Monitoring Physical Activity from Active Transport

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Australian Health Guidelines

“Put together at least 30 minutes of moderate-intensity physical activity on most, preferably all, days”

Department of Health and Aging, Australian Government, 1999
US Guidelines

“For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week”

U.S. Department of Health and Human Services, 2008
Cancer Report Recommendation 2

Be physically active as part of everyday life

PUBLIC HEALTH GOALS

The proportion of the population that is sedentary to be halved every 10 years

Average physical activity levels (PALs) to be above 1.6

Measurement Issues

“Physical activity is rarely measured precisely. Ideally, studies would record the frequency, intensity, and duration of people’s physical activity over an extended period — day and night. But studies are generally not designed to obtain this information. Objective measures such as pedometers and microcomputer sensors are not often used in large studies. Instead, questionnaires are most frequently used.”

p201, WCRF/AICR, 2007
Categories of Physical Activity

Temporal
- Morning
- Afternoon
- Evening

Spatial
- Inside
- Outside

Source
- Transport
- Household
- Recreation
- Work
Physical Activity Bouts

Intensity

Frequency

Duration

High
Medium
Low

Sporadic
Short
Long

Sedentary
Light
Moderate
Hard
Very Hard
Conventional Survey Instruments

- Expensive: data collection, entry & error checking
- Accuracy for measuring physical activity?
  - Under-reporting of trips (eg. walking)
  - Resolution (durations & intensity)
  - Therefore, average speed is not accurate (underestimation)
- Self reporting still widely used
  - *Victorian Integrated Survey Travel & Activities (VISTA)*, DOT, 2007
  - *The Active Australia Survey*, AIHW, 2003
  - *Victorian Lifestyle and Neighbourhood Environment Study (VicLANES)*, VicHealth, 2007
  - *International Physical Activity Questionnaire (IPAQ)*
Self Reporting Methods

- International Physical Activity Questionnaire (IPAQ)
- Travel Surveys (eg. VISTA)
- ABS CENSUS (eg. Journey to work)
- Health Surveys (eg. NHANES & VicLANES)
Measuring Physical Activity

Data Fusion

Integration of ICT for monitoring physical activity

- Geographic Information Systems (GIS)
- Global Position Systems (GPS)
- Accelerometers
- PDA’s & mobile phones
Accelerometer Data

GPS Data

PAL

PA

TEE
Accelerometers

- Measure movement in terms of *acceleration*
- Acceleration is proportional to external force
- Measure locomotor activity
- Low subject burden (esp. memory)
- Objective data
- Unobtrusive (over multiple days)
- Collect data inside buildings (cf. GPS)
Actigraph GT1M

- Measures activity counts (4 milli G’s per sec.)
- Summed over an epoch (eg. 1 minute)
- When worn on waist, estimates the number of steps in each epoch

Has been used in a number of large scale health surveys (eg. NHANES)…
Accelerometer Applications

- Estimate Energy Expenditure
- Walking (frequency, duration & intensity)
- Movement within buildings (eg. between meetings & stairs)
- Estimate PALs
- In conjunction with GPS assist in determining mode & activity
Activity Count profile from accelerometer

<table>
<thead>
<tr>
<th>Date</th>
<th>Light</th>
<th>Moderate</th>
<th>Hard</th>
<th>Very Hard</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/07/2008</td>
<td>1338</td>
<td>51</td>
<td>45</td>
<td>6</td>
<td>694136</td>
</tr>
</tbody>
</table>
Combing accelerometer & GPS data
Global Position Systems (GPS)

- Automatically & accurately determine: WHEN & WHERE of outdoor movement
- Also provides speed of motion

- Procedures developed for determining:
  - HOW (travel mode)
  - WHY (travel purpose)
  - WHAT (activity node)
Speed-Time Training

Speed (km/hr) 28.72
14.36
0
854.1
1708.2 (Time, sec)
Estimating Physical Activity Levels (PALs)

\[ \text{PAL}_i = 1.1 + \sum_j \Delta \text{PAL}_{ij} \]  

