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Flexibility, muscle strength and running biomechanical adaptations in older runners

Reginaldo K. Fukuchi [a,c,*], Darren J. Stefanyshyn [b], Lisa Stirling [b], Marcos Duarte [c], Reed Ferber [a]

[a] Running Injury Clinic, Faculty of Kinesiology, University of Calgary, Canada
[b] Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Canada
[c] Biomedical Engineering, Federal University of ABC, Santo André, Brazil

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ABSTRACT

Background: The increased injury risk in older runners has been associated with alterations in muscle strength, flexibility, and gait biomechanics. This study investigated whether older runners exhibit changes in muscle strength, flexibility and running biomechanics compared to younger runners, and possible relationships between these changes.

Methods: Thirty-five young (20–36 yrs) and 35 older (55–71 yrs) recreational runners participated in the study. Measures of three-dimensional biomechanical data during treadmill running at 2.7 m/s and measures of muscle strength and flexibility were compared between groups. A correlation analysis between biomechanical and clinical variables was also performed.

Findings: Older runners demonstrated an overall reduction in muscle strength and flexibility, and altered running patterns compared to young runners but correlations between clinical and biomechanical variables were scarce. Reduced hip, ankle and trunk excursions along with reduced knee and ankle positive work were found in older runners. Older runners also exhibited increased knee abduction impulse, ankle abduction impulse and vertical loading rates. In contrast, older runners did not present a distal-to-proximal lower extremity joint moment redistribution.

Interpretation: We observed age-related reduced strength and flexibility concomitant with alterations in running biomechanics, but a lack of correlation between these variables. This finding hampers the use of single, or even a subset of characteristics to better understand age-related changes in runners. The observed changes are complex and multivariate in nature. Clinicians will most likely have to monitor both clinical and biomechanical characteristics to optimize care. However, future studies need to prospectively address what are biomechanical age-related risk factors in runners.

1. Introduction

Over the last decade, a substantial increase in the number of older runners has been observed (Jokl et al., 2004). However, an increased number of running-related injuries among older runners have also been reported (Fields, 2011). The increased injury rate may be partly explained by the changes in musculoskeletal function such as loss in muscle strength (Faulkner et al., 2007) and joint mobility (Nonaka et al., 2002) and also partly explained by the changes in running patterns associated with aging (Bus, 2003; Fukuchi and Duarte, 2008). Although the underlying mechanisms remain unknown, previous studies suggest that age-related changes during walking are caused by musculoskeletal function degeneration (McGibbon, 2003).

Age-related biomechanical alterations during walking have been strongly suggested as a consequence of reduced muscle strength observed in older individuals (McGibbon, 2003). However, the association between reduced muscle force output and changes in kinetics during running in older runners has not been well investigated and has, to-date, been limited to the sagittal plane of the ankle and knee joints (Karamanidis and Arampatzis, 2005). One could hypothesize that reduced muscle force output would result in an overall reduced joint work during running.

Loss of range of motion (ROM) with aging (Scott et al., 2007) has been associated with sagittal plane gait changes such as reduced knee and ankle joint angle excursion in older runners (Bus, 2003; Karamanidis and Arampatzis, 2005). However this association has not been consistently observed in the secondary plane of motion. For example, Lilley et al. (2011) reported increased peak knee internal rotation and ankle eversion whereas these findings were not present with other studies (Bus, 2003; Fukuchi and Duarte, 2008). The conflicting literature may be partly explained by a high level of inter-subject variability in secondary plane kinematic data, possibly due to the small

* Corresponding author at: Running Injury Clinic, Faculty of Kinesiology, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada.
E-mail addresses: r.fukuchi@ucalgary.ca, regifukuchi@gmail.com (R.K. Fukuchi).
URL: http://www.runninginjuryclinic.com/ (R.K. Fukuchi).

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sample sizes used in these studies. In addition, these previous studies assumed that flexibility is reduced in older runners but did not measure these variables of interest (Bus, 2003; Fukuchi and Duarte, 2008; Karamanidis and Arampatzis, 2005). In light of the limited description of the secondary plane kinematics and the fact that they are linked to running injuries, a description of the lower extremity joint kinematics, along with measures of flexibility in older runners is necessary to determine whether modifiable risk factors can be identified.

Another observed change in the older adults' walking is the joint moment redistribution across lower extremity joints. Specifically, a higher hip joint moment has been reported to possibly compensate for the reduced moments generated by distal joints to produce the same overall support moment (DeVita and Hortobagyi, 2000). However, this distal-to-proximal shift in the moment distribution across the lower extremity joints has only been documented in walking. It is unknown whether this adaptation is also present or amplified during running to help explain the disparate injury occurrence in older runners compared to their younger counterparts, presumably due to increased loading in proximal joints. Previous studies have limited their research to include only running biomechanics of the knee and ankle joints (Fukuchi and Duarte, 2008; Karamanidis and Arampatzis, 2005). It has been shown that trunk movement patterns are influenced by lower extremity joint moments during walking (Nott et al., 2010). Therefore, one can postulate that trunk kinematics would also be affected if a change in the distribution of joint moments occurs during running in older adults. To our knowledge, no study has measured trunk kinematics in older runners.

