Biomechanical approach in facilitating long-distance walking of healthy elderly people

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KEY MESSAGES

1. Regular walking gives tremendous health benefits to elderly people.
2. Gait analysis has been used to evaluate effectiveness of assistive devices on gait of people with neuro-musculoskeletal disorders, but seldom to facilitate long distance walking of healthy elderly people.
3. Our comprehensive gait analysis has revealed biomechanical reasons for lack of walking among elderly people.
4. Changing the forces applied to the lower limbs during walking using modified insoles addresses the biomechanical problem and shows signs of improving ability to walk long distances.

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Introduction

Elderly persons who walk more have lower mortality rate, cognitive decline, and risk of fall. Lack of motivation could be the reason for the sedentary lifestyle. Nonetheless, lack of motivation alone cannot explain the physical inactivity of most people.[1]

Biomechanical factors could play a role in maintaining regular walking. Ageing is associated with significant reduction of muscle strength,[2] which could impair gait. Discomfort and pain at the plantar (bottom) surface of the foot could be another factor. Elderly people usually have lower shock absorption ability of the soft tissue at the plantar foot,[3] and are more susceptible to foot pain upon repeated loading at the feet.

Gait analysis could aid in understanding the cause of difficulty in walking. Taking an additional step in modifying the force systems applied to the lower-limb by use of external devices offer the chance of facilitating long-distance walking. Traditionally, orthopaedic insoles are used to treat patients with foot pain and muscle imbalance caused by muscle and bone related diseases. Little attempt has been made to facilitate long-distance walking of elderly people.

This study aims (1) to identify the changes in gait patterns among healthy adults over long-distance walking, (2) to investigate if modification of shoe inserts facilitates long distance walk of the elderly, and (3) to evaluate the performance in managing different terrains with the use of the new shoe inserts.

Methods

This study was approved by the university's Human Subject Ethic Sub-committee, and informed consent was obtained from all participants. Gait analysis was conducted over-ground along a straight 8-m walkway. An eight-camera motion capture system was synchronised with two force platforms embedded midway on the walkway. Ground reaction forces in the vertical and anterior directions, walking speed, cadence, stance time, step length, angles, moments and powers of the ankle, knee and hip joints were analysed using commercial Visual 3D™(C-Motion, Germantown, US).

Subjects were required to provide a score (allowing decimals in any numbers) based on a Borg CR10 scale (Fig 1), a valid measure to assess fatigue and tiredness after physical activity in older adults,[4] to reveal the degree of perceived exertion. Subjects were also asked to rate their level of lower limbs pain and fatigue as well as walk stability by marking on a 10-cm line in the visual analogue scale (Fig 1).

We recruited 28 subjects aged ≥65 years who were living in a community-based setting and capable of ambulation without any walking aids. They had no cardiovascular or pulmonary diseases, cancer, uncontrolled hypertension, history of fall in the past year, diabetes, lower-limb pain, or deformities that affect walking.

The 28 subjects walked on a treadmill without holding the handrails at self-selected speeds for two consecutive walking sessions of 30 minutes each. Gait analysis and subjective assessments were conducted (1) before the treadmill walking, (2) after

Marks	Exertion scale
0	Nothing at all
0.5	Extremely light
1	Very light
2	Light
3	Moderate
4	Somewhat strong
5	Strong
6	
7	Very strong
8	
9	
10	Extremely strong

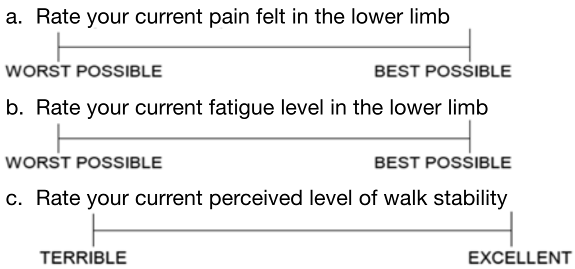

FIG 1. Borg's CR10 scale (upper) and Visual Analogue Scale (lower) assessing perceived level of exertion, pain, fatigue and walk stability

the 1st 30-minute session, and 3) after the 2nd 30-minute session. An additional yes/no question was asked to each subject at the end of the 1st 30 minutes of treadmill walking: "Does this level of exertion normally cause you to stop and take a rest?". Subjects who answered with "No" were assigned to group A. Subjects with a "Yes" answer were assigned to group B.

