RUNNING BIOMECHANICS IMPROVE FOLLOWING AN IN-SEASON INTERVENTION PROGRAM BASED ON PRE-TEST FUNCTIONAL MOVEMENT SCREEN SCORES IN COLLEGIATE DISTANCE RUNNERS

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The purpose of the study was to determine if 12 weeks of correcting underlying movement patterns (stepping, squatting, lunging) would change running mechanics in college distance runners. 10 runners underwent pre and post Functional Movement Screen (FMS) testing and motion analysis of running kinematics [bilateral peak hip adduction (HADD), hip internal rotation (HIR), contralateral pelvis drop (CPD), rearfoot eversion (REV), ankle dorsiflexion (AKD) and knee flexion (KFLEX)]. They performed corrective exercises 3x/week based on FMS results. FMS (pre 14 ± 1.5 vs post 16.4 ± 1.8, *p*=.001) and left KFLEX (pre 36.4º ± 11.3º vs post 42.2º ± 5.2º, *p*=.024) significantly changed. Right and left HADD, HIR, and CPD decreased indicating a trend toward improvement. Results show that correcting underlying movement patterns shows promise to reduce pathomechanics.

KEY WORDS: gait training, gait mechanics, corrective exercise

INTRODUCTION: Running-related injuries (RRI) in collegiate cross country runners in the United States have been reported at rates of 4.66 and 5.85 per 1000 athlete exposures for males (95% CI = 4.04,5.28) and females (95% CI=5.14,6.56), respectively (Kerr et al., 2016). Most RRI in runners occur to the lower extremity with 50-75% of all RRI classified as overuse and occurring more often in females than males (Kerr et al., 2016; Taunton et al., 2001). Faulty running biomechanics such as increased hip adduction (HADD), hip internal rotation (HIR), contralateral pelvis drop (CPD), and rearfoot eversion (REV) have been linked to RRI (Bramah, Preece, Gill, & Herrington, 2018; Becker, James, Wayner, Osternig, & Chou, 2017; Noehren, Hamill & Davis, 2013). Mokha and Gatens (2018) found that collegiate runners with excessive HADD (cut-point of peak HADD maximized at 9 deg) were more likely to sustain RRI. A running gait biomechanical analysis is beginning to be a fundamental component of a collegiate athlete's pre-participation physical examination (PPE) (Mokha & Gatens, 2018; Souza, 2016) so that intervention programs can be instituted to modify pathomechanics. Such intervention strategies include verbal, visual or auditory cues and feedback, cadence alteration, strength training, and/or functional movement pattern training. These methods have shown promise with injured runners, but preventative gait modification strategies are minimal. Mokha et al. (2016) used the functional movement pattern approach and significantly reduced peak knee valgus and HIR in healthy runners. Specifically, they constructed programs for each runner based upon Functional Movement Screen (FMS) scores. The FMS is qualitative screen used to rate proficiency in functional movement patterns such as stepping, lunging and squatting that elicit simultaneous demands of strength, reflex stabilization, mobility, and motor control. The patterns are considered foundational for complex activity-specific movement patterns such as running and throwing. Improving functional movement patterns may change running biomechanics related to RRI. This approach in a collegiate setting would be especially applicable where runners can be screened at PPEs, and programs instituted as part of strength and conditioning sessions and/or warm-up. Therefore, the purpose of this exploratory study was to determine if a 12-week corrective exercise program aimed at improving FMS scores would change mechanics in a group of healthy, collegiate distance runners in-season. We hypothesized that FMS scores would increase and peak values of pelvis, hip, and ankle motion would decrease, and knee motion would increase.

METHODS: Nine healthy, collegiate male (n=2) and female (n=7) cross country runners (age, 18.9 ± 1.1 yrs; height, 1.64 ± 0.09 m; mass, 56.7 ± 6.3 kg) from the same university team participated in this quasi-experimental pretest posttest study. Participants underwent a laboratory-based biomechanics gait evaluation and FMS as part of their pre-participation physical examination, and the pre-test data were extracted from this evaluation. FMS tests were conducted by Level I FMS certified professionals. A posttest evaluation was conducted after a 12-week in-season corrective exercise program by at least one of the same pre-testers for the FMS. The program was administered by the team's certified athletic trainer.

