Effectiveness of a 6-week Injury Prevention Program on Kinematics and Kinetic Variables in Adolescent Female Soccer Players: a Pilot Study

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Background: Incidence of knee injuries in female soccer players is 2-6 times that of male counterparts. The objective was to determine whether an injury prevention program incorporated into the athlete's regular soccer practice is effective for improving landing mechanics.

Methods: Two competitive adolescent female soccer teams (n = 30) participated in the study. One team served as the control group while the other team participated in a 6-week injury prevention program. Muscle strength, muscle length, and 3-dimensional kinematics and kinetics during a single legged drop jump and single legged squat task were measured pre and post-intervention. A 2 x 2 repeated measures multivariate analyses of variance (MANOVA's) were used to compare strength and flexibility measures as well as knee joint kinematics and kinetics. Significant multivariate results were followed with appropriate univariate analyses.

Results: Quadriceps strength increased significantly (p=.004) following the injury prevention program while other strength and flexibility measurements were unchanged. Differences in knee joint angles and moments during the drop jump and squat tasks showed varied results with a tendency for improvement in the intervention group.

Conclusions: Flexibility and strength do not appear to be affected by a short injury prevention program. Knee joint injury predisposing factors improved minimally but did not reach statistical significance with a short injury prevention program integrated as warm-up into soccer practice. Further research with a larger sample size is needed to explore the effectiveness of such programs. [*P R Health Sci J 2010;1:40-48*]

Key Words: ACL, Drop jump, Knee, Landing, Soccer

Soccer is the most popular team sport in the world and participation is at all time high (1-2). In the United States, it is estimated that 18.2 million people participate (3) and 43% of these players are women (4). The American Academy of Pediatrics (5) reports that approximately three million soccer participants are registered in high school or youth soccer associations. Though soccer participation provides many youths an opportunity for healthy physical activity, participation results in many injuries. The US Consumer Product Safety Commission (6) estimates that 146,000 to 160,000 soccer injuries occurred from 1992 to 1994 and approximately 45% of these injuries occurred in participants younger than 15 years of age.

Lindenfeld et al. (7) reported that overall injury rates per 1000 player-hours are similar for male and female players. However, an analysis of the specific injuries sustained by soccer players reveals that while male players sustain a significantly higher rate of ankle injuries, female players sustain a significantly higher rate of knee injuries. Furthermore, incidence of serious knee injury is reported to be six-times higher in female athletes than male counterparts (7-10). The most commonly injured knee ligament in female athletes is the anterior cruciate ligament (ACL) (11). Many of these injuries require surgery, lengthy non-surgical treatment, or both. The total financial burden of serious knee injuries in female athletes is approximately $17,000 per patient (F. R. Noyes, unpublished data, 1999), reaching a total of $100 million when high school and collegiate athletes are combined (12). This figure does not, however, consider

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the cost of treating the potential long term complications such as post-traumatic degeneration that occur in many participants who sustain ACL injuries, even those who undergo surgical reconstruction (13). Chandy and Grana (14) reported that school-aged girls have nearly five times as many knee surgeries as boys do and knee surgeries make up 70% of all surgeries for girls. Preventive programs may be able to decrease the number of knee surgeries required and thus present a cost-effective solution to this serious problem.

The majority of ACL injuries sustained during sports participation are non-contact in nature with most of these occurring during landing from a jump or during cutting/pivoting maneuvers (1, 15-17). Some biomechanical and neuromuscular factors that appear to play a major role in non-contact ACL injuries in female athletes are: reduced hip and knee flexion angles, greater knee valgus moments and angles, and greater hip internal rotation with knee external/internal rotation than males during pivoting/cutting and single-leg landings (1-2, 18-20).

Biomechanical studies have shown that body movement patterns can be altered through intervention programs (21-22). Prapavesis et al. (22) showed that children were able to minimize ground reaction forces when landing from a jump when they were given verbal feedback on proper landing techniques. Hewett et al. (21) demonstrated that after a 6-week jump training program, female volleyball players had lower landing ground reaction forces, decreased knee valgus moments and greater hamstring function. However, the training program used by Hewett et al. (21) was time intensive (two-hours a day, three-times a week on alternating days), making it impractical or unworkable for many. Short injury prevention programs integrated as warm-up into women's team handball and soccer have been shown to be effective for reducing injury incidence across a season (23-24).