The 15 elderly subjects (11 males and 4 females) who responded "Yes" participated in an additional trial with the use of orthopaedic insoles. The insoles were incorporated with two features: (1) 5-mm-thick full-length silicone gel insoles and (2) 20-mm Ethylene Vinyl Acetate heel lifts. The full-length insole and the heel lift were adhered together and inserted in a standard running shoe after removing the original shoe insoles.

Each subject participated in two walking sessions, wearing the same types of running shoes. The two sessions were conducted on separate days. The subjects wore the prescribed insoles on both feet in one walking session. On the other walking session, the subjects wore the original insoles provided by the running shoe. The order of the two walking sessions for each subject was randomised.

The 15 subjects were asked to walk upslope, downslope, upstairs, downstairs, and along a circle under four conditions: with and without the use of the prescribed insoles as well as before and after 60 minutes of treadmill walking. In addition to the level of perceived fatigue and pain, subject marked on visual analogue scale to indicate perceived level of walk stability.

All statistical analysis (two-way mixed-design ANOVA and Bonferroni-adjust post hoc tests) was conducted using SPSS (Windows version 20; IBM Corp, Armonk [NY], US).

Results

Four subjects dropped out. Fourteen subjects (9 males and 5 females) were allocated to group A, with a mean age of 69.5 years (SD, 5.0), height of 162.2 cm (SD, 8.2), mass of 62.9 Kg (SD, 9.1). Ten subjects (7 males and 3 females) were allocated to group B with a mean age of 70 y (SD 5.0), height of 162.5 cm (SD 6.8), and mass of 60.3 Kg (SD, 11.9).

The mean score in the Borg scale in group B was significantly increased (higher perceived exertion) from 1.5 (SD 1.0) at baseline to 3.6 (SD 0.8) and 4.2 (SD 0.9) after 30 minutes ($P=0.038$) and 60 minutes ($P<0.001$) of walking, respectively. Although the Borg score in Group A increased from 0.94 (SD 0.8) at baseline to 1.1 (SD 0.8) and 1.4 (SD 1.1) after 30 minutes and 60 minutes of walking, respectively, the differences were not statistically significant. Similar results were found in fatigue and pain scores, with only Group B reporting significantly increased levels of pain and fatigue after 30 minutes and 60 minutes of walking. No significant differences in age, height, mass and basal Borg score were found between Groups A and B.

Most significant changes in measured parameters across the three time-points along the long-distance walk occurred in group B only. Compared to the baseline, dominant sided step length and swing time of group B increased significantly after both walking sessions ($P<0.001$), while in the opposite side the two parameters decreased significantly ($P=0.015$). On the contrary, stance time decreased significantly in the dominant side and increased significantly in the opposite side after both walking sessions ($P<0.001$).

After 60 minutes of walking, Group B had significant reductions in the dominant-side (1) plantar flexion angle at about 10% of the gait ($P<0.001$), (2) dorsiflexion angle at about 50% of the gait ($P<0.001$), (3) plantar flexor power absorption (~10% of the gait) ($P>0.01$), (4) plantar flexion angle at about 60% of the gait ($P=0.003$), plantar flexion moment ($P=0.043$) and the concentric plantar flexor power generation ($P=0.033$) (~ 50% of the gait), after the treadmill walking (Fig 2).

