Step by Step: Brief History of Ambulatory Activity Measurement and its Application to Rehabilitation Sciences

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Practical Pedometry

- Expected values
- Standard protocols
- Screening
- Surveillance
- Program evaluation
- Step indices
- Intervention tool
Summary of validity evidence

- Review of 25 articles since 1980
  - median $r = .86$ with different accelerometers
  - median $r = .82$ with time in observed activity
  - median $r = .68$ with different measures of energy expenditure
  - median $r = -.38$ with self-reported sitting time
  - median $r = .33$ with self-reported physical activity

Tudor-Locke et al., *Sports Med* 2002
What I Do and Do Not Know Now

- What I know now
  - Commercial items
  - Patents
  - Change
  - Buyer beware
  - Choose, rationalize, and justify your own choice

- What I don’t know
  - The best instrument for all situations
  - How well they translate
  - Obsolescence
  - Future
2005-2006 NHANES (20+ year olds)

Tudor-Locke et al., *Medicine and Science in Sport and Exercise*, 2009
Inspiration

- Yamanouchi et al. (1995) RCT
  - First to look at 10,000 step/day goal
  - Dieting patients (living in hospital) with type 2 diabetes took 19,200 steps/day and lost 17lbs over 6-8 weeks compared to control group that averaged 4,000 steps/day and lost 9 lbs
Too High for Sedentary Individuals

- Assembled from published literature: 3,500-5,500 steps/day for individuals living with disabilities and chronic illnesses (Tudor-Locke and Myers, 2001)
- Proposed sedentary lifestyle index is <5,000 steps/day (Tudor-Locke et al., 2001)
- Achieving 10,000 steps/day requires a 2-3 fold increase in daily activity
Translating recommendations

- Baseline = 5000 steps/day
- 30 minute walk, 3 days/week
  = 6200 steps/day
  \((60 \text{ min/3 days} = 7500/\text{steps/day})\)
- 30 minute walk, 5 days/week
  = 7100 steps/day
  \((60\text{min/5days} = 9200 \text{ steps/day})\)
- 30 minute walk, 7 days/week
  = 8000 steps/day
  \((60 \text{ min/7days} =11000 \text{ steps/day})\)
Meta-analysis of change in steps/day in pedometer-based programming

Bravata et al., JAMA, 2007
Figure 1: Predicted steps/day for 5, 10, 20, 30, 40, 50 and 60 min/day of moderate to vigorous physical activity (MVPA) in 20+ year old females (□) and males (●): NHANES 2005-2006 (n = 3,523).

Female: $R^2 = 62.0$

p-value < 0.001

n = 1742

Male: $R^2 = 67.3$

p-value < 0.001

n = 1781

Tudor-Locke et al., Preventive Medicine, 2011
At least 6,000 daily steps in moderate-to-vigorous physical activity

At least 15,000 steps/week in moderate-to-vigorous physical activity, e.g., 3,000 daily steps in moderate-to-vigorous physical activity most days of the week

Boys 6-11 years

Girls 6-11 years

Pre-school children

Adolescents 12-19 years

4-6 years

Adults 20-65 years

Healthy older adults 65+ years

Individuals living with disability and/or chronic illness

Arrows indicate that higher is even better

Additional benefits can come from adding in vigorous intensity activity

Tudor-Locke et al., IJBNPA, 2011
Synthesis of 7 treadmill/track/corridor studies

Metabolic Equivalent (MET); 1 MET=3.5 ml oxygen consumption per kg per minute

Tudor-Locke et al., *IJBNPA*, 2011
Studies of observed natural cadence in real-world settings

Steps/min

New York City street

112.5

New York City street

117.5

Various streets in Amsterdam

113.6

Level sidewalk on a busy street in Linköping, Sweden ≅ 100 m from a major shopping center

118.8

Lane through a park in Amsterdam where scenery was inviting

104.4

Residential area, level and uncrowded sidewalk in Fukuoka, Japan (near a women’s junior college)

