Gait Biomechanics Improve in Collegiate Distance Runners Following an In-Season Intervention Based on Functional Movement Screen Scores

Original Research

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Open Access

Published: May 13, 2021

Research Directs in Health Sciences: *2021, Volume 1 (Issue 1): 5*

Abstract

Introduction: Gait retraining techniques vary with little known on how correcting underlying functional movement patterns may remediate the more specialized skill of running. Therefore, the purpose of this exploratory study was to determine if an in-season corrective exercise program aimed at improving Functional Movement Screen™ (FMS) scores would alter running biomechanics in a group of healthy distance runners.

Methods: Nine healthy NCAA Division II male (n=2) and female (n=7) cross country runners (age, 18.9 + 1.1 years; height, 1.64 + 0.09 m; mass, 56.7 + 6.3 kg) underwent a laboratory-based 3D gait evaluation and FMS as part of preparticipation physical examinations. Team-based corrective exercises were developed from the FMS pretest scores and administered 2-3x/week for 12 weeks. FMS total scores, bilateral pelvis, hip, knee and ankle stance kinematics during running were compared before and after the corrective exercise program using paired samples t-tests, $p \leq 0.05$.

Results: FMS (pre 14 ±1.5 vs post 16.4 ± 1.8, p=.001) and left KFLEX (pre 36.4o ± 11.3 vs post 42.2 ± 5.2, p=.024) significantly changed. There were no significant changes in bilateral pelvis, hip or ankle stance kinematics.

Conclusions: Correcting underlying functional movement patterns shows promise in improving faulty running mechanics in healthy distance runners.

Key Words: gait training, running pathomechanics, distance running

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Introduction

Running-related injuries (RRI) occur with an annual incidence rate between 19.4 and 79.3% and are a major barrier to participation.[1,2] Rates vary depending on the type of runners studied. Specific to participants in the current study, the National Collegiate Athletic Association's (NCAA) Injury Surveillance Program captured 216 and 260 injuries from the men's and women's cross-country between the 2009-2010 and 2013-2014 academic years. This accounted for injury rates of 4.66 and 5.85 per 1000 athlete exposures for men's and women's cross-country, respectively. Most RRI occur to the lower extremity[4] with 50-75% of all RRI classified as overuse[5] and occurring more often in females than males.[6]

Faulty running biomechanics including increased hip adduction (HADD), hip internal rotation (HIR), contralateral pelvis drop (CPD), and rearfoot eversion (REV) during the stance phase of running have been linked to RRI and specifically in runners with iliotibial band syndrome,[7] patellofemoral pain,[8] Achilles tendon pathology,[9] and tibial stress fractures.[10] Mokha and Gatens[11] found that collegiate distance runners with excessive HADD (> 9 deg) were more likely to sustain RRI. Thus, gait retraining has gained popularity as an intervention to alter faculty mechanics and reduce tissue loads while still maintaining level of activity.[12] Gait retraining strategies have included 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 and colleauges[13] used the functional movement pattern approach and significantly reduced peak knee valgus and HIR in a group of healthy recreational runners. Specifically, they constructed individualized corrective exercise programs based upon runners' Functional Movement Screen™ (FMS) scores. The FMS is 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. Clinicians using the FMS infer that there may be a greater likelihood of similar deficits with higher level tasks (e.g. running) either causing or contributing to dysfunction.[14] A running gait biomechanical analysis is becoming a fundamental component of a collegiate runner's pre-participation physical examination (PPE).[11,15] Improving functional movement patterns may influence running biomechanics related to RRI. This approach in a collegiate setting would be especially applicable where runners can be screened at PPEs, and team-based programs instituted as part of strength and conditioning sessions and/or session preparation work. Therefore, the purpose of this exploratory study was to determine if a 12-week corrective exercise program aimed at improving runners' FMS scores would change biomechanics in a group of healthy, collegiate distance runners.

Scientific Methods

Participants

Nine healthy, collegiate male (n=2) and female (n=7) cross country runners (age, 18.9 $\pm$ 1.1 yrs; height, 1.64 $\pm$ 0.09 m; mass, 56.7 $\pm$ 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 PPE. A posttest evaluation was conducted after a 12-week in-season corrective exercise program. Subjects were excluded from the gait evaluation if they had a musculoskeletal injury including orthopedic surgery, within the past 30 days. The corrective exercise program was administered by the team's certified athletic trainer (AT) who is also Level I credentialed with the FMS. All participants provided informed consent, and the study was approved by the Institutional Review Board at Nova Southeastern University.

Protocol

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 ½" retroreflective markers were placed bilaterally on the participants according the specifications of Vicon's Plug-in Gait model. The subjects wore sports bra (women), spandex shorts, and running shoes. 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 10 sec beginning at minute 8 and three consecutive steps for each limb 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.

