CORRECTING FUNCTIONAL MOVEMENT PATTERNS REDUCES FAULTY RUNNING BIOMECHANICS

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The purpose of the study was to determine if 6-weeks of correcting underlying movement patterns (stepping, squatting) would change running gait. 26 runners were screened using the Functional Movement Screen (FMS); those scoring $\leq$14/21 or having asymmetries qualified for the study. 12 runners underwent pre- and post-motion analysis of their running kinematics [peak hip adduction (HADD), hip internal rotation (HIR), knee valgus (KVAL), contralateral pelvis drop (CPD)] and performed corrective exercises based on their FMS results. FMS scores (pre 13 $\pm$ 1.2 vs post 16 $\pm$ 1.2 (p<.001) and KVAL (pre 17.5° $\pm$ 8.7° vs post 8.8° $\pm$ 9.3°, p=.05) significantly improved. HIR improved (pre 23.9°$\pm$12.5° vs post 14.5°+5.3°, p=.08). HADD and CPD did not significantly change, p>.05. Results show that correcting underlying movement patterns shows promise to train gait in runners.

INTRODUCTION: Running-related musculoskeletal injuries occur with an overall yearly incidence rate between 19.4 and 79.3% (van Gent et al., 2007). Most occur to the lower extremity with 50-75% of all running injuries classified as overuse (Taunton et al., 2002) and occurring more often in females than males (Boling et al., 2010). Faulty running biomechanics have been linked to overuse injury in runners and specifically in runners with iliotibial band syndrome (ITBS) (van der Worp et al., 2012), patellofemoral pain (Noehren, Hamill & Davis, 2013), Achilles tendon pathology (Donoghue, Harrison, Laxton & Jones, 2008), and tibial stress fractures (Milner et al., 2006). Evidence suggests that altered neuromuscular control of the hip abductors and external rotators (Ferber, Noehren, Hamill & Davis, 2010) contributes considerably to the development of knee related pathologies. Runners with ITBS display frontal and transverse plane deviations including increased hip adduction (HADD), internal rotation (HIR), and contralateral pelvis drop (CPD) at initial contact. Researchers and practitioners have advocated therapy interventions such as hip strengthening, mirrored gait retraining, and stride length and rate manipulation with inconsistent results. Snyder et al. (2009) significantly increased strength of hip abductor and external rotator muscles and decreased stance phase rearfoot eversion in a group of healthy runners using a 6-week hip strengthening program, but failed to significantly alter hip adduction or internal rotation motion. Sato and Mokha (2009) improved 5k run times in a group of 10 healthy, runners with 6 weeks of Swiss ball core training, but did not significantly change impact, breaking or propulsive forces. Runners with patellofemoral pain who underwent a 3-week hip strengthening program demonstrated increased strength, less pain, and reduced stride-to-stride knee-joint variability, but no change in peak genu valgum angle (KVAL) (Ferber, Kendall & Farr, 2011). No significant changes were produced in hip or knee running biomechanics in a group of female runners who completed a 6 week hip strengthening and movement education program consisting of mirror and verbal feedback on proper mechanics (Willy & Davis, 2013). Mirror feedback, the conscious changing of the running pattern through step rate manipulation and real time kinematic feedback has shown promise. Noehren and colleagues (2011), and Willy et al. (2012) utilized gait retraining where participants were cued to contract their gluteal musculature to produce reductions in excessive hip adduction and CPD during treadmill running. Subjects in both studies exhibited reduced peak HADD and CPD, and significant decreases in pain.

Pain and injury affect central processing of motor control and can result in movement pattern alterations (Tsao, Tucker & Hodges, 2011). Functional movement patterns are considered foundational movements such as stepping, lunging and squatting that elicit simultaneous demands of strength, reflex stabilization, mobility, and motor control. They are considered foundational for complex activity-specific movement patterns such as running and throwing. Improving functional movement patterns may change aberrant biomechanics commonly seen in runners with injury history. In a controlled case report, Mokha and colleagues (2015) demonstrated the utility of functional movement pattern training to reduce pain, vertical impact force, and peak values of HADD and rearfoot eversion on the affected side of a competitive female runner with hip pathology. The purpose of this exploratory study was to determine if a 6-week corrective exercise program aimed at improving FMS scores would change running mechanics in a group of healthy, competitive runners. HADD, HIR, KVAL and CHD during stance were the selected mechanics due to their established link to lower extremity injury in runners. We hypothesized that FMS scores would increase and peak values during stance of hip, knee and pelvis motion would decrease.

METHODS: Twenty-six adult, healthy runners who ran at least 20 miles (32.2 km) per week were recruited via flyers for an initial FMS screening. Those scoring $\leq$14/21 or having any left/right asymmetry in the FMS scores were asked to continue in the study. Twelve runners (26.4 $\pm$ 9.6 yrs, 1.75 $\pm$ 0.78 m, 64.2 $\pm$ 9.8 kg) qualified and agreed to participate in the remainder of the study. They underwent motion capture of their running biomechanics in the laboratory and received a 6-week corrective exercise program based on their FMS results. The study was approved by the university's institutional review board.