In view of the high incidence of non-contact ACL injuries in young female athletes, intervention programs that address the biomechanical and neuromuscular factors that seem to place female athletes at risk for injuries are needed. The intervention program, however, must be feasible for the coaches and this young competitive population. The purpose of this study was to determine whether a six-week injury prevention program incorporated as warm-up into the athlete's regular soccer practice session would be effective for improving landing mechanics. We hypothesized that adolescent female soccer players participating in the injury prevention program would present a reduction in injury predisposing factors during two functional tasks, and an improvement in strength and flexibility measures in muscles targeted by the intervention.

Methods

Participants

Two competitive female soccer teams between the ages of 14 and 17 years were recruited for this study. A brief description of the study was distributed to coaches, athletes and parents. The first two teams in the same age group to respond to the request for participants were entered into the study. Both teams entered into the study were in the category under 15 years of age at the start of the soccer season. Therefore, all participants were between the ages of 14 and 15 years at the time of the study. All participants reported playing regularly with their teams and were injury free at time of recruitment. Any subject not able to participate regularly in her soccer practice or game due to an injury was excluded. Prior to participation in the study, informed consent forms approved by University Institutional Review Board were read and signed by athletes and their parents.

Instrumentation

Muscle strength and length measures

Lower-extremity muscle strength and length were measured with a computer-automated system using the BEP-IIIa hand-held dynamometer and BEP-VII electronic inclinometer (Human Performance Measurement, Inc., Arlington, TX [HPM]). The BEP for Windows® Software (Human Performance Measurement, Inc., Arlington, TX [HPM]) was used to operate the modules and record data on a portable personal computer. The reliability of the BEP-IIIa dynamometer for measuring muscle strength at the hip and knee has previously been determined in two separate studies ($ICC_{3,2}$ = 0.94,(25) $ICC_{3,1}$ = 0.85-0.97 (26)). In our study, the BEP-IIIa was used to measure maximal isometric force produced by the hip extensors, hip abductors, hip external rotators, knee extensors (Figure 1), and knee flexors. Muscle torque in Newton-meters (Nm) was calculated using estimated segment lengths based on each participant's height. The standard error associated with estimated segment lengths based on height is approximately 1.0-cm when compared with measured segment lengths (27). The BEP-VII electronic inclinometer was used to measure muscle length of the iliopsoas (Figure 2), rectus femoris, hamstrings, and gastrocnemius indirectly by measuring joint range of motion (ROM) of the joints simultaneously crossed by these muscles. The BEP-VII has previously been shown to have excellent intrarater reliability for the measurement of hamstring length (ICC = .94)(28). The electronic inclinometer was calibrated according to manufacturer's recommendation each time the system was powered up.

Kinematic and kinetic measures

Thirty-five retro-reflective markers were placed bilaterally on bony prominences on the participants' acromioclavicular joint, anterior-superior iliac spine (ASIS), sacrum, thigh, shank, ankle, and foot. A static trial with the participant standing in a shoulder-width stance and approximately 20° of knee flexion was collected to compute the joint coordinate system. After the static trial, the medial epicondyle and medial malleolus markers were removed to prevent interference between medial markers and lower extremities during tasks.

Figure 1. Strength testing of knee extensors using the BEP-III hand-held dynamometer. A strap secured to an immovable object was used to stabilize the dynamometer while the tester kept the dynamometer properly positioned on the leg.

The motion analysis system consisted of six digital cameras connected to the data collection computer using Visol Multi-capture software (Visol Corp., Seoul, Korea) for data collection at 60 Hz. Two AMTI force plates (AMTI, Watertown, MA) were used to sample ground reaction forces at 1000 Hz and were time synchronized to the motion analysis system using an external 32-channel A/D box (Visol Corp., Seoul, Korea). Joint angles were derived from residual analysis of three-dimensional trajectory of retro-reflective markers filtered through a second order low pass Butterworth filter (6 Hz). Joint angles were defined as knee flexion/extension, valgus/varus and external/internal rotation as the first, second and third rotation, respectively. Joint moments were estimated by an inverse dynamics method instrumented in Kwon 3D software (Visol Corp., Seoul, Korea). The motion analysis system was calibrated at the beginning of each day of data collection using a 48-point polymorphic calibration frame (Visol Corp., Seoul, Korea).

Procedures

Muscle strength, muscle length, and three-dimensional lower extremity kinematics and kinetics were collected prior to the 6-week intervention and no later than two-weeks after completion of the intervention for both teams. Height and weight measurements were taken on each participant prior to performance of any tests. Leg dominance was determined as the leg preferred to kick a soccer ball.