All 15 subjects completed the two walking

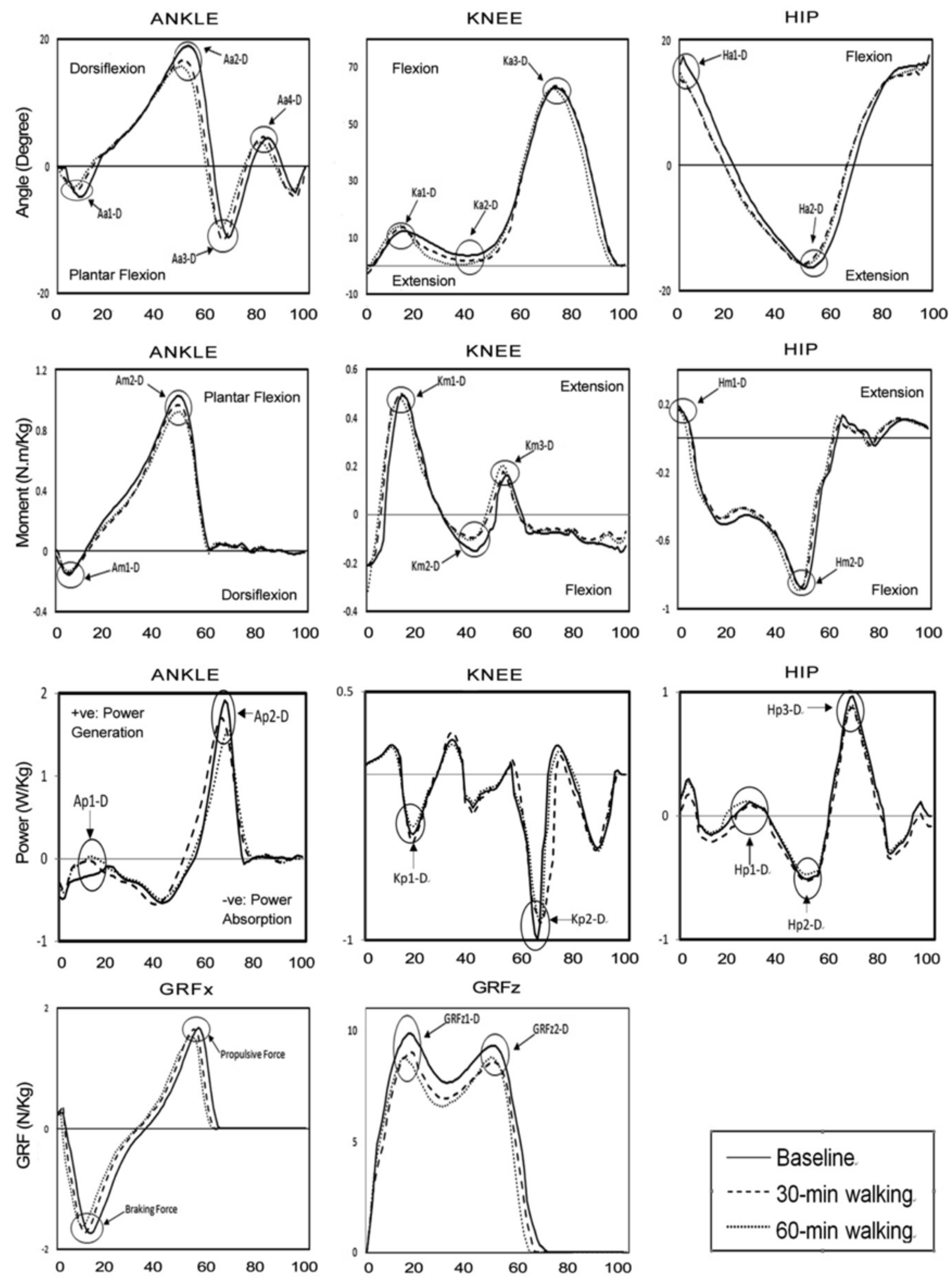

FIG 2. Group B joint angles, moments and powers of the ankle, knee, and hip joints and the ground reaction forces averaged among the subjects in a complete gait cycle for the dominant side.

sessions. They had a mean age of 71.6±6.1 years, height of 162.8±7.4 cm, and weight of 63.3±6 Kg.

Without using the prescribed insoles, the subjects gave significantly higher scores on Borg's scale (perceived higher level of exertion) than the same group of subjects using the insoles ($P<0.001$) after 30 minutes and 60 minutes of walking (Fig 3). Significant changes in visual analogue scale scores along the 60 minutes of walking, indicating the subjects perceived significantly more pain and fatigue, were found only in the session of not using the prescribed insoles only.

