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To See the Role of Cross-Training in Preventing Risk of Injury in Female Recreational Athletes

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ABSTRACT

Background : Participation of female athletes in recreational and organized sports has significantly increased, leading to a parallel rise in sport-related injuries. Cross-training, which integrates multiple forms of exercise—such as cardiovascular, strength, endurance, and flexibility training—offers a balanced approach that may help prevent injury by promoting muscular symmetry, reducing repetitive strain, and improving overall fitness. This study aimed to determine the role of cross-training in reducing the risk of injury among female recreational athletes.

Methods : An experimental study was conducted on 40 female recreational athletes aged 13–18 years, who were randomly divided into two groups: Group A (n=20, control) received conventional training, while Group B (n=20, experimental) underwent an 8-week structured cross-training program conducted four days per week. Outcome measures included the Sit and Reach Test (SRT) for flexibility, Back Scratch Test (BST) for upper-body flexibility, Push-Up Test (PUT) for upper-body endurance, Vertical Jump Test (VJT) for lower-body strength, and the 1.5-Mile Run Test for cardiovascular endurance. Data were analyzed using SPSS version 23, applying paired *t*-tests and one-way ANOVA with significance at $p < 0.05$.

Results : The cross-training group showed statistically significant improvements ($p < 0.05$) across all physical parameters: mean gain of 7.35 in SRT, 1.30 in BST, 4.45 in PUT, 3.87 in VJT, and 4.95 in the 1.5-Mile Run Test. These findings indicate enhanced flexibility, strength, and cardiovascular endurance in participants following the cross-training intervention. In contrast, the control group displayed only minor, non-significant changes in most outcomes.

Conclusion : The findings confirm that an eight-week structured cross-training program significantly enhances overall physical fitness among female recreational athletes. Cross-training effectively improves flexibility, strength, endurance, and cardiovascular capacity—key components in reducing the likelihood of sports-related injuries. Incorporating varied exercise modalities provides a safer, more holistic alternative to single-modality training, supporting both performance enhancement and injury prevention in young female athletes..

Keywords: *Cross-training, Risk of injury, Female recreational athlete, Endurance training, Cardiovascular endurance, Flexibility training, Strength training, Conventional training*

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1. INTRODUCTION

Over the past few decades, the active participation of female recreational athletes in various sports and fitness programs has increased substantially. This rise has brought numerous physical and psychological benefits; however, it has also led to a parallel increase in sports-related injuries, particularly among young women who engage in physical activities without structured guidance. Preventing these injuries has become an essential focus, as female athletes are statistically more prone to certain musculoskeletal injuries compared to males due to anatomical, hormonal, and neuromuscular differences[1,2].

Among these injuries, anterior cruciate ligament (ACL) tears are particularly common in female athletes, resulting from differences in biomechanics, joint kinematics, and neuromuscular control[1]. Females typically exhibit greater knee valgus angles and reduced hamstring strength, which increase susceptibility to non-contact ACL injuries. Hormonal fluctuations can further influence ligament laxity, predisposing women to soft-tissue injuries. Apart from ACL tears, stress fractures and overuse injuries occur more frequently among females because of lower bone density and endocrine variations[2]. These trends underscore the importance of developing training strategies that target female-specific risk factors for injury prevention.

Cross-training has emerged as an effective approach to address these challenges. It integrates multiple forms of exercise—resistance training, aerobic conditioning, flexibility exercises, and neuromuscular drills—to achieve balanced muscular development and comprehensive fitness[3,6]. Unlike sport-specific programs that emphasize repetitive motion, cross-training enhances muscular balance, promotes cardiovascular fitness, improves flexibility, and reduces repetitive strain[4]. Studies suggest that alternating between exercise modes allows specific muscle groups to recover while maintaining training intensity, thereby decreasing the risk of tendinitis, stress fractures, and overuse syndromes[4].

