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# BIOMECHANICAL RUNNING GAIT ADAPTATIONS IN OLDER RUNNERS

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## INTRODUCTION

Changes in locomotion biomechanics have been associated with muscle weakness and increased joint stiffness during biological ageing. To counteract these negative effects on the musculoskeletal (MSK) system, older adults have increased their participation in physical activity programs, particularly recreational long distance running. Unfortunately, a concomitant increase in the incidence of MSK injuries has been reported primarily related to changes in gait biomechanics [1,5]. Nevertheless, there is limited understanding about the effects of ageing on lower extremity (hip, knee and ankle joints) running biomechanical movement patterns [1]. Therefore, the aim of this study was to conduct a three-dimensional (3D) running gait analysis in young and older runners. We hypothesized that older individuals would have an overall decrease in joint kinematic values, as well as an increased knee frontal plane joint moment and an ankle-to-hip moment shift during running compared to younger runners.

## METHODS

Twenty-four older runners (16 males and 8 females; age: 60±3 years; BMI: 23.8±1.3 kg/m$^2$) and 24 young adult runners (13 males and 11 females; age: 28±5 years; BMI: 23.1±2.5 kg/m$^2$) were examined in this study. The height, weight, BMI and training hours per week were similar between groups (p=0.64, p=0.36, p=0.23 and p=0.87, respectively). The inclusion criteria required that the participants were injury free and running at least three times per week, with a total weekly mileage between 10 and 30km. Prior to their participation, each subject signed an informed consent form.

Kinematic data were collected using rigid clusters of retro-reflective markers attached on the pelvis, thigh, shank and foot of the right leg. Individual markers were also placed on bony anatomical landmarks to define the segmental co-ordinate systems during the standing calibration trial. After the calibration trial, the anatomical markers were removed and the participants ran on a treadmill at 2.7 ms$^{-1}$. Eight Vicon cameras (Vicon, Oxford, UK) collected 3D marker co-ordinates at 200 Hz and an instrumented treadmill (Bertec, Columbus, OH) recorded the ground reaction force (GRF) data at 1000 Hz. The kinematic and GRF data were filtered using a fourth order low-pass Butterworth filter at 10 Hz and 50 Hz cutoff frequencies, respectively. Data for 30 complete footfalls were collected following a three-minute run, allowing for familiarization with the treadmill. The participants wore standard running shoes (Nike Air Pegasus, Nike Inc, USA).

3D hip, knee and ankle joint angles were calculated using cardan angles with the distal segment expressed relative to the proximal segment. An inverse dynamics approach was used to compute the net, internal joint moments during stance phase. Visual 3D software (C-motion Inc, Germantown, MD) was used to perform all kinematic and kinetic calculations.

A total of 36 kinematic and 35 kinetic variables from the stance phase were extracted for further analysis. These variables have been suggested as being age-related discriminatory variables [1,2]. The kinematic variables included joint angle at initial contact (IC), peak joint angle, angular excursion (max-min value) and time to the peak angle (% of stance). The IC angle of the foot with respect to the laboratory coordinate system was also quantified. In addition, the kinetic variables of peak hip, knee and ankle internal joint moments and powers were computed. Furthermore, the peak GRF in the antero-posterior ($GRF_{a\text{-}p}$), medio-lateral ($GRF_{m\text{-}l}$) and vertical directions ($GRF_{vert}$) were extracted. Independent t-tests ($\alpha$=0.05) were conducted for between group comparison. Discrete variable extraction and statistical analysis were undertaken in Matlab 7.1 (Mathworks Inc, Natick, MA).

## RESULTS AND DISCUSSION

Compared to younger runners, older runners exhibited reduced hip joint frontal plane (7.5±2.8º vs. 10.0±2.4º; p<0.01) and ankle joint sagittal plane (35.5±3.8º vs. 39.0±3.8º; p<0.01) excursion (Figure 1). In addition, peak hip adduction occurred later in stance (42.8±21.3% vs. 32.7±5.7%; p=0.03) for the older runners. Previous research [2] has also reported reduced angular displacement of the ankle joint in the sagittal plane in older individuals. Although hip frontal plane gait biomechanics has been widely related to running injuries, to our knowledge, this is the first study that investigates this parameter in older individuals during running. The observed reduction in hip and ankle joint mobility is likely due to increased joint stiffness and muscle tightness that occur with ageing.

The older runners also exhibited a decreased knee extension moment (1.3±0.4Nmkg$^{-1}$ vs. 1.6±0.3Nmkg$^{-1}$; p=0.04) (Figure 2) and peak ankle power (9.6±1.7Wkg$^{-1}$ vs. 11.5±2.2 Wkg$^{-1}$; p<0.01) compared to the younger runners (Figure 1).

