Brief report

Frequency domain characteristics of ground reaction forces during walking of young and elderly females

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Abstract

Objective. To examine the frequency domain characteristics of the ground reaction forces of young and elderly females during free walking.

Design. Independent t-tests were used to examine the frequency content of all three components of the ground reaction force.

Background. Frequency domain analysis has the potential to assist in identifying changes in gait that may be masked in the time domain. No research has been done to identify changes in gait due to age-related impairments in the frequency domain.

Methods. Ten young and ten elderly females walked at a prescribed speed while ground reaction forces were collected via a force platform. The highest frequency required to reconstruct the 99% of the signal’s power in each direction was calculated from the ground reaction forces.

Results. The frequency content significantly decreased in the anterior–posterior direction for the young group. No significant differences were found for the other two directions (vertical and mediolateral) between the two groups. The elderly had a significantly higher frequency content compared with the young in the anterior–posterior direction.

Conclusions. Ageing differences were detected using the frequency domain analysis for the anterior–posterior direction. It is possible that these differences were the result of the decrease in walking speed associated with the elderly group.

Relevance

Frequency domain analysis of the ground reaction forces is a useful addition to the gait analyst’s armamentarium especially when such changes are not obvious in the time domain.

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1. Introduction

The literature [1,2] reports changes in gait parameters of elderly adults including decreases in step frequency, step length, and walking speed. However, limited research exists regarding kinetic differences and, specifically, ground reaction forces (GRF) [3]. Standard GRF evaluations performed with young volunteers typically use time domain parameters [4,5]. However, these parameters may lead to erroneous conclusions in cases when two different trials of the same person are examined before and after treatment; they might have nearly the same time domain parameters and having no apparent treatment effect.

Frequency domain analysis has been previously used to assess normal [6,7] and pathological [8,9] gait. Such an analysis has the potential to assist in identifying changes in gait due to age-related impairments or in evaluating the treatment of gait disorders.

The study of variability in gait parameters can yield important insights. Recently it was shown that variability in cadence is an important predictor of fall risk in elderly population [10]. Variability and reliability of GRF patterns during walking have previously been examined in various populations and conditions [5,7], but not for the elderly.

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The purpose of this study was to examine the frequency domain characteristics and variability of the GRF of young and older individuals during walking. We hypothesized that the elderly will exhibit higher frequency content in comparison with the young group.

2. Methods

Written consent was given by ten healthy young (age 24.6 (SD, 3.2) years; mass 61 (SD, 10) kg) and ten healthy elderly (age 73.7 (SD, 4.9) years; mass 62.6 (SD, 5.8) kg) females with no clinical history of falling or any other musculoskeletal or neurological problems. A Kistler (Type 9281-B11, Amherst, NY, USA) force platform system sampling at 960 Hz was used to collect GRF during walking. The walking speed was recorded using a photo-electronic timing system.

The subjects were asked to walk at a comfortable speed. The walking distance for each trial was approximately 15 m. Each subject performed at least 10 walking trials for familiarization with the experimental setting. Subjects wore their regular sports shoes to assure normal and comfortable performance. Regular resting breaks were given so the subjects would not experience undue fatigue. The comfortable walking speed was recorded in all trials. When this speed was constant for three subsequent trials the subjects were considered ready for recording. Every subject was required to walk at this speed (±5%) for 10 trials.

Overall, there were 200 trials (2 groups × 10 subjects × 10 trials). In each trial the mediolateral (M-L) the anterior-posterior (A–P) and the vertical (V) components of the GRF were recorded. Each signal was transformed in frequency domain and the power spectral density was calculated using MATLAB. We used a similar criterion developed previously [7–9], but instead of using the amplitude of the harmonics, we used the frequency content in comparison with the young group. We hypothesized that the elderly people will exhibit higher GRF frequency content in comparison with the young group. Statistical significance was found only for the A–P GRF component (P < 0.01) but in the opposite than the predicted direction (Table 1). The decrease by 2.5 Hz in the A–P frequency content for the elderly group may be due to the differences in the walking speed. The young subjects walked on the average 0.19 m/s faster than the elderly (Young: 1.43 m/s; Elderly: 1.24 m/s). Walking is a sagittal plane movement and speed differences will be reflected mostly in the A–P component. For the other two GRF components, no significant differences were found (Table 1).

A general observation from our data is that the mean M-L frequency had the highest frequency content (gross mean 24.37 Hz). This GRF component was followed by the A–P (gross mean 13.22 Hz) and then by the V (gross mean 12.48 Hz) frequency content values. These results are in agreement both in order and in numerical values with previous studies examining young adults [7] and adolescents with scoliosis [8].

Regarding intra- and inter-subject variability, our results showed differences between the two groups (Table 2). While the M-L was the most variable component for both groups, the elderly had smaller values especially for inter-subject variability. This result indicated a more homogenous M-L response across the ageing individuals. Interestingly, the young group had smaller values for the other two components both between and with subject. Further research is necessary to investigate the reasons and clinical relevance of these observations.

### Table 1

<table>
<thead>
<tr>
<th>Force Component</th>
<th>Young (n = 10)</th>
<th>Elderly (n = 10)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-L</td>
<td>22.40 (4.57)</td>
<td>26.35 (5.54)</td>
<td>0.100</td>
</tr>
<tr>
<td>A–P</td>
<td>14.38 (2.02)</td>
<td>12.06 (0.80)</td>
<td>0.002†</td>
</tr>
<tr>
<td>V</td>
<td>12.73 (0.94)</td>
<td>12.21 (0.84)</td>
<td>0.170</td>
</tr>
</tbody>
</table>

The P-values for the three t-tests between groups are also listed.

† indicates a significant difference at the 0.05 level.

### Table 2

<table>
<thead>
<tr>
<th>Force Component</th>
<th>Young (n = 10)</th>
<th>Elderly (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IntraCV</td>
<td>InterCV</td>
</tr>
<tr>
<td>M-L</td>
<td>20.69</td>
<td>37.12</td>
</tr>
<tr>
<td>A–P</td>
<td>6.32</td>
<td>5.95</td>
</tr>
<tr>
<td>Vertical (V)</td>
<td>6.59</td>
<td>7.99</td>
</tr>
</tbody>
</table>

The Intra- and Inter-subject coefficient of variation of the frequency content of each GRF component for both groups.
A limitation of the present study is that the elderly subjects were not screened by a geriatrician for occult clinical conditions. Subjects themselves may or may not recognize that they have had a mild stroke, a mild peripheral neuropathy, or other central or peripheral conditions that can affect gait. Thus, they may report themselves as healthy even with impairment. The results of the present study should be viewed with this limitation in mind.

In summary, this study revealed statistical differences in the frequency content between the young and elderly in the A–P direction. No such differences were found for the other two directions.

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References