BIOMECHANICS AND MOVEMENT PATTERN DEFICITS IN RUNNERS ON THE SAME UNIVERSITY TEAM: IMPLICATIONS FOR PREVENTATIVE SPORT HEALTHCARE

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We sought to describe running kinematics and movement patterns in a university cross country team with relevance to injury prevention. During pre-participation physical examinations, 27 runners underwent Functional Movement Screen™ (FMS) and motion analysis of running kinematics [bilateral knee flexion (KFLEX) and ankle dorsiflexion (ADF) at initial contact, and hip adduction (HADD), contralateral pelvis drop (CPD), KFLEX, rearfoot eversion (REV), and ADF at midstance]. Results of HADD (Left 10.5 ± 3.8^0, Right 11.2 ± 5.2^0), CPD (Left -7.1 ± 2.8^0, Right -6.0 ± 2.1^0) and REV (Right 4.4 ± 3.9^0, Left 5.0 ± 4.0^0) at midstance and FMS (13.7 ± 2.4) indicate the need for team based corrective exercises. Sport healthcare providers in team settings may benefit from these analyses.

KEY WORDS: running-related injuries, gait mechanics, motion capture

INTRODUCTION: Sport healthcare providers such as athletic trainers and sports physiotherapists in team based settings conduct functional testing at the time of pre-participation physical examinations (PPE) to identify injury risk. Results are used to design and implement team-based corrective exercise or injury prevention programs. This process is different than care provided to an individual athlete or patient once they become injured; and from intervention studies where recreationally active participants are provided a home program. A running gait biomechanical analysis is beginning to be a fundamental component of a university runner's PPE (Mokha & Gatens, 2018; Souza, 2016) so that intervention programs can be instituted to modify faculty mechanics. Running-related injuries (RRI) in university 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 university competitive runners with excessive HADD (cut-point of peak HADD maximized at 9°) were more likely to sustain RRI. Running requires balance, stability, muscular strength and limb symmetry (Dimundo, Saunders, Turner & Linton). 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. Results can be used to design specific corrective exercises for runners that may minimize injury (Loudon, Parkerson-Mitchell, Hildebrand, & Teague, 2014). Total scores of ≤14 out of 21, and the presence of asymmetries have been shown to increase injury risk (Kiesel, Butler, & Plisky, 2014; Mokha, Sprague, & Gatens, 2016). Sport healthcare providers in university settings are uniquely positioned to address corrective strategies when biomechanical and movement pattern deficits are known. Therefore, the purpose of this study was to describe the running kinematics and movement patterns in a university cross country team with emphasis on variables linked to RRI. Based on previous team analysis at this same university, we hypothesized that most runners would show need for corrective strategies for core control as indicated by excessive CPD and HADD during midstance and low FMS scores.

METHODS: 27 male (n=10) and female (n=17) distance runners (age, 18 - 23 yrs; height, 1.82 ± 0.57 m; mass, 58.4 ± 6.8 kg) from the same university team participated in this descriptive study. Participants underwent a laboratory-based biomechanics gait evaluation and FMS as part of their pre-participation physical examination. FMS tests were conducted by Level I FMS certified professionals.

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 increase athletic injury risk (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 2.12) captured running mechanics. Anthropometrics were measured and 16 (14 mm diameter) retroreflective markers were placed bilaterally on the participants according to 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 6 min run on a treadmill at a self-selected pace (2.5-4.3 m/s). Data were captured for 10 sec beginning at minute 7 and five consecutive steps were evaluated. Specific kinematic variables of interest were right and left knee flexion (KFLEX) and ankle dorsiflexion (AKD) angles at initial contact, and right and left hip adduction (HADD), contralateral pelvis drop (CPD), KFLEX, rearfoot eversion (REV), and ADF angles at midstance. Values for these variables were identified for each of the five steps in Vicon's Polygon (ver. 4.4) and then averaged per participant.

Analysis: Data were extracted to an Excel file and Statistics Package for Social Sciences (ver. 27; IBM Corporation, New York, NY, USA) calculated the descriptive statistics for the group. Where appropriate, running kinematic averages were interpreted relative to previously published research identifying RRI (Bramah, Preece, Gill, & Herrington, 2018; Mokha & Gatens, 2018; Noehren, Hamill & Davis, 2013; Souza, 2016).

RESULTS: Table 1 presents the mean values for all runners for right and left KFLEX and ADF at initial contact. Interlimb differences appear negligible with both angles less than 1°.

Table 1. Lower Extremity Running Kinematics at Initial Contact, N=27.

