Real Time Dose-Response Assessment Tool Applicable in Exercise Therapy

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Abstract. In this paper we present a new tool, which enables the study of the dose-response relationship in real time, through the assessment of the level of physical activity using METs, and applicable in exercise therapy. A validation protocol for METs algorithm was performed, and METs values were obtained for various real-world and lifestyle and sporting activities. These values were compared with the results from the state-of-the-art work in the field for the same activities. Results have proven to be accurate, according to the model by Crouter, allowing the assessment of physical activity level. Our tool is intended for practitioners working addressing exercise activities and exercise therapy in a wide range of areas, one of which is psychology. According to the obtained results, the base hardware holds comparable performance with the advantage of being wearable and wireless, and thus convenient to be used on the daily monitoring of the patients daily routines.

1 Introduction

Associated with both morbidity and mortality, depression is a major public health problem throughout the world and is characterized by lowered mood, loss of capacity to experience pleasure, increased sense of worthlessness, fatigue, and preoccupation with death and suicide [1]. Exercise therapy is known to play a major role in the reduction of morbidity and mortality [1]; several studies consistently found relation between physical activity and disorders such as depression [1–5] and it has become generally accepted that regular physical exercise ultimately results in benefits to participants [2, 3]. Evidence of a dose-response relationship between physical activity and protection against symptoms of depression and anxiety has also been documented [4, 6].

Biosignal measurement and analysis stand as an important resource, for practitioners to better support prevention and intervention strategies aimed at decreasing depression and anxiety disorders. Strategies applicable to populations inexpensively and without side effects, are needed, as current estimates point psychological disorders such depression to be the leading burden of disease worldwide by the year 2020 [4]. In this

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paper we present a tool capable of monitoring the dose of physical activity in real-time and record data for future analysis. This will allow practitioners to better study the dose-response of physical activity in exercise therapies, and to be used in the future by patients to monitor their activity level. The rest of the paper is organized as follows: Section 2 describes the tool targeted at the study of dose-response relationship between physical activity and depression; Section 3 presents the acquisition system and validation procedures; Section 4 outlines the main results, and Section 5 highlights the overall conclusions .

2 Measuring Physical Activity

Our proposed tool is capable of monitoring and evaluate the level of physical activity based on the metabolic equivalent for task (MET). METs are used to estimate the level of physical activity, and it is defined as the resting metabolic rate, that is, the amount of oxygen consumed at rest. As such, exercise at 2 METs requires twice the resting metabolism, and so on [7]. METs can be computed as a function of the magnitude of the accelerometer signal. For this, a real time bandpass filter was implemented, based on a Infinite Impulse Response model determined for a 2 nd order Butterworth filter within the 0.25-1.4 Hz passing band. This filter was used since these frequencies correspond to the range of human activities are performed.

Based on uniaxial Actigraph devices, the input signal corresponds to the acceleration signal in a range of 0.05-2 G, and the output signal to the filtered acceleration signal, which is subsampled at 10 Hz.. Then, $counts \times min^{-1}$ and the coefficient of variation of $counts$, $c_v = \frac{\sigma}{\mu}$, are determined each 10 seconds over a period of one minute. For this operation, the range of the accelerometer is divided into levels of 0.001664 g, being each level considered 1 $count$. The number of $counts$ is determined by how many levels the difference of the magnitude of the acceleration between samples corresponds to during this period [8]. Then the $counts \times min^{-1}$ are converted into METs through a non-linear signal processing algorithm using two regression equations based on the method described by Crouter et al. [9].

The output values presented to the user, in the visual display alongside with the raw data signals, are the METs, as shown in Figure 1. The raw data is represented in a window with a dimensionless auto-scale y-axis. If the user chooses to record the data, the parameters recorded are the $counts \times min^{-1}$ and METs. Table 1 shows the typical classification of the physical activity according with the METs results [10].

Table 1. Classification of activity level using the METs values.

