Measuring Energy Expenditure After Stroke
Validation of a Portable Device

Sarah A. Moore, BSc; Kate Hallsworth, BSc; Les J.C. Bluck, DPhil; Gary A. Ford, FRCP; Lynn Rochester, PhD; Michael I. Trenell, PhD

Background and Purpose—Current means of assessing physical activity and energy expenditure have restrictions in stroke, limiting our understanding of its role in therapeutic management. This study validates a portable multisensor array for measuring free-living total energy expenditure compared with a gold standard method (doubly labeled water) in individuals with stroke.

Methods—Daily energy expenditure was measured in 9 participants with stroke (73±8 years) over a 10-day period with 2 techniques: a portable multisensor array and doubly labeled water.

Results—Bland-Altman analysis revealed a mean difference of 94 kcal/day (3.8%) in total energy expenditure measures given by the multisensor array in comparison to doubly labeled water with lower and upper limits of agreement of −276 to 463.8 kcal/day (2473±468 versus 2380±551, \(P=0.167\)). There was strong agreement between the multisensor array and labeled water methods of capturing total daily energy expenditure (\(r=0.850, P=0.004\)).

Conclusions—The multisensor array is a portable and accurate method of capturing daily energy expenditure and may assist in understanding how stroke influences free-living energy expenditure and aid in clinical management. (Stroke. 2012;43:00-00.)

Key Words: accelerometry ■ doubly labeled water ■ physical activity

Stroke is a leading cause of functional impairment.1 The direct neurological effects of stroke can lead to diminished energy expenditure and physical fitness levels, resulting in an increased risk of further stroke and cardiovascular disease.2,3 Low levels of total daily energy expenditure (TEE), incorporating nonexercise and sedentary activity, have been linked to chronic conditions such as cardiovascular disease, Type 2 diabetes, and all-cause mortality.3,4 A major limit to objectively evaluating, and as a result understanding, energy expenditure after stroke is the lack of validated and accessible methods. Although doubly labeled water (DLW) is the gold-standard measure of free living TEE,5 it is expensive, technically demanding, and requires upper limb dexterity for urine collection, which can be problematic after stroke. A solution to this problem may be the use of a portable multisensor array.6 This study aimed to (1) compare measures of TEE estimated by a portable multisensor array with those measured by DLW; and (2) estimate the limits of agreement.

Subjects and Methods

Subjects
Nine subjects (>6 months poststroke; Table) took part in the study. Participants had mild gait deficit (asymmetry of gait/reduced stance time/increased swing time in the affected limb) but were able to walk 10 m independently with/without an aid. Participants were excluded if they had deficits in communication or cognitive problems that would limit their participation, mobility problems before stroke, or a comorbid neurological disorder. All participants gave written informed consent for the study. The study was approved by the National Health Service County Durham and Tees Valley Research Ethics Committee.

Doubly Labeled Water
A dose of DLW containing 174 mg/kg body weight of \(^{18}\)O and 70 mg/kg body weight of \(^{2}\)H was prepared for the participants to drink. Urine samples were then collected daily for 10 days at a similar time of day but not the first void of the day.

Multisensor Array
A multisensor array (Sensewear Pro3; Bodymedia Inc) was positioned on the back of the participant’s nonaffected upper limb, midway between the shoulder and elbow. The multisensor array gathers raw physiological data on movement (through a biaxial accelerometer), heat flux, skin temperature, near body temperature, and galvanic skin response. Algorithms process the raw data into energy expenditure levels. The monitor was worn for 10 days over the same period as DLW, only removing for water-related activity.

Data Acquisition and Analysis
DLW analysis was carried out using isotope ratio mass spectrometry as described previously.7 Basal metabolic rate and fat mass were estimated from published equations.8 Activity energy expenditure was calculated by TEE—basal metabolic rate.
Statistical Analysis
Differences were evaluated using the Mann-Whitney U test with Spearman rank correlation coefficients applied to show relationships between methods. Agreements between methods were assessed using a Bland-Altman plot. A predefined value of \( \pm 300 \) kcal/day was set as an upper and lower limit of agreement for reasons previously described.\(^{10}\) All statistical analysis was carried out using SPSS Version 17 (SPSS Inc, Chicago, IL). All data are presented as means±SD unless otherwise stated. Statistical significance was indicated if \( P<0.05. \)