Grier et al. (2015) demonstrated that participants following structured cross-training programs experienced fewer injuries compared to those engaged in single-modality routines[4]. Similarly, Deyab (2024) found that cross-training significantly improved muscular endurance, flexibility, speed, and agility in gymnasts, directly translating into enhanced performance and reduced injury occurrence[5]. These findings confirm the role of multi-modal training in promoting physical resilience and preventing repetitive strain.

Evidence from Yu and Kanchanathaweekul (2023) further supports cross-training's efficacy, reporting notable improvements in cardiovascular endurance, muscular strength, and flexibility after eight weeks of intervention[6]. Such outcomes reinforce the adaptability of cross-training across varied populations and its potential in promoting musculoskeletal stability and injury resistance.

Epidemiological studies have shown that recreational athletes—those who engage in exercise without professional supervision—are at an increased risk of injury. An analysis involving 986 adult fitness participants revealed an injury rate of 7.83 per 1,000 hours of activity, with the majority involving musculoskeletal strain[7]. Lower-limb injuries are particularly prevalent, especially in running, athletics, and team sports[8,9]. Reports indicate that female athletes are two to six times more likely to experience ACL injuries than males participating under similar conditions[10–12].

Exercise-based preventive strategies, such as strength and neuromuscular training, have been proven to reduce injury incidence significantly[10,11]. Within this framework, cross-training serves as a multidimensional preventive intervention, addressing strength deficits, flexibility, and cardiovascular conditioning in a single program.

For female athletes, cross-training yields both physiological and psychological benefits. Lower-limb and core strengthening enhance joint stability, which is vital in reducing non-contact ACL injuries[13]. Low-impact aerobic activities such as swimming and cycling help maintain endurance while minimizing repetitive joint stress[9,13]. Additionally, incorporating yoga and Pilates within cross-training improves flexibility, posture, and muscle balance, further contributing to injury prevention[11].

Despite its advantages, widespread implementation of cross-training among female recreational athletes remains limited. This is often due to a lack of structured programs, awareness, and professional supervision[14]. Therefore, systematic research assessing the impact of cross-training on injury prevention, flexibility, and endurance development among female athletes is essential.

The present study was conducted to evaluate the effectiveness of an eight-week structured cross-training program in improving cardiovascular endurance, muscular strength, flexibility, and overall functional performance among female recreational athletes aged 13–18 years. It also aimed to determine whether cross-training can effectively reduce injury risks through systematic enhancement of key physical fitness components.

2. AIM OF THE STUDY

To investigate the effect of an eight-week structured cross-training program on overall fitness and injury risk reduction in female recreational athletes.

3. OBJECTIVES

To assess the impact of cross-training on cardiovascular endurance, flexibility, muscle strength, and endurance.

To evaluate the effectiveness of cross-training in reducing the risk of injury among female recreational athletes.

Hypotheses

H_1: Cross-training has a significant effect on reducing injury risk and improving physical fitness.

H_0: Cross-training has no significant effect on injury risk or physical fitness improvement.

4. MATERIALS AND METHODS

Study Design

This study adopted a pre-test and post-test experimental design, aimed at assessing the impact of cross-training on injury prevention and physical fitness among female recreational athletes. The intervention duration was eight weeks, with outcome measures recorded before and after the training period.

Study Setting

The research was conducted at Doon International School, Riverside Campus, Pondha, Dehradun, in collaboration with the Department of Physiotherapy, Ras Bihari Bose Subharti University, Dehradun, Uttarakhand. Prior to commencement, ethical clearance and institutional permission were obtained from the Institutional Review Board.

Sample Size and Sampling Technique

A total of 40 female recreational athletes, aged between 13 and 18 years, were recruited for the study. Participants were selected using a simple random sampling technique and were divided into two equal groups:

Group A (Control Group): 20 participants who received conventional training only.

Group B (Experimental Group): 20 participants who received conventional training along with an 8-week structured cross-training program.

Each participant provided written informed consent, and for minors, consent was also obtained from parents or guardians.

Inclusion Criteria

Female athletes aged between 13–17 years.

Participants without any musculoskeletal pathology in the upper or lower limbs.

Individuals willing to participate and comply with the study protocol.

No history of recent injury within the last six months.

