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Benefits of Strength Training for Injury Prevention in Novice Student Athletes

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Abstract
This study examines the benefits of strength training programs in preventing injuries among novice student athletes at the Faculty of Sports and Health Sciences (FIKK), Universitas Negeri Makassar (UNM). Injuries among novice athletes remain a significant concern in sports science, with musculoskeletal injuries being the most prevalent. This research employed a quasi-experimental design with a sample of 60 novice student athletes who participated in a structured 12-week strength training program. Data were collected through pre-test and post-test assessments, including musculoskeletal strength measurements, functional movement screening, and injury incidence monitoring. Results indicated a significant reduction in injury rates among participants who completed the strength training program compared to the control group. Specifically, the intervention group demonstrated a 68% decrease in lower extremity injuries and a 54% reduction in upper extremity injuries. Furthermore, participants showed significant improvements in muscular strength ($p<0.05$), joint stability ($p<0.01$), and functional movement patterns ($p<0.01$). The findings suggest that systematic strength training programs are highly effective in enhancing neuromuscular control, improving biomechanical efficiency, and reducing injury susceptibility in novice athletes. This study contributes to the growing body of evidence supporting the integration of strength training as a fundamental component of injury prevention strategies in university sports programs. Recommendations include implementing mandatory strength training protocols for all novice athletes and developing individualized training programs based on sport-specific injury risk profiles.

Keywords: strength training, injury prevention, novice athletes, musculoskeletal health, sports performance

INTRODUCTION

The landscape of collegiate sports has evolved dramatically over the past decades, with increasing participation rates among university students in various athletic disciplines (Andersen & Williams, 2020). In Indonesia, particularly at the Faculty of Sports and Health Sciences (FIKK) at Universitas Negeri Makassar (UNM), there has been a substantial increase in the number of students engaging in competitive and recreational sports activities. However, this growth in participation has been accompanied by a concerning rise in sports-related injuries, particularly among novice athletes who lack adequate physical preparation and conditioning (Wijaya & Kusuma, 2021). The transition from recreational physical activity to structured athletic training presents numerous physiological and biomechanical challenges that, if not properly managed, can lead to both acute and chronic injuries that may compromise athletic performance and long-term health outcomes.

Sports injuries among college athletes represent not only a health concern but also a significant economic burden, affecting academic performance, quality of life, and future athletic careers (Malisoux et al., 2020). Research indicates that novice athletes are particularly vulnerable to injury during their initial years of training, with injury rates ranging from 30% to 70% depending on the sport and level of physical preparation (Emery et al., 2020). The most common injuries among this population include muscle strains, ligament sprains, tendinopathies, and stress fractures, with the lower extremities being the most frequently affected region (Sugimoto et al., 2021). These injuries often result from a combination of factors including inadequate neuromuscular control, poor biomechanical technique, muscle imbalances, insufficient strength levels, and inappropriate training load progression (Lauersen et al., 2020).

The concept of injury prevention in sports has gained considerable attention in the sports science community, with researchers emphasizing the importance of implementing evidence-based strategies to reduce injury risk (Bahr & Krosshaug, 2021). Among various prevention approaches, strength training has emerged as one of the most effective interventions for reducing injury incidence across different sports and athlete populations (Lauersen et al., 2020). Strength training, defined as the systematic use of resistance exercises to improve muscular strength, power, and endurance, provides numerous physiological adaptations that enhance the body's ability to withstand the mechanical stresses associated with athletic performance (Suchomel et al., 2021). These adaptations include increased muscle cross-sectional area, improved neuromuscular coordination, enhanced tendon stiffness, greater bone mineral density, and improved joint stability (Myer et al., 2020).

The theoretical foundation for using strength training as an injury prevention strategy is rooted in several biomechanical and physiological principles. First, increased muscular strength improves the body's capacity to absorb and dissipate forces during athletic movements, thereby reducing the mechanical stress placed on passive structures such as ligaments, tendons, and cartilage (Hewett et al., 2020). Second, strength training enhances neuromuscular control and proprioception, which are critical for maintaining proper movement patterns and joint alignment during dynamic activities (Sarto et al., 2022). Third, systematic resistance training promotes favorable adaptations in connective tissues, making them more resilient to the repetitive loading experienced during sports participation (Bohm et al., 2020). Fourth, strength training can address muscle imbalances and asymmetries that often predispose athletes to injury, particularly when one side of the body or one muscle group is significantly weaker than its counterpart (Bishop et al., 2021).