Muscle strength and length

All muscle strength measurements were taken bilaterally in gravity lessened positions. Participants were allowed one practice trial for each test prior to the measured trials. For each measurement, participants were asked to gradually start pushing against the dynamometer and then to push as hard as possible until an audible "beep" signified the end of the five-second trial. A second trial was performed in the same manner after a brief 2-3 second pause. A strap was used to stabilize the dynamometer for measurement of knee flexors and extensors (Figure 1), thereby removing tester strength as a variable. We were not, however, able to utilize a strap for measurement of hip abductors and external rotators. The average muscle torque value of the two trials for each muscle was used for data analysis.

All muscle length measurements were taken in the supine position measuring the range of motion allowed by the muscle when it was simultaneously lengthened over all joints that it crosses (Figure 2). To measure iliopsoas muscle length, participants were positioned in supine with the knees flexed toward their chest just enough to flatten the low back against the treatment table. One knee was held in this position while the measured leg was slowly lowered into hip and knee extension toward the table. The hip and knee extension movement was stopped at the moment the low back started to increase its lordosis. While maintaining this position, the BEP VII was used to measure the amount of hip extension allowed by the iliopsoas. Normal length of the iliopsoas allows the thigh to lie flat on the table while a short iliopsoas results in an end position of hip flexion (Figure 2). Therefore, the recorded measurement is that of hip flexion. Rectus femoris muscle length was measured in a similar fashion with the exception that the knee of the measured leg was kept in a flexed-relaxed position. The amount of knee flexion allowed by the rectus femoris was measured. To measure hamstring muscle length, the subject was positioned in supine with the hip flexed to 90°. The participant then actively extended her knee while the tester manually maintained the 90° of hip flexion. Amount of knee extension allowed by the hamstrings was measured. To measure gastrocnemius muscle length, the participant laid supine on the treatment table with her knee fully extended. Amount of ankle dorsiflexion allowed by the gastrocnemius muscle as the participant actively dorsiflexed while keeping the knee extended was measured. Two trials were conducted for each motion and the mean of the two measurements was used for data analysis. At the end of each testing session, one muscle length or one muscle strength test was randomly selected to be repeated on each participant to be used for calculation of reliability.

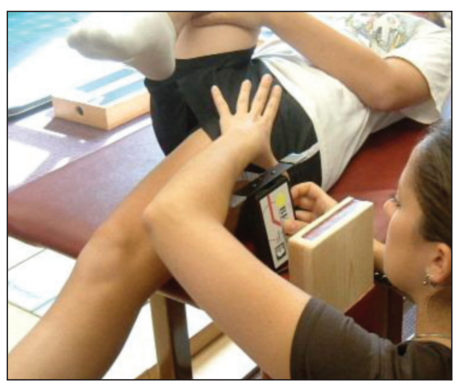

Figure 2. Muscle length testing. After calibration, the electronic inclinometer was used to assess muscle length of the hip flexors.

Kinematics and Kinetics

The participants performed two trials of a 33-cm single-legged drop jump (dominant leg) and two trials of a single-leg squat (dominant leg) in random order during both test sessions. The dominant leg was determined by asking the athletes which leg they preferred to use to kick the soccer ball. Participants were allowed to practice each test until they felt comfortable with their performance. The two test trials of each functional activity (single leg drop and single leg squat) were videotaped for future data analysis. The specific procedures for each test were as follows:

1) Single-legged drop jump: Each participant stood with feet shoulder width apart on a 33-cm step. They were asked to assume the single-leg position when the "ready" command was given. The participant then dropped from the box onto the force plate as soon as she felt ready to do so. Peak joint angles and moments were measured. Participants were asked to stick the landing and if they were not able to stick the landing the trial was repeated.

2) Single-leg squat: Each participant stood on the force plate in a single-legged stance with arms to the side for balance purposes. The same commands as the drop jump were used to prepare the participant for the test. The participant was then asked to squat as low as possible on the stance leg without losing her balance and then to return to the upright position. If the participant was not able to keep her single-leg stance throughout the test, the trial was repeated. Peak joint angles and moments were measured.

Intervention

Once both teams had completed the pre-training measurements, a random draw was conducted to determine group assignment. The team that randomly drew assignment to the control group continued its regular practice and game schedule as previously. The team that randomly drew assignment to the intervention group participated in a 6-week sport injury prevention program (SIPP). All SIPP training sessions were conducted by two physical therapists who routinely implement injury prevention programs with sport teams in the local area. The SIPP consisted of the following: a) 7 lower extremity flexibility exercises, b) 6 lower extremity functional strengthening exercises, and c) 5 jumping and landing exercises that focused on controlling hip and knee position during execution and landing (Table 1). The program was incorporated into the first 20-25 minutes of the team's regular soccer practice twice a week. At the end of the 6-weeks, all pre-training measurements of muscle strength, muscle length and three-dimensional kinematics and kinetics during functional tests were repeated on both teams. All testers were blinded to group assignment. Once all measurements were completed, the control team was given the option of receiving the injury prevention training.