Participants not engaged in any other clinical intervention or study.

Exclusion Criteria

History of recent fractures or surgeries within the last six months.

Restricted range of motion in any joint.

Presence of neurological, cognitive, or psychiatric disorders.

Active participation in other physiotherapy or training interventions.

Variables

Independent Variable:

Cross-training program.

Dependent Variables:

Cardiovascular fitness

Muscular strength

Muscular endurance

Flexibility

Intervention Protocol

The experimental group (Group B) underwent a structured 8-week cross-training program designed to enhance strength, flexibility, and endurance. Training sessions were held four days per week, lasting 40–60 minutes per session.

The control group (Group A) continued with conventional physical training under supervision but without cross-training intervention.

Each session for the experimental group included warm-up, main training, and cool-down phases.

Warm-Up Phase

A 10–15-minute routine was performed before every session to prepare the body for physical activity. It included dynamic stretching, mobility drills, and low-intensity aerobic exercises such as jogging and skipping to increase heart rate and enhance muscle elasticity.

Main Training Phase

The training schedule alternated weekly between single-week and bi-weekly programs, ensuring variety and full-body conditioning.

Single-week program (Weeks 1, 3, 5, 7):

Monday & Wednesday: Muscular strength and endurance training

(Exercises: push-ups, pull-ups, dumbbell swings, leg raises, “V” sit-ups, planks, and walking lunges)

Tuesday & Thursday: Cardiovascular and flexibility training

(Activities: running, cycling, dance-based cardio, static stretching, standing forward bends, seated forward bends, snake pose, and downward-facing dog)

Bi-weekly program (Weeks 2, 4, 6, 8):

Monday & Wednesday: Strength and flexibility training

(Exercises: semi-squat jump, deep squats, touch jumps, standing long jumps, and dynamic stretches)

Tuesday & Thursday: Endurance and cardiovascular training

(Activities: resistance band work, reverse curls, kneeling push-ups, aerobic sessions, and cycling)

Each exercise was performed for 3 sets of 10–15 repetitions, depending on individual tolerance, with 1–2 minutes of rest between sets.

Cool-Down Phase

After each session, participants completed 5–10 minutes of low-intensity activity (slow walking or cycling) followed by static stretching to gradually restore resting heart rate and prevent muscle soreness.

Outcome Measures

To evaluate the effects of cross-training, the following standardized physical fitness assessments were used:

Sit and Reach Test (SRT):

Assessed lower back and hamstring flexibility. Participants sat on the floor with extended legs and reached forward as far as possible along a measuring line[17,27].

Back Scratch Test (BST):

Measured upper-body flexibility, particularly shoulder mobility. The distance between fingertips was recorded[25,29].

Push-Up Test (PUT):

Evaluated upper-body muscular endurance. Participants performed as many push-ups as possible while maintaining correct form[28].

Vertical Jump Test (VJT):

Assessed lower-body explosive power by measuring the difference between standing reach and jump height[16,26].

1.5-Mile Run Test:

Measured cardiovascular endurance. Time taken to complete the 1.5-mile distance was recorded and used to calculate VO_2 max (ml/kg/min) using the formula:

VO_2 max = 3.5 + 483 / time (min)[18,27].

All tests were administered **before (pre-test)** and **after (post-test)** the 8-week intervention.

Data Analysis

Data were analyzed using SPSS version 23. Descriptive statistics (mean and standard deviation) were calculated for all variables.

Paired *t*-tests were applied to assess within-group differences (pre vs. post).

Independent *t*-tests compared post-intervention results between groups.

Statistical significance was set at $p < 0.05$.

Graphical representations and tables were created using Microsoft Excel and Word for visual comparison of data.

5. RESULTS

A total of 40 female recreational athletes participated in the study, equally divided into two groups — Group A (Control) and Group B (Experimental). Both groups completed the full 8-week intervention period. Statistical analysis was performed using SPSS version 23, applying *paired* *t*-tests for within-group comparisons and *independent* *t*-tests for between-group analyses. A *p*-value of less than 0.05 was considered statistically significant.