Despite the growing evidence supporting the benefits of strength training for injury prevention, implementation of such programs remains inconsistent in many university sports settings in Indonesia (Pratama & Hidayat, 2022). Several barriers have been identified, including limited access to proper training facilities, lack of qualified strength and conditioning coaches, insufficient knowledge among coaches and athletes regarding proper training protocols, and competing demands on athletes' time from academic and athletic commitments (Rahman & Santoso, 2021). Furthermore, there exists a knowledge gap regarding the specific benefits and optimal implementation strategies of strength training programs tailored to the unique needs and constraints of novice student athletes in the Indonesian context.

At FIKK UNM, where students pursue degrees in physical education, sports coaching, and sports science, there is a unique opportunity to examine the effectiveness of strength training interventions in a population that represents both the current and future generation of sports professionals in Indonesia. These students often engage in various sports activities as part of their curriculum and extracurricular involvement, yet many enter the program with limited prior exposure to systematic strength training (Yusuf & Anwar, 2023). This situation creates both a challenge and an opportunity to implement evidence-based injury prevention strategies that can serve as a model for other institutions throughout the country.

Previous research has demonstrated that well-designed strength training programs can reduce injury risk by 30% to 50% across various sports (Lauersen et al., 2020). However, most of this research has been conducted in Western countries with different athlete populations, training cultures, and resource availability. There is a critical need for context-specific research that examines the effectiveness of strength training interventions within Indonesian university sports programs, taking into account cultural factors, available resources, and the specific injury patterns observed in this population (Nugroho & Wijaya, 2022). Additionally, understanding the barriers to and facilitators of successful program implementation can inform the development of sustainable injury prevention strategies that can be realistically integrated into existing sports programs at Indonesian universities.

The significance of this research extends beyond immediate injury prevention outcomes. By demonstrating the benefits of strength training for novice student athletes, this study can contribute to a culture change within Indonesian sports programs, emphasizing the importance of physical preparation and long-term athlete development over immediate performance gains (Setiawan et al., 2021). Furthermore, given that many FIKK UNM students will become physical education teachers, coaches, and sports administrators, their personal experience with evidence-based injury prevention strategies can influence their future professional practice, creating a ripple effect that benefits the broader sports community in Indonesia.

Therefore, this study aims to comprehensively examine the benefits of a structured strength training program for injury prevention among novice student athletes at FIKK UNM. Specific objectives include: (1) evaluating the effect of a 12-week strength training intervention on injury incidence and severity; (2) assessing changes in muscular strength, functional movement quality, and neuromuscular control following the intervention; (3) identifying sport-specific injury patterns and their relationship to baseline strength levels; and (4) exploring athletes' perceptions and experiences with the strength training program to inform future implementation strategies. By addressing these objectives, this research seeks to provide empirical evidence to support the integration of strength training as a foundational component of athlete development programs at Indonesian universities.

METHODS

This study employed a quasi-experimental design with a non-equivalent control group to investigate the effects of a structured strength training program on injury prevention among novice student athletes at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar. The research was conducted over a period of 16 weeks, including a 4-week baseline assessment phase, a 12-week intervention period, and post-intervention assessments. The study received ethical approval from the Research Ethics Committee of Universitas Negeri Makassar, and all participants provided written informed consent prior to participation.

The study population consisted of first and second-year students enrolled at FIKK UNM who were actively participating in organized sports activities during the 2023-2024 academic year. Sample selection employed purposive sampling technique with specific inclusion criteria to ensure participant suitability for the intervention. Inclusion criteria required participants to be between 18 and 22 years of age, have less than two years of experience in organized competitive sports, be actively training at least three times per week, have no current injuries that would prevent participation in strength training activities, and have no previous systematic experience with structured strength training programs. Exclusion criteria included any history of major musculoskeletal surgery within the past year, current use of medications that could affect muscle function or bone health, and any medical conditions contraindicated for high-intensity resistance exercise. Based on power analysis calculations with an expected effect size of 0.65, alpha level of 0.05, and desired power of 0.80, a minimum sample size of 52 participants was determined. Accounting for potential attrition, 60 participants were recruited and randomly allocated to either the intervention group or control group using a computer-generated randomization sequence, with 30 participants in each group.

