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The Usefulness of Activity Trackers in Elderly with Reduced Mobility: A Case Study

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Abstract

This study was conducted to determine the accuracy and usefulness of two current commercially available activity trackers in rollator dependent elderly with reduced mobility (RME), compared with elderly with normal mobility (NME) and healthy adults (HA).

Methods: Accuracy of pedometers placed at hip (Fitbit Ultra and Samsung GT-I9300 mobile phone) and wrist (Fitbit Ultra) were evaluated against actual steps (video) in RME (n=5), NME (n=7) and HA (n=6). Walk speed, Tinetti gait score and device percent error was calculated and analyzed in SPSS using Kruskal-Wallis, Mann-Whitney U and correlation tests.

Results: NME and HA walked significantly faster ($p = 0.001$) than RME, had significantly higher gait score ($p < 0.05$). Gait scores were correlated with walking speed and negatively with pedometer percent error ($p < 0.01$). Estimation error in RME were >60% at all device locations

Conclusions: Slow walking speed and gait disorders hamper the utility of pedometers for physical activity measurement in rollator dependent elderly, with estimation errors >60%. The tested devices are better suited for use by ostensibly healthy elderly or adult populations.

Keywords:

Motion Sensors, Gait Monitoring, Frail Elderly, Walking, Gait Disorder.

Introduction

In the elderly population, physical activity is an important part of lowering the risk of falls and maintaining the ability to perform everyday tasks unassisted. Despite the importance of physical exercise, this demographic have a very sedentary lifestyle [1], with elderly in nursing homes estimated to spend up to 80% of living hours with little to no physical activity (sitting or lying) [2]. As part of the European Ambient Assisted Living project GameUp, an effort is being made to improve the activity of elderly with normal and reduced mobility and thus lowering the risk and fear of falling, by focusing on improving strength, mobility, flexibility and stamina/endurance through various activities. Stamina/endurance improvements can be achieved through activities such as walking, with a goal of a certain amount of steps per day, similar to the 10,000 daily steps recommended for adults. Evaluating the physical activity level of elderly people and providing optimal feedback and intervention requires a method of accurately quantifying physical activity of elderly people [3]. Non-intrusive body-worn sensors such as pedometers/accelerometers provide an objective method of estimating number of steps taken by the wearer [4] and can be feasible due to low cost [5], [6] and the automated nature of the devices. Cohen-Mansfield et al. (1997) examined the feasibility of pedometers in a nursing home setting, reporting that the devices were easy to use and well tolerated by the elderly [7], making this technology a beneficial choice for the elderly demographic. However, the shuffling/abnormal gait pattern of some older adults may contribute to pedometer error in detecting actual steps taken [8], [9], [10] and gait impairments (such as hemiparesis and ataxia) are shown to compromise pedometer accuracy with community-dwelling stroke patients [11]. Some researchers also speculate that the use of pedometers may be precluded due to the slow paced walking that is often seen in elderly people [9]. Although seemingly feasible for elderly people, the technology may not be able to function correctly or accurately enough for this group. However, newer commercially available pedometers and high-end mobile phones support use in multiple location for step detection and should therefore be investigated, to determine if feasible in the elderly population with reduced mobility.

The purpose of this initial study is therefore to examine the accuracy of two present activity trackers in elderly nursing home residents with reduced mobility and normal mobility relative to healthy adults. We tested the Fitbit Ultra activity tracker and a Samsung GT-I9300 mobile phone with a pedometer application installed, located at the hip and at the wrist in elderly people with reduced mobility, elderly with normal mobility and healthy adults and compared results using SPSS and Excel 2011.

Materials and Methods

Participants

Elderly with reduced mobility (RME) and Healthy Elderly (NME) were recruited from a local nursing home in the municipality of Seville and Healthy Adults (HA) were recruited from the University of Seville. Gross mobility classification of participants was done using the Kurtzke Expanded Disability Status Scale (EDSS) [12]. In this study, elderly with reduced mobility were classified as people of age 65 or above, with an EDSS score of 6.5 – 7.0 and who utilize a rollator walking aid (sometimes referred to as wheeled walkers or rolling walkers). Elderly with normal mobility were classified as people of age 65 or above, with an EDDS score < 6.0. Healthy Adults were classified as people of age 25 – 45 with no gait disabilities. Global exclusion criteria were cognitive impairment that compromises the understanding of the test and any additional disabilities or other limitations that would hinder gait and correct placement of recording devices.