Within-Group Comparison (Group A – Control Group)

Group A participants underwent conventional training without cross-training intervention. Pre- and post-intervention mean values (±SD) of the outcome measures are summarized in Table 1.

Table 1. Comparison of pre- and post-training results within Group A (Control Group)

Outcome Measure	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	t-value	p-value	Result
Sit and Reach Test (SRT)	15.85 ± 2.03	16.12 ± 2.12	8.03	0.0001	Significant
Back Scratch Test (BST)	3.40 ± 2.06	3.31 ± 2.00	3.21	0.005	Significant
Push-Up Test (PUT)	8.15 ± 2.75	10.65 ± 1.59	4.26	0.0001	Significant
Vertical Jump Test (VJT)	27.05 ± 5.09	27.02 ± 4.13	0.69	0.498	Not Significant
1.5-Mile Run Test	26.81 ± 2.95	26.87 ± 2.94	1.36	0.191	Not Significant

Interpretation:

Group A showed statistically significant improvements ($p < 0.05$) in the Sit and Reach Test, Back Scratch Test, and Push-Up Test, suggesting moderate gains in flexibility and upper-body endurance. However, improvements in the Vertical Jump Test and 1.5-Mile Run Test were not statistically significant ($p > 0.05$), indicating that conventional training alone had limited impact on lower-body power and cardiovascular endurance.

Within-Group Comparison (Group B – Experimental Group)

Group B underwent conventional training combined with an 8-week structured cross-training program. The pre- and post-intervention results demonstrated substantial improvements across all outcome measures (Table 2).

Table 2. Comparison of pre- and post-training results within Group B (Experimental Group)

Outcome Measure	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	t-value	p-value	Result
Sit and Reach Test (SRT)	23.50 ± 1.70	30.85 ± 2.08	25.92	0.0001	Significant
Back Scratch Test (BST)	3.30 ± 2.07	2.00 ± 1.12	2.90	0.009	Significant
Push-Up Test (PUT)	7.60 ± 2.60	12.05 ± 3.13	7.11	0.0001	Significant
Vertical Jump Test (VJT)	27.25 ± 3.53	31.12 ± 3.87	33.73	0.0001	Significant
1.5-Mile Run Test	28.67 ± 2.80	33.62 ± 3.03	22.85	0.0001	Significant

Interpretation:

Group B exhibited highly significant improvements ($p < 0.001$) across all five outcome measures. The most notable gains were observed in Sit and Reach Test (+7.35 units), Push-Up Test (+4.45 units), Vertical Jump Test (+3.87 units), and 1.5-

Mile Run Test (+4.95 units), indicating substantial enhancement in flexibility, muscular endurance, explosive strength, and cardiovascular performance.

Between-Group Comparison (Post-Test Results)

Post-intervention results were compared between the two groups to assess the relative efficacy of cross-training over conventional training.

Table 3. Comparison of post-intervention mean scores between Group A (Control) and Group B (Experimental)

Outcome Measure	Group A (Post Mean ± SD)	Group B (Post Mean ± SD)	Comparison Result
Sit and Reach Test (SRT)	16.12 ± 2.12	30.85 ± 2.08	Group B significantly higher
Back Scratch Test (BST)	3.31 ± 2.00	2.00 ± 1.12	Group B significantly higher
Push-Up Test (PUT)	10.65 ± 1.59	12.05 ± 3.13	Group B significantly higher
Vertical Jump Test (VJT)	27.02 ± 4.13	31.12 ± 3.87	Group B significantly higher
1.5-Mile Run Test	26.87 ± 2.94	33.62 ± 3.03	Group B significantly higher

Interpretation:

Comparison of post-intervention scores indicates that Group B (cross-training group) outperformed Group A (control) in all parameters. The differences were statistically significant across all tests ($p < 0.05$), confirming the superior effectiveness of the cross-training intervention.

