ANKLE JOINT COMPLEX KINEMATIC AND KINETIC ADAPTATION DURING THIRTY-MINUTES OF TREADMILL RUNNING: A CASE STUDY

Sydni Wilhoite, Li Li, Jessica Mutchler, and Barry Munkasy

Georgia Southern University, Statesboro, USA

The purpose of this study was to assess kinematic and kinetic adaptation during a 30 min run. It was hypothesized that kinematics and kinetics would adapt at different rates. A recreationally trained runner with approximately 10 years of running experience was recruited for the study. Three dimensional kinematic and kinetic variables were assessed during a 30 minute run. All measures exhibited varied adaptation trends with most measures not stabilizing during the exercise period. A longer running period may be needed in running gait analysis to produce a more comprehensive adaptation profile.

KEYWORDS: running biomechanics, footwear, ankle kinematics, overuse injuries

INTRODUCTION: Although running provides many physical benefits, it is also known to be associated with a high injury rate. During a training year, 80% of runners will experience at least one musculoskeletal injury in response to their training regimen (Sinclair, Richards & Shore, 2015). Overuse injuries such as Achilles tendon pathologies, medial tibia stress, and stress fractures generally occur when an anatomical structure is exposed to a large number of repetitive forces with inadequate recovery (Hreljac, Marshall & Hume, 2000). Biomechanical measures commonly used to investigate overuse injuries include rear foot kinematics and kinetic variables such as ground reaction forces (GRF).
The magnitude and rate of foot pronation has been suggested to be a contributing factor to overuse running injuries (Hreljac et al., 2000). Kinetic variables such as impact, loading, and active GRF forces have been commonly assessed. Hreljac, Marshall, and Hume (2000) reported that active forces may serve as discriminators between groups of injured and uninjured runners. Although these biomechanical measures are commonly utilized, investigating rear foot kinematics and GRF characteristics does not explain overuse injuries. For example, the main function of the Achilles' tendon is to transfer forces experienced by the gastrocnemius and soleus muscles to the calcaneus. Over time, excessive loading of the tendon can cause collagenous materials degradation and increase a runner's injury risk (Sinclair et al., 2015). Although GRF characteristics are helpful for inferring forces applied to the tendon, examination of moments and power allow for a more comprehensive understanding of how the muscles are controlling these impactful loads (Sinclair et al., 2015). To assess characteristic joint kinematics and kinetics during running, adequate time is needed to achieve stabilization. Previously it was thought that kinematics stabilize within 3 - 8 minutes of treadmill running, while force and loading rate stabilize within 2 minutes of running (White, Gilchrist & Christina, 2002). Conversely, Moore and Dixon (2014) reported kinematic stabilization occurs within 11 - 20 minutes of running. Therefore, a lack of consensus exists for the adequate time needed to achieve stabilized gait. Investigation of the time course to stabilized gait will provide a better basis for understanding running overuse injury. Therefore, the purpose of this study was to assess the adaptation time required to achieve stabilized kinematic and kinetic gait data during a 30 minutes run.

METHODS: One male recreational runner (45 years; 70 inches; 79.1 kg) was recruited for this study. The participant attended one 1.5 hour laboratory session. Prior to data collection, a health screening, informed consent, and other relevant data (i.e. age, height, body mass, segment length, and years of experience) were collected. The participant was aged between 18 - 45 years of age, had no existing injuries at test time, and answered "No" to all PAR-Q questions.

For each session, retro-reflective marker cluster sets were placed on the participant's pelvis, right and left lateral thighs, right and left lateral shanks, and right and left lateral heels. The participant performed a 10 minute walk/run warm-up on the instrumented treadmill in his habitual running shoes to become accustom to the treadmill and placement of tracking clusters. Following the warm up, 16 retro-reflective anatomical markers were placed on the left and right iliac crests, greater trochanters, lateral and medial femoral epicondyles, lateral and medial malleoli, and the first and fifth metatarsal heads (Weinhandl, Joshi, & OConnor, 2010). A 5 s standing static trial was recorded and then the anatomical markers were removed. The participant was instructed to run at a self-selected pace for 30 minutes on an instrumented treadmill (AMTI, Newton, USA) in Hoka maximalist shoes (Hoka One One; Goleta, CA) provided by the lab. Marker and GRF data were collected for 10 s at 5-min intervals starting at 1 min. Marker trajectories were tracked using a 3-D motion capture system (Bonita 10 cameras; Nexus 2.3.0.88202; Vicon Motion Systems Ltd., Oxford, UK).
Three-dimensional ankle joint kinematics and kinetics were assessed for every stride in each of the 10 s of data collected for minutes 1/6/11/16/21/26/31. Visual 3D (Visual 3D, Version: 6.00.27, C-Motion Inc., Germantown, MD) was used for analysis of joint angle, angular velocity, joint moment, and joint power. Trend analysis was utilized to classify how outcome variables changed with time. Linear, quadratic, and cubic trends were assessed. Higher ordered trends were recognized only if differences between R^2–values were significant.

