HERMDAA COMPARISON OF CADENCE AND CENTER OF MASS DISPLACEMENT BETWEEN HEALTHY AND RECENTLY INJURED RECREATIONAL RUNNERS

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The purpose of this study was to compare running cadence and the vertical center of mass (CoM) displacement between healthy and recently injured runners. An existing database was queried for recreational runners injured within the prior six weeks with limitation to their running participation (N=32) who were then matched with healthy runners (N=64). Cadence, CoM displacement, and lower extremity joint excursion assessed with 3D videography at self-selected speed were compared between groups using analyses of variance. CoM displacement was significantly reduced in recently injured runners (8.26±1.25cm vs 8.94±1.17cm, p=0.01); no other differences were found. Findings suggest an adaptation to reduce joint forces due to pain rather than a risk factor for injury; as such, this finding be relevant to injury prevention and rehabilitation.

KEY WORDS: cadence, gait, running

INTRODUCTION: Recreational running is an extremely popular sport with millions of participants worldwide. Several studies have demonstrated that runners experience high rates of musculoskeletal injury with incidence rates of lower extremity injuries of up to 80% in some studies (van Gent et al., 2007). Recent investigations have indicated that running cadence may be an easily identified biomechanical marker for injury risk, as low cadence rates have been associated with increased patellofemoral joint contact forces and ground reaction forces during running as well as reduced biomechanical and metabolic efficiency (Chumanov & Heiderscheit, 2013; Morin, Samozino, Zameziati, & Belli, 2007; Farley & Gonzalez, 1996; Herman, 2014). As such, cadence alteration may have clinical application as a modifiable risk factor for injury that can be taught to runners with relative ease. Alteration of cadence can affect the center of mass (CoM) displacement during the gait cycle, as faster cadences reduce the CoM displacement (Herman, 2014).

Despite these associations with reduced efficiency and increased forces experienced during running, no studies have prospectively investigated cadence as a risk factor for injury, nor compared cadence between injured and uninjured populations. The aim of this study was to compare running cadence, CoM displacement and other lower extremity biomechanical characteristics between healthy and recently injured recreational runners. We hypothesized that compared to healthy recreational runners, injured recreational runners would demonstrate lower cadence rates, increased CoM displacement, and increased joint excursion during stance phase while running at a self-selected speed.

METHODS: This was a secondary analysis from data obtained of larger cross sectional study of runners. This study and its procedures were approved by the University of Florida Institutional Review Board and it complies with the guidelines of Declaration of Helsinki for the treatment of human subjects.

A total of 96 recreational runners were included in this analysis and split in a healthy (n=64) and injured (n=32) runners Healthy runners reported no injuries within the preceding six months causing a decrease in weekly running mileage, whereas injured runners reported at least one injury within the preceding six weeks causing a decrease in weekly running mileage. Further inclusion criteria were: between 18-75 years of age; currently running at least 12 km/week; willing and able to run on a treadmill for 20 minutes at a self-selected pace. The exclusion criteria were: free of symptomatic cardiovascular disease; current use of medications that affect balance; any neurodegenerative disorders that precluded understanding of the details in the study protocol. Demographic data were collected, as well as information on their running experience and weekly running distance. Pain and functional status were assessed via the Short Form-12 Pain and Physical Function Subscores as well as the Lower Extremity Functional Scale (LEFS).

All participants wore non-reflective, tight fitting clothing and their typical running shoes. The study team applied 33 retro-reflective markers to anatomical landmarks and body segments. (lateral and medial metatarsals, lateral and medial malleoli, heel, tibial tuberosity, thigh, medial and lateral femoral condyles, anterior and posterior superior iliac spines, scapular offset, acromion processes, lateral elbow, wrist, triceps and forearm). After a static calibration trial was collected, the participant began the treadmill protocol. After a five minute warm-up period of jogging, participants were asked to run at a self-selected speed that would be used on a typical long run. Participants ran on the treadmill for ten minutes at this self-selected speed. Motion was sampled for 10 seconds at the end of the 10 minute trial. Kinematic data were determined from marker data using standard rigid body mechanics equations implemented within commercially available software (Visual3D, C-motion, Inc.). Kinematic data were collected using a high speed 12 camera optical motion analysis system (EGL-500RT, Motion Analysis Corp, Santa Rosa, CA, USA) that captured images at a rate of 200 Hz. The range of motion (ROM; minimum and maximum excursion) of the lower extremity joints was determined in the sagittal plane during the stance phase of gait.

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS, v. 21). Descriptive measures and frequencies were compared at baseline between the two groups. Analyses of variance (alpha = 0.05) were performed with dependent variables being the kinematic measures (cadence, CoM displacement, joint ROM).

RESULTS: Demographic data are listed in Table 1. Of note, the injured runners demonstrated significantly lower (worse) LEFS Total Scores and lower (worse) SF-12 Pain Subscores. Although injured runners had a lower weekly running distance (approximately 75% that of the uninjured runners), this did not reach statistical significance.

Table 1

Subject Demographics. Means and standard deviation (SD) are shown.

