Pedometer Accuracy and Reliability at Slow Walking Speeds in Healthy Older Adults

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CO-SUPERVISORS: Dr. Janice Eng and Dr. Jeremy Noble
Presentation Outline

- Literature background
- Study rationale
- Hypotheses
- Methods
- Results/Discussion
- Question Period
Background

- Aging Canadian population (Statistics Canada, 2009)
- Benefits of regular physical activity (Marsh et al., 2007)
- Need for a reliable outcome measure (Bassett et al., 2000)
- Walking – preferred method of exercise for older adults (Yusuf et al., 1996; Cyarto et al., 2004; Marsh et al., 2007)
Pedometers can be inexpensive, and have been shown to increase physical activity (Holbrook et al., 2009)

Have the potential to be used in a variety of settings
- Hospitals
- Nursing Homes
- Community

Vary in accuracy depending on (Schneider et al., 2003):
- Internal mechanism
- Walking speeds

Few studies have been conducted which look at slow walking speeds (< 0.9 m/s) (Bassett et al., 2000)
Definition of terms

- **Reliability**
  - Whether a pedometer consistently records the same number of steps over multiple trials

- **Accuracy**
  - How closely the pedometer recorded steps correspond to the actual number of steps measured by a gold standard

- **Gold Standard**
  - Manual hand count, video capture, ActiCal Accelerometer have been used
Pedometer Mechanisms

- Coil spring (Yamax DW 200)/ Lever Arm (SportLine 330)
- Magnetic Reed Proximity Switch (Omron HJ 105)
- Piezoelectric (NewLifestyles 2000, ActiCal)
Cyarto et al. (2004)

- **Device:** Yamax Digiwalker 200 (Spring lever)
- **Population:** Nursing home and community dwelling seniors
- **Speeds:** 0.35 - 0.48m/s, 0.87 - 1.02m/s
- **Results:** 74% error at slowest speeds in nursing home residents and 25% in community dwelling
Devices: 10 pedometer models of differing mechanisms

Population: Healthy adults (mean age 34)

Speeds: Self selected speeds (1.29 - 1.9m/s) and pre-selected treadmill (0.9 - 1.78m/s)
FIGURE 1—Mean error scores (actual – pedometer) ± SE in number of steps during a 400-m track walk at self-selected speeds. *P < 0.05.
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Schneider et al. (2003)
FIGURE 1—Mean error scores (actual – pedometer) ± SE in number of steps during a 400-m track walk at self-selected speeds. * $P < 0.05$. 
Melanson et al. (2005)

- Devices: Walk-4-Life, Step-Keeper (spring lever), Omron HF 100 (piezoelectric)
- Population: Healthy adults ages 19-85
- Speeds: 0.4 - 1.15m/s on a treadmill
Device: ActiCal (accelerometer)

Population: Healthy adults (mean age 34.3)

Speed: 0.83 - 1.38m/s walk on treadmill

Results: 7.4% error at slow speed, 0.01% at faster speeds

Esliger et al. (2007)
Conclusions from Previous Studies

- Piezoelectric pedometers and the Yamax DW 200 are accurate in healthy adults at speeds >0.9 m/s (Cyarto et al., 2004; Schneider et al., 2003; Melanson et al., 2004)

- ActiCal is most accurate at speeds >1.38 m/s (Esliger et al., 2007)
To determine whether any of 5 commercially available pedometers with differing mechanisms are accurate at recording steps taken by healthy older adults at speeds <0.9m/s

- Slower walking speed associated with populations at risk of health problems related to decreased physical activity

To identify a reliable outcome measure for monitoring walking activity in older adults
Hypotheses

- No significant difference between pedometers in terms of accuracy at pre-set gait speeds <0.9 m/s in healthy older adults

- Accuracy and reliability of all pedometers tested will decrease as speed decreases regardless of brand or internal mechanism
Ethics Approval

- Obtained from the Office of Research Ethics, University of British Columbia
- All participants provided written informed consent prior to commencement of the trial
## Inclusion Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
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<tbody>
<tr>
<td>Males and Females ages 50 +</td>
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<tr>
<td>Able to follow instructions in English</td>
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<tr>
<td>Able to ambulate 100 meters without a gait aid (cane, walker, etc.)</td>
</tr>
<tr>
<td>No recent musculoskeletal trauma (fracture, muscle strain, ligamentous sprain, etc.); No neuromuscular deficits</td>
</tr>
<tr>
<td>BMI &lt; 30 kg/m² (Shepherd et al., 1999)</td>
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<tr>
<td>No significant or uncontrolled health conditions that contraindicate exercise – ACSM Screening tool</td>
</tr>
<tr>
<td>Timed up and go (TUG) score within age-based normal value (Bohannon, 2006)</td>
</tr>
</tbody>
</table>
Participants