Participants were given an oral and written introduction to the test and the purpose of the study. Participants were asked to sign an informed consent form and/or provide oral consent. Ethical approval for this study was obtained from Comité Ético de Experimentación (CE)/Experimental trials ethical committee, Seville, Spain.

Instruments

The setup for the test requires multiple pedometers, mobile phones and video recording devices.

Commercial activity tracker Fitbit Ultra and Samsung GT-I9300 Android mobile phone with Noom app installed were used to record number of steps in this test, recorded from different locations on the participants. Actual steps taken during the trial ($Steps_{ACTUAL}$) were recorded using a video camera (Canon HF R17). Prior to the test, the instruments were calibrated.

Procedure

A straight path of 20 meters, with clearly outlined start and finish positions, was marked out on the floor in the nursing home. The area was closed off for other activities and traffic during the trial to eliminate interfering factors. The trial for the HA group was conducted at a similar setting at the University of Sevilla.

Participants were individually introduced to the walking path and offered a practice walk at their own normal pace, using their usual walking aids. Additional practice walks were allowed if desired by the participant. Pedometers were placed by a researcher: 1 Fitbit Ultra clipped to the belt/pants pocket on the dominant leg ($Fitbit_{HIP}$), 1 Fitbit Ultra in the Fitbit wrist sleeve around the wrist of the dominant hand ($Fitbit_{WRIST}$) and 1 Samsung GT-I9300 in the pants pocket of the dominant leg ($Phone_{HIP}$), in accordance with manufacturer recommendations. Initial device values (step count) were noted or devices reset where possible.

The participant was asked to commence walking along the path at his or her own normal pace and to stop when reaching the finish position or when instructed. Actual steps taken were recorded using a video camera operated by one of the researchers present during the study. A stopwatch was used to record the time elapsed of each trial. To ensure the safety of the participant in groups RME and NME, a doctor of sports medicine accompanied each participant in the trial, by walking next to him/her and providing support when necessary. Upon completion, a researcher collected devices, recorded values and video for storage. At this stage, the participants were informed that the trial has been concluded.

Video footage was inspected post-trial by two researchers to determine actual steps and to examine possible related gait disorders using the gait subscale of Tinetti's Performance-Oriented Mobility Assessment (POMA gait score, a test for assessing subject gait and balance abilities that provides more detail than EDSS) [13]. Inter-rater reliability of the POMA, measured via percent agreement, has been reported as 85 ± 10% [13]. A correlation of gait scores with physical performance test scores supports the concurrent validity of the subscale (Pearson r = 0.78) [14].

Statistical analysis

Descriptive data are presented as means, SD, and 95% confidence intervals (CI) for all continuous variables. The absolute error percentage of devices was calculated as

$$Error_{PERCENT} = \frac{|Steps_{DEVICE} - Steps_{ACTUAL}|}{Steps_{ACTUAL}} \cdot 100 \qquad (1)$$

Values close to zero indicate more accurate instrument results.

Independent Kruskal-Wallis analyses were used to evaluate differences between the groups RME, NME, HA in each continuous quantitative variable, using a significance level of $\alpha = 0.05$. Mann-Whitney U tests, with Bonferroni corrected α-value ($\alpha_c = 0.017$) were conducted on each pair, where significant difference was detected in the Kruskal-Wallis tests. Correlation tests were also performed to detect any relation between measured parameters. Supplementary analyses were conducted if a significant interaction effect emerged. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0 and Microsoft Excel 2011.

Results

A total of 18 participants were recruited for the study, 5 RME (4 female/1 male, age 87.6 ± 3.91), 7 NME (6 female/1 male, age 84.14 ± 3.67) and 6 HA (6 male, age 35.33 ± 6.53). All fulfilled the criteria for participation, all completed the study and none opted out of the study subsequently.