Prior to the intervention, all participants underwent comprehensive baseline assessments conducted by trained research assistants who were blinded to group allocation. The assessment protocol included anthropometric measurements such as height, weight, and body composition analysis using bioelectrical impedance. Muscular strength was evaluated through one-repetition maximum testing for major muscle groups including squat, bench press, deadlift, and overhead press exercises, following standardized protocols established by the National Strength and Conditioning Association (Haff & Triplett, 2020). Functional movement quality was assessed using the Functional Movement Screen, a validated tool consisting of seven fundamental movement patterns that identify limitations and asymmetries in movement quality (Cook et al., 2020). Neuromuscular control was evaluated through single-leg balance tests, Y-balance test, and vertical jump landing analysis using two-dimensional video analysis software. Additionally, participants completed questionnaires regarding their training history, previous injury experiences, and current physical activity levels.

The intervention group participated in a periodized strength training program designed specifically for novice athletes, following evidence-based guidelines from sports science literature. The program was supervised by certified strength and conditioning specialists and conducted in the FIKK UNM training facilities three times per week for 12 weeks. Each training session lasted approximately 60 to 75 minutes and included a standardized warm-up consisting of dynamic stretching and mobility exercises, followed by the main strength training component and concluding with cool-down activities. The strength training program was divided into three 4-week mesocycles with progressive increases in training intensity and complexity. The first mesocycle focused on teaching proper exercise technique and developing muscular endurance using moderate loads, the second mesocycle emphasized hypertrophy and strength development with increased loading, and the third mesocycle incorporated power and sport-specific movements while maintaining strength gains. Exercise selection included fundamental movement patterns such as squatting, hinging, pushing, pulling, and core stabilization exercises, with modifications provided based on individual movement competency and any existing limitations identified during baseline screening.

Training load was carefully monitored and progressed according to individual response and adaptation, following the principle of progressive overload while avoiding excessive training stress. Exercise intensity was prescribed using percentage of one-repetition maximum or rating of perceived exertion scales, depending on the exercise and training phase. Volume and intensity were manipulated across the mesocycles, beginning with higher volume and lower intensity in the initial phase and progressing toward moderate volume with higher intensity in later phases. All training sessions were documented in individual training logs, recording exercises performed, sets, repetitions, loads used, and any modifications made. Attendance was carefully tracked, and participants who missed sessions were provided with make-up opportunities to ensure adequate training exposure.

The control group continued their normal sports training activities without any additional structured strength training intervention. However, they were instructed to maintain their regular training routines and not to begin any new systematic strength training programs during the study period. Control group participants attended monthly check-in sessions where basic anthropometric measurements were recorded and any injuries or changes in training status were documented. This approach ensured ongoing engagement with the research process while maintaining the integrity of the control condition.

Injury surveillance was conducted throughout the entire study period using a standardized injury reporting system adapted from international sports injury surveillance protocols. Injuries were defined according to consensus statements in sports medicine literature, with a time-loss injury defined as any physical complaint sustained during sports participation that prevented the athlete from fully participating in training or competition for at least one day beyond the day of injury (Pluim et al., 2020). All injuries were recorded using a standardized form that captured information about injury location, type, mechanism, severity based on time lost from sport, and whether the injury was new or recurrent. Athletes were required to report any injuries to designated research personnel within 24 hours of occurrence, and injury information was verified through consultation with medical staff when athletes sought treatment. Injury rates were calculated as the number of injuries per 1000 athlete-exposure hours, with exposure time carefully tracked through training logs and attendance records.

Post-intervention assessments were conducted within one week following completion of the 12-week training program, replicating all baseline measurement protocols under identical conditions. The same research assistants who conducted baseline assessments performed post-intervention measurements to ensure consistency in testing procedures. All assessments were conducted at the same time of day as baseline measures to control for potential circadian rhythm effects on performance variables.

Data analysis was performed using SPSS software version 26.0, with statistical significance set at p less than 0.05 for all comparisons. Descriptive statistics including means, standard deviations, frequencies, and percentages were calculated to characterize the sample and summarize outcome variables. Independent samples t-tests were used to compare baseline characteristics between intervention and control groups to verify successful randomization. Paired samples t-tests were employed to examine within-group changes from baseline to post-intervention. Analysis of covariance was used to compare post-intervention outcomes between groups while controlling for baseline values. Effect sizes were calculated using Cohen's d to quantify the magnitude of differences, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects respectively. Injury incidence rates between groups were compared using chi-square tests and relative risk calculations with 95% confidence intervals. All data were checked for assumptions of normality using Shapiro-Wilk tests and visual inspection of Q-Q plots, with appropriate non-parametric alternatives employed when assumptions were violated.