FMS

The FMS is a comprehensive screen used to identify limitations and asymmetries in 7 fundamental movement patterns. The 7 tests are the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. The protocol for administering the FMS is fully described by Cook (2010). After each test was administered, a score of 0 to 3 was awarded according to FMS criteria. A score of 3 indicated the movement was completed as instructed and was free of compensation and pain. A score of 2 indicated the subject completed the movement pain-free but with some level of compensation, while a score of 1 indicated the subject could not complete the movement as instructed. A score of 0 was assigned if the subject experienced pain during the movement, or during a clearing test designed to provoke pain and identify injury. Five of the 7 tests (hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability) are scored independently for the right and left sides of the body, allowing for asymmetries detection. Scores of $\leq$14 out of a maximum of 21, and the presence of asymmetries have been shown to predict athletic injury (Kiesel, Butler & Plisky, 2014; Mokha, Sprague & Gatens, 2016), and thus were used as inclusion criteria in this study.

Running kinematics

Pre and post running mechanics were captured using a 10 infrared camera (120 Hz) Vicon motion analysis system (Vicon Peak, Lake Forest, CA, USA) with Vicon Nexus software (version 1.7.1). Anthropometric measures were collected and retroreflective markers were placed bilaterally on the subject according the specifications of Vicon's Plug-in Gait model. The runners began both testing sessions with a warm-up consisting of general dynamic stretching and a 5 minute run on a treadmill at a self-selected pace, but approximately 6.0 mph (9.7 km/hr). Participants then ran the length of the lab's runway (15 m) at a speed of 3.8-3.9 m/s. This running speed was recorded and presented using Polygon version 4.0 and was consistent to that of the post-training trial. Data were captured so that two steps for the right leg and two steps for the left leg were viewed. Data were averaged across two usable trials for analysis. Specific variables of interest were peak hip adduction (HADD) and internal rotation (HIR), contralateral pelvis drop (CPD), and knee valgus (KVAL) during stance.

Corrective exercise program

Participants completed an individualized 6-week corrective exercise program aimed at improving movement patterns identified as dysfunctional or asymmetrical by the FMS. Exercises were done 4x/week, 2 supervised sessions with the investigators, and 2 home sessions. Exercises were adjusted when the runner was able to complete them to protocol. The protocol was guided by Functional Movement Systems.™ A sample session of corrective exercises aimed at improving the rotary stability test would be:

1. 60 sec of foam rolling of the mid and upper back

2. 2 x 5 opposite arm and leg raises in quadruped
3. 2 x 5 upper body rolling supine to prone
4. 2 x 8 chops from tall kneeling

None of the exercises directly target running mechanics. Changes in pre- and post-FMS scores and running kinematics were evaluated using dependent *t*-tests via SPSS (ver. 23), alpha=.05.

RESULTS: Table 1 presents the mean FMS scores and peak values of the running kinematics.

Table 1. Mean FMS scores and peak values of hip, pelvis and knee kinematics and after 6-weeks of corrective exercise

Variable	Pre (Mean+/- SD	Post (Mean+/- SD	*p* value
FMS (out of 21)	13.0 $\pm$ 1.2	16.0 $\pm$ 1.2	<.001*
HADD (^{0})	10.1 $\pm$ 3.1	10.9 $\pm$ 3.5	.12
HIR (^{0})	23.9 $\pm$ 12.5	14.5 $\pm$ 5.3	.08
CPD (^{0})	7.2 $\pm$ 3.1	7.0 $\pm$ 5.0	.41
KVAL (^{0})	17.5 $\pm$ 8.7	8.8 $\pm$ 9.3	.05*

Note: * denotes statistically significant difference, $p \leq .05$.

Figure 1 provides an illustration of the changes observed in running mechanics in a sample participant (photo taken during the warm-up treadmill run).

Figure 1. Right leg stance kinematics in a sample runner pre- and post-training.

DISCUSSION AND CONCLUSIONS: The purpose of this study was to determine if improving fundamental movement patterns such as squatting, lunging and stepping would have an effect on running mechanics in a group of healthy runners. The FMS was used to identify dysfunctional and asymmetrical movement patterns. The finding of increased FMS scores was expected. All participants improved and earned scores of >14 which puts them at a reduced risk for injury. Results indicate that this novel approach to training running gait was also significantly effective in reducing peak values of KVAL. HIR, although not statistically significant, was reduced by ~9 deg. All runners but two experienced reductions in KVAL and HIR; however, they were not the same two runners. HADD and CPD remained unchanged overall. Changes in CPD can affect hip segment position since CPD moves the thigh and pelvis closer medially. Participants in this study remained unchanged possibly due to the fact that the pre-test values for both HADD and CPD were not excessive (Noehren, Hamill, & Davis, 2013). Corrective exercises were implemented to move the body through previously restricted ranges of motion and restore normal neuromuscular responses. This should promote improved muscle timing and resolve the changes in motor control that have been linked to athletic injury. Exercise interventions attending to multiple segments of movement designed to influence proprioceptive response and motor planning have been shown to have efficacy in the rehabilitation of neurologically impaired individuals. Pain and injury affect central processing of motor control and can result in movement pattern alterations (Tsao,Tucker & Hodges, 2011). Thus, a pattern approach seems logical and may have greater carryover from a motor control viewpoint than simply targeting the running technique itself. However, this is unknown at this time. Functional movement patterns set the foundation for complex activity-specific movement patterns (Cook, 2010) such as running. Improving functional movement patterns appear to have positively influenced at least two known faulty running mechanics, KVAL and HIR.

We conclude that correcting underlying functional movement patterns may reduce known running pathomechanics. This novel approach may be effective in developing injury prevention programs as well as used to retrain gait in competitive runners.

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