Data Analysis

Data were analyzed using SPSS 11.0 for Windows® (SPSS Inc., Chicago, IL). All variables were screened for normality and outliers by using frequency analysis, histograms and the Shapiro-Wilk test. If outlying values were identified for any of the variables they were deleted from the specific analysis. Analysis of variance (ANOVA) was conducted using repeated measures of randomly selected muscle length and strength tests to calculate intraclass correlation coefficients ($ICC_{3,2}$) as an estimate of test-retest reliability. A 2 X 2 repeated measures multivariate analysis of variance (MANOVA) was used to test differences between and within groups on measures of muscle length and strength. Two MANOVAs; one for knee joint angles and another for knee joint moments, were performed to assess differences during the functional tasks. When baseline differences were found between groups for kinematic variables, a 2 x 2 repeated measures multivariate analyses of covariance (MANCOVA) was used to test for differences using baseline values as the covariate. An alpha level of 0.05 was used for all statistical analyses.

Table 1. Sports injury prevention program (SIPP) used for intervention group.

Warm-Up Runs Across Field	
Jogging	1 pass
Side shuffling	1 pass
Backpedaling	1 pass
Flexibility Training	
Quadriceps Stretch	2 x 15 seconds
Hip Flexor Stretch	2 x 15 seconds
Hamstring Stretch	2 x 15 seconds
Figure 4 Stretch	2 x 15 seconds
Spinal Twist Stretch	2 x 15 seconds
Groin Stretch	2 x 15 seconds
Calf Stretch	2 x 15 seconds
Functional Strength Training	
Bridging with Ball	20
Walking Lunges	20
Double Leg Squat	20
Single Leg Squat	20
Resisted Tubing Sidesteps	20/direction
3 Way Kicks	20/direction/leg
Jump Training	
Squat Jumps	10
Single Leg Hops	10
Side-To-Side Hops	10
Lunge Jumps	10
180 Degree Jumps	10

Results

Thirty of the 31 young women who were pretested completed the intervention and returned for the posttest measurements. One person from the control group did not return for the posttest due to a scheduling conflict resulting in 16 participants in the control group and 14 in the treatment group. One participant in the control group was left leg dominant while all other participants were right leg dominant. A summary of subject characteristics is shown in Table 2.

Table 2. Characteristics of participants by group.

Characteristic	Mean(SD)	Range
Height (cm)		
All*	161.0 (5.7)	144.8 - 175.3
Treatment Group†	161.6 (4.3)	154.9 - 167.6
Control Group‡	160.5 (6.8)	144.8 - 175.3
Body weight (kg)		
All	53.8 (7.9)	37.3 - 68.2
Treatment Group	55.3 (7.1)	45.9 - 66.8
Control Group	52.5 (8.4)	37.3 - 68.2

*n = 30; †n = 14; ‡n = 16

Reliability

Calculated $ICC_{3,2}$ as an estimate of test-retest reliability revealed excellent reliability (0.94-0.96) for all muscle length measurements using the electronic goniometer with the exception of iliopsoas muscle length measurements (ICC=0.45). Reliability coefficients for muscle strength measurements using the BEP-IIIa hand-held dynamometer were also very good with ICC's ranging from 0.89 to 0.99 with the exception of hip abductor strength. Hip abductor strength reliability was found to be very poor (ICC=0.03). Due to poor test-retest reliability of iliopsoas muscle length and hip abductor strength measurements, these two variables were discarded and no further analyses were conducted.

Strength and Flexibility

Multivariate analysis of variance (MANOVA) of muscle length (rectus femoris, hamstring, gastrocnemius) and strength (hip extensors, hip external rotators, knee extensors and flexors) measurements before and after intervention revealed no statistically significant interaction (p = .124) on the left side. No further analyses of these variables were conducted on the left. The same analysis (MANOVA) conducted on the right side revealed a significant time (pre-post) by group interaction (p = .001). Subsequent univariate analyses (ANOVA) revealed significant interaction effects for gastrocnemius muscle length (p = .002) and knee extensor strength (p =. 004). Analysis of simple main effects using related samples t-tests revealed that a 28.83 Nm increase in knee extensor strength in the treatment group was statistically significant (p = .001) but the 2.95 Nm increase in the control group was not significant (p = .627). Only the control group had an increase in gastrocnemius muscle length that was statistically significant (p = .028). However, it should be noted that the increase in gastrocnemius muscle length in the control group was only 4.16 degrees.