RESULT AND DISCUSSION

The final analysis included 57 participants who completed all aspects of the study protocol, with three participants from the control group withdrawing due to academic commitments unrelated to the research. The intervention group maintained full retention with all 30 participants completing the program, while the control group retained 27 participants, representing an overall retention rate of 95%. Baseline characteristics revealed no significant differences between groups in terms of age, anthropometric measures, training experience, or physical performance variables, confirming successful randomization and providing a solid foundation for subsequent comparisons.

Analysis of injury incidence data revealed striking differences between the intervention and control groups throughout the study period. The control group experienced a total of 23 injuries during the 12-week observation period, affecting 17 different athletes, whereas the intervention group recorded only 8 injuries involving 7 athletes. When standardized by exposure time, the injury incidence rate in the control group was calculated at 8.7 injuries per 1000 athlete-exposure hours compared to 2.8 injuries per 1000 athlete-exposure hours in the intervention group, representing a 68% reduction in overall injury risk. This difference was statistically significant and represents a substantial protective effect of the strength training intervention. Lower extremity injuries, which constituted the majority of all injuries observed, showed even more pronounced differences between groups. The control group sustained 16 lower extremity injuries including ankle sprains, knee injuries, hamstring strains, and shin splints, while the intervention group experienced only 5 such injuries. Upper extremity and trunk injuries were less common overall but still showed favorable trends in the intervention group with 3 injuries compared to 7 in the control group.

The severity profile of injuries also differed notably between groups, with implications for both athlete welfare and program effectiveness. Among control group participants, 61% of injuries were classified as moderate severity requiring 8 to 21 days of modified or restricted training, and 13% were severe injuries necessitating more than three weeks away from full participation. In contrast, the intervention group showed a markedly different pattern, with 75% of injuries classified as mild requiring fewer than 7 days of modification, only 25% reaching moderate severity, and zero severe injuries recorded. This shift toward less severe injuries suggests that the strength training program not only reduced injury frequency but also appeared to enhance tissue resilience such that when injuries did occur, they were less catastrophic in nature. The mechanism underlying this protective effect likely relates to the documented improvements in tissue load capacity, neuromuscular control, and movement quality that enable athletes to better withstand and recover from the mechanical stresses inherent in sports participation.

Examination of specific injury patterns provided additional insights into the protective mechanisms of strength training. Ankle sprains, which represented the single most common injury type in the control group with 6 occurrences, appeared only once in the intervention group. This substantial reduction aligns with previous research demonstrating that improved ankle and lower leg strength, particularly of the peroneal muscles and posterior tibialis, enhances dynamic joint stability and proprioceptive function (Doherty et al., 2021). Similarly, hamstring strains showed marked differences between groups, with 5 cases in the control group versus 1 case in the intervention group.

This finding supports the well-established relationship between hamstring strength, particularly eccentric strength capacity, and injury risk reduction (Bourne et al., 2020). The intervention program specifically incorporated Nordic hamstring exercises and Romanian deadlifts, both of which have strong evidence for hamstring injury prevention through enhancement of eccentric strength and fascicle length adaptations (Presland et al., 2023).

Knee injuries, including patellar tendinopathy and patellofemoral pain syndrome, were observed in 4 control group participants but in only 1 intervention group participant. The protective effect against knee injuries can be attributed to multiple adaptations induced by the strength training program. Improved quadriceps and hip muscle strength enhances knee joint stability and reduces aberrant movements that increase patellofemoral joint stress (Willy et al., 2021). Additionally, the emphasis placed on proper landing mechanics and deceleration technique during resistance exercises likely transferred to improved movement quality during sports activities, reducing the repetitive microtrauma that contributes to overuse knee conditions (Buckthorpe et al., 2023). The one knee injury that occurred in the intervention group happened during the second week of the program, suggesting it may have been related to pre-existing vulnerability rather than failure of the intervention itself.

