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Biomechanics of athlete movement: kinematic analysis and injury prevention

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Abstract: - Anterior cruciate ligament (ACL) injuries are prevalent and movement patterns linked to an increased risk of ACL damage can be seen in youngsters under the age of 10. Though the processes underlying these programs are mostly unclear, prevention systems have been demonstrated to lower rates of injury. Biomechanical alterations following injury prevention programs in children have not been extensively studied. In this study, we examine the manner in which modifications in bio-mechanical risk variables for an ACL injury in preadolescent female soccer players are affected by the F-MARC 11+ injury-preventing warm-up program. Our hypothesis was that training would enhance peak knee valgus moment (PKVM), the key risk factor for ACL injuries. Other kinematic and kinetic factors connected to ACL injury were also investigated. An intervention group and a control group were created from a total of 62 athletes who were recruited from soccer teams. F-MARC 11+ in-season sessions were attended by the intervention group fifteen times. Motion capture information from the pre and post-season was gathered while doing activities such as double-leg leap, single-leg jump, unanticipated cutting and preplanned cutting. A biomechanical modeling system called OpenSim was used to determine the angles and moments of the lower extremity joints. According to the results of the experiment, during the double-leg leap, athletes in the group that got intervention had a lower PKVM than those in the control group. This study suggests ways to improve injury prevention programs, especially for single-leg and cutting jobs, to reduce other ACL risk factors.

Keywords: ACL injury, F-MARC 11+ program, control group, intervention group, biomechanics, youth athletes

I. Introduction

Athletic injuries to the ACL frequently necessitate surgery and significant rehabilitation. For every 1000 hours of active play, it is estimated that 0.06 to 3.7 ACL injuries occur in soccer (training and matches). Soon after an ACL injury, about 25% of soccer athletes do not recover to their prior activity levels and 65% no longer play soccer 7 years later (Fältström et al., [1]). ACL injury rates among athletes have been demonstrated to decrease as a result of the development of various injury prevention strategies (Stephenson et al., [2]). However, it's unclear how these programs minimize injury rates (Gokeler et al., [3]). Anatomical, hormonal, neuromuscular and biomechanical aspects are among the multifactorial factors that contribute to the risk of ACL damage. The most promise for preventing injuries comes from biomechanical and neuromuscular aspects (Nùñez-Lisboa et al., [4]), which can be altered. Upon landing, the maximum knee valgus period is the biggest risk factor for noncontact ACL injury, according to research (Asaeda et al., [5]). Video research of a mix of hip adduction and noncontact injuries is also suggested, ankle eversion, tibial external rotation, knee valgus and internal rotation; these actions together produce "dynamic knee valgus," which raises the likelihood of injuries (ACL). Improved range of motion in the ankle in the joint moment and frontal plane has been demonstrated to be connected to an extra chance of injury to the ACL in female athletes while performing cutting and drop leaps.

While most injury prevention programs have not undergone a thorough evaluation, they aim to enhance biomechanical risk variables because training will improve those (Bonnette et al., [6]). ACL injuries affect female athletes 2–9 times more frequently than male athletes and the majority (~70%) is caused by noncontact causes. When it comes to cutting and jump-landing exercises, teenage female athletes show higher normalized landing pressures, loading rates and frontal plane motion than their male counterparts (Grammer [7]). Puberty is probably the root cause of the differences between female and male athletes. The late teens are the peak injury risk period for female athletes, although between the ages of 10 and 12, the prevalence of ACL injuries begins to rise. During landing activities, youngsters in their 10 years old exhibit "risky" patterns of motion, such as increased knee valgus and decreased knee flexion. Despite the paucity of evidence on the impact of injury prevention initiatives on children's under-13 biomechanics, preadolescent training could lower the likelihood of injuries (Taghizadeh Kerman et al., [8]). The effectiveness of preventative workouts in children is yet uncertain, based on a recent analysis of adolescent athletes' injury prevention methods.

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Avoiding the chance of being wounded soccer players is the goal of the F-MARC 11+ warm-up system preventing injuries (Pomares Noguera [9]). This program doesn't require any specialized equipment, can be finished in less than 30 minutes and only takes basic instruction to administer. Previous studies on the F-MARC 11+ system in teenage female and male players have shown up to an 81% reduction in total injury rates, but no particular ACL injuries were reduced. The research did not examine the biomechanical processes that contributed to the accomplishment of the program in minimizing injuries. Programs for more focused and efficient intervention address specific components that raise the risk of injury and can be developed with the help of a deeper comprehension of the processes through which the F-MARC 11+ system decreases the rate of injuries (Ummukulthoum [10]).