	Uninjured		Injured		
	Mean	SD	Mean	SD	P value
1. Age	36.6	9.4	37.2	10	0.781
2. Height (cm)	171.7	8.7	171.8	10.2	0.972
3. Mass (kg)	68.9	12.5	69.9	14.7	0.736
4. Body Mass Index (kg/m^2)	23.2	2.6	23.5	3	0.636
5. Running Experience (yrs)	11.4	9.8	11.2	10.4	0.901
6. Weekly Running Distance (miles)	20.7	9.7	16.6	10.1	0.060
7. Self Selected Speed (miles per hour)	6.8	4.8	6.6	5.5	0.306
8. SF12 Pain Subscore (points)	98	8.1	89.5	20.2	0.004*
9. SF12 Physical Function Subscore (points)	99.6	3.2	97.6	9.9	0.137
10. LEFS Total Score (points)	1990.6	22.9	1893.5	115.3	< 0.000*

Kinematic data are listed in Table 2. Injured runners demonstrated a lower magnitude CoM displacement, but no significant differences were observed in cadence or joint excursion.

Table 2

Kinematic Data.

	Uninjured		Injured		
	Mean	SD	Mean	SD	P value
Cadence (Steps per minute)	168.3	9.1	170.1	9.8	0.389
Center of Mass Displacement (cm)	8.9	1.2	8.3	1.3	0.011*
Left Ankle ROM (°)	49.2	5.9	48.2	8.2	0.515
Right Ankle ROM(°)	48.9	6	48.4	7.8	0.744
Left Knee ROM(°)	84.4	10.7	81.2	10.9	0.174
Right Knee ROM(°)	84.4	10.3	80.8	11.2	0.124
Left Hip ROM(°)	55.6	6.7	54.9	5.5	0.609
Right Hip ROM(°)	54.3	6.1	53.8	5.7	0.702
Pelvis ROM(°)	8.4	2.1	8.2	2.6	0.649

ROM= range of motion during one gait cycle.

DISCUSSION: The comparison of running kinematics between uninjured and injured runners revealed a lower CoM displacement in the injured group; however, this sole significant finding was in the opposite direction as hypothesized. As such, the study hypothesis is rejected.

The study hypothesis was developed around previous work which demonstrated a greater CoM displacement, increased patellofemoral contact forces and ground reaction forces, and decreased biomechanical and metabolic efficiency with decreasing cadence. The premise of this study was an extension of these findings in that low cadence may increase the risk of injury. However, the findings of these previous studies may also help provide insight as to the mechanism for the unanticipated finding of a decreased CoM displacement in the injured group in the present analysis. Potentially, as these runners were recovering from an injury, runners adopted a form that reduced the forces acting at the lower extremity joints to limit any concomitant pain. The result would be less vertical excursion of the CoM which would reduce pain associated with impact and eccentric loading during weight acceptance in early stance phase. Similar adaptations in CoM displacement have been observed in runners after running to exhaustion, runners tested soon after completing an ultramarathon, and in ultramarathon runners after undergoing a muscle biopsy procedure to the vastus lateralis muscle (Morin, Samozino, Fasson, Geyssant, & Millet, 2009; Morin, Samozino, & Millet, 2011; Morin, Tomazin, Edouard, & Millet, 2011; Dutto & Smith 2002; Millet et al., 2012)

The mechanism by which the injured runners achieved this potential change is unclear. Any restrictions in joint excursion in the sagittal plane were likely small and/or distributed among the different joints. In previous studies, reductions in the CoM displacement appear to have been mediated by increases in cadence. While not significant, cadence was very marginally higher in the injured runners in this study; furthermore, a recent study by this group noted moderate (0.4) correlation between cadence and CoM displacement (Herman, 2014). As such, it is possible that the pain and functional differences between the injured and uninjured groups in this study were insufficient to drive a need for larger CoM displacement adaptations and more notable differences in cadence. It is also noteworthy that, while not statistically significant, the injured runners demonstrated a marginally lower self-selected speed than the uninjured runners. If a standard speed was employed, it is possible that an influence from cadence could become more evident.

While the original question of the influence of these factors on injury risk remains unanswered, the results may provide clinical relevance with application to the rehabilitation of injured athletic populations. Dampening CoM displacement may be a cue that rehabilitation specialists and other professionals can use to facilitate participation in sporting activities to maintain cardiopulmonary fitness during rehabilitation. This cue can be used for helping patients recover from acute injury or cope with chronic conditions such as osteoarthritis. The mechanisms underlying CoM displacement for each population requires further investigation, with other future variables of interest, potentially including stride length, stride angle, and kinetic variables. Further studies using more powerful designs such as prospective cohort and randomize control trials are also needed to determine the influence of these factors on injury risk and injury prevention.

CONCLUSION: Recreational runners with a recent injury that limited running participation demonstrated lower CoM displacements during running at a self-selected speed than healthy controls. This difference may represent a post-injury adaptation intended to decrease pain during running. Such adaptations may be used by health care professionals as a cue to help reduce pain and increase participation in injured athletes. However, the mechanisms by which this is achieved in different populations, and how variation of the CoM displacement modifies injury risk require further investigation.

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