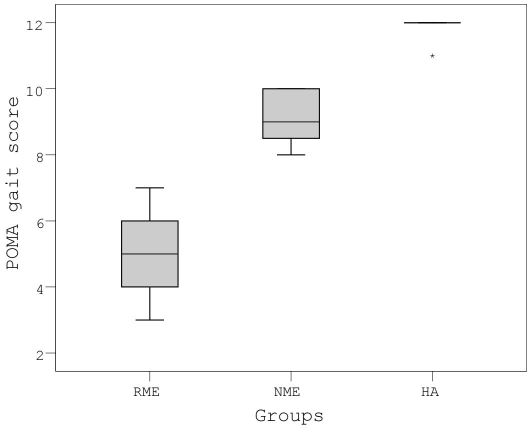

Figure 1 - Boxplot of POMA gait scores for sample groups RME, NME and HA. Higher scores indicate less impairment, 12 indicates maximum possible score

Analysis of Variance

The average score for the POMA gait subscale test (Figure 1) showed significant difference ($p < 0.05$) between sample groups RME (5 ± 1.58), NME (9.14 ± 0.9) and HA (11.83 ± 0.41), across all comparisons. Time to complete the 20 m walk was also shown to vary significantly ($p = 0.001$) across all groups (Figure 2), as well as average speed (derived parameter) during trial ($p = 0.001$).

In $Fitbit_{HIP}$, significant difference ($p = 0.008$) was detected in $Error_{PERCENT}$, with RME performing more poorly than HA ($p = 0.009$). In $Fitbit_{WRIST}$, significant difference ($p = 0.005$) was detected in $Error_{PERCENT}$, with RME performing more poorly than both NME ($p = 0.003$) and HA ($p = 0.004$). $Phone_{HIP}$ also showed significant difference in $Error_{PERCENT}$ ($p = 0.015$), with RME performing more poorly than both NME ($p = 0.005$) and HA ($p = 0.017$). No significant post hoc differences in $Error_{PERCENT}$ were detected between HA and NME.

Data Correlations

The POMA gait score was highly negatively correlated (Pearson 2-tailed, $\alpha = 0.05$) with participant age (rs = -0.734, $p = 0.001$), the time taken to complete a 20 m walk (rs = -0.864, $p < 0.01$) and number of steps (actual steps) to complete a 20m walk (rs = -0.829, $p < 0.01$). Results were also highly positive-

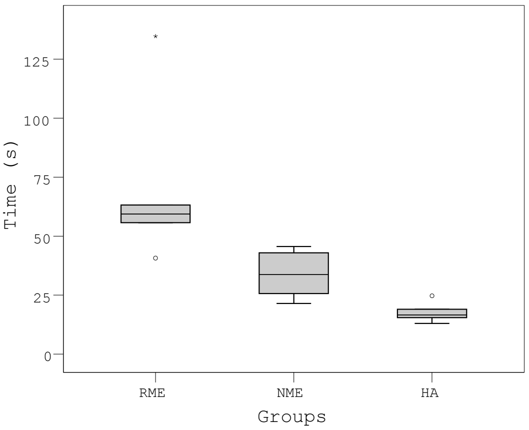

Figure 2 - Boxplot of time taken to complete the 20 m walk for groups RME, NME and HA

ly correlated with the average speed (rs = 0.881, $p < 0.01$) during trial. The POMA gait score was additionally found significantly negatively correlated with the percentage error ($\text{Error}_{\text{PERCENT}}$) of both $\text{Fitbit}_{\text{WRIST}}$ (rs = -0.663, $p = 0.003$) and $\text{Phone}_{\text{HIP}}$ (rs = -0.658, $p = 0.003$) and $\text{Fitbit}_{\text{HIP}}$ (rs = -0.670, $p = 0.002$).

Time to complete the 20 m walk and number of steps taken during the walk were both found significantly positively correlated with $\text{Error}_{\text{PERCENT}}$ at all locations ($\text{Fitbit}_{\text{HIP}}$ rs = 0.778, $p < 0.01$/rs = 0.666, $p = 0.003$; $\text{Fitbit}_{\text{WRIST}}$ rs = 0.551, $p = 0.018$/rs = 0.518, $p = 0.028$; $\text{Phone}_{\text{HIP}}$ rs = 0.561, $p = 0.15$/rs = 0.490, $p = 0.039$), though only moderately (rs < ± 0.7), save the correlation between time to complete the walk and $\text{Fitbit}_{\text{HIP}}$.

