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Measuring energy expenditure following stroke; validation of a portable device

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Figures: 2

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Abstract

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 multi-sensor array for measuring free-living total energy expenditure compared with a gold standard method (doubly labelled water) in individuals with stroke.

Methods - Daily energy expenditure was measured in nine participants with stroke (73 ± 8yrs) over a ten-day period with two techniques: a portable multi-sensor array and doubly labelled water.

Results - Bland-Altman analysis revealed a mean difference of 94kcal/day (3.8%) in total energy expenditure measures given by the multi-sensor array in comparison to doubly labelled water (DLW), with lower and upper limits of agreement of -276 to 463.8kcal/day (2473 ± 468 vs. 2380 ± 551, p=0.167). There was a strong agreement between the multi-sensor array and DLW methods of capturing TEE (r=0.850, p=0.004).

Conclusion - The multi-sensor 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.

Introduction

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].

Low levels of total daily energy expenditure (TEE), incorporating non-exercise and sedentary activity, have been linked to chronic conditions such as cardiovascular disease, diabetes and all-cause mortality[3, 4]. A major limit to objectively evaluating, and as a result understanding, energy expenditure following stroke, is the lack of validated and accessible methods. Although doubly labelled water 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 following stroke. A solution to this problem may be the use of a portable multi-sensor array.[6] This study aimed to 1) compare measures of TEE estimated by a portable multi-sensor array to those measured by DLW, and 2) estimate the limits of agreement.

Subjects and methods

Subjects: Nine subjects (>six months post stroke, Table 1) 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 10m independently with/without an aid. Participants were excluded if they had deficits in communication or cognitive problems which would limit their participation, mobility problems prior to stroke or a co-morbid neurological disorder. All participants gave written informed consent for the study. The study was approved by the National Health Service County of Durham and Tees Valley Research Ethics Committee.

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

Multi-sensor array: A multi-sensor array (Sensewear Pro_3, Bodymedia Inc, PA, USA) was positioned on the back of the participant's non-affected upper limb, midway between the shoulder and elbow joint. The multi-sensor array gathers raw physiological data on movement (via a bi-axial 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 ten 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 (BMR) and fat mass were estimated from published equations[5, 8]. Activity energy expenditure was calculated by TEE - BMR.

Statistical analysis: Differences were evaluated using the Mann-Whitney U test with Spearman's rank correlation coefficients applied to show relationships between methods. Agreements between methods were assessed using Bland-Altman plot. A predefined value of ± 300 kcal/day was set as an upper and lower limit of agreement for reasons previously described[9]. All statistical analysis was carried out using SPSS version 17 (SPSS Inc., Chicago, IL, USA). All data are presented as means ± SD unless otherwise stated. Statistical significance was indicated if $p<0.05$.

Results

Baseline characteristics are given in Table 1. Adherence with the multi-sensor array was excellent with all nine participants wearing the monitor for >95% of the recording period. DLW and multi-sensor array measures of TEE were not significantly different (2473 ± 468 vs. 2380 ± 551, p=0.167). There was a strong relationship between DLW and multi-sensor 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% confidence interval: 49-236, 3.8%) in TEE measures given by the multi-sensor array in comparison to DLW (Figure 2). Only one individual was outside the pre-defined 300 kcal/day upper and lower limits of agreement.

Discussion

This study demonstrates that the portable multi-sensor array accurately measures TEE compared to DLW, in stroke survivors with mild gait deficit. As with-in subject measures of daily TEE with DLW can vary by 8% (200 kcal/day)[10] a mean difference of 93kcal per day between the two methods is minimal. Importantly, the multi-sensor 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 multi-sensor 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 following 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 following stroke[11], estimation of TEE from accelerometry counts is inaccurate[13] due to differences in efficiency of movement[14]. The multi-sensor array may hold benefits over accelerometry alone by determining energy expenditure from a mixture of movement, temperature 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 multi-sensor 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 multi-sensor array may assist in understanding alterations in energy expenditure in stroke and potentially assist in identifying new therapeutic avenues.