Variable	Left limb Mean ± SD	Right limb Mean ± SD
Knee flexion (°)	13.7 ± 5.4	14.5 ± 5.6
Ankle dorsiflexion (^{0})	3.4 ± 5.8	3.5 ± 6.0

Table 2 shows the mean values for all runners for right and left CPD, HADD, KFLEX, ADF, and REV at midstance. Interlimb differences appear negligible with all angles less than or equal to 1.1°.

Table 2. Lower Extremity Running Kinematics at Midstance, N=27.

Variable	Left limb Mean ± SD	Right limb Mean ± SD
Contralateral pelvis drop (°)	-7.1 ± 2.8	-6.0 ± 2.1
Hip adduction (°)	10.5 ± 3.8	11.2 ± 5.2
Knee flexion (°)	39.1 ± 6.3	40.1 ± 7.3
Ankle dorsiflexion (°)	24.1 ± 5.7	24.1 ± 4.5
Rearfoot eversion (°)	4.4 ± 3.9	5.0 ± 4.0

Table 3 shows the individual test and total test scores and symmetry frequency for the FMS. Scores of 2 indicate acceptable movement pattern proficiency, meaning the pattern was accomplished, but with a compensation. Results show the group was proficient in the deep squat, hurdle step, inline lunge and shoulder mobility tests. Scores of 1 indicate movement pattern dysfunction, meaning the movement pattern was not accomplished according to test criteria. The trunk stability push-up and the rotary stability tests for the group were below acceptable. One participant had a 0 in the shoulder mobility pattern, and another participant had a 0 in the rotary stability test. Of note is eight of 27 runners (30%) had asymmetries in the hurdle step.

Table 3. Functional Movement Screen Scores, N=27.

FMS Test	Score Mean ± SD	Asymmetries #, %
Deep squat	2.0 ± 0.6	NA
Hurdle step	2.0 ± 0.4	8, 30
Inline lunge	2.2 ± 0.7	1, 3
Shoulder mobility	2.4 ± 0.8	2, 7
Active straight leg raise	2.1 ± 0.8	3, 11
Trunk stability push-up	1.9 ± 0.9	NA
Rotary stability	1.3 ± 0.5	3, 11
Total FMS Scores	13.7 ± 2.4	NA

Note: NA denotes not applicable

DISCUSSION: The purpose of this study was to describe the running kinematics and functional movement patterns of a university team of cross country runners. Results will be useful for sport healthcare providers who create corrective exercise or injury prevention programs for athletes based on functional testing. Results of this study may be limited to university teams in the United States categorized as Division II by the National Collegiate Athletic Association. Nonetheless, this study is the first known by the authors that presents functional gait and movement pattern results measured during pre-participation physical examinations for a university team. Findings of interest regarding increased injury risk include low FMS, and excessive CPD and HADD. REV may be an additional concern and will be expanded upon. Total FMS scores $\leq$ 14 and/or the presence of asymmetries have been shown to increase injury risk (Kiesel, Butler, & Plisky, 2014; Mokha, Sprague, & Gatens, 2016). The rotary stability test is especially low with over 50% of the runners scoring a 1 which indicates a dysfunctional pattern. The trunk stability push-up is also low for the group. Both tests incorporate significant core stability and control, with the rotary stability being especially relevant with anti-rotation ability. Given the torques created at the trunk during running and the importance of muscular balance and core stability to preventing injury in runners (Fredericson & Moore, 2004), corrective exercises for this pattern are recommended. CPD was greater than 6° in 70% of runners, and HADD was greater than 9^0 in 63% of runners. Bramah et al. (2018) studied the differences in kinematics of injured runners versus injury-free controls and found that for every 1° of CPD there was an 80% increase in the odds of being classified as an injured runner. Mokha & Gatens (2018) found in a group of runners like those in this study, university team distance runners that 9° was the cut-point in HADD for determining injury risk. The Bramah et al. (2018) study reported health controls had > 9° of HADD and injured had a mean of 13°. Perhaps the larger values are reflective of the participants who were older, heavier and ran less kilometers per week than the university team participants. University team runners may be more sensitive to smaller deviations in HADD given their training load compared to recreational runners. Our REV values may put our runners at increased injury risk as they are congruent with injured runners in Bramah and colleagues (2018) study. However, they are much less than Becker and colleagues (2017) and Noehren and colleagues (2013) who both reported close to 10°. Thus, we interpret REV with caution.

CONCLUSIONS: Team-based functional evaluations of running gait and movement patterns are informative. Sport healthcare providers in university NCAA Division II settings may expect to construct corrective exercise programs to target excessive CPD and HADD during running and dysfunctional rotary stability and trunk stability movement patterns.

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