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Functional gait assessment in fall prevention exercises

Motivation

It is estimated that one-third of older adults fall each year. Several fall risk factors have already been identified and interventions to decrease fall risk, such as exercise programmes, have been proposed. The Otago Exercise Programme is a fall prevention programme executed at the older adult's home according the prescriptions of an instructor. Those prescriptions are based on visits to the patient. The development of a gait analysis system to assess senior's performance while doing the exercises and extract objective parameters can provide useful information to the instructor. Moreover, this type of exercises is more challenging than free walking exercises usually used to assess gait, and its evaluation may offer valuable information to healthcare professionals.

Additionally, the gold standard in gait analysis is 3-dimensional motion analysis systems. However, these systems are not widely available as they require expensive equipment, trained personnel and specialized laboratories. Hence, inertial measurement sensors (IMUs) are promising alternatives as they are low-cost, easy-to-use, wearable and non-invasive.

Methods

The developed solution uses data collected with one Pandlet placed on the lateral side of each ankle. Pandlets incorporate an IMU constituted by a 3-axis accelerometer, a 3-axis gyroscope and 3-axis magnetometer. Data was sampled at 50 Hz frequency and transmitted using Bluetooth.

The proposed methodology evaluates two exercises from the Otago Exercise Programme: heel and toe walking. The exercises consist in walking 10 steps, turning around and walking 10 more steps. The steps during turning are not of interest and turn detection is used to remove those steps. The extracted parameters are number of steps, duration of each stride, start and end of each step, stride length and cadence. Parameters related to acceleration, angular velocity and ankle angle are also collected.

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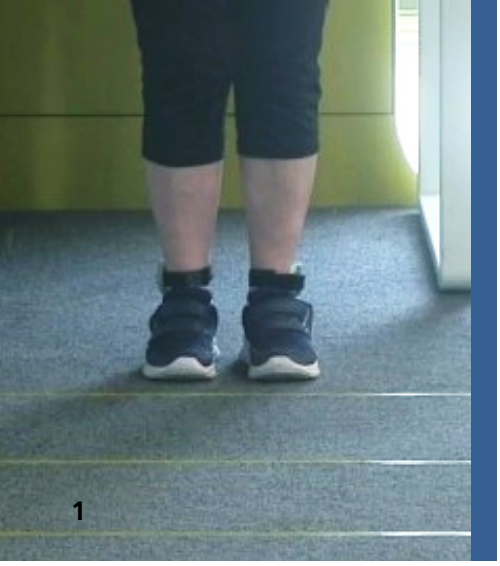

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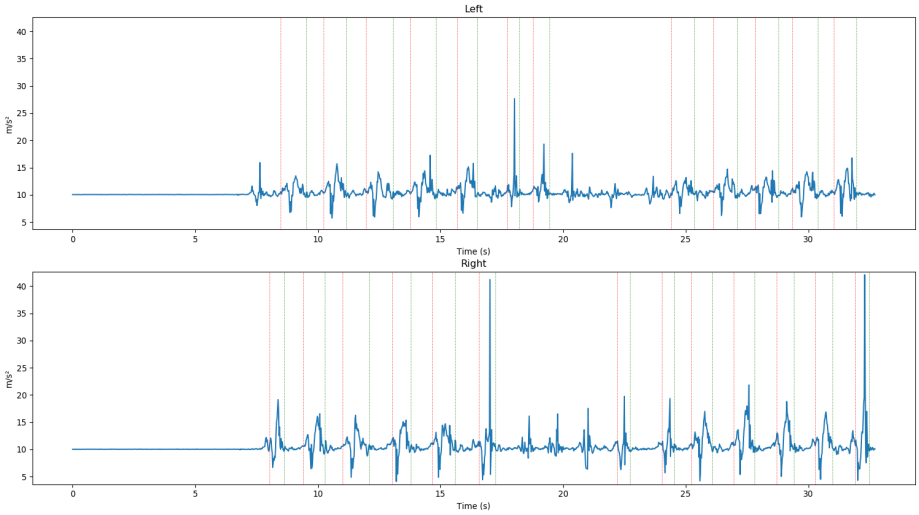

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1 *Sensor placement during the exercises.*

2 *Magnitude of the acceleration signal with step detection for toe walking exercise for left foot (top) and right foot (bottom).*

3 *Experimental setup for data acquisition. Participants walked on the marked path while being video-recorded.*

Results

This methodology was validated with data from a group of 14 older adults (73,2 ± 4,4 years) and 14 younger adults (23,5 ± 1,6 years). Inertial data and video were recorded while the participants performed the exercises. Start, end and traveled distance of each step were annotated from the video. Those measures were considered the ground truth and were compared to algorithm's results. Mean errors for number of steps, start and end of each step, stride length and turn duration are shown in table 1.

Table 1 - Mean error for number of steps, start and end of the step, stride length and turn duration

	Toe walking exercise	Heel walking exercise
Number of steps	7,6%	11,2%
Start	0,8%	0,7%
End	0,8%	1,0%
Stride length	22,5%	30,8%
Turn duration	12,8%	19,6%

Detection of steps and their limits was accurate, yet the considerable error in stride length prevents its use in additional analysis such as trajectory estimation.

Mean, standard deviation and min-max range of acceleration, angular velocity and ankle angle were compared between groups and for each participant. Toe walking exercise had no significant differences between groups while heel walking exercise had significant higher values for range of ankle angle, acceleration and angular velocity, and for mean and standard deviation of acceleration and angular velocity in the older group.

Observed differences between exercises suggest that heel walking was more challenging exposing gait impairments not distinguishable in the toe walking exercise. Higher values among older adults suggest that this group showed more gait variability, usually associated with walking difficulties.

Intra-subject comparisons can show significant differences between limbs when performing the exercise suggesting they can be used to evaluate gait symmetry. For example, a participant with a known walking impairment in the right leg, showed significant higher values of mean acceleration, standard deviation and range in that leg in both exercises. Specifically in the heel walking exercise, mean angular velocity was also significantly higher for the impaired leg. These findings suggest less stability in that leg. Moreover, differences in angular velocity may also be associated with gait adaptations in order to decrease pain or instability.

Conclusions and Future Work

Detection of steps and their limits was successful, however, further work is necessary to improve stride length estimation and turn detection.

Inter and intra-subject comparisons of acceleration, angular velocity and ankle angle metrics suggest that this methodology can be used to find gait differences between age groups and evaluate gait symmetry. The analysis of other gait exercises could provide more insight to corroborate these findings.