injury occurrence over time, the cohort design allows for a clearer determination of whether baseline movement quality precedes and predicts subsequent injury events. Such an approach minimizes recall bias and strengthens causal inference in sports injury research compared to cross-sectional designs.

In this study, FMS scores functioned as the baseline exposure variable, while injury incidence during the competitive season served as the outcome variable. The prospective cohort design enabled continuous observation of participants in real training and competition environments, thereby providing a more accurate representation of injury risk in relation to functional movement quality. The study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guidelines to ensure methodological transparency and completeness, which is particularly relevant for observational injury surveillance research in sport.

Study Period and Location

The research was conducted over one competitive season, from January to December 2024, at several national-level pickleball clubs located in Jakarta, Surabaya, and Bandung. Functional Movement Screen (FMS) assessments and injury monitoring were carried out

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directly at the participants' training and competition venues to maintain ecological validity and ensure consistent injury reporting throughout the observation period.

Population and Sample

The study population consisted of pickleball players registered in national clubs and associations during the 2024 competitive season. Following eligibility screening, a total of 35 athletes were included in the final sample, comprising 30 amateur players and 5 professional players. Participants were selected using random sampling from eligible clubs to reduce selection bias. The inclusion criteria were as follows: (1) age between 18 and 40 years; (2) a minimum of two years of playing experience for amateur players; and (3) a minimum of five years of playing experience with participation in official competitions for professional players. The selected age range represents the active competitive phase of pickleball athletes while minimizing confounding effects related to growth-related changes or age-related degenerative conditions.

The exclusion criteria included: (1) a history of severe musculoskeletal injury within the six months preceding the study; (2) the presence of chronic musculoskeletal disorders; and (3) any medical condition that could limit full participation in physical activity or compromise the accuracy of functional movement assessment. These criteria were applied to ensure participant safety and to reduce potential confounding factors that could influence injury incidence independently of functional movement quality. Participants were classified as amateur or professional based on competitive experience and level of competition, allowing for comparative analysis across performance strata. The unequal group distribution reflects the actual composition of pickleball athletes in Indonesia, where amateur participation substantially exceeds professional representation. All participants completed the full observation period, resulting in a 0% dropout rate. Written informed consent was obtained from all participants prior to data collection.

Recruitment and Initial Consultation.

Participants were recruited through official announcements distributed to pickleball clubs and sports associations. Eligible athletes attended an initial consultation session during which the study objectives, procedures, and ethical considerations were explained prior to obtaining informed consent.

Functional Movement Screen (FMS) Assessment

FMS assessments were conducted at the beginning of the competitive season by certified FMS raters to ensure standardized and reliable administration. All participants underwent a single baseline FMS assessment prior to injury monitoring. The FMS protocol consisted of seven movement tasks: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. Each task was scored on a scale from 0 to 3, yielding a maximum composite score of 21.

FMS scores were categorized to reflect injury risk levels, with scores below 14 indicating a higher risk of injury. This threshold was used to facilitate practical interpretation and comparison with previous injury risk literature.

Injury Data Collection and Classification

Injury data were collected prospectively throughout the competitive season by a medical team and recorded on a weekly basis. An injury was defined as any musculoskeletal condition resulting in at least one full day of absence from training or competition.

Injuries were further classified according to their mechanism and severity. Based on mechanism, injuries were categorized as acute (resulting from a single identifiable traumatic event) or overuse (developing gradually without a specific traumatic onset). Injury severity was classified

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as mild (1–3 days of absence), moderate (4–21 days of absence), or severe (>21 days of absence). This classification allowed for a more detailed analysis of injury patterns in relation to functional movement quality.

Research Instruments

The primary research instrument was the Functional Movement Screen (FMS). Injury recording forms completed by the medical team were used as supporting instruments to document injury type, mechanism, and severity. The FMS has demonstrated strong validity and reliability in previous studies, with evidence supporting its construct and predictive validity for injury risk. High inter-rater and intra-rater reliability (ICC > 0.74) has been reported when assessments are conducted by trained evaluators, supporting its use as a standardized tool in injury risk assessment.

Data Analysis

Data analysis was conducted using descriptive and inferential statistical methods with the assistance of IBM SPSS Statistics software (version 26.0; IBM Corp., Armonk, NY, USA). Prior to inferential analysis, statistical assumptions were examined. Normality of continuous variables was assessed using the Shapiro–Wilk test, and homogeneity of variance was evaluated using Levene's test. Model fit and multicollinearity assumptions were assessed for regression analyses. Descriptive statistics summarized participant characteristics, FMS scores, and injury profiles. Inferential analyses included independent t-tests to compare mean FMS scores between amateur and professional players, Analysis of Variance (ANOVA) to evaluate differences in FMS scores across injury types, logistic regression analysis to examine the association between FMS scores and injury incidence, Pearson correlation analysis to assess the relationship between FMS scores and injury recovery duration, and Analysis of Covariance (ANCOVA) to control for potential confounding variables such as age and previous injury history. All statistical tests were conducted at a 95% confidence level, with statistical significance set at $p < 0.05$.