Squat

MANOVA at baseline showed no statistically significant differences between groups for knee joint angles (p = .077) and knee internal joint moments (p = .362) for the dominant leg. The 2X2 MANOVA for knee joint angles showed a statistically significant time (pre-post) by group interaction (p = 0.002). Analysis of simple main effects of time (pre/post) for each group revealed non-statistically significant changes in knee joint angles between sessions for the control (p = .720) and intervention (p = .862) groups. Simple main effects of group showed a non-statistically significant difference in knee joint angles at the 6-week follow-up (p = .065). See Figure 3 for pre-post by group effects of the knee joint angles during the squat. The MANOVA for the squat knee joint moments revealed non-statistically significant interaction (p = .123) and main effects of group (p = .641) and session (p = .264). See Figure 4 for squat knee joint moments.

Drop Jump

The between groups MANOVA revealed a statistically significant difference at baseline for peak knee joint angles (p = .034) but not for the peak knee internal moments (p = .343). Therefore, baseline kinematic values were used as covariates in the MANCOVA to analyze knee joint angles. The MANCOVA for joint angles showed no statistically significant time by group interaction (p = .353), session main effect (p = .080) and group main effect (p = .353). Please see Figure 5 for MANCOVA's joint angles results during the drop jump. The MANOVA used to analyze joint moments showed no statistically significant interaction (p = .158) or group main effect (p = .161) but a significant pre-post session main effect (p = .053) revealing that both groups improved significantly over the 6 week treatment period (Figure 6).

Discussion

We hypothesized that adolescent female soccer players participating in the short injury prevention program would demonstrate an improvement in strength and flexibility measures in muscles targeted by the intervention, and a reduction in injury predisposing factors during two functional tasks. We anticipated seeing no change in the control group of players. However, this investigation showed varied results with some findings supporting the study hypothesis and others contradicting it.

As expected, the control group had no significant changes in strength in any of the muscle groups tested. In the treatment group, the only significant change in muscle strength was an improvement in the quadriceps. We had expected improvement in the hip extensors, hip external rotators, and hamstring muscle groups because the intervention targeted these muscles somewhat in an attempt to improve landing mechanics. The quadriceps muscle group was not targeted directly, yet we found a mean improvement of 28.83 Nm after the intervention. This finding was troublesome because studies have shown that high levels of quadriceps activity especially when coupled with hamstring weakness results in more anterior tibial translation and therefore an increased risk for ACL injury (29). Female athletes often are found to be quadriceps dominant meaning that they have a tendency to selectively recruit their quadriceps over other muscle groups such as the hamstring muscles during landing and cutting activities (29-33). We would have liked to have seen a concomitant increase in hamstring strength in the treatment group but this did not occur.

We also found no significant changes in muscle length (flexibility) following intervention in the treatment group and a small (4.16°) though statistically significant increase in gastrocnemius muscle length in the control group. This finding of nonsignificant changes in muscle length was not surprising given that participants in the treatment group performed stretching 2 times per week (sometimes less if a practice was cancelled due to weather). The literature shows that for optimal muscle length changes to occur, a muscle should be held in its stretch position for 30 seconds and the stretching should be performed 5 times per week (34-35). It is possible that stretching 2 times per week was not enough to achieve changes in muscle length. Additionally, the participants performed each stretch twice, holding each stretch for 15 seconds for a total of 30 seconds. It is possible that performing the stretches this way does not have the same effect as holding one repetition for 30s. It is also possible that a short (20-25 minute) injury prevention program performed twice a week for 6 weeks was not enough to produce significant changes in muscle length and strength. Compliance was not an issue as the athletes in the injury prevention group performed the program under direct supervision of a physical therapist or physical therapist-trained coach. Some practices, however, had to be cancelled due to inclement weather so the intervention group actually received a total of 10 training sessions rather than the desired 12 training sessions over the 6 week period.