Graphical Representation

Figure 1. *Comparison of mean pre- and post-test scores within Group A (Control Group)*

Shows moderate improvements in SRT, BST, and PUT; minimal changes in VJT and 1.5-Mile Run

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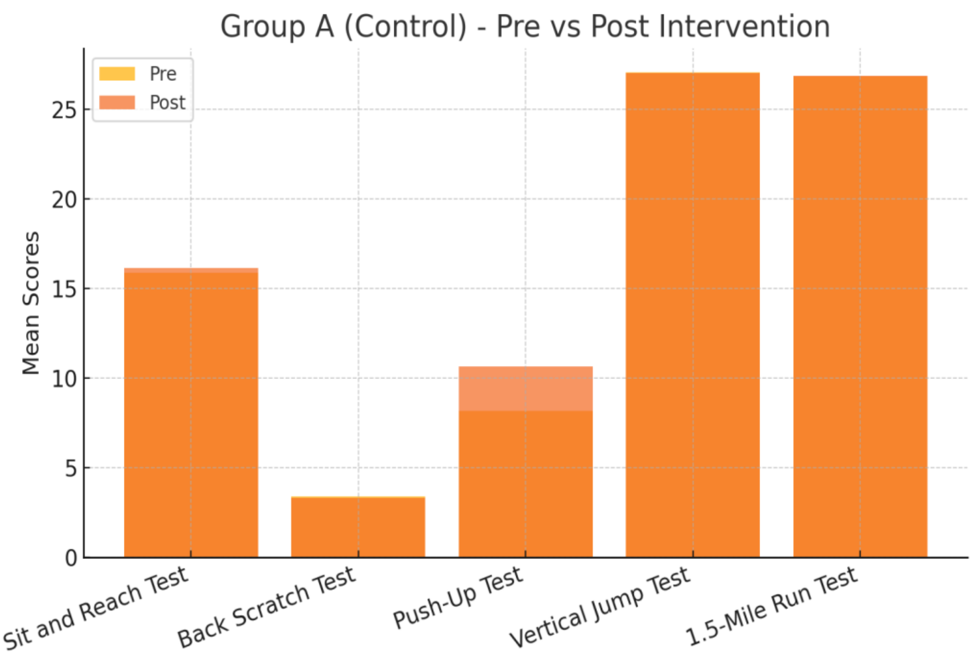


Figure 2. Comparison of mean pre- and post-test scores within Group B (Experimental Group
Shows marked improvements across all outcome measures.