(PAL for person i)

\[ \text{BEE}_i = 247 - 2.67a_i + 401.5h_i + 8.6w_i \quad \text{if } g_i = \text{female} \]
\[ \text{BEE}_i = 293 - 3.8a_i + 456.4h_i + 10.12w_i \quad \text{if } g_i = \text{male} \]

\[ \Delta \text{PAL}_{ij} = \frac{[(\text{MET}_j - 1) \times (1.15/0.9) \times d_{ij}] / 1440}{\text{BEE}_i / (0.0175 \times 1440 \times w_i)} \]

where,

\( \text{BEE}_i \) = basal energy expenditure for person i
\( a_i \) = age of person i (years)
\( h_i \) = height of person i (meters)
\( w_i \) = weight of person i (kg)
\( g_i \) = gender of person i (‘male’ or ‘female’)
\( \text{MET}_j \) = metabolic equivalence of activity j
\( d_{ij} \) = duration of activity j for person i (minutes)
\( \Delta \text{PAL}_{ij} \) = energy expenditure of activity j for person i

## PAL → PA

<table>
<thead>
<tr>
<th>Physical Activity Level (PAL)</th>
<th>PA Men</th>
<th>PA Women</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1, 1.4)</td>
<td>1</td>
<td>1</td>
<td>Sedentary</td>
</tr>
<tr>
<td>[1.4, 1.6)</td>
<td>1.12</td>
<td>1.14</td>
<td>Low Active</td>
</tr>
<tr>
<td>[1.6, 1.9)</td>
<td>1.27</td>
<td>1.27</td>
<td>Active</td>
</tr>
<tr>
<td>[1.9, 2.5)</td>
<td>1.54</td>
<td>1.45</td>
<td>Very Active</td>
</tr>
</tbody>
</table>

Estimating Total Energy Expenditure (TEE)

\[
TEE_i = 864 - 9.72a_i + PA_i(14.2w_i + 503h_i) \quad \text{if } g_i = 'male' \\
TEE_i = 387 - 7.31a_i + PA_i(10.9w_i + 660.7h_i) \quad \text{if } g_i = 'female'
\]

where,

\( TEE_i \) = Total Energy Expenditure for person \( i \) (kcal/day)  \\
\( a_i \) = age of person \( i \) (years)  \\
\( h_i \) = height of person \( i \) (metres)  \\
\( w_i \) = weight of person \( i \) (kg)  \\
\( g_i \) = gender of person \( i \) (‘male’ or ‘female’)  \\
\( PA_i \) = physical activity of person \( i \)

## Cycling METs

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>METs</th>
</tr>
</thead>
<tbody>
<tr>
<td>For leisure or work &lt; 16 km/h</td>
<td>4</td>
</tr>
<tr>
<td>General</td>
<td>8</td>
</tr>
<tr>
<td>Fast, vigorous effort (22-25 km/h)</td>
<td>10</td>
</tr>
</tbody>
</table>

*Ainsworth et al, 2000*
# Walking MET Examples

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed less than 3.2 km/h, level ground, strolling very slow</td>
<td>2</td>
</tr>
<tr>
<td>From house to car or bus, from car or bus to go places, from car or bus to and from the worksite</td>
<td>2.5</td>
</tr>
<tr>
<td>Speed at 5km/h, level, moderate pace, firm surface,</td>
<td>3.3</td>
</tr>
<tr>
<td>Carrying 6.8kg bag on level ground</td>
<td>3.5</td>
</tr>
<tr>
<td>Speed of 8 km/h</td>
<td>8</td>
</tr>
</tbody>
</table>

Ainsworth et al, 2000
Travel Mode Detection

- Trip segment statistics
  - Duration, distance & travel speed
- Start & End stop information
  - Closeness to public transport stop (bus, train & tram)
  - Land-use type
- Path (network alignment)
- Rules developed using CART procedures and travel survey data
  - GPS data & VISTA07

Eg. $x < 1.5km$ & $v < 6km/h$ & $\Delta t < 25 min \Rightarrow WALK$
GPS & GIS Integration

- Activity Determination
  GPS → (Latitude, Longitude) → Address → Land Use Type → Activity

- Mode Determination for Trip Stages
  Daily Log → Trips → Trip Stages
  - Rules developed for determining trips & trip stages
    - Travel speeds (mean, maximum & SD)
    - Origin & Destination land use types
    - Duration
    - Distance
    - Steps (accelerometer)
Daily Energy Expenditure from Activity, Transport & Sleep
Duration of Physical Activity from Transport
Duration of Moderate & Vigorous PA
Current Research

- Data fusion & interpretation (iPhone)
- Mode detection algorithms (DOT)
- Gestational Diabetes (MIHR)
- Active commuting for sedentary occupations (drivers)
- Active transport coaching
- Pre-diabetes & weight management
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