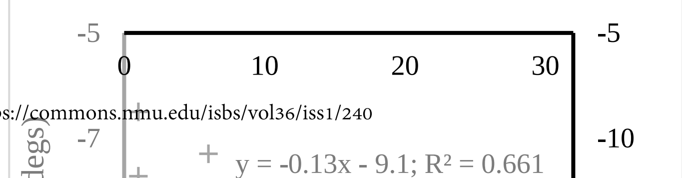
RESULTS: Various trend types were exhibited (Table 1). A strong linear relationship was observed for rear foot eversion angle (R^2=.661). Strong quadratic trends were observed in both ankle abduction (R^2=.519) and adduction (R^2=.645). There was a strong linear trend observed in the rear foot inversion moment (R^2=.588). Power generation (R^2=.355) and absorption (R^2=.372) presented similar quadratic trends.

Table 1: R^2 Values for Linear, Cubic, and Quadratic Trends for Angle, Angular Velocity, Moment, and Ankle Power.

		Linear	Quadratic	Cubic
Angle	DF	**0.4501**	0.4556	0.4704
	RE	**0.6614**	0.7088	0.7088
	RI	0.0166	**0.1797**	0.1839
	ABD	0.2235	**0.5186**	0.5281
Velocity	DF	**0.4794**	0.5412	0.5450
	RE	**0.2429**	0.2430	0.2575
	RI	**0.1568**	0.1593	0.2109
	ABD	**0.1159**	0.1633	0.2312
Moment	DF	0.2930	**0.4306**	0.4806
	RE	**0.4448**	0.4450	0.4613
	RI	**0.5875**	0.5880	0.6639
	ABD	0.0383	0.1495	**0.3836**
Power	Gen	0.0553	**0.3554**	0.4168
	Absorb	0.0528	**0.3722**	0.4369

Note: DF= dorsiflexion, PF= plantar flexion, RE=rear foot eversion, RI= rear foot inversion, ABD= abduction, ADD= adduction, Gen= generation, Absorb= absorption, bold= power trend accepted

Each metric assessed is visually presented in Figure 1a-d. For angle (Figure 1a), a strong linear relationship was found for rear foot eversion while a weak quadratic one was found for plantar flexion angle. Similarly, a strong linear relationship was found for inversion moment and a weak quadratic relationship for plantar flexion moment was found (Figure 1b). No strong trends were exhibited for velocity (Figure 1c) or power (Figure 1d) metrics.



