Determination of 6-minute walk test using accelerometer-based ambulatory monitoring device for the assessment of patient's progress in cardiac rehabilitation

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Abstract—**Cardiovascular Disease (CVD) is a leading health problem in Australia, USA and other western countries. The management of CVD, following a cardiac event, is managed through cardiac rehabilitation (CR) programs over 4 to 12 weeks, which also prescribes a daily recommendation of at least 30 minutes of moderate physical activity, as outlined by most national bodies of CVD guidelines. Currently, there is no way of measuring physical activity other than through self-reporting or diary or 6 minute walk test (6MWT) at the hospital exercise clinics.**

Following a validation study of metabolic expenditure (MET) derived from accelerometer-based ambulatory monitors with the traditional measure of MET from oxygen consumption (VO2) output from a breath gas analyzer (Cosmed srl, Italy), resulting in a highly linear correlation (r^2=0.88), it was tested on 23 patients undergoing a 6-week CR program at 2 Queensland hospitals. The patients wore the accelerometer device continuously at home and during exercise sessions at the hospital. Different stages (PRE, END, and EXIT) of CR program of patient progress were assessed using 6MWT and compared with ambulatory MET values.

Increases in patients' free living MET values from PRE, to END and EXIT stages significantly correlated with that of 6MWT measures at the exercise clinic (r^2=0.72, p<0.01). Ambulatory assessment of MET through accelerometers can be used as surrogates of clinical 6MWT to measure physical activity for CR programs in home-based care.

Keywords— **cardiac rehabilitation, six-minute walk test, accelerometer, ambulatory monitoring**

I. Introduction

A number of studies indicate that six minute walk test (6MWT) is a prognostic marker of patients with cardiovascular diseases [1]. The 6MWT has been shown to represent functional capacity of undergoing rehabilitation. It is often conducted in a clinical setting which may be contaminated by factors pertaining to the clinical environment and guidance of the clinical coordinator the patient's is being examined under. Regardless, the 6MWT still remains as the more readily used measure of functional capacity in the assessment of patient's progress in cardiac rehabilitation to determine their functional capacity. As home-care monitoring and community care model for secondary prevention and cardiac rehabilitation of CVDr patients is becoming the initiative in most developed countries, a surrogate measure of functional capacity needs to be determined for such a care model. Ambulatory monitoring has been looked upon as a means to measure patients health condition in such free-living environment and hence, 6MWT in these environments will obviate some of the limitations or contamination that prevails in the current method of 6MWT measurement and assessment.

The purpose this study is to demonstrate the ability to determine a surrogate measure of physical activity from an accelerometer-based ambulatory monitor that correlates with 6MWT on cardiac rehabilitation patients.

II. Methods

A. Clinical trial preparation

Twenty three patients were recruited from two hospitals' cardiac rehabilitation programs and consented to participate in an ambulatory monitoring clinical trial. The ambulatory monitor consisted of a 3-axes accelerometer (Heart Monitor, Alive Technologies, Gold Coast, Australia), which is worn around the waist using a customized belt with a mobile phone pouch.

B. Clinical trial protocol

The 6 week CR program consisted of 12 exercise sessions, 2 sessions per week at the respective hospital gym. Consented patients were required to wear the device continuously for 24 hours from the 3rd session to the final, 12th session, during and outside the CR hospital exercise clinic. Only exceptions to the continuous wear of the devices were during shower or bath and the patient's choice taken to either wear or not to wear during sleep at night.

Fitting the device on a patient's waist and the collection of SD memory cards, containing the monitored acceleration data from the device were conducted by a clinical staff

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member coordinating the CR program. SD memory data collection and replacement for each patient were performed just prior to the start of each exercise session. At the same time the device battery was replaced. Data were downloaded for offline data analysis outside of the CR sessions by the authors.

C. Data Analysis

In a separate study (unpublished), we derived metabolic expenditure (MET) from the accelerometer data which showed a high linear correlation (r^2=0.88) with energy expenditure derived from simultaneous measurement of VO_2 via breath gas analysis. Eight healthy subjects were each fitted with an accelerometer on their the Queensland Institute of Sports, Brisbane, Australia. The subjects performed eight different one-minute tasks with varying intensity including three levels of walking on a treadmill. A linear regression equation was derived between the measured accelerometer and breath gas analyzer data. The resulting equation was used to estimate the free living MET from acceleration signals:

$$SMA = \int (AccX(t) + AccY(t) + AccZ(t))\, dt \qquad (1)$$

where SMA is the signal magnitude area and AccX(t), AccY(t), AccZ(t), are acceleration values x, y, and z, respectively, at time t

$$VO_2 = 1.1*SMA + 5.7 \qquad (2)$$

where VO2 is the oxygen consumption and SMA is the magnitude acceleration as per Equation (1)

MET values were calculated over each 15 seconds of raw acceleration signals. *Daily MET levels* (or absolute MET levels) were derived from these by calculating the mean MET values over a 24 hour period. The means were calculated after passing the 24 hour MET values through a sliding filtering window.

