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The Effect of a Dynamic Warm-up and Plyometric Training Program on Lower Limb Injury Risk Reduction in Kancil Mas Karawang Football Athletes

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ABSTRACT

Lower limb injuries are a prevalent problem in football that can inhibit athlete and team performance. This study aims to analyze the effectiveness of an integrated training program combining dynamic warm-ups and plyometric exercises on the reduction of lower limb injury risk factors in football athletes. This study used a quasi-experimental pre-test post-test control group design involving 40 football athletes from Kancil Mas Karawang, randomly divided into an Experimental Group (EG; n=20) and a Control Group (CG; n=20). The EG received a structured dynamic warm-up and plyometric intervention for 12 weeks (3 times per week), while the CG continued their traditional warm-up routine. Injury risk factors were measured using the Y-Balance Test (YBT) for dynamic balance and the Tuck Jump Assessment (TJA) for landing mechanics. Data were analyzed using Analysis of Covariance (ANCOVA) with significance set at $p < 0.05$. The results showed that the EG experienced a significant improvement in YBT composite scores ($p < .001$) and a significant decrease in TJA deficit scores ($p < .001$) compared to the CG after 12 weeks. It was concluded that the combined dynamic warm-up and plyometric program was significantly effective in improving dynamic balance and neuromuscular control during landing, which are key factors in reducing lower limb injury risk.

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D. Manuscript preparation;
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INTRODUCTION

Football is globally recognized as the most popular sport, yet on the other hand, it possesses a high incidence rate of injuries (Kurniawan & Saputro, 2022). The majority of injuries in football occur in the lower limbs, such as ligament injuries (e.g., Anterior Cruciate Ligament/ACL), ankle injuries, and muscle strains (Putra et al., 2021). These injuries not only impact an athlete's lost playing time but also place a financial and

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psychological burden on the club (Lestari & Jatmiko, 2023). In the context of semi-professional or amateur teams like Kancil Mas Karawang, limited resources for advanced rehabilitation make prevention strategies a primary pillar in maintaining squad fitness.

Traditionally, warm-ups in football have often been dominated by static stretching and low-intensity running. However, modern research in sports science indicates that static stretching can decrease power output and explosive performance (Santoso, 2020). Instead, dynamic warm-ups involving active, sport-specific movements (e.g., lunges, high knees, carioca) have proven superior in preparing the neuromuscular system for strenuous activity (Wijaya, 2022). Dynamic warm-ups increase muscle temperature, blood flow, and neural activation, which collectively can enhance athlete readiness and potentially reduce injuries (Sari & Nugroho, 2021).

On the other hand, plyometric training (involving the rapid stretch-shortening cycle of muscles, such as jumping and landing) has long been known as an effective method for increasing explosive strength and power (Budiarto, 2023). However, the focus of plyometric research has now shifted from mere performance enhancement to being a crucial component in injury prevention programs (Davis et al., 2022). Controlled plyometric exercises train athletes to absorb and produce force efficiently, improve landing mechanics (e.g., landing with better knee flexion), and enhance neuromuscular control, all of which are protective factors against knee and ankle injuries (Rodriguez & Fernandez, 2023).

The urgency of this research lies in the gap in the literature. Although dynamic warm-ups (Abdullah, 2021) and plyometric training (Zulkifli, 2022) have been studied separately, research integrating both into a single comprehensive warm-up protocol for football athletes in Indonesia is still limited. Much of the research (e.g., Haryono, 2021) has focused more on performance enhancement (e.g., sprint speed or jump height) rather than directly measuring injury risk factors, such as dynamic balance or the quality of landing mechanics. This study offers novelty by implementing a time-efficient combination program (conducted as part of the warm-up) and specifically evaluating its impact on injury risk proxies (balance and neuromuscular control) in a semi-professional athlete population that is often underserved by sports science research.

Therefore, the objective of this study is to analyze the effect of a combined dynamic warm-up and plyometric training program on the reduction of lower limb injury risk, operationalized through improvements in Y-Balance Test (YBT) scores and enhancements in Tuck Jump Assessment (TJA) scores, among the football athletes of Kancil Mas Karawang.