In summary, considering that muscle weakness and reduced muscle flexibility have been commonly associated with atypical walking biomechanics in older adults, it is likely that a connection between these factors may also be found in running. Despite the evidence suggesting that older runners are more prone to injuries, there is limited understanding on the association between clinical (flexibility and strength) and running biomechanical factors in this population. Therefore, the aim of this study was to investigate differences in muscle strength, flexibility and running gait biomechanical patterns, in a representative sample of young and older runners. We hypothesize that older individuals would exhibit (1) a distal-to-proximal shift in the lower extremity joint moments similarly to walking studies, as measured via angular impulse, to maintain (2) the same overall support moment. In addition, older runners would demonstrate a (3) reduced joint angle excursions concomitant with an (4) overall reduced joint flexibility and a (5) reduced muscle force output compared to their younger counterparts. In addition, we also hypothesize that these biomechanical and clinical variables would be correlated.

2. Methods

2.1. Participants

Thirty-five younger recreational runners (21 males and 14 females) and 35 older runners (22 males and 13 females) were examined in this study. Participants were recruited from local races and posted flyers. Prior to their participation, each subject signed an informed consent form. The demographic information of both groups of subjects can be found in Table 1. Each participant had to meet the following inclusion criteria: be injury free in the last 3 months; have a weekly running distance of 10–20 km; be familiar with treadmill running (e.g. include treadmill running into their weekly training). In addition, participants were excluded if they presented one or more of the following: lower extremity injury or surgery within the last 3 and 8 months, respectively; head injury or vestibular disorder within the last 6 months. The sample size was determined based on a priori statistical power analysis on the ankle abduction angle at heel strike (Fukuchi and Duarte, 2008). Considering a within-group SD of 3° and expected difference between groups of 2°, a minimum of 34 subjects in each group was required to adequately power the study ($\alpha = 0.05, \beta = 0.8$).

Table 1
Mean (SD) subject demographics information of the young and older groups.

	Young	Older	*P*-value
Demographics			
Age (years)	28.9 (4.7)	60.2 (4.2)	<0.01[a]
Mass (kg)	67.9 (11.5)	68.4 (11.0)	0.87
Height (cm)	171.7 (8.8)	171.1 (9.6)	0.77
BMI (kg/cm^2)	22.9 (2.4)	23.2 (1.8)	0.54
Weekly training (hours)	3.5 (1.9)	3.2 (0.8)	0.49

[a] Indicates significant differences between groups.

2.2. Muscle strength and flexibility measurements

The right leg was used as the test extremity for muscle strength and flexibility measures. Maximal voluntary isometric contraction (MVIC) testing was performed on the following muscle groups: hip abductors (HABDS), hip extensors (HEXTS), knee extensors (KEXTS), ankle plantar-flexors (APFS) and hip external rotators (HERS). Muscle force was measured using a hand-held dynamometer (HHD) (range:0–1330 N; accuracy: $\pm$1%; resolution: 1 N; Nicholas MMT, Lafayette Instruments, Lafayette, USA) and non-elastic adjustable straps. The straps were anchored to the testing bed and the subjects performed each test by pushing into the dynamometer and against the strap. Hence, it was expected that this procedure removed any potential for tester strength or experience to influence the assessment. In all strength measures, the participants were asked to maximally push against the dynamometer by moving the joint toward the instructed direction for 5 s. One practice trial and three experimental trials were performed, with 15 s of rest in between. The mean force (N) of the three MVIC trials was then normalized as a percentage of body weight (%BW).

The hip abductors strength and hip external rotators strength were tested similarly to Snyder et al. (2009). The hip extensors strength test was performed with the subject lying in prone with the right knee in 90° of flexion. The knee extensors strength was tested similarly to Reese (2012) with the participants in a seated position with their hips and knees in 90° of flexion.

Joint (ROM) measures were taken by using either a universal goniometer or a digital inclinometer (Pro 360 digital; SmartTool Technology, Inc., Oklahoma City, OK, USA). The hip adduction ROM and hip extension ROM were tested similarly to those described and illustrated by Ferber et al. (2010). Hip external rotation ROM and hip internal rotation ROM were assessed while the subjects were seated with their hips and knees at 90° while the tester passively moved the lower leg towards the desired direction (Norkin and White, 2003). Ankle dorsiflexion ROM was assessed similarly to Johanson et al. (2008) with the knee both extended and flexed at 90° to better isolate gastrocnemius and soleus muscle flexibility. The hip flexion ROM was measured through a straight leg raise test. The participant's hip was passively moved into flexion while keeping the knee in full extension. An inclinometer was then placed in the anterior aspect of the thigh to quantify the available ROM. A detailed description and illustration of the MVIC and flexibility measures are provided as a supplementary online document (Appendix A). Intra-class correlation coefficient (ICC 2,1) was calculated to determine intra-tester reliability for flexibility and strength measures for five volunteers prior to the commencement of the study.

2.3. Biomechanical measures

Biomechanical data were collected using an eight-camera system (MX3, Vicon Motion Systems, Oxford, UK). A combination of anatomical and technical markers was used as illustrated in Fig. 1. This kinematic gait model has displayed good reliability and a detailed description of the model can be found in a previous study (Pohl et al., 2010).