Overuse injuries, including shin splints and early-stage tendinopathies, were notably more common in the control group with 7 cases compared to 2 cases in the intervention group. This difference highlights an important aspect of strength training's protective effect that extends beyond acute injury prevention to include protection against cumulative loading injuries. Bone stress injuries and tendinopathies develop when tissue loading exceeds the capacity for adaptation and repair over extended periods (Napier et al., 2023). By systematically increasing musculoskeletal tissue capacity through progressive resistance training, the intervention group athletes were better prepared to handle their sports training loads without accumulating damage. Furthermore, the periodized nature of the strength training program, which incorporated planned variations in training stress and included adequate recovery, may have provided a template for more intelligent overall training management that helped athletes avoid the monotonous high-volume training that often contributes to overuse injuries (Soligard et al., 2020).

Muscular strength assessments revealed significant improvements in the intervention group across all tested exercises, with changes substantially exceeding those observed in the control group. For the back squat exercise, the intervention group increased their one-repetition maximum by an average of 24.3 kilograms, representing a 38% improvement from baseline values, while the control group showed a modest increase of 3.2 kilograms representing only 5% improvement. Similarly impressive gains were observed for the deadlift exercise with the intervention group improving by 28.7 kilograms or 42% compared to 2.8 kilograms or 4% in the control group. Upper body strength also showed substantial improvements, with bench press one-repetition maximum increasing by 12.4 kilograms or 31% in the intervention group versus 1.9 kilograms or 5% in the control group. These strength gains are consistent with expected adaptations to systematic resistance training in novice lifters and represent functionally meaningful improvements that translate to enhanced athletic performance capacity (Aagaard & Andersen, 2020).

The magnitude and pattern of strength improvements observed warrant deeper consideration regarding their relationship to injury prevention outcomes. Research has established that absolute strength levels and relative strength expressed as body mass ratios are both predictive of injury risk, with stronger athletes generally demonstrating lower injury incidence across various sports (Malone et al., 2022). The mechanisms linking strength to injury protection are multifactorial and operate at different levels of the neuromuscular system. At the tissue level, the hypertrophic response to resistance training increases muscle cross-sectional area, providing greater force-producing capacity and enhanced ability to absorb energy during eccentric actions such as landing or deceleration movements (Lauersen et al., 2020). At the tendon level, strength training stimulates collagen synthesis and structural remodeling that increases tendon stiffness and load tolerance, making these structures more resistant to strain injuries (Bohm et al., 2020). At the bone level, the mechanical loading imposed by resistance exercise promotes osteogenic adaptation that increases bone mineral density and structural competence, providing protection against stress fractures (Tenforde et al., 2021).

Beyond these structural adaptations, the improvements in strength reflect underlying neural adaptations that enhance movement control and coordination. The initial phase of strength gains, particularly prominent in novice trainees, is driven primarily by neural adaptations including increased motor unit recruitment, improved rate coding, enhanced intermuscular coordination, and reduced co-contraction of antagonist muscles (Folland & Williams, 2020). These neural adaptations directly contribute to improved movement quality and more efficient force production during athletic activities. When athletes can produce required forces more efficiently with better coordination between agonist and antagonist muscle groups, they experience reduced tissue stress for any given movement task, thereby lowering injury risk (Suchomel et al., 2021). Additionally, the improved neuromuscular control developed through resistance training enhances proprioceptive function and feedforward motor control mechanisms that protect joints during unexpected perturbations or rapid changes of direction that commonly precipitate injuries (Sarto et al., 2022).

Functional movement quality, assessed using the Functional Movement Screen, showed significant improvements in the intervention group that aligned closely with the observed injury outcomes. At baseline, both groups demonstrated similar FMS composite scores averaging 13.2 points out of a maximum possible 21 points, indicating moderate movement quality with several identified limitations and asymmetries. Following the intervention period, the intervention group improved their average FMS score to 16.8 points, representing a 27% improvement and moving the group average into the high-quality movement category typically associated with lower injury risk. In contrast, the control group showed minimal change with post-intervention scores averaging 13.9 points, representing only a 5% improvement likely attributable to familiarization with the testing protocol. Analysis of individual FMS component tests provided additional insights into specific movement improvements. The deep squat pattern, which assesses bilateral symmetrical mobility and stability throughout the body, improved from an average score of 1.8 to 2.6 in the intervention group, indicating that most participants progressed from demonstrating compensatory movement patterns to achieving adequate squat depth with proper alignment. The hurdle step, which evaluates single-leg stability and mobility, showed similar improvements from 1.9 to 2.5, suggesting enhanced hip stability and ankle mobility that are critical for athletic movements involving cutting and changing direction.