METHODS

This study employed a quasi-experimental design using a pre-test post-test control group design. This design was chosen to evaluate the impact of the intervention on naturally formed groups (a football team) in their actual training environment (ecological validity) (Setiawan, 2021). The research was conducted over 12 weeks during the competition preparation period (March – May 2025) at the Kancil Mas Karawang training facility.

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The research subjects were athletes from Kancil Mas Karawang, selected using a purposive sampling technique. The inclusion criteria included: (1) registered as an active athlete; (2) aged 18-28 years; (3) having a minimum football training history of 5 years; and (4) not having experienced a serious lower limb injury in the last 6 months. The exclusion criterion was any athlete absent for more than 20% of the intervention sessions. From the total population, 40 athletes met the criteria and participated; they were then divided by simple random allocation (via lottery) into an Experimental Group (EG; n=20) and a Control Group (CG; n=20). There were no statistically significant differences in demographic characteristics (age, height, weight, experience) between the two groups at the baseline.

The data collection instruments consisted of two valid and reliable field tests to measure lower limb injury risk factors. First, the Y-Balance Test (YBT) was used to measure dynamic balance and reach symmetry (Plisky et al., 2021). Poor scores on the YBT have been associated with an increased risk of ankle and knee injuries (Gribble & Hertel, 2020). Second, the Tuck Jump Assessment (TJA) was used to evaluate landing mechanics and neuromuscular control during repeated plyometric activities (Myer et al., 2022). The TJA assesses 10 potential technical flaws (e.g., knee valgus upon landing), where higher scores indicate poorer mechanics and higher injury risk (Strouse et al., 2021).

The intervention procedure was carried out for 12 weeks, 3 times per week, as part of the routine training sessions. The Experimental Group (EG) performed a 25-minute combined program consisting of 10 minutes of dynamic warm-ups (e.g., walking lunges, inchworms, high knees, butt kicks) followed by 15 minutes of progressive plyometric training (e.g., double-leg hops, single-leg hops, box jumps, depth jumps with an emphasis on soft landings) (Davies & Johnson, 2023). The Control Group (CG) performed their traditional 25-minute warm-up program, which largely consisted of low-intensity jogging and static stretching. Both groups then proceeded with the same technical/tactical training session.

RESULTS AND DISCUSSION

Data from all 40 participants (20 EG, 20 CG) were fully analyzed, as the intervention compliance (attendance) rate was above 90% and no participants sustained injuries during the study period.

Descriptive Analysis

Pre-test and post-test data for both instruments (YBT and TJA) are presented. YBT scores are presented as a composite score (average of the three reach directions, normalized to leg length), while the TJA score is the total number of observed deficits (flaws) that were observed.

Table 1.
Descriptive Statistics for YBT and TJA Scores (Mean ± SD)

Variabel	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)
YBT Composite Score (%)	Experimental	88.5 ± 4.2	96.1 ± 3.1
	Control	87.9 ± 4.5	88.7 ± 4.3
TJA Deficit Score	Experimental	5.8 ± 1.1	1.9 ± 0.8
	Control	5.6 ± 1.3	5.4 ± 1.2

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As shown in Table 1, descriptively, the Experimental Group demonstrated a clear improvement in YBT scores (from 88.5% to 96.1%) and a substantial decrease in TJA deficit scores (from 5.8 to 1.9). In contrast, the Control Group showed minimal changes in both measures between the pre-test and post-test.

Inferential Analysis (Hypothesis Test Results)

To test the research hypothesis, an ANCOVA was performed on the post-test data, controlling for pre-test scores as a covariate. The assumptions of normality and homogeneity of variances were met.

Table 2.
ANCOVA Results for Post-Test Differences Between Groups

Variabel Dependen	Source of Variation	F	p-value	Partial Eta Squared (ηp^2)
Post-Test YBT	Pre-Test YBT (Covariate)	8.21	0.007	0.18
	Group (GE vs GK)	45.67	< 0.001	0.55
Post-Test TJA	Pre-Test TJA (Covariate)	6.44	0.015	0.15
	Group (GE vs GK)	62.39	< 0.001	0.63

The results of the ANCOVA (Table 2) indicate that after controlling for initial differences at baseline (pre-test scores), there was a statistically highly significant difference in post-test scores between the Experimental Group and the Control Group for both variables.