We aim to examine the impact of the F-MARC 11+ warm-up system on ACL injuries in preadolescent female soccer athletes associated with biomechanical risk factors. We hypothesize that training will reduce PKVM and other ACL injury-related factors.

Key contributions:

1. Teenage female soccer players exhibit biomechanical markers of risk for ACL injury. Our research offers new insights into how well the F-MARC 11+ preparation method modifies this risk.

2. By demonstrating reduced PKVM following intervention, our findings suggest practical implications to improve preventive injury efforts, particularly in activities involving single-leg and cutting movements.

3. Our work lays the groundwork for future research aimed at refining and optimizing ACL injury prevention strategies in youth athletes.

II. Related work

Zago et al., [11] examined on the effect of fatigue on joint kinetics and kinematics during periodic changes of direction (CoDs) to ACL risks. Inner moment and orientations of the knee joints were computed using 3D ground response and kinematic forces. Several exercise metrics included peak post-blood lactate focus, perceived effort and heart rate. It was revealed that weariness could lead athletes, in particular, to move in ways that increase their risk of injury, but it also stressed the value of considered individual kinematics while control fatigue to avoid injuries. Taylor et al., [12] examined individuals who participated in an anterior cruciate ligament injury prevention program (ACL-IPP) varied from those who did not in terms of biomechanical, anthropometric, demographic and performance factors. Before following their randomized into a 6-week ACL-IPP, 43 teenage female athletes underwent biomechanical and performance testing. With the use of those findings, doctors could be able to predict which patients would not benefit from an ACL-IPP and provide tailored instruction to those who were most vulnerable to harm. Di Paolo et al., [13] examined the motions of female soccer players varied in lab and field settings. Researchers investigated lower limb kinematics, or leg and joint motions. With respect to on-field movements, lab movements were specifically slower and involved smaller bends at the pelvis ankle and knee. The high variations occurred when the athletes landed and absorbed force. The implication was that past initiatives designed to avoid ACL injuries that relied only on laboratory results hadn't adequately represented the hazards that athletes faced when they play real sports. Di Paolo et al., [14] studied the youth football players' lower limb biomechanics were affected by their motor coordination during on-pitch training. To measure players' motor coordination, each participant completed a training exercise that included sport-specific motions and the Harre circuit test (HCT). Athletes were classified as well-coordinated (WC) or poorly-coordinated (PC) based on the existing standard and the HCT outcomes. Focused training for the avoidance of ACL injuries could be improved by tracking on-field biomechanics and motor coordination. Fotaki et al., [15] investigated the problem using a biomechanical method, found any gaps in the process and suggested tests that could prove appropriate. The grand plié was the most prevalent dance move that could induce meniscus damage due to its compressive stresses, axial rotations and excessive range of motion. Neither the active grand pliés nor the intermediate leg postures required an in-depth three-dimensional kinematic evaluation of the lower leg joints.

To provide helpful insights for avoidance of injuries and athletic enhancement, Liu et al., [16] found it difficult to integrate different data sources. To solve those difficulties, an integrated biomechanical informatics system (IBIS) was created. It was web-based platform came with integrated capabilities for visualization, data analysis and inter-institutional cooperation. IBIS essentially established a central core for productive biomechanics research. As a result, new information was discovered and the research procedure and data analysis were optimized. Saito et al., [17] investigated the effect of trunk posture during single-leg landing on the angle of the knee and activation of muscles. In that experiment, forty healthy college students performed a right single-leg landing from a platform 40 cm high while using their trunk muscles in extension, flexion, neutral and lateral flexion. The study found that the trunk-flexion posture had a much greater knee flexion angle, lower biceps femoris (BF) and rectus femoris (RF) muscle activation and a decreased risk of anterior cruciate ligament damage than other trunk postures. Robinson et al., [18] looked at the landing mechanics of adolescent female soccer players deemed more vulnerable to ACL damage. A six-week training program aimed at optimal landing, hip strength and motor control methods was examined, as well as 36 subjects leaping motions were analyzed using a non-randomized methodology. It proved the efficacy of brief training sessions to enhance landing mechanics in young female soccer athletes and the use of motion analysis tools was to evaluate injury concerns. Sadeqi et al., [19], the effects of whole body (WB) factors on cartilage at the joint stress, contact force and ACL strain were examined during activities with single-leg cross-drop and single-leg drop. The study discovered that the WB features that were most indicative of poor articular cartilage biomechanics and excessive ACL strain were lower medial gastrocnemius, gluteus maximus and gracilis muscle forces; also, higher anterior shear load at max strain was seen. Among 291 runners, healthy and wounded, Jauhiainen et al., [20] sought to established discrete groupings with uniform gait characteristics. Five unique subgroups were discovered by hierarchical cluster analysis. However, runners with similar injury kinds did not cluster together indicated that homogenous gait patterns exist regardless of the injury site. It was suggested that these underappreciated patterns should be considered while developing injury prevention or recovery techniques.