There were some reliability issues with testing of iliopsoas muscle length and hip abductor strength resulting in the removal of these measurements from further analyses. Measurement of iliopsoas length is problematic due to the difficulty in performing the test consistently and accurately (36). Although we adhered to standardized test procedures recommended for testing of iliopsoas muscle length (37), we still achieved poor test-retest reliability for this measurement. The very poor reliability associated with measurement of hip abductor strength was even more problematic as hip abductor strength is considered to be an important variable in landing performance during functional tasks. Part of the low reliability stemmed from an unanticipated small sample of participants (n=5) who actually completed a re-test of this measurement. Participants were randomly assigned a muscle to be re-tested at the completion of the session for reliability purposes. Additionally, testing hip abductors using a hand-held dynamometer presents challenges. Hand-held dynamometry testing should be performed in a gravity minimized position so we selected the prone position for testing the hip abductors. If we were to repeat this study, we would utilize straps to stabilize the dynamometer versus manual stabilization in order to remove tester strength as a variable.

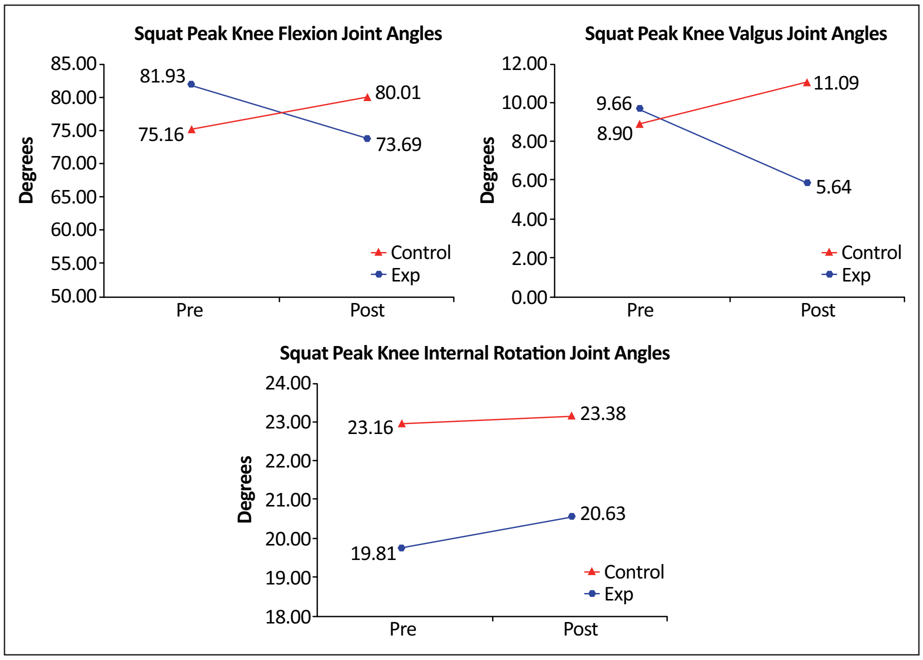

Figure 3. Peak joint angles (in degrees) during the squat task pre and post-intervention for the injury prevention group and the control group.

The results of the squat exercise were varied for peak knee joint angles and moments. Unexpectedly, the intervention group exhibited a decrease of 8° of knee flexion in the single-leg squat from baseline measures whilst the control group increased knee flexion by 5°. We do not have an explanation for this finding. We can speculate that the athletes in the experimental group chose to flex their knees less due to a possible increase in hip flexion gained by flexing the trunk forward. Consequently, they were able to squat to the same depth as the control group without an increase in knee flexion joint angles. We highly recommend analysis of hip joint kinematics in combination with knee joint angles in future studies to account for the effect of hip motion on knee alignment during dynamic tasks.

Results of peak joint valgus angles during the squat task seem to support our hypothesis. The control group exhibited an increase of 2° in peak knee valgus joint angle whereas the

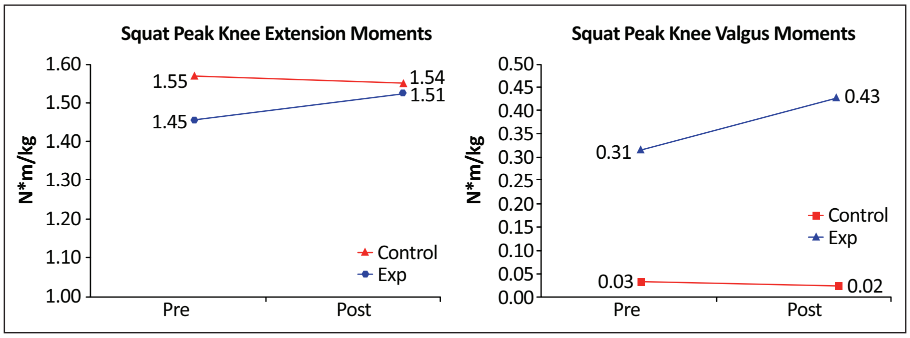

Figure 4. Peak knee joint moments (Nm/kg) during the squat task pre and post-intervention for the injury prevention group and the control group.