- Recruited from local seniors centers and community centers
- Further snowball sampling

<table>
<thead>
<tr>
<th>N</th>
<th>Male</th>
<th>Female</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>TUG (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>6</td>
<td>12</td>
<td>63.6 (7.26)</td>
<td>68.6 (13.6)</td>
<td>166.7 (7.48)</td>
<td>6.51 (1.33)</td>
</tr>
</tbody>
</table>

Table 1: Subject Demographics – Mean (sd)
Yamax Digiwalker 200 (spring lever) - $20
Omron HJ 105 (magnetic switch) - $12
Sportline 330 (coil spring lever) - $20
New Lifestyles 2000 (piezoelectric) - $75
ActiCal accelerometer (piezoelectric) - $ >500
1 unit of each model was randomly selected
2 models were worn at a time, 1 on each hip
ActiCal was worn for every trial on the left hip
Subjects completed a series of 80m walking trials on an oval, 40m track at selected cadences. Cadences, dictated by a metronome, corresponded to walking speeds of:

- Slow – 80bpm (0.71-0.9m/s)
- Very slow – 66bpm (0.51-0.7 m/s)
- Slowest - 50bpm (0.3-0.5m/s)
- Self-selected speed (1.2-1.4m/s)
Speed order was randomized for each subject

Practice trial at slowest speed

For each trial, 2 researchers followed the subject and manually counted steps (gold standard)

Time to complete a 3m portion of track was recorded and gait velocity calculated

Steps were recorded from all devices between trials

The 4 trials were repeated with the remaining 2 models of pedometers
Statistical Analysis

- SPSS Version 11.0 (IBM, Armonk NY)
- Repeated-measures ANOVA between speed conditions
- Percentage error and mean percentage error for each pedometer at each speed
- Bland-Altman plot for graphical representation of deviation from gold standard
- Two-way mixed intraclass correlation coefficients (ICC (3,2)) for within brand reliability
**Speed**

Repeated-measures ANOVA to ensure 3 pre-selected cadences and self-selected speed gave velocities that were significantly different from each other ($F(3,51) = 157.38; p < 0.0001$)

<table>
<thead>
<tr>
<th>Target Cadence (bpm)</th>
<th>Mean Velocity - m/s (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.46 (0.41 - 0.50)</td>
</tr>
<tr>
<td>66</td>
<td>0.66 (0.60 - 0.72)</td>
</tr>
<tr>
<td>80</td>
<td>0.85 (0.79 - 0.91)</td>
</tr>
<tr>
<td>Self-selected</td>
<td>1.305 (1.19 - 1.42)</td>
</tr>
</tbody>
</table>

Table 1: Walking speeds
Pedometer trials that failed to register any steps were eliminated from analysis (Melanson et al., 2004)
- Removed so as not to skew % error scores

May be due to:
- Lack of sensitivity at slow speeds
- Subject’s gait pattern
Unable to calculate ANOVA due to drastically unequal group sizes (44% of trials removed for Omron at 50bpm)

<table>
<thead>
<tr>
<th>Cadence</th>
<th>Omron</th>
<th>NL</th>
<th>SportLine</th>
<th>Yamax</th>
<th>Actical</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>66</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>80</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Self-selected</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: Number of trials that failed to register steps
Percent error scores calculated for each model at each speed

<table>
<thead>
<tr>
<th>Target Cadence (bpm)</th>
<th>Omron</th>
<th>NewLifestyles</th>
<th>SportLine</th>
<th>Yamax</th>
<th>Actical</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>45.31</td>
<td>69.42</td>
<td>46.77</td>
<td>66.88</td>
<td>53.66</td>
</tr>
<tr>
<td>66</td>
<td>44.39</td>
<td>43.84</td>
<td>34.08</td>
<td>40.76</td>
<td>37.17</td>
</tr>
<tr>
<td>80</td>
<td>24.93</td>
<td>9.60</td>
<td>11.92</td>
<td>22.74</td>
<td>22.55</td>
</tr>
<tr>
<td>Self-selected</td>
<td>11.94</td>
<td>1.75</td>
<td>8.76</td>
<td>4.65</td>
<td>14.13</td>
</tr>
</tbody>
</table>

Table 3: Percent error mean with zeros removed
Overall Trend

- Mean percentage error

Figure 1: Mean % error of each pedometer across all speeds
Overall Trend

- Mean percentage error average

![Bar Chart](Image)

Figure 2: Average mean % error across devices, stratified by speed
Bland-Altman plots to show agreement between pedometers counts and hand counted steps