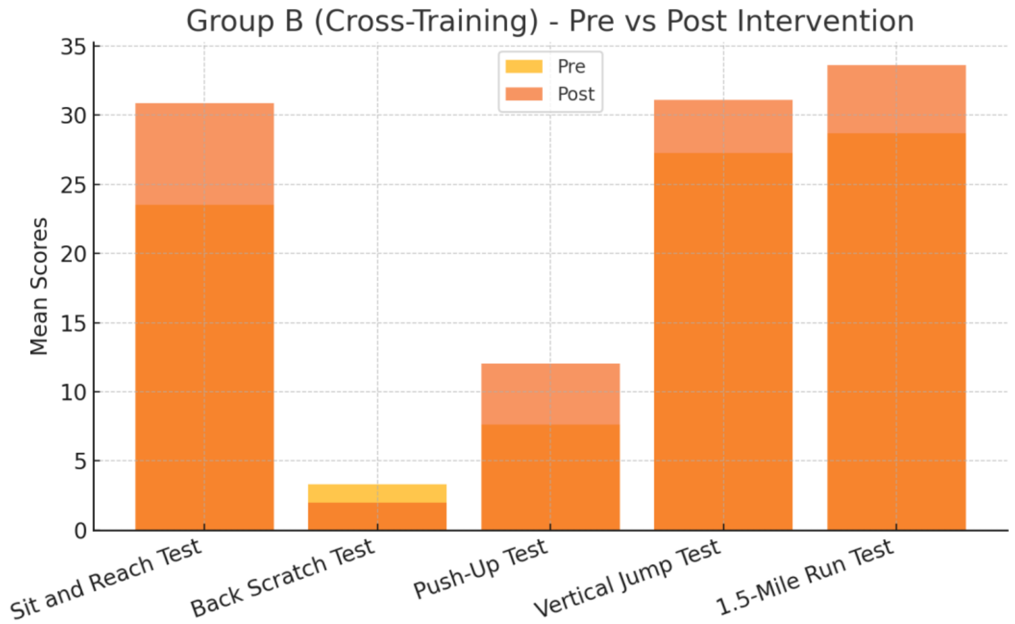
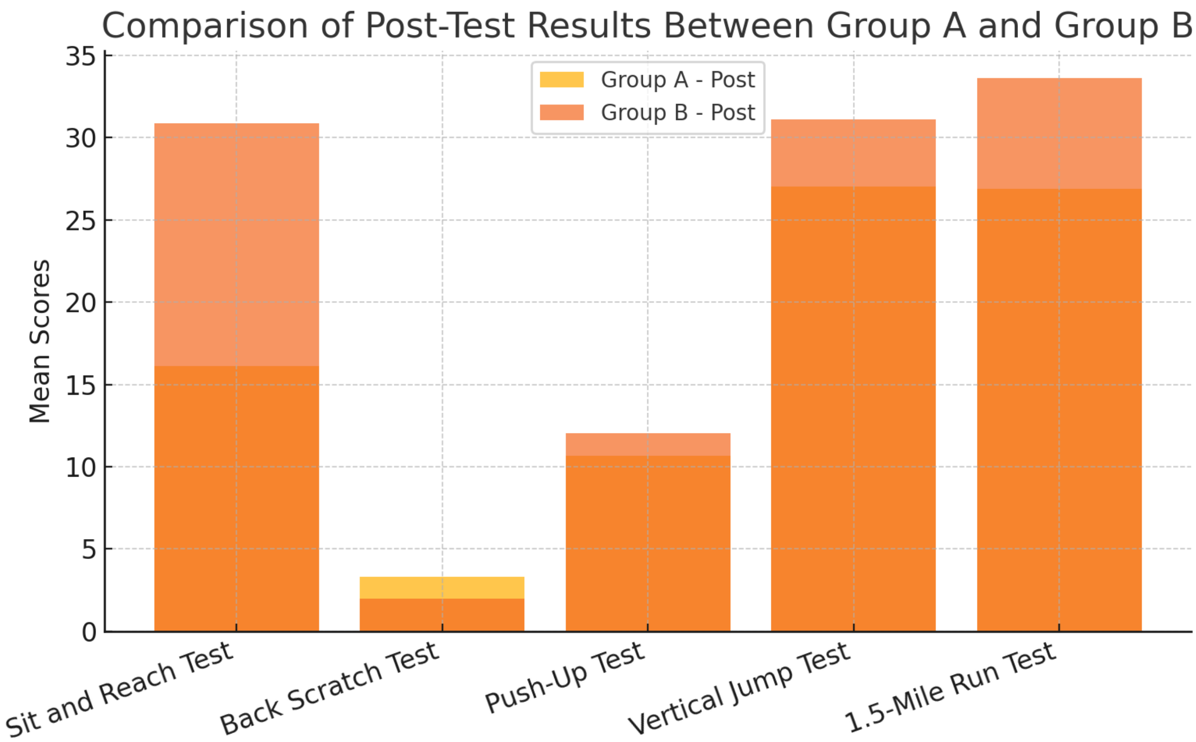


Figure 3. Comparison of post-intervention mean scores between Group A and Group B
Depicts significantly higher scores for Group B, indicating better outcomes with cross-training.



Summary of Findings

Group A (Conventional Training) showed minor improvements limited to flexibility and upper-body endurance.

Group B (Cross-Training + Conventional) demonstrated statistically significant gains in all five performance domains.

Cross-training led to comprehensive improvements in flexibility, strength, endurance, and cardiovascular fitness, all of which contribute to injury prevention among female recreational athletes.