Dischiavi et al., [21] investigated whether exercises designed to prevent ACL injuries targeted the mechanics that put athletes at risk. The study identified four key elements in ACL injury mechanisms. Exercises that challenged three or more elements were rare and hardly any addressed all four elements at once. Its many common ACL injury prevention exercises could not target the most critical movement patterns that lead to injury. The study concluded that future training programs should focus on incorporating more exercises that address these key elements to improve their effectiveness in preventing ACL injuries. Otsuki et al., [22] looked at how early-, late and post-pubertal female basketball players' knee mechanics were suffering from an injury to the anterior cruciate ligament preventive program. The outcomes of the research represented that the early-pubertal control group had a higher chance of high knee abduction moment, reduced range of movement in the knee flexion and increased medial knee displacement. The treatment enhanced the knee mechanics of post-pubertal teenagers. According to the study, an injury prevention program might begin in early puberty and go until adulthood. Markström et al., [23] aimed to evaluate the impact of peak athletic training on dynamic movement control and knee robustness in elite athletes. The results showed that elite athletes had superior knee function but had similar finite helical axis (FHA) inclination angles to non-athletes. However, the study found that there was room for improvement in reduced FHA inclination angles linked to dynamic knee robustness, potentially decreasing knee injury risk. Lempke et al., [24] checked the kinetics and kinematics of single and dual-task functional motions among healthy volunteers and discovered little changes. Dual-tasking increased peak vertical ground forces during jump landing but reduced force during dominant leg cutting. Research on injury risk and functional mobility evaluations can be impacted by these findings. Before therapeutic adoption, further study was needed to understand how different cognitive and movement activities combine to affect functional mobility in diseased groups. Turgut et al., [25] examined into the scapula kinematics of junior overhead athletes. An electromagnetic tracking gadget was used to obtain data on scapula plane glenohumeral elevations and examined from various angles. The findings revealed that overhead athletes' scapulas were more upwardly rotated and anteriorly inclined than non-overhead athletes. The majority and minority shoulders of the serve did not differ from one another. The findings suggested that doctors consider junior overhead athletes for possible alterations.

III. METHODOLOGY

A. Research participants

For this study, Local soccer teams recruited 62 female soccer players ranging in age from 10 to 13 years. Before participation, formal consent was obtained as documented in Table 1. ACL injuries in the past, lower limb surgeries within the last year, significant lower extremity injuries in the past six months requiring more than four weeks off from sports and any history of involvement in ACL injury prevention programs were among the exclusion criteria.

The laboratory testing phase involved 34 players from two different soccer clubs. All athletes from these teams received on-field injury prevention training, regardless of their participation in the research. As a control group, 28 athletes from eleven additional teams underwent baseline testing in the lab. Before evaluation, the analysis of variance revealed that there were no substantial variations in mass (P =0.141) or height (P =0.098) between the control groups and intervention. However, a minor but statistically considerable difference in age of 0.8 years was found (P =0.021).