117.9

1990 in December 1991 in September

Large suburban mall

124.6

NHANES cadence

<table>
<thead>
<tr>
<th>Cadence (steps/minute)</th>
<th>Minutes/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-movement</td>
<td>zero</td>
</tr>
<tr>
<td>incidental movement</td>
<td>1 to 19</td>
</tr>
<tr>
<td>sporadic movement</td>
<td>20 to 39</td>
</tr>
<tr>
<td>purposeful steps</td>
<td>40 to 59</td>
</tr>
<tr>
<td>slow walking</td>
<td>60 to 79</td>
</tr>
<tr>
<td>medium walking</td>
<td>80 to 99</td>
</tr>
<tr>
<td>brisk walking</td>
<td>100 to 119</td>
</tr>
<tr>
<td>faster locomotion</td>
<td>120+</td>
</tr>
</tbody>
</table>

Tudor-Locke et al., *Preventive Medicine*, 2011
NHANES 2005-2006 (n=3522)

<table>
<thead>
<tr>
<th>Steps/min</th>
<th>Total Sample</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak 30-min cadence</td>
<td>100.7</td>
<td>100.9</td>
<td>100.5</td>
</tr>
<tr>
<td>Peak 1-min cadence</td>
<td>71.6</td>
<td>73.7</td>
<td>69.6*</td>
</tr>
</tbody>
</table>
Walk More

Tudor-Locke and Schuna, Frontiers in Endocrinology, 2012

Exercise

Accumulate $\geq 3,000$ steps/day at $\geq 100$ steps/min

Sit Less

Avoid taking $< 5,000$ steps/day and limit prolonged sitting bouts

Take $\geq 7,500$ steps/day
7,500+ steps/day
[Physically Active Lifestyle]
5,000-7,499 steps/day
[Low Active Lifestyle]
< 5,000 steps/day
[Sedentary Lifestyle]

Meeting MVPA recommendations
Not meeting MVPA recommendations

Non-exercise physical activity deficiency; Lack of movement; Higher accumulated time in sedentary behaviors

The First Step Program

Adoption
- 4 weeks
- group meetings
- repetitive agenda
- weekly walks
- individual goal-setting
- self-monitoring with pedometer and activity calendar

Adherence
- 12 weeks
- limited contact (no group meetings)
- individual goal-setting
- self-monitoring with pedometer and activity calendar
- booster session (if needed)
Average steps/day

Tudor-Locke et al., *Patient Education and Counseling*, 2002
Characteristics of pedometers

- Most sensitive to ambulatory activity
- Simple estimate of physical activity volume expressed as steps/day
- Displays accumulated steps taken
- Able to censor out “non-steps”
- Acceptable to end users
- Affordable, valid and reliable instruments available
- Small and unobtrusive, typically attached to the waist band

- Accessible technology, low-literacy friendly, immediately understandable
- Offers readily available and personalized visual feedback
- Useful self-monitoring, goal-setting, and feedback tools
- Immediately increases awareness of physical activity levels
- Increasingly available resource materials to support measurement and motivation efforts

Characteristics of program

- Need to clearly articulate underlying program theory
- Minimally, a program of self-monitoring, incremental goal-setting, and personalized feedback
- Fundamental importance of a goal, possibly 10,000 steps/day, possibly self-selected, but little alternative research has been conducted
- Flexibility in structure of a personalized regimen

- Need to record and submit daily values
- Follow-up contact as one form of social support
- Opportunities to build self-efficacy
- Activating personal support networks
- Peer delivery is effective and may enable dissemination
- Optimal program duration and pattern of contact unknown to support sustainability

Characteristics of participants

- Majority of participants have been women; may reflect recruitment strategies to some extent
- Maybe only appealing for short-term behavior monitoring in men
- Those most likely to complete are overweight and obese Class I
- Attrition indicated by lower initial incremental changes in steps/day, regression to baseline values
- Individual responses vary
- Little is known about who benefits most