intervention group presented with a reduction of 4°. These data support the notion that an injury prevention program can help improve mechanics of functional activities in the frontal plane (38). Improved mechanics can be accomplished by using the hip musculature to keep the lower limbs in better frontal plane alignment (38). In addition, ability to control downward movement of the body and femoral internal rotation provides an indication of hip and knee muscle function (38). The statistically significant increase in quadriceps strength found in our intervention group supports the premise that ability to control downward movement of the body may be improved following an intervention program such as ours. Strength of hip abductors and external rotators are the main dynamic control for femoral adduction and internal rotation (39). Unfortunately, we had to discard our hip abductor strength data due to reliability issues and our data did not support an increase in hip external rotator strength in the intervention group. It is important to emphasize that the squat exercise performed in this investigation was performed in a controlled and slow manner which is unlike the forces that athletes are likely to encounter while participating in sports. The valgus stresses on the knee joint during a slow, controlled squat are minimal in comparison to real sporting maneuvers. Therefore, we recommend that this maneuver not be used to assess healthy young athletes given that it appears to possess a ceiling effect in this population.

The drop jump is a dynamic athletic task that creates high impact loads to the lower extremities (40). The success of this maneuver depends on the eccentric loading ability of several muscles of the lower extremities to prevent downward collapse of the limb (40). Contrary to our hypothesis, there were no differences in joint angles between groups during the execution of this task following the intervention. Although neuromuscular changes are expected to occur within the first few weeks of training as a response to new stimuli, both groups improved equally from baseline measures. Even though the athletes in the intervention group increased knee joint flexion by 1.48° and reduced valgus by 1.64° whilst the control group decreased their knee flexion by .41° and increased valgus by .83°, these results were not significant. Possible explanations for these findings are the following. First, the height of the step used to perform the drop jump may have been too low (33 cm.) Although the height of the box used in our study was similar to that used by other investigators studying the same population, at least one study showed that women start presenting knee injury predisposing factors when landing from heights higher than 40 cm (41). Based on findings by Huston et al. (41) in 2001, we recommend that future studies use drop jump heights of

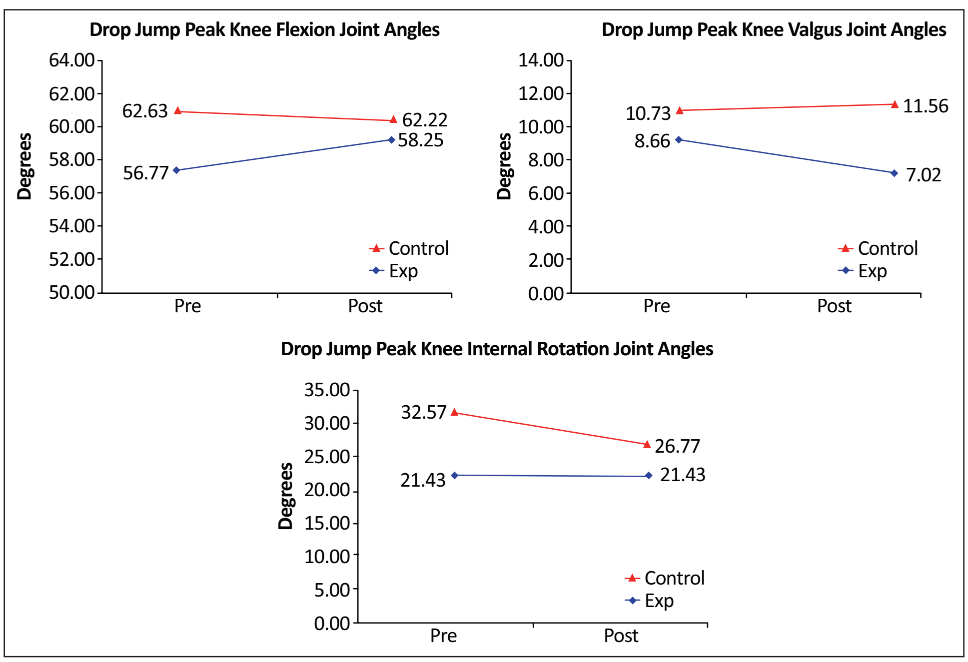

Figure 5. Peak joint angles (in degrees) during the drop jump pre and post-intervention for the injury prevention group and the control group.

no less than 40-cm to discriminate among differences pre and post intervention programs and to decrease the possibility of a ceiling effect. Another possible explanation for our results is that the differences in observed peak knee joint angles were not true changes in performance. It has been documented that the standard error of measurement for knee flexion and valgus joint angles during the drop jump for two trials is 6.5° and 2.5°, respectively (42). Therefore, the changes exhibited by the intervention group were within the measurement error for these variables. Both groups exhibited improvements in joint moments during the execution of the drop jump from baseline to 6-weeks. These changes can be attributed to a learning effect where individuals learned to control their center of mass and point of force application close to the knee joint by repeating the maneuver on the posttest.