Table (1): Pretest and Posttest Measurements of Intervention and Control Groups

Group	Measurement	Pretest (n = 34 for Intervention, n = 28 for Control)	Posttest (n = 30 for Intervention, n = 22 for Control)
Intervention	Age (y)	11.8 ± 0.8	—
	Height (m)	1.54 ± 0.08	1.55 ± 0.08
	Mass (kg)	41.6 ± 8.5	42.3 ± 8.7
Control	Age (y)	11.2 ± 0.6	—
	Height (m)	1.49 ± 0.08	1.51 ± 0.09
	Mass (kg)	38.1 ± 6.0	38.2 ± 6.3

B. Pre-implementation Testing

Data collection was conducted using three floor-mounted force plates, which were synchronized to record at 2000 Hz. This setup was integrated with the spatial tracking of 36 retro-reflective markers, which includes an advanced eight-camera motion capture system captured at 200 Hz. To ensure the accuracy of the data, each participant was required to undergo a preliminary calibration process, involving standing in a specified position.

Participants performed two types of jump-landing tasks in an arbitrary order from a 30-cm high box: a single-leg leap using their dominant limb and a double-leg jump, as depicted in Figure 1, panels B and C. The leg with which each participant was going to kick the soccer ball longest was utilized to determine which of their limbs was dominant. For the double-leg jump, participants were told to advance by jumping from the box and landing on two force plates spaced apart at 50% of their body height. To obtain maximal vertical height, they conducted a counter movement jump. The single-leg jump required individuals to jump forward from the box on only one force plate set at 40% of the body's height with their dominating leg, then perform a reverse jump to maximum height.

During the jump-landing workouts, the subjects conducted two cutting tasks, one scheduled and another unplanned. In both participants, tasks had to speed up at 4.1 ± 0.7 m/s while fusion sports timing gates tracked their movements and they had to perform a sidestepping cut from their dominant leg at an angle of around 45 degrees to the direction of approach, as shown in Figure 1 (A-C). The location for the unanticipated cutting task was determined randomly using one of two-timing lights. An investigation was deemed successful if the participant consistently landed on the designated force plate with their dominant foot throughout the task.

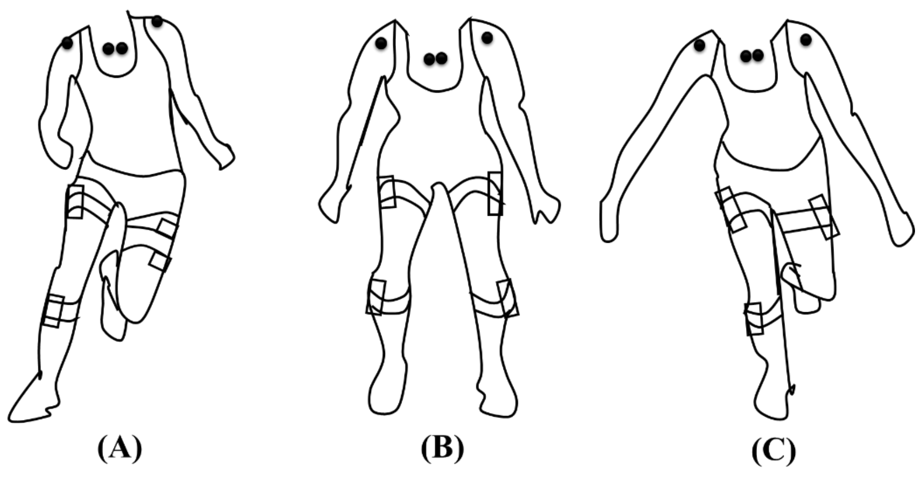

Figure 1: Athlete positioning after initial contact is demonstrated, along with marker placement, in the following exercises: (A) planned and unplanned cutting, (B) double-leg leap, and (C) single-leg jump.

C. Interventional approach

Approximately two weeks after the initial tests (mean [± SD], 10 ± 5 days), the F-MARC 11+ system for warming up to prevent injuries was initiated. The treatment period consisted of 20 sessions, averaging about 3 sessions per week over 6-7 week duration during the soccer season. Every intervention group included a 30-minutes exercise in their pre-practice preparation routine.

The program comprised 3 main components:

1. Three dynamic running and cutting drills aimed at enhancing agility and reaction time.

2. Six targeted exercises designed to improve balance, power and jump-landing techniques, structured into three progressive levels of difficulty.