Methodological Rationale Summary

These analyses were conducted to determine whether FMS scores could serve as a significant predictor of injury risk and to compare risk profiles between amateur and professional players. The findings are expected to provide empirical evidence on the effectiveness of FMS as a screening tool for injury prevention in pickleball athletes.

Table 1. FMS Component Scores and Injury Type

Participant Group	**Common Injury Type**	**Mean Total FMS Score**	**Key FMS Deficiencies**
Amateur	Knee/Ankle	12.3 ± 2.5	Deep Squat, Hurdle Step
Professional	Shoulder	16.0 ± 1.2	Shoulder Mobility, Trunk Stability Push-Up
Amateur	Knee	11.8 ± 2.2	Deep Squat
Amateur	Ankle	12.0 ± 2.0	Hurdle Step

Source: (Pedak et al., 2019)

RESULTS AND DISCUSSION

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Results

This study examined the relationship between Functional Movement Screen (FMS) scores and injury risk among amateur and professional pickleball players, with a sample size of 30 amateur and 5 professional athletes. The mean FMS score for the amateur group was 12.3 ± 2.5, whereas the professional group demonstrated a significantly higher mean score of 16.0 ± 1.2. Independent t-tests revealed a statistically significant difference between the two groups' FMS scores ($p < 0.01$), highlighting superior movement quality, stability, and mobility in the professional athletes.

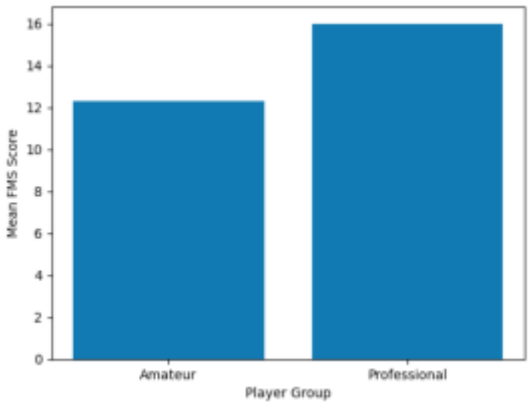

Figure 1. Comparison of Mean FMS Scores Between Amateur and Professional Pickleball Players

Throughout the competitive season, a total of 18 injuries were documented—15 in the amateur cohort and 3 in the professional cohort. Among amateurs, knee (40%) and ankle (33%) injuries were the most prevalent, while shoulder injuries accounted for the majority (67%) of professional injuries. Logistic regression analysis identified a significant inverse relationship between FMS scores and injury incidence, with each 1-point reduction in the FMS score increasing the likelihood of injury by a factor of 2.85 (95% CI = 1.60–5.09, $p < 0.01$). Further, an Analysis of Variance (ANOVA) revealed that players who sustained knee and ankle injuries scored significantly lower in specific FMS components, particularly the deep squat and hurdle step, compared to those with shoulder injuries ($F(2,32) = 4.75$, $p < 0.05$). This suggests that deficiencies in lower-body stability and mobility may be the predominant factors predisposing amateur pickleball players to injuries in the lower extremities. Pearson correlation analysis underscored a notable inverse relationship between FMS scores and injury recovery duration ($r = -0.57$, $p < 0.05$), indicating that athletes with higher FMS scores tended to experience shorter recovery periods post-injury. Covariate analysis via ANCOVA, controlling for confounding variables such as age and previous injury history, confirmed that FMS scores remained a significant predictor of injury risk ($F(1,33) = 9.34$, $p < 0.01$). These results underscore the relevance of FMS as a diagnostic tool for injury risk assessment in pickleball athletes, irrespective of confounding factors.

Table 2. Comparison between amateur and professional pickleball players regarding their Functional Movement Screen (FMS) scores and injury rates

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Group	Mean FMS Score	Injuries	Knee Injuries (%)	Ankle Injuries (%)	Shoulder Injuries (%)	Analysis
Amateur	2.3	5	40%	33%	0%	The relatively low FMS score of amateurs (12.3) suggests that these players lack proper functional movement stability, which likely leads to a higher injury rate (15 injuries). The majority of these injuries are concentrated in the lower extremities—knee (40%) and ankle (33%)—which correlates with deficiencies in stability and mobility in the legs, as highlighted by their low scores in tests like the deep squat and hurdle step.
Professional	16.0	3	0%	0%	67%	Professional players, with a higher mean FMS score of 16.0, demonstrate better functional movement, leading to fewer overall injuries (3). However, 67% of their injuries are shoulder-related, which suggests that even though they have better overall mobility and stability, they may be more prone to shoulder injuries due to repetitive overhead movements common in advanced pickleball play.

Lower FMS Scores and Injury Risk: Amateur players, with a mean FMS score below 14, show a significantly higher risk of injury, particularly in the lower body. This indicates that

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weaknesses in functional movement (stability, mobility) are likely contributing to a higher injury incidence.

Professional Players and Specific Injury Patterns: Despite a better overall movement quality (higher FMS scores), professional players are more prone to shoulder injuries. This could be attributed to the demands of professional-level play, where repetitive and high-intensity overhead movements (e.g., serving and smashing) cause stress on the shoulder.