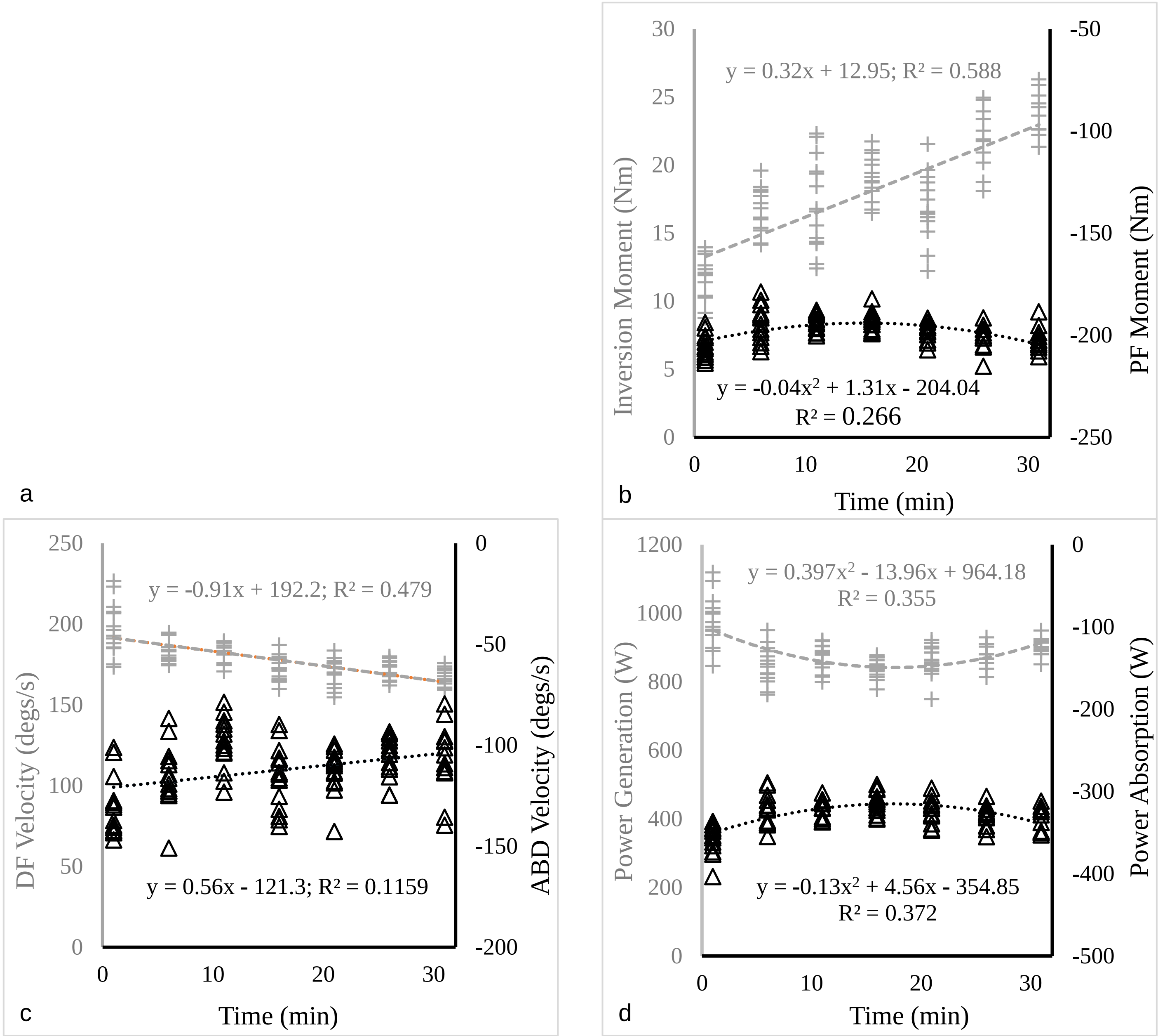


Figure 1a-d: Linear and Quadratic Trends for Angle (a), Moment (b), Angular Velocity (c), and Power (d) between Different Plane Motions. Note: DF=dorsiflexion, PF=plantarflexion, ABD=abduction.

DISCUSSION: The aim of the study was to assess the adaptation time required to achieve stabilized kinematic and kinetic gait during a 30 minute run. Results indicated that the kinematics and kinetics of running adapt differently. For a majority of the angular kinematics examined adaptation followed either a linear or quadratic trend. Representative trends were exhibited in the frontal and transverse planes for rear foot eversion, abduction, and adduction. The linear trend observed for rear foot eversion suggests that the angular kinematics never stabilized over the 30 minute run. The runner continued to demonstrate an increase in rear foot eversion angle over time. Increased rear foot eversion may lead to a higher prevalence of lateral ankle sprains (Beynnon, Renstrom, Alosa, Baumhauer & Vacek, 2001) because ankle everters become fatigued and are unable to resist inversion (Lentell et al., 1995). Representative quadratic relationships suggest that there is an angular kinematic change in abduction and adduction in the middle of the run, but then a return to the initial movement pattern.

Angular velocity followed mostly linear relationships; however, no significant trends were observed. Ankle moments in each motion plane primarily followed a linear or quadratic trend. The positive linear trend exhibited suggests a continual increase in inversion moment during a prolonged run. This result is expected because the eversion angle increased over time. It has been suggested that inversion moments occur in response to errors of medial foot placement (Friel, McLean, Myers & Caceres, 2006).Power generation and absorption both followed quadratic trends. However, neither was representative and therefore suggest no change over time.
The continuous changes in eversion angles and inversion moments could be due to fatigue; however, the participant was an experienced runner who normally ran longer than 30 minutes for his training regimen. The participant's foot type was not recorded, and could potentially provide reason for the increases in eversion angles observed. It is important to note that a larger sample size could influence the results of the study.

CONCLUSION

For ankle joint complex motion, there were at least one kinematic or kinetic measure that exhibited a trend suggesting that a stabile adaptation did not occur within 30 minutes of running. The results from this study suggest that some kinematic and kinetic variables continue to change throughout a 30 minute run. Therefore, the measures that do stabilize may not adequately represent ankle joint complex motion. It may be necessary to assess various ankle joint complex kinematic and kinetic measures during a run longer than 30 minutes in order to allow adaptation to stable running gait. This information may be useful when biomechanics researchers are consulting with physicians and shoe designers. It is imperative to accurately analyse stable gait to provide physicians and the shoe industry with appropriate information concerning injury risk and optimal performance.

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