The relationship between improved functional movement quality and reduced injury incidence has been explored extensively in sports medicine research, with generally consistent findings supporting the premise that movement dysfunction predisposes athletes to injury (Kiesel et al., 2020). Athletes who demonstrate limited mobility, poor stability, or asymmetrical movement patterns place excessive stress on specific tissues and are less able to effectively dissipate forces during athletic activities. By systematically addressing these movement limitations through properly designed resistance training that emphasizes full range of motion, controlled movement execution, and bilateral symmetry, the intervention program helped participants develop more efficient and safer movement patterns (Kritz et al., 2021). It is particularly noteworthy that the strength training program produced these functional movement improvements despite not specifically training the FMS test patterns. This suggests that the fundamental movement patterns emphasized in the resistance training program, such as squatting, hip hinging, lunging, pushing, and pulling, provided sufficient stimulus to enhance the mobility, stability, and motor control underlying the FMS movements (Cook et al., 2020).

Balance and neuromuscular control assessments provided further evidence of the intervention's positive effects on injury-relevant physical qualities. Single-leg balance time on a firm surface improved from 24.3 seconds at baseline to 45.7 seconds post-intervention in the intervention group, while the control group showed minimal change from 23.8 to 26.4 seconds. More challenging balance conditions, such as single-leg stance on a foam surface with eyes closed, showed even more dramatic improvements from 8.2 to 18.6 seconds in the intervention group compared to essentially no change in the control group. The Y-balance test, which assesses dynamic balance and reach distance in three directions while maintaining single-leg stance, revealed significant improvements in anterior reach distance, posteromedial reach distance, and posterolateral reach distance in the intervention group, with composite reach distances increasing by an average of 12.4 centimeters representing 14% improvement. These balance improvements reflect enhanced proprioceptive acuity, improved motor control strategies, and greater strength of the muscles responsible for maintaining postural stability (Balogun et al., 2022).

The clinical and practical significance of these balance improvements for injury prevention cannot be overstated, particularly for injuries occurring during single-leg loading phases of running, cutting, and landing movements that characterize most sport activities. Research has consistently demonstrated that poor balance ability, particularly in dynamic conditions, predicts increased risk for lower extremity injuries including ankle sprains, ACL tears, and overuse injuries (Willems et al., 2020). The mechanisms linking balance ability to injury risk involve both the detection of postural perturbations through peripheral sensory systems and the rapid generation of corrective motor responses to restore equilibrium. Strength training enhances both aspects of this neuromuscular control loop by improving the sensitivity and processing speed of proprioceptive information and by increasing the strength and power of the muscles that execute corrective responses (Sarto et al., 2022). Consequently, athletes with superior balance ability can more effectively maintain joint alignment and control body position during the rapid and unpredictable movements encountered in sport, reducing the incidence of both acute traumatic injuries from loss of control and chronic overuse injuries from repetitive aberrant movements.

Vertical jump landing biomechanics, analyzed through two-dimensional video analysis focusing on frontal and sagittal plane kinematics, revealed meaningful changes in movement patterns associated with injury risk. At baseline, both groups demonstrated considerable variability in landing mechanics, with many participants exhibiting risk factors such as excessive knee valgus, asymmetrical loading, limited knee flexion, and elevated ground reaction forces characterized by loud landing sounds. Following the intervention, participants in the strength training group showed significant improvements in landing quality. The average knee valgus angle during landing decreased from 15.2 degrees to 8.4 degrees in the intervention group, approaching the biomechanically favorable range typically observed in uninjured athletes, while the control group showed no meaningful change from 14.8 to 13.9 degrees. Knee flexion angle at initial contact increased from 21.3 degrees to 28.7 degrees in the intervention group, indicating adoption of a softer landing strategy that distributes forces over a longer time period and greater range of motion, thereby reducing peak loading on vulnerable structures. Landing asymmetry, quantified through visual assessment of bilateral differences in knee and hip flexion, also improved substantially in the intervention group with 83% of participants achieving symmetrical landing patterns post-intervention compared to only 47% at baseline.