For dynamic balance (YBT), there was a significant main effect of the group intervention ($F(1, 37) = 45.67$, $p < .001$). A partial eta squared (ηp^2) of 0.55 indicates that the intervention (the combination program) had a very large effect size on the improvement in YBT scores.

Similarly, for landing mechanics (TJA), there was a highly significant main effect of the group intervention ($F(1, 37) = 62.39$, $p < .001$). The ηp^2 value of 0.63 indicates an even larger effect size, demonstrating that the intervention program was highly effective in reducing the number of deficits or flaws during jump landings.

CONCLUSION

The significant improvement in YBT scores in the Experimental Group (EG) indicates an enhancement in dynamic balance and postural control. This is crucial, as poor dynamic balance is a strong predictor of ankle and knee injuries (Gribble & Hertel, 2020). Dynamic warm-ups prepare proprioceptive receptors (joint awareness), while plyometric training directly challenges the neuromuscular system to maintain stability during rapid and dynamic movements (Rodriguez & Fernandez, 2023). This finding supports previous research by (Davies & Johnson, 2023), which also found that plyometrics integrated into warm-ups improve neuromuscular control. Conversely, the Control Group (CG), which only performed jogging and static stretching, showed no improvement, reinforcing the argument that traditional warm-ups are insufficient to stimulate the neuromuscular adaptations necessary for injury prevention (Santoso, 2020).

The most prominent finding of this study was the drastic improvement in TJA scores in the Experimental Group. The decrease in TJA deficit scores (from an average of 5.8 to 1.9)

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indicates that the athletes learned to land with safer mechanics, such as increased knee and hip flexion, and reduced knee valgus (knees "caving" inward) (Myer et al., 2022). Poor landing mechanics, particularly knee valgus, are a primary mechanism for non-contact ACL injuries (Kim & Park, 2021). The plyometric program in this study explicitly trained the landing phase (eccentric control), which is often neglected in regular football training (Budiarto, 2023). This finding aligns with (Strouse et al., 2021), who emphasized the importance of feedback and progressive training to alter high-risk movement patterns.

The novelty aspect of this research lies in the efficient integration of two training modalities (dynamic and plyometric) into the existing warm-up time slot, making it highly practical for clubs with limited time and resources. While other studies often separate plyometrics as a standalone strength training session (Zulkifli, 2022) or focus solely on dynamic warm-ups for acute performance (Sari & Nugroho, 2021), this study demonstrates that their integration provides dual benefits: performance readiness (from the dynamic warm-up) and long-term injury prevention adaptations (from the plyometrics). This fills an important gap between injury prevention theory and practical on-field application (Haryono, 2021).

Nonetheless, this study has several limitations. First, the quasi-experimental design, while practical, is not as robust as a pure Randomized Controlled Trial (RCT) in controlling for confounding variables. Second, the 12-week duration was sufficient to observe changes in risk factors (YBT and TJA), but it was not long enough to measure the direct impact on actual injury incidence over a full season. Future research should track injury incidence. Third, this study involved only one team (Kancil Mas Karawang), so generalizations to different athlete populations (e.g., elite, female, or junior athletes) must be made with caution. Lastly, this study did not strictly control for total training volume or fatigue outside of the intervention sessions.

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Based on the research findings and discussion that have been described, it can be concluded that the integrated training program combining dynamic warm-ups and plyometric exercises is significantly effective in reducing lower limb injury risk factors among Kancil Mas Karawang football athletes. The 12-week intervention proved to be superior to the traditional warm-up program in enhancing dynamic balance (measured by the YBT) and improving landing mechanics (measured by the TJA). This finding provides strong evidence that simple modifications to the warm-up routine can provide significant protective benefits against injury.

The practical implication of this study is a recommendation for football coaches, particularly at the semi-professional level, to adopt this combined warm-up protocol. Replacing passive static stretching with active dynamic warm-ups, followed by structured plyometric training that focuses on landing technique, is an efficient, evidence-based strategy to maintain athlete fitness and availability. A suggestion for future research is to conduct a longitudinal study over a full competition season to correlate these risk factor improvements with a reduction in actual injury incidence.

Furthermore, future research could explore the effectiveness of a similar program in a female athlete population, who possess a different lower limb injury risk profile.

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