Results
Baseline characteristics are given in the Table. Adherence with the multisensor array was excellent with all 9 participants wearing the monitor for >95% of the recording period. DLW and multisensor array measures of TEE were not significantly different (2473±468 versus 2380±551, \( P=0.167).\) There was a strong relationship between DLW and multisensor array methods of capturing TEE (\( r=0.850, P=0.004; \) Figure 1). Bland-Altman analysis revealed a mean difference of 94 kcal/day (95% CI, 49–236; 3.8%) in TEE measures given by the multisensor array in comparison to DLW (Figure 2). Only 1 individual was outside the predefined 300-kcal/day upper and lower limits of agreement.

**Discussion**
This study demonstrates that the portable multisensor array accurately measures TEE compared with DLW in stroke survivors with mild gait deficit. Because within-subject measures of daily TEE with DLW can vary by 8% (200 kcal/day),\(^{11}\) a mean difference of 93 kcal/day between the 2 methods is minimal. Importantly, the multisensor array produced an estimation of TEE within 160 kcal/day in individuals with marked gait asymmetries. Combined with ease of use, these data demonstrate that the multisensor array is a novel and valid assessment tool, which may assist understanding TEE in stroke and potentially its clinical management.

To date, physical activity levels after stroke have been measured using observation, self-report, or objective measurement by accelerometry.\(^{11,12}\) Subjective methods have recall and social desirability bias and are inaccurate in determining frequency, duration, and intensity of physical activity, limiting their applicability in stroke.\(^{13}\) Although accelerometry has been demonstrated to be an accurate and reliable measure of step count after stroke,\(^{11}\) estimation of TEE from accelerometry counts is inaccurate\(^{13}\) due to differences in efficiency of movement.\(^{14}\) The multisensor array may hold benefits over accelerometry alone by determining energy expenditure from a mixture of movement, temperature,

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**Table. Participant Characteristics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Stroke, Mean±SD</th>
<th>95% CI for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>73±8</td>
<td></td>
</tr>
<tr>
<td>Gender, female/male</td>
<td>3/6</td>
<td></td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27±2</td>
<td></td>
</tr>
<tr>
<td>National Institute of Health Stroke Scale (0–42)</td>
<td>2±2 (range, 0–7)</td>
<td></td>
</tr>
<tr>
<td>Walking speed, m/s</td>
<td>1.4±0.3</td>
<td></td>
</tr>
<tr>
<td>Body fat mass predicted from BMI, %</td>
<td>28±7</td>
<td></td>
</tr>
<tr>
<td>Basal metabolic rate, kJ</td>
<td>6809±1209</td>
<td></td>
</tr>
<tr>
<td>Total energy expenditure by doubly labeled water, kcal/d</td>
<td>2473±468</td>
<td>2114–2833</td>
</tr>
<tr>
<td>Total energy expenditure by multisensor array, kcal/d</td>
<td>2380±468</td>
<td>1956–2803</td>
</tr>
<tr>
<td>Active energy expenditure by doubly labeled water, kcal/d</td>
<td>855±321</td>
<td>608–1101</td>
</tr>
<tr>
<td>Active energy expenditure by multisensor array, kcal/d</td>
<td>753±332</td>
<td>498–1009</td>
</tr>
</tbody>
</table>

SD indicates standard deviation; CI, confidence interval; BMI, body mass index.

**Figure 1.** Relationship between the multisensor array and doubly labeled water measures of total energy expenditure.
ture, and galvanic skin responses, which are more sensitive to changes in movement efficiency.

DLW provides highly accurate data; however, it is a complex and expensive technique limiting its application to smaller groups. Caution is therefore required when interpreting the data due to the small sample size and inclusion of individuals with mild stroke, which limits the generalizability of findings. Further studies exploring the accuracy of this technique in individuals with moderate stroke are warranted.

In summary, this study demonstrates that the multisensor array provides an accessible and accurate method of objectively measuring TEE in individuals with mild stroke and may reduce the inaccuracies observed when TEE is estimated from accelerometry. The multisensor array may assist in understanding alterations in energy expenditure in stroke and potentially assist in identifying new therapeutic avenues.

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Disclosures
None.

References
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