Functional Movement Screen
The FMS is a comprehensive screen used to identify limitations and asymmetries in seven fundamental patterns. The seven tests are the deep squat, hurdle step, inline 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). Each pattern is scored as a 0 (pain present), 1 (not completed as instructed), 2 (completed with compensation), or 3 (completed as instructed). Total scores of $\leq$14 out of 21, and the presence of asymmetries have been shown to predict athletic injury (Kiesel, Butler, & Plisky, 2014; Mokha, Sprague, & Gatens, 2016).

Gait Evaluation
A 10 infrared camera (120 Hz) Vicon motion analysis system (Vicon, Centennial, CO, USA) with Vicon Nexus software (version 2.8) captured running mechanics. Anthropometrics were measured and 16 (14 mm diameter) retroreflective markers were placed bilaterally on the participants according the specifications of Vicon's Plug-in Gait model. Participants wore sports bra (women), spandex shorts, and the running shoes in which they most frequently trained. Runners began the testing session with a warm-up consisting of general dynamic stretching and a 7 min run on a treadmill at a self-selected pace (3.5-4.5 m/s). Data were captured for 15 sec beginning at minute 8 and three consecutive steps were evaluated. Specific kinematic variables of interest were peak values of hip adduction (HADD) and internal rotation (HIR), contralateral pelvis drop (CPD), knee flexion (KFLEX), rearfoot eversion (REV), and ankle dorsiflexion (ADF) during stance. Values for these variables were identified in Vicon's Polygon (ver. 4.4).

Corrective Exercise Program
Participants completed a team-based 12-week corrective exercise program aimed at improving movement patterns identified as dysfunctional or asymmetrical by the FMS. It began the second week of the participants' in-season cross country schedule and was divided into 4 microcycles lasting 3-weeks each. The program was guided by Functional Movement Systems. Exercises were done 3x/wk and supervised by the team's certified athletic trainer. None of the exercises were directly targeted at running mechanics.
A sample session from the first microcycle is shown below.

1. 20 repetitions active leg lowering
2. 20 repetitions leg lock bridge
3. 20 repetitions half kneeling rotation with a dowel
4. 10 repetitions hard rolling

Changes in pre-test post-test FMS scores and running kinematics were evaluated using dependent *t*-tests via SPSS (ver. 26) with alpha = .05.

RESULTS: All participants improved their individual FMS total score; FMS significantly increased for the group from 14.0 $\pm$ 1.5 to 16.4 $\pm$ 1.8 out of 21, $t(8) = -5.5$, $p = .001$. Table 1 presents the group results from the running kinematics. Only left knee flexion significantly changed. Six runners showed $\geq$2 degree reductions bilaterally for HADD. Four of those 6 had concomitant reductions in bilateral CPD.

Figure 1 provides an illustration of the changes observed in running mechanics in a sample participant.

Table 1. Peak value lower extremity kinematics at midstance before and after 12-weeks of corrective exercise

Variable	Pre (Mean+/- SD)	Post (Mean+/- SD)	*p* value
Left HADD (^{0})	10.7 ± 4.9	9.6 ± 3.2	.423
Right HADD (^{0})	12.9 ± 3.9	11.7 ± 4.3	.147
Left HIR (^{0})	11.9 ± 24.3	6.4 ± 19.2	.263
Right HIR (^{0})	11.2 ± 10.9	7.4 ± 11.7	.473
Left CPD (^{0})	-6.0 ± 3.6	-5.6 ± 3.3	.612
Right CPD (^{0})	-5.5 ± 2.3	-4.7 ± 1.9	.255
Left KFLEX (^{0})	36.4 ± 11.3	42.2 ± 5.2	.050*
Right KFLEX (^{0})	39.0 ± 5.0	41.4 ± 7.4	.237
Left ADF (^{0})	29.1 ± 5.2	26.4 ± 4.8	.121
Right ADF (^{0})	27.4 ± 4.1	26.9 ± 2.4	.727
Left REV (^{0})	5.1 ± 5.5	4.6 ± 3.7	.614
Right REV (^{0})	6.4 ± 2.9	5.8 ± 2.8	.637

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

Figure 1. Left leg stance kinematics in a sample runner pre- and post-intervention.