(Schneider et al., 2003)
Figure 3: Bland Altman Plot for NL 2000
Piezoelectric/accelerometer pedometers thought to be more accurate in measuring step count as compared to pedometers with mechanical internal mechanisms (Schneider et al., 2003 & Crouter et al., 2003)
ICC to demonstrate within brand reliability (only calculated for self-selected speed)

- Note wide 95% confidence intervals

<table>
<thead>
<tr>
<th></th>
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<th>NewLifestyles</th>
<th>SportLine</th>
<th>Yamax</th>
<th>Actical</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC Value (95% CI)</td>
<td>0.26 (-1.20 – 0.75)</td>
<td>0.98 (0.95 – 0.99)</td>
<td>0.36 (-0.71 – 0.76)</td>
<td>0.70 (0.20 – 0.89)</td>
<td>0.81 (0.62 – 0.90)</td>
</tr>
</tbody>
</table>

Table 4: ICC between pedometer and hand counted steps at self selected speed
Comparing to Ryan *et al.*, 2006
- Note the high ICC for ActiPal (Piezoelectric), and low ICC for Omron (mechanical)

<table>
<thead>
<tr>
<th></th>
<th>Omron HJ 109</th>
<th>Yamax Digiwalker 200</th>
<th>ActiPal</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC Value</td>
<td>0.01</td>
<td>0.48</td>
<td>0.99</td>
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Ryan *et al.*, 2006 Values: based on 500 outdoor track of “slow” self-selected speeds
<table>
<thead>
<tr>
<th>Speed (m/s)</th>
<th>Current Study NL 2000</th>
<th>Current Study ActiCal</th>
<th>Grant NL 2000</th>
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<td>10%</td>
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<td>&gt; 0.91</td>
<td>2%</td>
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<th>Current Study OM HJ105</th>
<th>Current Study SL 330</th>
<th>Grant Yamax SW 200</th>
<th>Cyarto Yamax SW 200</th>
<th>Furlanetto Yamax SW 701</th>
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**Table 5: Comparison of percent error at different speeds for piezoelectric vs. mechanical devices**

Cyarto et al., 2004, March et al., 2007, Grant et al., 2008, Furlanetto et al., 2009, Basset et al., 2010
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Cyarto et al., 2004, March et al., 2007, Grant et al., 2008, Furlanetto et al., 2009, Basset et al., 2010
Comparing Mechanisms

- Current study: New Lifestyles 2000 (piezoelectric) had one of the highest % errors at the two slowest speeds
  - 69 % at 0.46m/s
  - 44 % at 0.66m/s.

- No significant difference in accuracy from one mechanism to the next at slow speeds
ActiCal as Gold Standard

- Bassett *et al.* (2010) - Conflicting evidence on intra-device reliability of ActiCal
  - Welk *et al.* (2004): ActiCal had lowest intra-device reliability of all accelerometers tested

- Current study – ActiCal no more accurate than any other devices even at the fastest, self-selected speeds.

- What might contribute to the variability in results?
  - Short track (80m) and short time (2 min) – Accelerometers designed to record activity over longer period of time (Welk *et al.*, 2004)
Hypotheses Revisited

All pedometers were less accurate at slower speeds and there was no significant difference between mechanisms.
Limitations

- Few units per brand
- Length of track (inflation of percent error)
- Preferentially recruiting healthy older adults who normally walk at a faster pace and do not have any gait impairments
- Pre-set cadence may affect gait pattern
- Sample of convenience
Why This Study is Different

- Examines gait speeds that are representative of older adults speeds
  - Lower than speeds used in some previous research
- Walking over ground instead of treadmill
  - Treadmills alter normal gait patterns (Ryan et al., 2006)
  - Treadmill walking is not the preferred mode of exercise in older adults
  - Want to examine normal, everyday walking activity
- Mean age (63.6 years)
  - Closer to target population – older adults
Why This Study is Different

- Comparison of multiple units of differing mechanisms
- Examines use of ActiCal accelerometer as a gold standard
Future Research

- Measure in more realistic environment
- Ankle vs. Hip mounted pedometers at slower speeds
- Validate the mathematical correction factor for missing steps proposed by Ichinoseki-Sekine (2006)
- Alternative outcome measure for recording physical activity in slow walking older adults
- Investigate pedometer accuracy and reliability in adults with slow self-selected walking speed and gait impairments
Acknowledgements

- Dr. Janice Eng
- Dr. Jeremy Noble
- Chihya Hung, Lab manager
- Everyone at the Rehab Research Lab
- Participants
References

- Bohannon, R. W. Reference values for the timed up and go test: A descriptive meta-analysis.


Thank you

Any questions?