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Figure Legends

Figure 1 Relationship between the multi-sensor array and doubly labelled water measures of total energy expenditure

Figure 2 Bland-Altman Plot showing limits of agreement between multi-sensor array and doubly labelled water total energy expenditure measures. The unbroken horizontal lines are ±2SD and broken are ±300 kcal limits of agreement

Table 1 Participant Characteristics

Variable	Stroke Mean ± SD	95% Confidence Interval for Mean
Age (yrs)	73 ± 8	
Gender (F/M)	3/6	
Body mass index (kg/m²)	27 ± 2	
National Institute of Health Stroke Scale (0-42)	2 ± 2 (range 0-7)	
Walking speed (m/s)	1.4 ± 0.3	
Body fat mass predicted from BMI (%)	28 ± 7	
Basal metabolic rate (KJ)	6809 ± 1209	
Total energy expenditure by doubly labelled water (kcal/day)	2473 ± 468	2114-2833
Total energy expenditure by multi-sensor array (kcal/day)	2380 ± 468	1956-2803
Active energy expenditure by doubly labelled water (kcal/day)	855 ± 321	608-1101
Active energy expenditure by multi-sensor array (kcal/day)	753 ± 332	498-1009

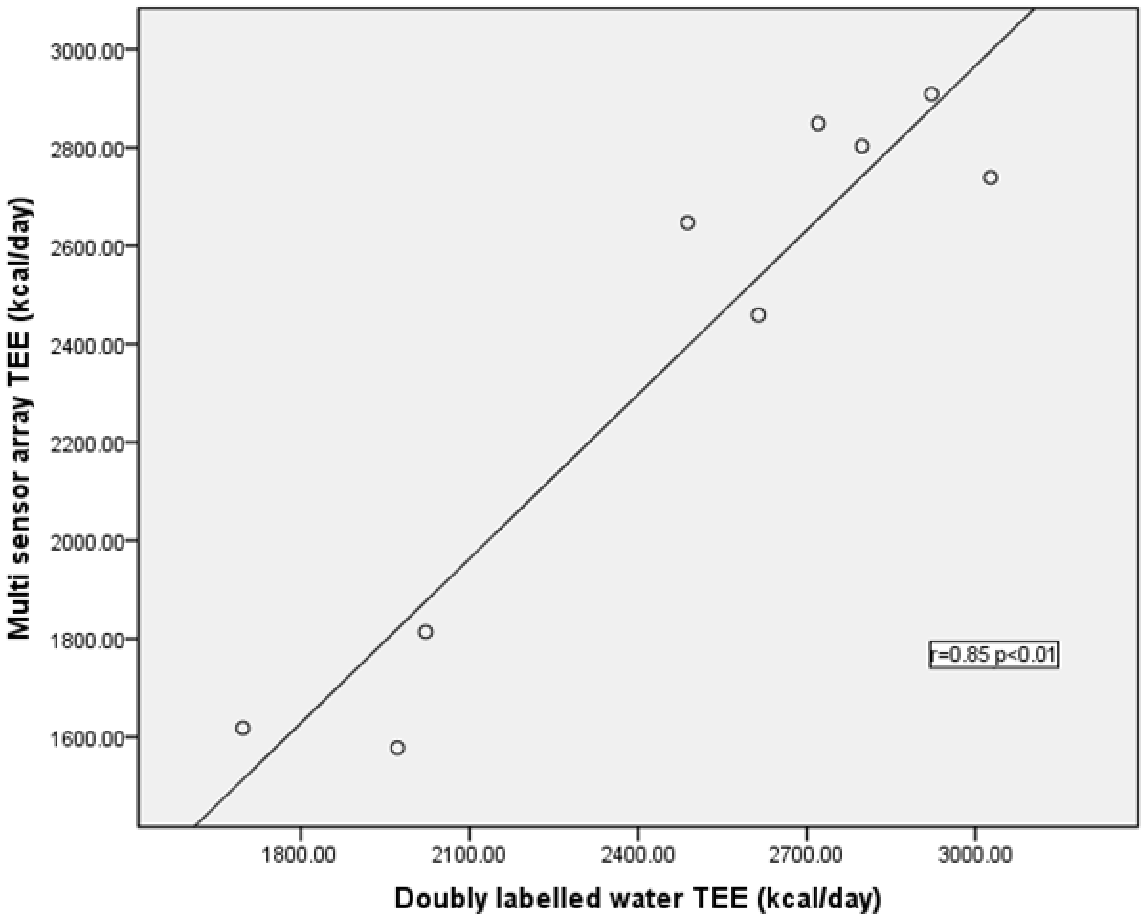

Figure 1- Relationship between the multi-sensor array and doubly labelled water measures of total energy expenditure