3. Six moderate-paced running exercises combined with controlled collaborative interaction and dynamic stretching.

Progression to more challenging levels of a particular exercise was contingent upon athletes maintaining proper form throughout the activity. Each training session was monitored by at least one of six trained research staff members who provided feedback on the technique and ensured adherence to the program protocols (see Figure 2 for further details). The average attendance rate for the athletes was 70.2% ± 14.0%, indicating the proportion of training sessions attended out of the total offered. This rate also reflects instances of partial attendance during the sessions.

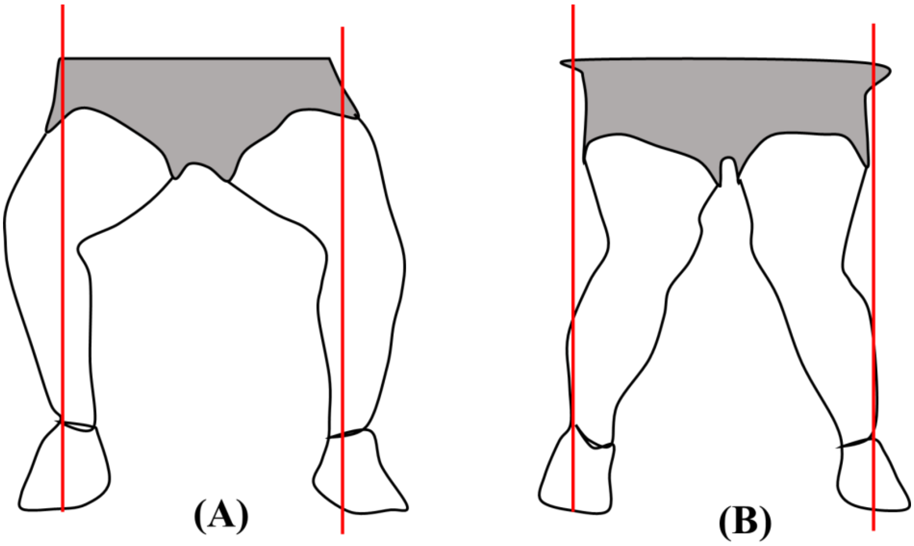

Figure 2: Using a double-leg leap, one may demonstrate (A) an optimal lower limb position and (B) an improper position (knee valgus).

D. Post-implementation Testing

Three weeks after completing the intervention, the athletes returned for post-implementation testing in the laboratory (mean [± SD], 7 ± 5 days). Through this interval, individuals continued their regular team training and competitive matches. The methodology for collecting post-implementation data mirrored that of the pre-implementation phase to ensure consistency in measurement.

From the intervention group, 30 participants returned for the post-implementation assessment (mean, 71 ± 11 days post-initial testing). Scheduling conflicts led to one athlete missing the follow-up and another was excluded due to injury. In the control group, 22 participants underwent further tests in the lab after a similar period (mean, 67 ± 9 days post-initial testing). Here, 4 participants withdrew from the study because of an injury and 6 others were unavailable for follow-up due to scheduling conflicts.

E. Musculoskeletal System Simulation

With an exclusion frequency of 30 Hz, a sixth-order, severely damped filter was used to low-pass filter the ground-reaction pressure data. Using OpenSim software version 4.2, we processed three trials for each task and participant. Markers positioned on anatomical landmarks facilitated the scaling of a generic 38-degree-of-Musculoskeletal freedom model to align with individual participants' anthropometric measurements.

We used the inverse kinematics tool in OpenSim to calculate joint angles. This tool replicates observed motion patterns by minimizing the discrepancies between the positions of virtual markers in the simulation model and those of actual markers captured during experiments, using a weighted least-squares method. The inverse dynamics tool, which is part of the OpenSim package, was then used to predict joint moments using kinematic data. To further reduce kinetic artifacts, the similar 30-Hz filter previously applied to the statistics on ground reaction forces was again used on the joint moment's data. Musculoskeletal moments were converted to the athlete's height and body weight ($\%BW \times HT$) and documented as attached moments.

F. Quantitative Analysis

Each action was carried out within three trials. We called this phase of weight acceptance the interval from first ground contact to maximal knee flexion and the highest values for each test, activity and parameter of the same group were adopted for analysis. To assess the primary effects of time, a recurrent measure analysis of variance (Analysis of variance (ANOVA)) was carried out (pretest vs. posttest), group (control vs. intervention) and their interaction on each variable by using the average value from the three trials. Paired-sample s tests were applied to compare the pretest and posttest PKVM angles within each group. SPSS software was used for statistical analysis, with a significance threshold of α=0.05. The average result from each experiment is displayed in the data as mean ± standard error.