The subjects had inconsistent changes in gait patterns along the 60 minutes of walking in the two walking sessions. In many measured gait parameters, significant changes in gait patterns along the treadmill walking were observed only when the prescribed insoles were not used.

No significant differences were found in walk stability visual analogue scale scores comparing between with and without the prescribed insoles in each of the walk conditions.

Discussion

This is the very first study investigating long-distance walking of the older adults. About half of subject perceived that they would need a rest at or before 30 minutes of walking. They felt significantly increased levels of physical exertion, lower-limb pain and fatigue along the treadmill walking. This phenomenon was not seen in the other group of subjects who did not need rest after the 30 minutes of walking. Their gait characteristics have implied that some biomechanical factors played an important role in their long-distance walking ability.

The step length, stance and swing time at the dominant and the non-dominant legs of Group B changed significantly in opposite directions, widening the differences between both legs, after the long-distance walk. It should be noted that asymmetry in these gait parameters was positively correlated to risk of fall and dependency in daily living activity among older adults.[5] This sparks concern if this implied higher risk of fall in some healthy older adults who are less able to walk long distances.

After the long-distance walk, group B had significant reductions in the plantar flexor power absorption and generation. Such reductions could be signs of fatigue of plantar flexors and fatigue of these muscles could well explain the observed changes in walking pattern along the 60 minutes of walking.

Heel lift and silicon insoles are generally used to relieve plantar pain and to reduce the strain on the plantar flexors. We applied a combination of both and our results showed not only did the prescribed insoles reduce subject fatigue and pain levels, they also have also induced some positive effects on gait patterns. The positive effects could be explained by the characteristic of the silicon-gel insoles acting as shock absorber which help reduce fatigue and plantar pain. Heel lift positioned the ankle in more plantar flexed position during mid-stance of the gait. This may increase muscle activity of the tibialis anterior, while reducing the muscle activity of plantar flexors. No changes in perceived walk stability were found when walking with the prescribed insoles on different walking surfaces. Although gait analysis showed fatigue at the dominant-side plantar flexors, the insoles were applied to both feet for symmetric purposes. Future physical training may well target on the plantar flexors at the dominant side.

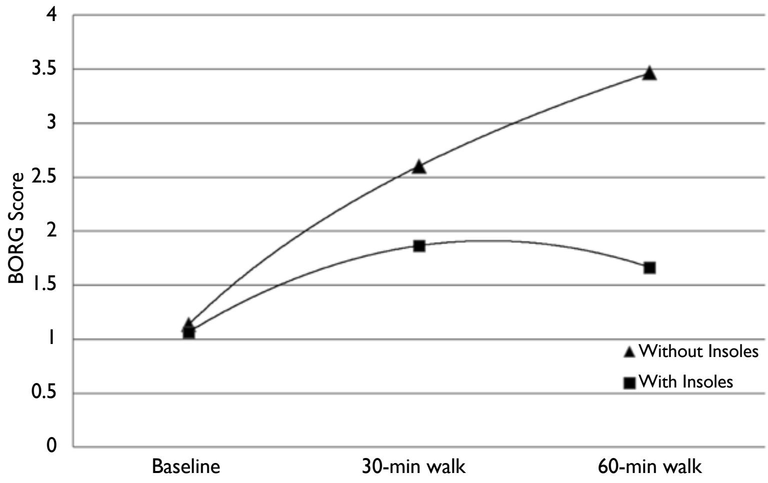

FIG 3. Borg's CR10 scores (perceived level of exertion) comparing with and without the prescribed insoles

Acknowledgements

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Results of this study have been published in: (1) Elhadi MM, Ma CZ, Wong DW, Wan AH, Lee WC. Comprehensive gait analysis of healthy older adults who have undergone long-distance walking. J Aging Phys Act 2017;25:367-77. (2) Elhadi MMO, Ma CZ, Lam WK, Lee WC. Biomechanical approach in facilitating long-distance walking of elderly people using footwear modifications. Gait Posture 2018;64:101-107.

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