6. DISCUSSION

The present study aimed to evaluate the role of cross-training in preventing injury risk and improving overall physical fitness among female recreational athletes aged 13–18 years. The results demonstrated statistically significant improvements in flexibility, muscular endurance, strength, and cardiovascular performance following an 8-week structured cross-training program. Participants in the experimental group (Group B) showed greater gains compared to the control group (Group A) across all outcome measures, thereby supporting the effectiveness of cross-training as a comprehensive training strategy.

The findings from this study align with previous research emphasizing that multi-modal training interventions promote balanced muscular development, neuromuscular coordination, and endurance in athletes[3,6]. In the present study, significant enhancement was observed in the Sit and Reach Test (SRT) and Back Scratch Test (BST), indicating improved flexibility and range of motion. These improvements are crucial for reducing muscle stiffness, enhancing joint mobility, and lowering the incidence of musculoskeletal strain and ligamentous injuries. The improvement in flexibility may be attributed to the incorporation of dynamic and static stretching, yoga poses (such as cobra and downward-facing dog), and consistent progression in mobility exercises included in the cross-training schedule. This is consistent with earlier work by Yu and Kanchanathaweekul (2023), who demonstrated that a combination of aerobic, flexibility, and resistance training significantly improved overall flexibility and cardiovascular fitness among university students[6].

The Push-Up Test (PUT) results showed a substantial increase in upper-body muscular endurance post-intervention in Group B compared to Group A. This finding corroborates the observations of Opoku-Antwi et al. (2024), who reported significant gains in muscular endurance following an eight-week conditioning program in female cadets of the Ghana Immigration Service Academy, emphasizing the role of combined upper-body and resistance training in enhancing endurance capacity. Similarly, Deyab (2024) found that cross-training enhanced muscle endurance, speed, and coordination among gymnasts, reflecting improved functional performance and reduced injury susceptibility[5]. In the present study, inclusion of exercises such as push-ups, bicep curls, triceps dips, and bent-over rows contributed to the development of upper-body strength, leading to better endurance and stability.

Significant improvement in the Vertical Jump Test (VJT) in Group B further supports the role of cross-training in improving lower-limb strength and explosive power. Exercises including squats, lunges, and plyometric jumps enhance neuromuscular efficiency, promoting muscle fiber recruitment essential for power-based activities. Tufano et al. (2020) similarly observed increased lower-limb power and squat strength after six weeks of structured resistance training, indicating that compound lower-body exercises are effective in developing muscular power in female athletes. This enhanced neuromuscular efficiency not only boosts athletic performance but also contributes to injury prevention by improving joint stability and proprioception[9,13].

The 1.5-Mile Run Test outcomes revealed significant enhancement in cardiovascular endurance for the cross-training group, which may be attributed to the inclusion of both aerobic and anaerobic components such as running, cycling, and dance fitness. These findings are in agreement with Zeeshan Habib et al. (2022), who demonstrated that cross-training is equally effective as aerobic training in improving cardio-respiratory endurance among middle-distance runners. Cross-training's combination of strength and endurance activities stimulates both central and peripheral adaptations — improving VO_2 max, cardiac efficiency, and muscular oxygen utilization[18,27]. The alternating training patterns of the present study allowed muscle groups to recover while maintaining cardiovascular stimulation, resulting in sustained performance improvement and reduced fatigue.

The Sit and Reach Test results, which improved by a mean of 7.35 cm post-intervention in Group B, signify a major gain in hamstring and lower-back flexibility. Improved flexibility has been associated with lower injury rates and better biomechanical efficiency during sports movements[16,26]. Similarly, the Back Scratch Test showed measurable enhancement in shoulder mobility and upper-body flexibility, important for preventing shoulder impingements and strains common in repetitive upper-limb movements. This aligns with Daneshmandi (2024), who demonstrated that cross-training after ACL reconstruction improved the activity intensity of key stabilizing muscles, enhancing joint function and movement control.

The collective improvement across all parameters in Group B can be explained by the comprehensive nature of cross-training, which integrates multiple exercise modalities, thereby promoting overall fitness rather than focusing on isolated components. Grier et al. (2015) previously established that such diversified training programs minimize repetitive loading and muscular fatigue, decreasing the likelihood of overuse injuries[4]. Furthermore, this variation in exercise types provides both physical and psychological benefits, maintaining athlete motivation and adherence throughout training.