IV. RESULT AND ANALYSIS

A. Peak Valgus Stress on the Knee

Exercise with the double-leg jump only showed a significant difference between the groups (-0.59 ± 0.29% $BW \times HT$ versus 0.27 ± 0.27%$BW \times HT$; P =0.036). In Figure 3 and 4, none of the remaining activities revealed a significant difference between the two groups in terms of average change in PKVM. (P =0.047; Table 2 and figure 3) indicates that after the double-leg leap, the intervention group had a drop in PKVM from 3.64 to 3.07 percent $BW \times HT$, whereas P =0.335 indicates that no significant improvement was seen in the control group. The one additional significant improvement seen was a rise in the PKVM right through the unanticipated cutting task (P =0.044). This suggests that there was an increase in both athletes had their PKVM groups from the pretest to the posttest (Table 3).

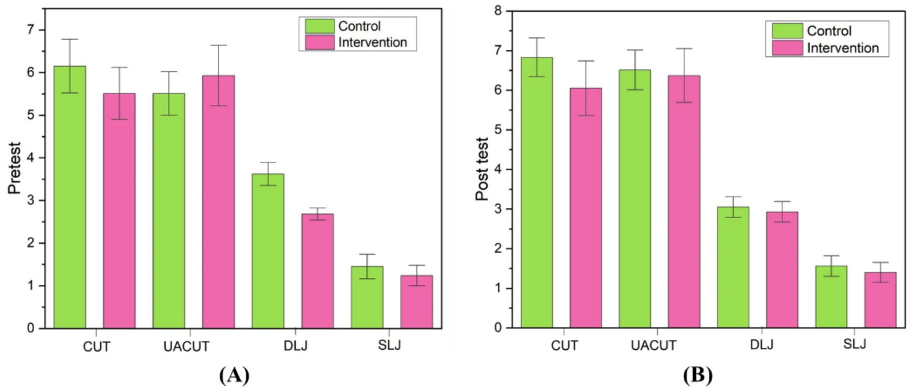

Figure 3: Changes in PKVM from Pretest to Posttest in Intervention and Control Groups

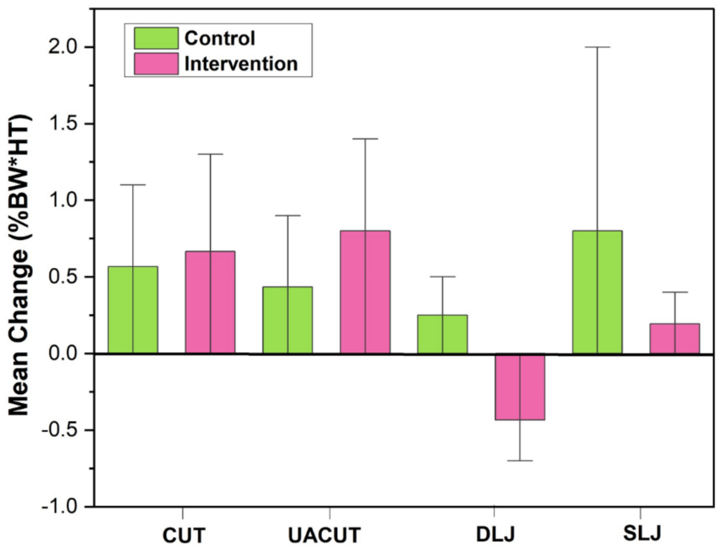

Figure 4: Average shift in the knee valgus moment peak

Table (2): During the transition from the pretest to the posttest, the intervention and control groups had PKVM.