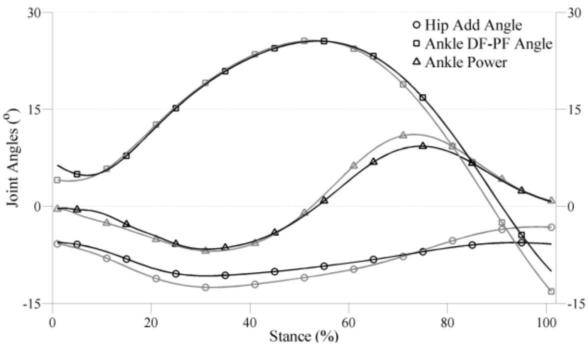


**Figure 1**: Mean hip adduction angle, ankle DF-PF angle and ankle power during stance phase of running for young (gray) and older (black) runners.

Previous studies have shown an age-related ankle-to-hip moment shift during walking with the distal joints being the most influenced by ageing [3]. However, contrary to our expectations, there were no differences for either the hip joint moment or power between groups. Therefore, it is reasonable to speculate that older runners presented different strategies to redistribute the torques across their lower extremity joints during running as opposed to walking. Further research on this topic is warranted.

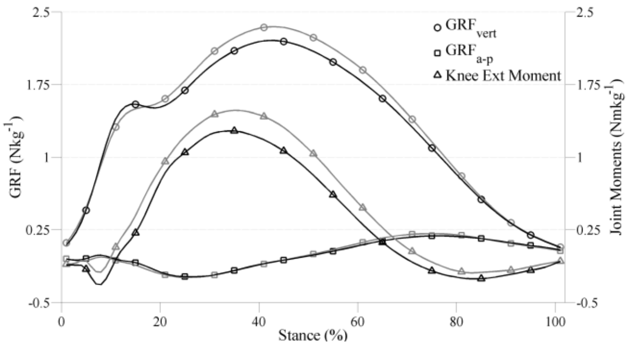


**Figure 2**: Mean $GRF_{a-p}$, $GRF_{vert}$ and knee extensor moment for young (gray) and older (black) runners.

The older runners showed an increased peak knee abduction moment ($0.82\pm0.30Nmkg^{-1}$ vs. $0.60\pm0.20Nmkg^{-1}$; $p<0.01$) compared to the younger runners (Figure 3). Previous studies have also reported this finding [4], which highlights a potential increase in medial compartment knee joint loading among older individuals during running. Therefore, we speculate that older runners are at a higher risk of either developing osteoarthritis or accelerating the progression of an existing condition unless protective measures such as improved muscle strength and flexibility are undertaken. Future studies can help answer this question.

A reduced ankle inversion moment was measured in the older runners compared to younger runners ($0.23\pm0.12$ $Nmkg^{-1}$ vs. $0.41\pm0.19Nmkg^{-1}$; $p<0.01$) (Figure 3). This result may be partly explained by the location of the center of pressure (COP) relative to the ankle joint center. The increased knee moment and reduced ankle moment in the frontal plane of older runners suggests that the COP was located closer to the ankle joint, thus decreasing the lever arm within the ankle joint. This proposed mechanism should be further explored in future studies.

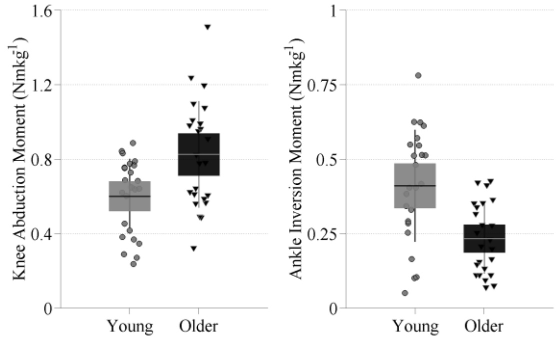


**Figure 3**: Distribution of the peak knee and ankle moments in the frontal plane for young (gray circles) and older runners (black triangles).

The peak vertical GRF was reduced in the older group ($2.2\pm0.2N.kg^{-1}$ vs. $2.4\pm0.2N.kg^{-1}$; $p=0.03$) compared to the younger group during the propulsion phase of running (Figure 2). This pattern has been previously observed and may be explained by the reduction in overall muscle strength associated with ageing [2,5]. In addition, the older runners exhibited a reduced peak $GRF_{a-p}$ ($0.19\pm0.03N.kg^{-1}$ vs. $0.21\pm0.03N.kg^{-1}$; $p<0.01$) that occurred later in stance ($76.3\pm2.0\%$ vs. $74.7\pm2.5\%$; $p=0.02$) compared to the younger runners (Figure 2). These results were likely due to the loss of lower extremity strength and contraction velocity also associated with biological ageing. This finding is in agreement with the smaller ankle joint power described in this study and previous research [2,5].

## CONCLUSIONS

The purpose of the current study was to investigate potential gait adaptations during running in older individuals. This is the first study to comprehensively investigate these adaptations during running gait. Overall, the results were in agreement with previous walking studies suggesting that these adaptations are similar or even amplified in some instances during running. The knee and ankle joints appear to be the most affected by biological ageing. Future work is required to determine whether these gait adaptations develop for safety (decrease injury risk) or economic reasons and whether therapeutic exercise can alter or minimize these changes.

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