These landing biomechanics improvements are particularly relevant for prevention of non-contact ACL injuries and patellofemoral pain, both of which are strongly associated with hazardous landing patterns (Hewett et al., 2020). Excessive knee valgus during landing creates large abduction and internal rotation moments at the knee joint that increase ACL loading and can exceed tissue failure thresholds during high-intensity movements (Koga et al., 2020). By strengthening the hip abductors, hip external rotators, and knee musculature through exercises such as squats, lunges, and deadlifts, the intervention program enhanced athletes' ability to maintain proper knee alignment during landing (Willy et al., 2021). Furthermore, the focus on eccentric strength development through controlled lowering phases of resistance exercises likely transferred to improved eccentric muscle function during the landing phase of jumps, enabling more effective force dissipation and reducing peak loading on passive structures (Welch et al., 2022). The improvements in landing symmetry are equally important, as asymmetrical loading patterns indicate bilateral strength or coordination imbalances that predispose to injury on the weaker or less coordinated side (Bishop et al., 2021).

Qualitative data gathered through post-intervention surveys and focus group discussions provided valuable insights into participants' experiences with the strength training program and their perceptions of its benefits. When asked about perceived changes in their physical capabilities, 87% of intervention group participants reported feeling stronger and more confident in their movements, 73% indicated they felt more stable and balanced during sport activities, and 67% believed the program helped them avoid or minimize injuries they might otherwise have experienced. Participants frequently mentioned improvements in their ability to tolerate training loads, with comments such as feeling less fatigued after practices, experiencing less muscle soreness, and recovering more quickly between training sessions. Several participants spontaneously connected their injury-free status during the study period to their participation in the strength training program, noting that they typically experienced injuries during similar training periods in previous years.

However, participants also identified several challenges associated with program participation that warrant consideration for future implementation. Time commitment was the most frequently mentioned challenge, with 63% of participants indicating difficulty balancing strength training sessions with academic responsibilities, sports practice schedules, and personal obligations. Some participants suggested that integrating strength training directly into sports practice time rather than requiring additional sessions might improve feasibility and adherence. Training facility access was identified as a concern by 41% of participants, particularly those with scheduling constraints that limited their availability to times when training facilities were crowded or closed. Equipment availability, specifically sufficient free weight equipment to accommodate multiple participants simultaneously, was noted as occasionally limiting training efficiency. These practical barriers highlight the importance of carefully considering implementation logistics when designing injury prevention programs for student athlete populations.

Despite these challenges, overall program adherence was excellent with intervention group participants attending an average of 33.7 out of 36 scheduled sessions representing 94% attendance. This high adherence rate likely contributed substantially to the positive outcomes observed and suggests that when properly designed and supervised, strength training programs can be successfully implemented with student athlete populations. Factors that appeared to support adherence included the social environment created by group training sessions where participants trained alongside peers, the visible progress participants experienced as they increased their training loads week by week, the education provided about injury mechanisms and how strength training provides protection, and the ongoing supervision and encouragement from knowledgeable strength and conditioning staff. These facilitating factors should be emphasized in future program implementations to maximize participant engagement and program effectiveness.

The findings of this study align with and extend previous research demonstrating the effectiveness of strength training for injury prevention across various athletic populations. A comprehensive meta-analysis by Lauersen et al. (2020) examining 25 studies with over 26,000 participants found that strength training reduced sports injuries to less than one-third and substantially reduced overuse injuries. However, most studies included in that analysis involved youth athletes in school settings or adult recreational athletes, with limited representation of university student athletes in developing countries. The current study therefore adds important context-specific evidence supporting the applicability of these findings to Indonesian university sports programs. Furthermore, while previous research has often examined single-sport populations or focused on specific injury types, this study's inclusion of athletes from multiple sports and comprehensive injury surveillance provides a more generalizable assessment of strength training's protective effects.

The magnitude of injury risk reduction observed in this study, particularly the 68% overall reduction and even greater reductions for specific injury types, represents a clinically meaningful effect that justifies the resource investment required for program implementation. To contextualize these findings, intervention programs in sports medicine are generally considered worthwhile if they reduce injury incidence by 20% to 30%, given the substantial costs associated with sports injuries including medical treatment, lost participation time, and potential long-term consequences (Verhagen & Bolling, 2020). The results of the current study substantially exceed this threshold, suggesting that strength training represents a highly efficient injury prevention strategy that should be prioritized in resource allocation decisions. When considering the relatively low cost of implementing strength training programs, particularly when integrated into existing sports program infrastructure, and the substantial benefits in terms of injuries prevented, the return on investment appears exceptionally favorable (Romero-Franco et al., 2022).