Activity	Group	Mean ± SD (Pretest)	Mean ± SD (Posttest)	P Value
CUT	Intervention	6.17 ± 0.65	6.84 ± 0.50	0.282
	Control	5.53 ± 0.63	6.07 ± 0.71	0.345
UACUT	Intervention	5.53 ± 0.53	6.53 ± 0.52	0.046
	Control	5.95 ± 0.73	6.39 ± 0.70	0.386
DLJ	Intervention	3.64 ± 0.29	3.07 ± 0.28	0.047
	Control	2.70 ± 0.16	2.95 ± 0.28	0.333
SLJ	Intervention	1.47 ± 0.31	1.58 ± 0.28	0.737
	Control	1.26 ± 0.26	1.42 ± 0.27	0.520

In Table 2, the values were adjusted by $\%BW \times HT$ and they are shown as mean 8 standard error of the mean. DLJ stands for double-leg jump; CUT stands for preplanned cutting; SLJ stands for single-leg jump and UACUT stands for unanticipated cutting. Pre and posttest values differed in a statistically significant way (P <0.5). In Table 3, a lower amount of pretest to posttest changes is indicated by a negative number.

Table (3): Comparative Analysis of Joint Angle and Moment Adjustments Pre- and Post-Intervention Across Study Groups

Activity	Measure	Pre			Post		
		Intervention (Mean ± SD)	Control (Mean ± SD)	P Value	Intervention (Mean ± SD)	Control (Mean ± SD)	P Value
CUT	Peak Hip Adduction	0.5 ± 0.11	0.1 ± 1.1	0.917	-0.46 ± 0.58	-0.42 ± 0.59	0.966
	Peak Knee Flexion	-1.8 ± 1.4	-0.5 ± 1.3	0.527	-0.63 ± 0.47	-0.03 ± 0.57	0.417
	Peak Ankle Eversion	0.2 ± 1.2	1.1 ± 1.1	0.588	-0.48 ± 0.32	0.57 ± 0.24	0.015
	Peak Knee Valgus	-1.2 ± 0.6	-2.1 ± 0.8	0.339	0.68 ± 0.61	0.54 ± 0.55	0.868
UACUT	Peak Hip Adduction	-2.0 ± 1.3	-2.7 ± 1.4	0.708	-0.01 ± 0.56	-0.16 ± 0.50	0.846
	Peak Knee Flexion	-1.1 ± 1.3	0.1 ± 1.5	0.537	-0.63 ± 0.62	0.78 ± 0.56	0.104
	Peak Ankle Eversion	-0.2 ± 1.1	3.2 ± 1.0	0.034b	-0.69 ± 0.29	0.59 ± 0.30	0.004
	Peak Knee Valgus	-0.8 ± 0.5	-3.1 ± 0.8	0.018b	0.99 ± 0.47	0.44 ± 0.50	0.428
DLJ	Peak Hip Adduction	-1.4 ± 0.8	-1.5 ± 0.8	0.938	0.09 ± 0.30	0.14 ± 0.27	0.903
	Peak Knee Flexion	-3.1 ± 1.9	-4.5 ± 2.1	0.609	0.03 ± 0.47	0.66 ± 0.50	0.362
	Peak Ankle Eversion	-0.5 ± 1.2	1.3 ± 1.2	0.325	-0.34 ± 0.22	0.45 ± 0.22	0.016
	Peak Knee Valgus	-2.5 ± 1.0	-5.3 ± 1.0	.060	-0.57 ± 0.27	0.25 ± 0.25	0.034
SLJ	Peak Hip Adduction	-0.6 ± 0.6	-1.0 ± 0.9	0.739	-0.53 ± 0.38	-1.04 ± 0.36	0.342
	Peak Knee Flexion	-1.5 ± 1.1	0.1 ± 2.0	0.468	0.37 ± 0.64	0.25 ± 0.63	0.900
	Peak Ankle Eversion	0.8 ± 0.6	1.7 ± 0.6	0.322	-0.23 ± 0.37	0.22 ± 0.30	0.363
	Peak Knee Valgus	-1.1 ± 0.4	-1.5 ± 0.6	0.532	0.11 ± 0.31	0.16 ± 0.25	0.888

1) 4.1.1. Biomechanical Parameters: Kinematics and Kinetics

The intervention group demonstrated significant differences for the majority of the variables measured (Table 3). Specifically, the intervention group had lower peak knee eversion moments at 3 time points (double-leg jump, P = 0.018; unanticipated cutting, P = 0.008; planned cutting, P = 0.017) and the peak knee eversion angle was also lower for unanticipated cutting (P = 0.036). The control group demonstrated only 1 significant difference at 1 time point, with the mean peak knee valgus angle being lower for unanticipated cutting posttest. All other significant differences between the groups were seen in supplementary kinetic variables when comparing the pretest to posttest. The time variable significantly affected only 1 supplementary kinetic variable, throughout the single-leg leap, the high hip flexion moment (P =0.008), with all athletes demonstrating a decrease in the mean high hip flexion those times from pretest to posttest.