The non-significant improvements seen in Group A across Vertical Jump Test and 1.5-Mile Run Test suggest that conventional training alone may be insufficient to enhance complex motor and endurance parameters within the same timeframe. The findings reinforce that traditional single-mode training, when not supplemented with variability and recovery periods, can limit adaptive responses and increase the potential for overuse-related fatigue and microtrauma[10,11].

Cross-training's preventive effects against injury stem from its ability to enhance neuromuscular control, proprioception, muscle balance, and joint stability, all of which are integral to safe and efficient movement patterns[13]. For example, yoga and Pilates components improve postural alignment and core strength, reducing compensatory stress on joints[11], while low-impact exercises such as cycling and swimming enable cardiovascular conditioning with minimal joint strain[9,13]. These multidimensional benefits support the conclusions of Mendez-Rebolledo et al. (2021), who reported that neuromuscular-based interventions significantly reduced overuse injuries such as medial tibial stress syndrome in young female athletes.

In the current study, the structured 8-week protocol alternated between strength, flexibility, endurance, and cardiovascular components to ensure muscle recovery and minimize fatigue. This periodization model is consistent with contemporary recommendations for sports conditioning and reflects findings by Da Silva-Grigoletto (2020), who emphasized that program structure and variation are essential to maximizing performance gains while minimizing injury risk in high-intensity functional training.

Overall, the findings of this study demonstrate that cross-training offers an effective and balanced approach for female recreational athletes by addressing the limitations of repetitive, single-modality training. The combination of aerobic, resistance, and flexibility exercises contributes to improved muscular symmetry, enhanced endurance, and reduced injury incidence, supporting both preventive and performance goals. The observed results confirm that integrating cross-training into regular training regimens can yield significant physical and functional benefits, making it an essential component of injury prevention strategies in sports rehabilitation and recreational fitness contexts.

7. CONCLUSION

The findings of the present study demonstrate that an eight-week structured cross-training program significantly improves flexibility, muscular strength, endurance, and cardiovascular performance among female recreational athletes, thereby contributing to a lower risk of sports-related injuries. Participants who engaged in the cross-training intervention (Group B) exhibited statistically significant improvements across all outcome measures—including the Sit and Reach Test (SRT), Back Scratch Test (BST), Push-Up Test (PUT), Vertical Jump Test (VJT), and 1.5-Mile Run Test—in comparison to those in the control group receiving conventional training alone.

The results indicate that cross-training provides a comprehensive and balanced conditioning approach, addressing multiple fitness domains simultaneously. Through systematic variation in exercise modalities—incorporating strength, endurance, aerobic, and flexibility training—athletes experience enhanced muscular coordination, neuromuscular control, and cardiorespiratory efficiency. These adaptations collectively promote physical resilience and reduce susceptibility to overuse and fatigue-related injuries, particularly in the lower limbs and core musculature[13].

The study supports previous evidence that integrating diverse exercise patterns minimizes repetitive loading and fosters muscular balance[4,6]. The inclusion of dynamic stretching, resistance-based activities, and aerobic conditioning effectively improved joint mobility, functional stability, and stamina, all of which are essential in preventing injury recurrence. Such improvements are particularly valuable for female recreational athletes, who are known to be at higher risk of musculoskeletal injuries due to anatomical and biomechanical differences[1,2,9].

From a physiotherapy and sports rehabilitation perspective, the findings highlight that cross-training is not merely an adjunct but an essential component of preventive conditioning. By alternating the physical stress placed on different muscle groups, cross-training optimizes recovery periods, enhances adaptive responses, and supports long-term participation in sports without compromising safety.

Hence, the present study concludes that cross-training is a safe, effective, and versatile intervention for improving overall physical fitness while reducing the risk of injuries in female recreational athletes. Regular incorporation of cross-training in training regimens can yield significant benefits for sports performance, injury prevention, and functional health, supporting a sustainable and injury-free athletic lifestyle.

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