FMS. FMS Level I certified members with at least 5 years of experience served as FMS testers. The FMS is a comprehensive screen used to identify limitations and asymmetries in seven fundamental patterns. The 7 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.[16] In brief, 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/or the presence of asymmetries have been shown to predict athletic injury.[17,18] Pre-test movement patterns that were dysfunctional (score of 1) or asymmetrical in $\geq$50% of the runners were targeted for team-based correction.

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 in $\geq$50% of the runners during the pre-test. The movement patterns identified were the trunk stability push-up, inline lunge, hurdle step and deep squat. The program began the second week of the participants' in-season cross country schedule and was divided into

4 mesoocycles each lasting 3 weeks. The program was guided by Functional Movement Systems™ database where exercise prescriptions to improve each movement pattern are provided. Exercises were completed three times per week and were instructed and supervised by the team's certified AT. None of the exercises directly targeted running mechanics. See Table 1 for sample corrective exercises included in each mesocycle.

Table 1. Sample corrective exercises for each 3-week mesocycle.

Mesocycle 1	Mesocycle 2	Mesocycle 3	Mesocycle 4
Active Leg Lowering, Single x 20	Advance Straight Leg Bridge x 20	Hip Hinge Single Leg with Dowel x 15	Active Leg Lowering, Double x 20
Leg Lock Bridge x 20	Heel Walking, Unsupported 20 yds	Bridge March x 20	Airplane Walks with Hop x 20
Half Kneeling Rotation with Dowel x 20	Toe Walking, Unsupported 20 yds	Bird Dog x 10	4-point Hip Extension and External Rotation x 15
Hard Rolling x 10	Side Plank from Feet with Hip Abduction and Chair Support x 20	Plank Twist with Leg x 20	Plank Diagonals x 20
	Standing Single Leg Hip Flexion (3 sec hold) 20 yds	Transverse Hops One, Two Hold x 15	Soft Rolling x 10

Statistical Analysis

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

Pre-test FMS results guided the corrective exercise program. Patterns with dysfunctional or asymmetry in $\geq$50% of the runners were the trunk stability push-up, inline lunge, hurdle step and deep squat. Eight of 9 participants improved FMS total scores; FMS significantly increased from 14.0 ± 1.5 to 16.4 ± 1.8 out of 21, $t(8) = -5.5$, $p = .001$. The trunk stability push-up, inline lunge, hurdle step and deep squat all improved (indicated by no score of 1 and/or no asymmetry). Table 2 presents the running kinematics data. Only left KFLEX significantly changed by flexing more in the post-test. Bilateral CPD, HADD, HIR and left ADF were reduced for the group, but not significantly.

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

Table 2. Peak value lower extremity stance kinematics before and after 12 weeks of corrective exercise.

	Pre (N = 9)	Post (N = 9)	*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

Data are Means ± SD

*Significantly greater left KFLEX after corrective exercises, $p = 0.05$.

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 biomechanics 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 may reduce injury risk.[17] The 9th participant had no change in their 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 less than 45 degrees have been associated with decreased shock absorption, increased stiffness and injury.[10,15,19] Both knee angles increased from less than 40 degrees to greater than 40 degrees leading to a better ability to absorb shock and protect against RRI.

HADD did not change significantly for the group. The pre-test mean values of approximately 11 and 10 degrees for the left and right legs, respectively are relatively low. The large standard deviations indicate that individual runners may have excessive HADD. Six of 9 runners showed greater than 2 degree decreases bilaterally. These changes may reduce the runners' risk of injury, especially for individuals who reduced to a peak of less than 9 degrees.[11] Four of the 6 who experienced bilateral reductions in HADD had concomitant decreases in CPD. Changes in CPD can affect hip segment position since CPD moves the thigh and pelvis closer medially. Bramah et al.[20] found that for every 1 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 may have resulted from the corrective exercise program.[14] Improved neuromuscular function at the hip may have also influenced the bilateral decreases in HIR. Although not statistically significant, individual runners may benefit from the reductions in HIR. ADF and REV were not notably altered, and both pre- and post-ankle values were within normal limits (@25 deg for ADK; @10 deg for REV)[21] indicating adequate ankle mobility.

This study is not without limitations. First, the lack of a control group introduces skepticism of the results. Secondly, this study was undertaken collaboratively with the university's sports team, 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. Results may not be generalizable to recreational or older runners. However, any positive changes in running kinematics demonstrated in these runners may be influenced by improvements in fundamental movement patterns.

Conclusions

Movement quality was evident during post-tests, implying improved movement control that may have manifested in better running biomechanics. An in-season program aimed at correcting underlying functional movement patterns shows promise in improving the biomechanics of more complex movements like competitive running. Clinicians and researchers may consider utilizing functional movement pattern and gait assessment for runners.

Acknowledgements

The authors would like to acknowledge the help of Audrey Curtis BS who assisted with the 3D running gait data collection.

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