B. Discussion

Forrest et al., [26] unwanted bowling mechanics might raise the chance of suffering from a low back injury. Community-level teenage pace players' bowling biomechanics were examined to see if an exercise-based injury prevention program (IPP) might help. Regarding shoulder counter-rotation and lateral trunk flexion in relation to the pelvis, there were notable treatment effects that favored the intervention group. The control group's shoulder counter-rotation increased by 2.2°. The following variables were unaffected by the intervention: ball velocity; front hip angle at FFC; lateral trunk flexion at ball release (BR); cervical rotation at BR; lateral trunk flexion at front foot contact (FFC); pelvis rotation at FFC and front hip angle at BR. Arumugam et al., [27] to conduct a thorough literature analysis on the prevalence and risk factors of rowing injuries and to gain understanding of the function of biomechanics in their treatment. The most often damaged anatomical regions include the lumbar spine, rib cage, shoulder and other locations. Higher injury risk and a lower hip: trunk score was associated with rowers whose rowing activity was driven by their trunks. It will take an athlete with a lumbar injury at least three to four months to heal. Nagelli et al., [28] objective was to assess how wheelchair basketball players' shoulder range of motion, muscular activity and overall functionality were affected by a comprehensive rehabilitation program. They included wheelchair basketball players who were adults and compete in the Italian Second League. They had an 8-week comprehensive rehabilitative program that includes data on prevented injuries causing upper limb discomfort, preventative exercises and kinematic analysis-based ergonomic improvement. Kozin et al., [29] those aimed to ascertain the impact of a program that includes eccentric, strength and closed-kinematic chain workouts on the injuries sustained by students who are rock climbers. It was discovered that the designed program had a major impact on the athletes in the intervention group experiencing less injuries. In the control group, the injury rate per 1000 AEs for injuries of every shoulder was 3.182, while in the intervention group, it was 0.5. There was an incidence rate ratio of 0.861 for mild shoulder injuries. The ratio of minor shoulder injuries to their incidence was 0.862. There was an incidence rate ratio of 0.864 for serious shoulder injuries.

The purpose of our project was to evaluate the F-MARC 11+ injury prevention warm-up routine on the body kinematics of the players who are at risk of ACL injuries and they are 11 years and younger. Our evaluation statistics showed that the test group experienced great biomechanical advances as compared with the control group. Peak knee eversion moment; the intervention group revealed a lower peak knee eversion moment in each of the three movements, double-leg jump (P = 0.018), unanticipated cutting (P = 0.008) and planned cutting (P = 0.017). The angle of the knee simulation at the maximum knee eversion was statistically lower in the intervention group (P = .036). Maximum knee valgus moments; the intervention group demonstrated a decrease in PKVMs from 3.64% BW×HT before intervention to 3.07% BW×HT after the intervention ($P < 0.45$), which proves that the intervention can be considered effective. Similarly, the control group also exhibited no statistically significant change, with the PKVMs showing an average difference from 2.68% BW×HT in the pretest to 2.93% BW×HT in the posttest (P=0.331). Post-tests are better than pre-tests because they measure the effects of an intervention, revealing any significant changes or improvements that occurred as a result of the treatment.

V. Conclusion

In pre-adolescent female soccer individuals, our data demonstrate a noteworthy impact of the F-MARC 11+ strategy for modifying particular biomechanics characteristics associated with risk for ACL damage. One important variable related to the preadolescent female soccer players are at risk for ACL injuries has average shift in the PKVM at post-testing, which showed very large effects in one intervention category. This implies that significant risk factors linked to the likelihood of these injuries could be modified by the F-MARC 11+. Our results suggest that, for enhanced athlete safety and to potentially lower the possibility of injury to the ACL in sports that require unanticipated single legged and cutting actions, the importance of implementing movement education and injury prevention programs specifically to patients involved in such sports should be emphasized. Finally, our findings can offer critical information for both assessing and modifying future F-MARC 11+. Such information could ultimately contribute to long-term positive health effects of similar programs for a broad range of young athletes in soccer and other similar sports.

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