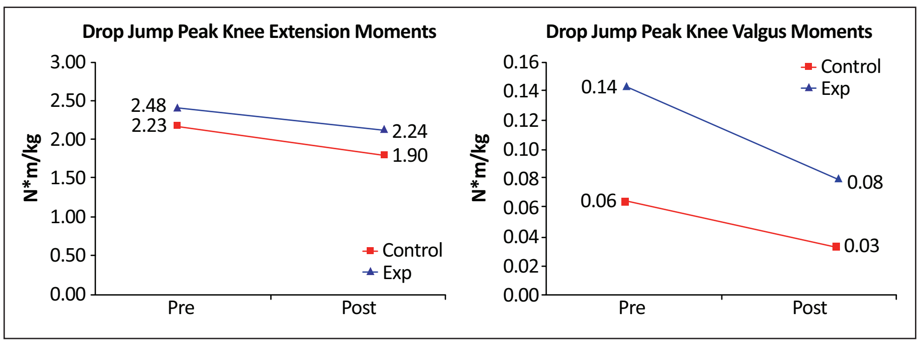

Figure 6. Peak knee joint moments (Nm/kg) during the drop jump pre and post-intervention for the injury prevention group and the control group.

Finally, we believe that the main reason that we did not see significant changes with the injury prevention program was due to the small sample size. Although we had an adequate sample size (n=30) in terms of power to assess changes in our outcomes, we did not consider that of the 30 athletes who participated in our study, probably less than half actually had the predisposing factors during the 2 functional activities. Therefore, only an estimated 6 or 7 participants at most in each treatment group had any room for improvement. That is, if the participant had good landing mechanics to begin with, how could she significantly improve on her kinematic and kinetic measures? In order to address this problem, we would have had to pre-screen athletes from many teams to identify at least 30 with poor landing mechanics. This would also have meant providing the injury prevention program to multiple teams and we did not have the manpower or funding to accomplish this.

Conclusion

The short injury prevention program used in our study did not produce significant changes in muscle length and strength with the exception of increased strength in the quadriceps muscle group. Differences in knee joint angles and moments during the drop jump and squat maneuvers between sessions and groups showed varied results with a tendency for improvement in the intervention group. We feel that repeating this study on athletes identified, as having poor landing mechanics a priori would provide valuable information.

Resumen

Trasfondo: La incidencia de lesiones de rodilla en jugadoras de fútbol es 2-6 veces mayor que en varones. Evaluar la efectividad the programas de prevención de lesiones incorporados a la práctica regular del deporte debe ser esencial. Métodos: Dos equipos de fútbol femenino (n = 30) participaron en este estudio. Un equipo sirvió como control mientras que el otro participó de un programa de prevención de lesiones por seis semanas. Fortaleza muscular, flexibilidad, cinemática tridimensional y cinética de la rodilla fueron evaluados antes y luego de la intervención durante un brinco de un cajón y una prueba de cuclillas. Un análisis de varianza multivariado de medidas repetidas (2 x 2) fue utilizado para comparar todas las variables entre grupos. Los análisis multivariados fueron seguidos de análisis univariados cuando los primeros fueron estadísticamente significativos. Resultados: El grupo experimental presentó un aumento en la fuerza del cuádriceps (p = .004) mientras que otras medidas de fortaleza y flexibilidad no cambiaron. Las pruebas cinemáticas y cinéticas de rodilla mostraron resultados combinados con una tendencia a mejorar en el grupo experimental. Conclusión: Aparentemente tanto fortaleza y flexibilidad muscular no presentan cambios con una intervención de prevención de lesiones corta. Factores biomecánicos predisponentes a lesiones mejoraron levemente, pero no alcanzaron significancia estadística. Futuras investigaciones con mayor número de participantes son necesarios para explorar dichos programas.

Acknowledgements

We would like to acknowledge Dr. Young-Hoo Kwon and his students of biomechanics for their assistance in collecting data used for motion analysis. We would also like to acknowledge Melissa Dunn and Chasity Short for their assistance in collecting muscle strength and flexibility data.

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