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Research Paper Review

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The effect of a hip-strengthening program on mechanics during running and during a single-leg squat

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ABSTRACT

Study Design: *Block randomized controlled trial.*

Objectives: *To investigate whether a strengthening and movement education program, targeting the hip abductors and hip external rotators, alters hip mechanics during running and during a single-leg squat.*

Background: *Abnormal movement patterns during running and single-leg squatting have been associated with a number of running-related injuries in females. Therapeutic interventions for these aberrant movement patterns typically include hip strengthening. While these strengthening programs have been shown to improve symptoms, it is unknown if the underlying mechanics during functional movements is altered.*

Methods: *Twenty healthy females with excessive hip adduction during running, as determined by instrumented gait analysis, were recruited. The runners were matched by age and running distance, and randomized to either a training group or a control group. The training group completed a hip strengthening and movement education program 3 times per week for 6 weeks in addition to single-leg squat training with neuromuscular reeducation consisting of mirror and verbal feedback on proper mechanics. The control group did not receive an intervention but maintained the current running distance. Using a handheld dynamometer and standard motion capture procedures, hip strength and running and single-leg squat mechanics were compared before and after the strengthening and movement education program.*

Results: *While hip abductor and external rotation strength increased significantly ($P<.005$) in the training group, there were no significant changes in hip or knee mechanics during running. However, during the single-leg squat, hip adduction, hip internal rotation, and contralateral pelvic drop all decreased significantly ($P = .006$, $P = .006$, and $P = .02$, respectively). The control group exhibited no changes in hip strength, nor in the single-leg squat or running mechanics at the conclusion of the 6-week study.*

Conclusion: *A training program that included hip strengthening and movement training specific to single-leg squatting did not alter running mechanics but did improve single-leg squat mechanics. These results suggest that hip strengthening and movement training, when not specific to running, do not alter abnormal running mechanics.*

Level Of Evidence: *Therapy, level 2b.*

ANALYSIS

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Background Information

Runners with abnormal hip and knee mechanics may be prone to several running-related injuries such as: tibial stress fractures, iliotibial band syndrome, and patellofemoral pain syndrome (PFPS). During running, PFPS is associated with excessive hip adduction, hip internal rotation, contralateral pelvic drop, knee/tibial external rotation and foot pronation. In females with PFPS, the same movement deficiencies are seen during single-leg squats, single-leg jump landings, and step-down maneuvers. This overall movement pattern is hypothesized to increase knee frontal plane loading and the dynamic quadriceps angle. This may result in lateral patellar tracking and abnormal patellofemoral joint loading. Previous studies suggest that females with PFPS may be subject to muscle weakness with hip abduction, hip external rotation, and contralateral pelvic drop (secondary to weak ipsilateral hip abductors) (1). Hip strengthening is often recommended to reduce PFPS, however it is inconclusive whether abnormal hip and knee mechanics are improved, particularly during functional activities such as running and squatting.

The purpose of this study is to examine the effect of a hip-strengthening program that included movement training for the single-leg squat on hip and knee mechanics during running and squatting in females who exhibited abnormal mechanics during running (NOTE: subjects did not have PFPS or any other musculoskeletal condition – see Study Methods below). The authors hypothesize that peak hip adduction, hip internal rotation, contralateral pelvic drop, and knee external rotation will be reduced during single-leg squats. Without neuromuscular training specific to running, a hip-strengthening program was not expected to alter hip and knee kinematics during running. No changes were hypothesized for the control group.

PERTINENT RESULTS

- Independent t tests showed no difference between training and control groups for age, weekly running distance, and body mass index, at baseline.
- Runners in the training group completed all sessions with 100% compliance and all runners in both the training and control groups complied with all running distances, activity restrictions, and post-intervention data collection.
- The training group improved peak isometric hip abduction (HABDS) and external rotation (HERS)

strength by [? SD] 3.0% ? 1.5% (BW x m) and 0.8% ? 0.4% (BW x m) respectively, while the control group remained the same. Post hoc analysis suggested the increases were significant and associated with large effect sizes.