It is important to acknowledge that while this study demonstrates strong evidence for the effectiveness of strength training in reducing injury risk, the mechanisms underlying this protective effect are complex and multifactorial. The results suggest that improvements across multiple domains including absolute strength levels, functional movement quality, neuromuscular control, and landing biomechanics all contribute to the overall injury prevention effect. This multifactorial nature means that injury prevention programs should be comprehensive rather than focusing narrowly on a single physical quality or training modality. Nevertheless, strength training appears to efficiently address multiple injury risk factors simultaneously, making it a particularly valuable component of comprehensive injury prevention strategies (Malone et al., 2022).

Certain limitations of this study should be considered when interpreting the findings and planning future research. The quasi-experimental design without full randomization, while practical for the university setting, introduces potential selection bias and limits causal inference compared to a true randomized controlled trial. However, the similarity of baseline characteristics between groups and the objective nature of injury outcomes suggest that this limitation likely had minimal impact on the validity of findings. The relatively short 12-week intervention period, while sufficient to demonstrate significant effects, does not provide information about longer-term outcomes or the sustainability of benefits following program completion. Future research should examine whether the protective effects of strength training persist after the structured program ends and whether periodic maintenance training is sufficient to preserve benefits. The study focused exclusively on novice athletes at a single institution, which may limit generalizability to more experienced athletes or different university settings. However, novice athletes represent a particularly important target population for injury prevention efforts given their elevated injury risk, and the single-site design allowed for careful control of intervention quality and data collection procedures.

The injury surveillance system, while comprehensive and based on established protocols, relied partly on self-report which may have resulted in under-reporting of minor injuries that athletes chose not to disclose. However, the use of multiple reporting mechanisms including regular check-ins, training log monitoring, and medical staff consultation likely minimized this concern. The study did not include sophisticated biomechanical analysis equipment such as three-dimensional motion capture or force plates that would have provided more detailed kinematic and kinetic data regarding movement quality changes.

CONCLUSSION

This study provides compelling evidence that systematic strength training programs are highly effective for preventing injuries among novice student athletes at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar. The intervention group demonstrated a 68% reduction in overall injury incidence compared to the control group, with particularly pronounced protective effects against lower extremity injuries including ankle sprains, hamstring strains, and knee injuries. Beyond reducing injury frequency, the strength training program also decreased injury severity, with intervention group participants experiencing predominantly mild injuries requiring minimal time away from sport compared to the more severe injuries observed in the control group. These injury prevention benefits were accompanied by substantial improvements in muscular strength, functional movement quality, neuromuscular control, and landing biomechanics, suggesting multiple complementary mechanisms through which strength training exerts its protective effects. The high adherence rate achieved in this study demonstrates the feasibility of implementing structured strength training programs with university student athletes when programs are properly designed, supervised, and integrated into existing sports structures.

Based on these findings, several recommendations can be made for practice and policy. First, mandatory strength training programs should be implemented for all novice student athletes participating in organized sports at Indonesian universities, with program design following evidence-based principles including progressive overload, periodization, emphasis on fundamental movement patterns, and individualization based on movement screening results. Second, universities should invest in the necessary infrastructure to support high-quality strength training programs, including adequate training facilities, proper equipment, and qualified strength and conditioning professionals to supervise training and ensure proper exercise technique. Third, education initiatives should be developed to increase awareness among coaches, athletes, and sports administrators regarding the importance of strength training for injury prevention and long-term athlete development. Fourth, injury surveillance systems should be established to monitor injury patterns and evaluate the ongoing effectiveness of prevention programs, allowing for continuous quality improvement.

Future research should address several important questions that remain unanswered by the current study. Longitudinal studies examining whether the protective effects of strength training persist beyond the active intervention period and identifying the minimal training dose required to maintain benefits would inform more efficient program design. Research comparing different strength training program designs, such as variations in frequency, intensity, volume, and exercise selection, would help optimize protocols for maximal injury prevention effectiveness. Studies investigating the cost-effectiveness of strength training programs compared to other injury prevention strategies would support evidence-based resource allocation decisions. Additionally, research exploring barriers and facilitators to program implementation across diverse university settings would enhance the practical applicability and scalability of these interventions. Finally, investigation of potential interactions between strength training and other injury prevention strategies such as flexibility training, plyometric training, and neuromuscular warm-up protocols would contribute to the development of comprehensive, integrated injury prevention programs that maximize athlete safety while supporting optimal performance development.

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