DISCUSSION: The purpose of this study was to determine if improving fundamental movement patterns such as squatting, lunging and stepping would affect running mechanics in a group of healthy collegiate distance runners during their in-season. The finding of increased FMS scores was expected. Eight of 9 participants improved 1-4 points and all earned scores of >14 which reduces injury risk (Kiesel, Butler, & Plisky, 2014). The 9th participant had no change in her score of 15. The approach of correcting functional movement patterns to indirectly improve more sport specific movements, in this case running biomechanics did not yield hypothesized group results. Only peak left knee flexion during stance was significantly affected. There was a mean increase of 4.8 degrees. KFLEX angles of < 45 degrees have been associated with decreased shock absorption, increased stiffness and injury (Dierks, Manal, & Hamill, 2011; Milner, Ferber & Pollard, 2006; Souza, 2016). Both knees increased from < 40 degrees to >40 degrees indicating a positive change for the group. The increases in KLEX may explain the decreases in ADF at the post-test. While HADD did not change significantly for the group, it is notable that 6/9 runners showed >2 degree decreases (clinical minimum for meaningfulness) bilaterally. These changes may reduce the runners' risk of injury, especially for those who reduced to a peak of <9 degrees (Mokha & Gatens, 2018). Four of the 6 who experienced bilateral reductions in HADD also showed decreases in CPD. Changes in CPD can affect hip segment position since CPD moves the thigh and pelvis closer medially. Bramah et al. (2018) found that for every one degree increase in CPD, there was an 80% increase in the odds of being classified as injured. Small but clinically meaningful changes in the present study may be explained by improved neuromuscular function at the hip that occurred as a result of the corrective exercise program. The lack of statistically significant changes in the kinematics may be due to the low number of participants, pre-test values not being excessive, and/or the influence of other in-season training variables.

CONCLUSIONS: Despite the limitations of a small sample size and no control group, we conclude that an in-season program aimed at correcting underlying functional movement patterns shows promise in improving running pathomechanics, specifically, HADD, CPD and KFLEX. The pattern correcting approach may be effective in developing injury prevention programs as well as used to retrain gait in competitive runners.

REFERENCES:

Becker, J., James, S., Wayner, R., Osternig, L., & Chou, L. S. (2017). Biomechanical factors associated with Achilles tendinopathy and medial tibial stress syndrome in runners. *Amer J Sports Med, 45*(11): 2614-2621.

Bramah, C., Preece, S. J., Gill, N., & Herrington, L. (2018). Is there a pathological gait associated with common soft tissue running injuries? *Amer J Sports Med, 46*(12):3023-3031.

Cook, G. E. (2010). Movement: Functional Movement Systems. Aptos, CA: On Target Publishing.

Dierks, T. A., Manal, K.T., Hamill, J., et al. (2011).Lower extremity kinematics in runners with patellofemoral pain during a prolonged run. *Med Sci Sports Exerc*, *43*(4):693–700.

Kiesel, K.B., Butler, R.J., & Plisky, P.J. (2014). Prediction of injury by limited and asymmetrical fundamental movement patterns in American football players. *J Sport Rehabil*, *23*:88-94.

Milner, C.E., Ferber, R., Pollard, C.D., Hamill, J., & Davis, I.S. (2006). Biomechanical factors associated with tibial stress fractures in female runners. *Med Sci Sports Exerc*, *38*(2):323-328.

Mokha, M. & Gatens, D. (2018). Hip and pelvis biomechanics during running as risk factors for injury in collegiate runners: A prospective study. *J Exerc and Nutr, (1)*4.

Mokha, M., Romanes, J., Kostzer, K., Sprague, P., & Gatens, D. (2016). Correcting functional movement patterns reduces faulty running biomechanics. *International Society of Biomechanics in Sports Conferences Proceedings, 34*(1): 815-818.

Mokha, M., Sprague, P. & Gatens, D. (2016). Predicting musculoskeletal injury in National Collegiate Athletic Association Division II athletes from asymmetries and individual-test versus composite functional movement screen scores. *J Athl Train, 51*(4): 276-282.

Noehren, B., Hamill, J., & Davis, I. (2013). Prospective evidence for a hip etiology in patellofemoral pain. *Med Sci Sports Exerc, 45*(5):1120-1124.

Souza, R. B. (2016). An evidence-based videotaped running biomechanics analysis. *Phys Med Rehabil Clin N Am, 27*(1): 217-236.

Taunton, J., Ryan, M., Clement, D., Mckenzie, D., Lloyd-Smith, D., & Zumbo, B. (2002). A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med, 36*:95 -101.