- All running data was normally distributed, except for peak hip adduction (HADD) in the control group.
- Analysis of the running data did not produce any interactions of the peak kinematic variables and no main effects between groups for HADD, hip internal rotation (HIR), or contralateral pelvic drop (CPD). Basically, the strength training did not seem to alter running mechanics.
- Significant main effect for knee external rotation (KER) between groups was found, yet no significant main effect for peak KER was found across time, suggesting no overall intervention effect.
- All single-leg squat data were normally distributed, with the exception of peak CPD in the training group. Significant reductions after strength training were noted for peak HADD ($P = 0.043$), peak HIR ($P = 0.38$), and CPD ($P = 0.05$) during the single-leg squat from pre-training to follow-up.
- Peak HADD, HIR, and CPD reductions for the single-leg squat were associated with large effect sizes, with no significant changes for the control group.

CLINICAL APPLICATION & CONCLUSIONS

True to the authors' hypotheses, the intervention training program was effective at altering hip mechanics for the single-leg squat, however no changes in running mechanics were noted. The training group increased hip strength through resistance exercise with body weight and resistance elastic bands. Gains in strength were expected, as participants were required to abstain from lower extremity strength training for 90 days before the trial. While hip strength increased, there were no significant decreases in peak HADD, HIR, and CPD during running. However, this finding is in line with the author's hypothesis and the work of Snyder et al. (2). Due to the abnormal hip mechanics of the study participants, there was great potential for change; however, the results show that even with hip strength increases, running mechanics are not necessarily altered. Thus, strengthening alone may not be sufficient to improve hip mechanics. It is possible that the gains in hip strength may have been influenced by the neuromuscular training that was assigned to the training group to improve single-leg squatting. Noehren et al (3) completed a study where runners received neuromuscular retraining (gait retraining), which produced significant changes in hip mechanics and pain reduction at follow-up. Further study should include intervention groups that focus on neuromuscular retraining compared to strength training. For now, evidence-informed clinicians should continue to incorporate hip strengthening exercises into training and rehabilitation programs for runners.

Exercises Utilized In This Study Included:

- Week 1: Side-lying hip abduction and external rotation (2 x 10 reps, 5 second hold), hip abduction against a wall with a straight leg (2 x 10 reps, 5 second hold)
- Week 2: Resistance band clamshell (2 x 10 reps), hip abduction against a wall with a straight leg (10 second hold)
- Week 3: Bilateral squat with resistance band targeting external rotators (2 x 10 reps, 5 second hold), contralateral pelvic hike against the wall (2 x 10, 5 second hold) – targeting hip abductors
- Week 4: side-stepping with resistance band (2 x 10 reps, bilateral), single-leg squat with hand support (2 x 10 reps)
- Week 5: Standing isometric hip abduction against the wall + pelvic hike against the wall (2 x 10 reps, 5 second hold), single-leg squat without hand support (2 x 10 reps)

- Week 6: Standing isometric hip abduction against the wall + pelvic hike against the wall (2 x 10 reps, 10 second hold), single-leg squat with resistance band targeting hip abduction (2 x 10 reps)

STUDY METHODS

Participants

- Female, between ages of 18 and 35 years old.
- Currently running at least 10 km per week.
- Required to abstain from any lower extremity resistance training for at least 90 days prior to enrollment in the study.
- Free of any musculoskeletal condition or surgery that would affect running or squatting mechanics.
- 43 female runners screened to obtain the 20 runners who met study criteria of excessive peak HADD of 20 degrees.