Age was not correlated with $\text{Error}_{\text{PERCENT}}$, but highly negatively correlated with POMA (results above) and average speed during trial (rs = -0.773, $p < 0.01$).

Data collected was in RME characterized by large undercounting errors ($\text{Fitbit}_{\text{HIP}}$ -27.45% ± 79.9%, $\text{Fitbit}_{\text{WRIST}}$ -99.64% ± 0.8% and $\text{Phone}_{\text{HIP}}$ -61.57% ± 25.5%, using non-absolute data) and additionally, $\text{Fitbit}_{\text{WRIST}}$ failed entirely to detect any steps in 80% the trials and detected only 1.79% of the steps taken in the trial where it collected data.

Discussion

The data for RME displayed very low accuracy ($\text{Error}_{\text{PERCENT}}$ > 60% for all devices in all locations) and poor precision (high standard deviation). The $\text{Fitbit}_{\text{WRIST}}$ seemingly displayed high precision, but very poor accuracy ($\text{Error}_{\text{PERCENT}}$ -99.64% ± 0.8%). This low standard deviation is however the result of device inability to detect steps taken during the trial when located at the wrist. The Fitbit device undercounted near 100% of steps taken, suggesting that the device is not precise when worn at the wrist. The poor results in this group may suggest devices are ill-suited for this demographic, faulty, or not placed in accordance with device recommendations. The possibility of device error was ruled out, due to devices being tested prior to the study and additionally being used on daily basis by the research personnel for testing purposes and devices were placed in accordance to manufacturer recommendations. The low accuracy and high precision was expected for the wrist-placed Fitbit in the RME group, due to the static vertical position of the wrist when holding onto the rollator handles. It was not possible to obtain technical information about the threshold for the displacement/acceleration required for the Fitbit Ultra to count steps, which could be an impacting factor on the devices ability to estimate steps in this demographic. Although the data shows that the device is unable to detect steps when worn at the wrist, the RME group consisted of only 5 participants, making the result more prone to effects from outliers.

The correlation of time to complete actual steps over the 20 m walk with $\text{Error}_{\text{PERCENT}}$ suggests that both the mobile phone and Fitbit devices may be less accurate, when walking slowly, or when taking short steps. This makes the devices more suitable for people with a faster and longer stride, but less suited for elderly people with reduced mobility, who, due to less strength, balance and flexibility, take shorter steps and walk slower than the average healthy adult.

For HA, the $\text{Error}_{\text{PERCENT}}$ of the hip-placed Fitbit showed the highest accuracy and precision (2.86% ± 2.34%) compared with the hip-placed mobile phone (18.56% ± 10.81%) and the wrist placed Fitbit (31.26% ± 30.68%). This suggests the better choice would be the Fitbit at the hip, but due to the small sample size ($N_{\text{HA}} = 6$) results should be considered preliminary.

Using activity trackers or mobile phones can be suitable for elderly people with normal mobility, but may not be useful for elderly with reduced mobility who use a rollator walking aid. In this group, a more favorable approach could be to record data from the rollator instead of from the person, e.g., devices that detect wheel rotations to estimate distance walked, instead of acceleration/displacement of body regions.

Due to sample size in this study, results should be considered preliminary. A repeated study with larger sample sizes would provide a firmer basis for confirming any suggested trends, investigating potential device over- and underestimation tendencies and reaching final statistical conclusions.

Future work is suggested and planned with larger sample size, to fully determine the optimal location for activity trackers in elderly with normal and reduced mobility, and if devices worn at the optimal location are accurate and precise enough. A device to record wheel rotations on a rollator and derive distance traveled is also in development and will be tested alongside activity trackers, to determine if this is a more viable technology alternative for elderly with reduced mobility who depend on rollators for walking.

Conclusion

Commercial activity trackers (Fitbit Ultra and Samsung GT-I9300 mobile phone) were shown to be very inaccurate in elderly with reduced mobility, (step estimation error >60%) when placed at hip or wrist, in accordance with manufacturer recommendations. Performance was negatively affected by gait disorders and walking slowly/taking small steps also increased error in step estimation, which occurs regularly in elderly dependent on bilateral walking aids. Wrist-located pedometers additionally fail to detect walking in people using rollators. The tested activity trackers are better suited for adults and ostensibly healthy elderly.

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