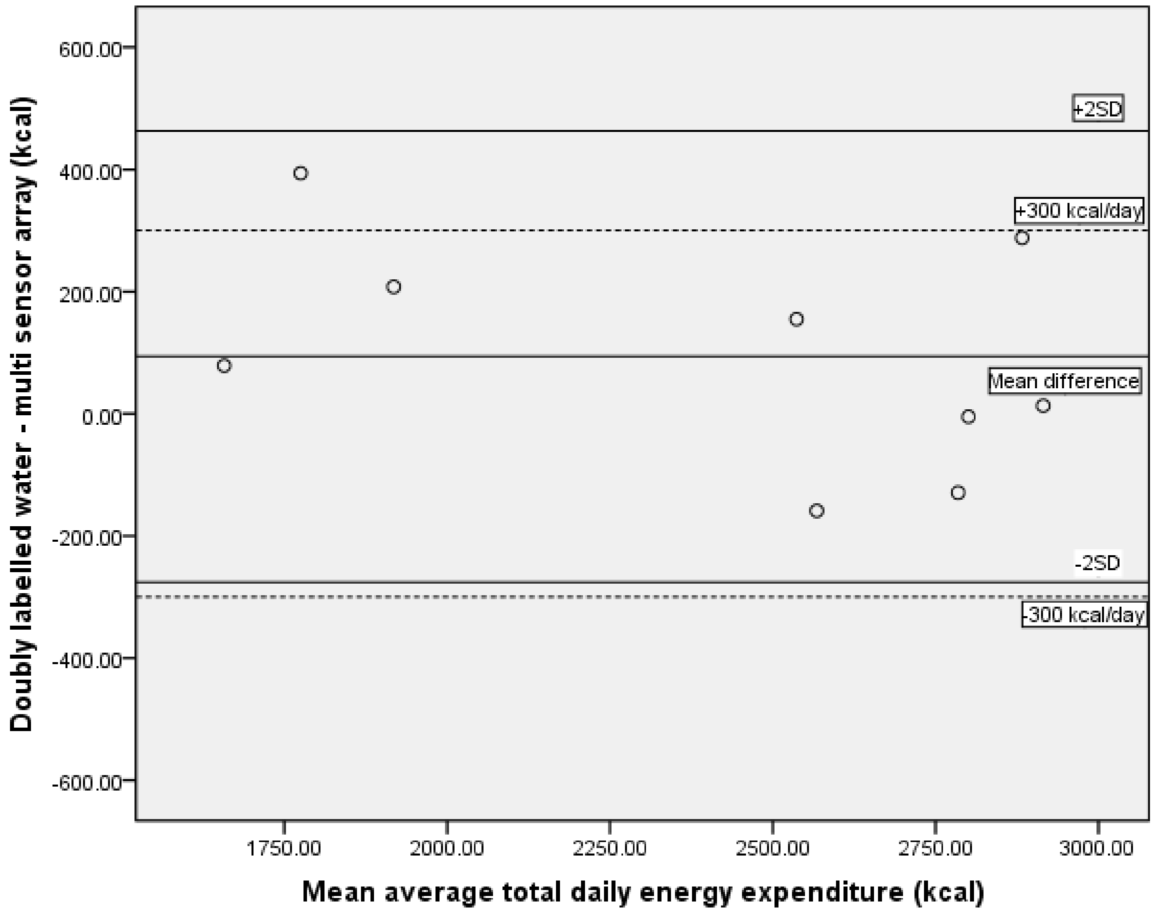

Figure 2- Bland-Altman Plot to demonstrate limits of agreement between multi-sensor array and doubly labelled water total energy expenditure measures. The unbroken horizontal lines represent the limits of agreement corresponding to ±2SD. The broken lines represent the ±300 kcal limits of agreement