Baseline Screening

- 35 retroreflective markers attached to lower extremities to analyze running kinematics. Anatomical marker placement was recorded via marker placement device that has been shown to increase the day-to-day reliability of kinematic data.
- Runners wore standardized neutral shoes (Nike Pegasus).
- Participants warmed-up for 5 minutes, then 5 consecutive strides were collected (3.35m/s or 8 min/mile) on an instrumental treadmill.
- Stance phase determined by establishing a threshold of 50 N of vertical ground reaction force. Hip joint centers calculated using a functional hip algorithm.
- Single-leg squat data collected by squatting to approximately 60 degrees knee flexion, maintaining rhythm of 1Hz for both ascending and descending phases. Data collected over 5 consecutive squats.
- Joint angles calculated in reference to proximal segments. Customized software used to determined peak values and means for variables of interest. Kinematic variables: peak hip adduction (HADD), peak hip internal rotation (HIR), peak contralateral pelvic drop (CPD), and peak knee external rotation (KER).
- Single-leg squat kinematic variables analyzed at 45 degrees of knee flexion (approximate angle of peak knee flexion during running).

Hip Dynamometry Procedures

- Peak isometric hip abduction (HABDS) and external rotation (HERS) strength were measured using a handheld dynamometer.
- HABDS was measured while lying on side and HERS was measured in prone with the hip neutral.
- Participants had 1 practice session, then performed 3 trials per muscle group, each with a maximal effort of 3 seconds to record peak force production (highest value used for analysis).

Strengthening Program

- Runners completed a 6-weeek, 3-times-per-week hip strengthening and movement education protocol that targeted hip abductors and external rotators.
- 6-week intervention chosen to be consistent with PFPS clinical trials.
- Exercises progressed weekly under supervision of orthopaedic physical therapist.
- Sessions were conducted on non-consecutive days to allow for adequate recovery.
- Each week, first exercise session conducted with physical therapist, subsequent 2 sessions per week conducted independently.
- Exercises were performed in 2 sets of 10 repetitions. Isometric hold times, resistance levels, and amount of external resistance was designed to cause significant fatigue by end of second set (this level of stimulus suggested to cause increase in muscle strength when applied 3 times per week for 6 weeks (4)).
- For the first 2 weeks, exercises were performed in non-weight bearing positions. Emphasis placed on contracting hip abductor and hip external rotator musculature.
- For the final 4 weeks, exercises progressed to weight-bearing positions.
- Resistance levels were chosen so participants were unable to complete full range of motion by end of second set.
- Proper lower extremity alignment emphasized. Participants received visual feedback from mirrors and verbal feedback from the physical therapist.
- During final 3 weeks, single-leg squats were added to program. Difficulty increased by decreasing external support.
- Runners in control group did not receive any intervention during the 6 week period.
- Regardless of intervention group, runners were required to maintain weekly running distance (variance of 10% permitted).

Follow-up Data Collection

- Following 6-week study duration, runners returned for follow-up strength and motion analysis.
- Data only collected on qualified limb.
- Running and squatting analysis and hip strength measures repeated as described above.
- Runners debriefed on blinded inclusion criteria at conclusion of study.

Statistical Analysis

- Power was determined using priori power analysis, effect size of 1.00. Minimum 9 runners per group required for adequate power. To account for 10% dropout rate, the authors recruited 10 runners per group.
- Mixed-model, 2-way analysis of variance (ANOVA) used.

- Strength measures and peak joint angles primary variables of interest.
- Kolmogorov-Smirnov test conducted on the difference scores to ensure normality for all variables with significant main effects.
- For normally distributed variables with significant main effects, post hoc dependent t tests were conducted and effect sizes calculated (small, 0.20, medium 0.50, large 0.80).
- Variables that were not normally distributed, the Wilcoxon signed-rank test and Glass's delta (effect size) were conducted for post hoc contrasts.
- Alpha level of $P < 0.50$ was used for comparisons.
- Data analyzed using SPSS.

STUDY STRENGTHS / WEAKNESSES

- Participants were required to abstain from lower extremity strength training for 90 days prior to the trial. If participants had been permitted to continue with their current activities until the trial, the strength gains collected at follow-up may have been reduced.
- In future studies, other measures of human performance should be used, such as muscular endurance.
- This study used only isometric strength testing, while isokinetic testing may be more valid for dynamic movements, such as running.
- Participants were all screened to be 'pain free', thus the results may not be generalizable to individuals with PFPS pain.
- Investigators collecting the kinematic and strength data were not blinded, which may have introduced bias.

Additional References

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