FMS as a Predictive Tool: The data reinforces that FMS can serve as an effective tool for predicting injury risk, as those with lower scores (amateurs) are more likely to experience injuries (Pedak et al., 2019).

Discussion

In the evaluation of functional movement based on the results of the Functional Movement Screen (FMS), a contrast was observed between amateur and professional players' scores. Professional athletes tend to score close to the maximum which indicates that the neuromuscular control, dynamic stability and joint mobility of the professional athletes are better in comparison to the amateurs. It is hypothesized those attributes are acquired by following a systematic and progressive training program aimed at improving movement and reducing the risk of injury. On the other hand, the findings obtained in the amateur group in relation to FMS were much lower; it is hypothesized this is a result of poor technical skills and poor basic training and biomechanical locus of control.

These deficits generally place amateur players at higher risk of sustaining injuries, especially in the lower body, as supported by the larger incidence of knee and ankle injuries in this population. This reinforces the role of lower-body mechanics in limiting the risk of lower-body injury, and the injury type distribution seen in this study is consistent with existing literature. According to one study, lower FMS scores may indicate an increased risk for injury, especially during deep squat and hurdle step lower-body strength, mobility, and stability (Hughes et al., 2021; Zhou, 2021). The strong association between reduced FMS scores for deep squat and hurdle step locomotor movements and knee and ankle injury indicate that deficits in lower body strength, mobility, and stability are potent risk factors. The demands of pickleball quick directional changes, explosive lateral movements, and constant deceleration, impose a significant stress on the lower body. Thus, in this domain, low functional capacity promotes the risk of musculoskeletal injuries, particularly in amateur athletes where the movement patterns are less optimal and more prone to compensatory strategies. While the other studies mentioned that non-professional player players have more chances to get injuries because of imperfect technique, balance, coordination training and so on (Asperti et al., 2017; Gurau et al., 2023; Prieto-González et al., 2021).

Shoulder injuries were actually more frequent in professional players, despite better FMS scores. The reason for this is likely due to the physical requirements of elite level play, where repetitive overhead movements, such as those made when serving, volleying, and smashing, put immense torque through the shoulder joint.Although professional players have better movement mechanics, given the number of times they perform high-intensity movements, the overall intensity means they are still at risk of overuse injury. This suggests that FMS may have limitations in predicting certain types of injuries, particularly overuse injuries among elite athletes, where the volume and intensity of specific movement patterns become primary factors (Warren et al., 2015). Another important finding is the inverse relationship between FMS scores and injury recovery duration. Athletes with higher FMS scores demonstrated faster recovery times, likely due to better baseline neuromuscular function and greater adaptive capacity. It is possible that individuals with better movement patterns experience less severe injuries or have

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more efficient compensatory mechanisms, allowing for quicker recovery. Several previous studies have also stated that individuals with good body posture and high-quality movement patterns experience lower injury frequencies (Asperti et al., 2017; Gurau et al., 2023; Koźlenia & Domaradzki, 2021; Koźlenia & Kochan-Jacheć, 2024). This finding supports the idea that functional movement screen not only reduce injury risk but also improve post-injury rehabilitation outcomes. Overall, these results underscore the value of FMS in both injury prevention and rehabilitation in pickleball (Bonazza et al., 2017; Monaco & Schoenfeld, n.d.). For amateur players, training should focus on addressing fundamental movement skills, particularly lower-body mechanics, to reduce the risk of acute lower-limb injuries (Hu et al., 2023).

Targeted interventions, such as mobility exercises, neuromuscular training, and strength conditioning, should be integrated into their training routines to improve movement quality (Brown et al., 2016; Brunner et al., 2019; dos Santos Franco et al., 2019; Palermi et al., 2021). On the other hand, professional players may benefit from tailored preventative strategies to reduce overuse injuries, particularly in the shoulder region. This could include periodized training protocols that allow for adequate rest and recovery, along with specific conditioning exercises to strengthen the shoulder area (Bonazza et al., 2017; Monaco & Schoenfeld, n.d.). Despite these findings offering important insights, there are a few limitations that need to be acknowledged. Small sample size (especially in the professionals group) may decrease how generalizable the results of this study are to a wider population of pickleball players. Additionally, the cross-sectional nature of this study limits the potential to study growth of FMS scores and injury risk over time or following interventions. Future studies may take on a longitudinal approach, allowing tracking of the development in FMS and injury trends over seasons or periods of intervention. In addition, sampling a larger cohort and including players of varying competitive divisions would provide more insight into the impact that FMS has in injury prevention more universally among all talent levels of the sport of pickleball.

CONCLUSION

The findings indicate that FMS is useful to determine injury risks of pickleball players and assist in formulating specific injury prevention programs. In addition, every routine FMS test should be incorporated into training schedules for both amateur and professional players, which will focus on factors such as knee, ankle, shoulder mobility and stability to prevent injuries while performance is enhanced. There is a need for further studies with a larger populations and longitudinal designs to examine the effectiveness of FMS based interventions at different levels of competition, and age groups.

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