III. Results

CR patients were assessed with a 6MWT at different stages of CR program (PRE, END and EXIT) with the distances covered in 6 minutes were recorded: before the first exercise session (PRE), after the last exercise session (END), and one month after the END (EXIT). The combined test results are shown in Figure 1.

The 6MWT results were used as a reference measure and were compared with the measured free living energy expenditure (in MET) during the days the patients did not attend the hospital exercise sessions (non-CR days).

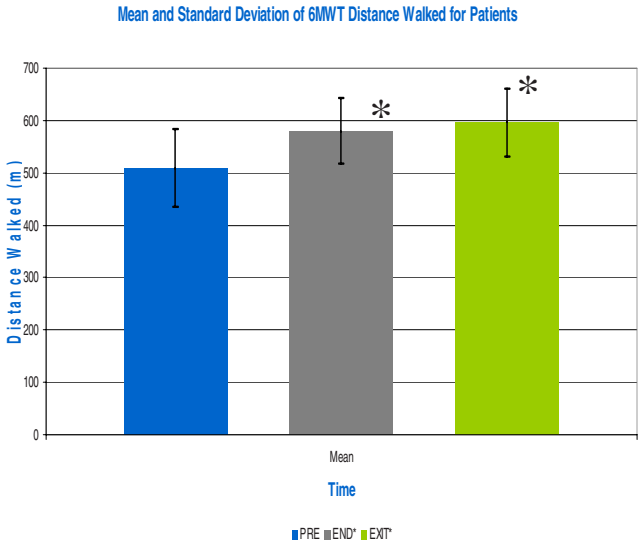

Figure 1: Bar chart showing 6MWT distances for CR patients at different stages (pre, end and exit) of the trial. The mean and Standard deviation of 6MWT distances along with t-test values are shown below in Table 1. * p<0.01 versus PRE

Table 1: Improvements in mean MET values derived from 3-axes accelerometers

	PRE	END	EXIT
Mean	509.38	580.04*	596.62*
SD	74.97	62.75	64.82
p		0.002	0.002

SD=standard deviation, p<0.05 versus PRE.

The mean distance covered at the end of CR improved by 70.66 metres (13.87%) at END and 87.24 metres (17.13%) at EXIT of CR compared to the mean of 509.38 metres observed at the start of the CRb. These improvements were found to be statistically significant (p<0.01, t-test) at 95% confidence interval.

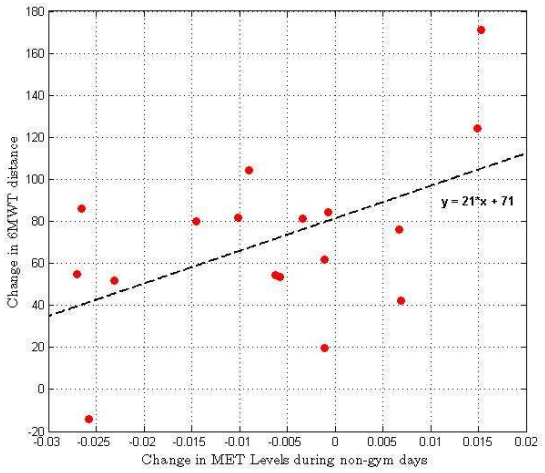

Figure 2: Change in MET levels recorded at home (x-axis) versus change in distance covered in 6MWT at the start and end of CR (y-axis).

Mean of Non-CR days *Daily MET level* with filter window of length 5 minutes had the highest correlation with 6MWT distance calculated at the end of the rehab (Correlation Coefficient, $r^2 = 0.72$ and p value < 0.01) .

IV. CONCLUSIONS

MET derived from accelerometers correlates highly with the traditional measure of MET from VO_2. Increases in patient's accelerometer-based MET in free-living environment from PRE, to END and EXIT stages of the CR significantly corresponds with the 6MWT measures at the exercise clinic (r^2=0.72, p<0.01). Hence, ambulatory assessment of MET through accelerometers can be used as surrogates of clinical 6MWT to measure functional capacity for CR programs in home-based care models.

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