METs	Activity level
≤ 3	Light
$3 >$ METs ≥ 6	Moderate
METs > 6	Vigorous

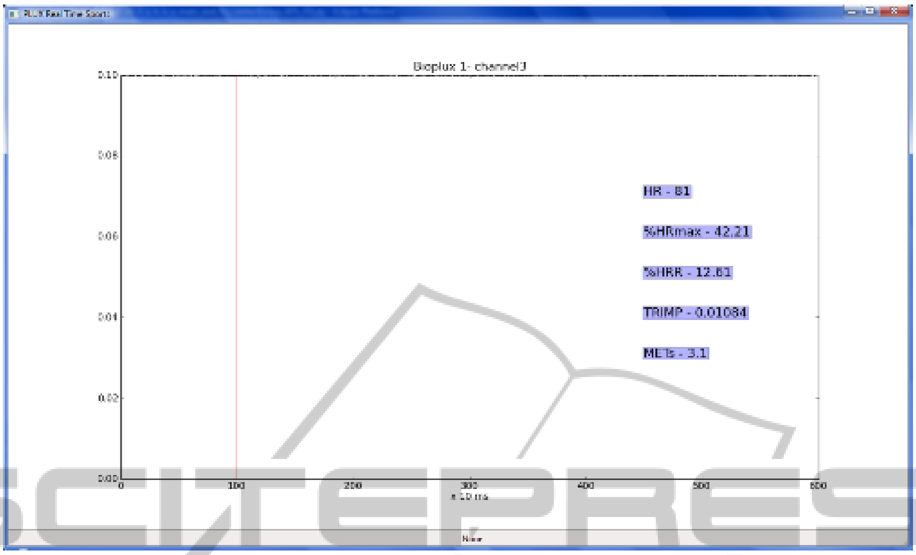

Fig. 1. Example of the display window with multilpe physical activity assessment parameters.

3 Experimental Evaluation

We used a bioPLUX motion data acquisition system [11]. This wireless system is also responsible for the signal's analog to digital conversion, using a 12 bit ADC, and Bluetooth transmission of data to a computer. This system can acquire data from an integrated 3-axis accelerometer at a maximum sampling rate of 1000 Hz. The bioPLUX allows to visualize the raw signal in real-time and save data in .txt file to post-processing. With this system we can see the METs values in real-time and compare these values with the offline values from the raw data. The comparison between real-time and offline values allowed to validate if the algorithm in real-time are correctly implemented.

To validate the real time algorithm for METs calculation based on the model defined by Crouter [9], a set of various lifestyle and sporting activities were performed. The selected activities were Lying, Standing, Computer work, Filling papers, Ascending/Descending stairs, Slow walk, Brisk walk and Slow run. These activities were selected based on those used by Crouter to validate his model. Each of these activities had a duration of 10 minutes, and were repeated only once producing a total of 60 METs values per repetition, since the algorithm determines the METs each 10 seconds. The mean value and standard deviation of METs per min were calculated to compare with Crouter model results for each activity.

It is intended that this tool is used by practitioners to study the dose-effect in different physical activity levels. The protocol used in these studies must be done by the practitioners according with their knowledge and intended therapeutic model.

4 Results and Discussion

Table 2 shows the mean and standard deviation (SD) METs values obtained by Crouter and by our METs algorithm for each activity [10]. As we can observe, the METs results from our algorithm for Lying, Standing, Computer work and Slow run are equal to those obtained by Crouter. For the Filling papers activity it is possible to verify a difference of 0.07 METs. For the activities of Slow walk, Brisk walk and Ascending/Descending stairs a difference of 0.27, 0.33 and 0.67 METs was found, respectively.

These differences can be explained by the fact that these activities involve free movement and/or depend heavily on the locomotion of the individual. Therefore, more tests must be done, preferably also using a gold standard device, but preliminarily we were able to prove experimentally the correct functioning of the algorithm. The lower values of SD obtained using METs algorithm are justified by the use of only one repetion instead of the fifteen performed by Crouter. The dose-response relationship study results will be obtained in future by practitioners using this tool, and will help to provide a better understanding of this relationship. This fact would be the most helpful for practitioners advising patients about the benefits of physical activity for both somatic and psychologic well-being [1]. Since this tool is already portable, it would be ready for use in the daily life of patients, allowing the real-time adjustment of the exercise therapy.

Table 2. Results from Crouter and METs algorithm.

	Crouter METs	METs alg.
Activity	Mean (SD)	Mean (SD)
Lying	1.00 (0.00)	1.00 (0.00)
Standing	1.00 (0.00)	1.00 (0.00)
Computer work	1.00 (0.00)	1.00 (0.00)
Filling papers	1.30 (0.67)	1.23 (0.56)
Slow walk	3.73 (0.42)	3.46 (0.05)
Brisk walk	4.71 (0.58)	4.38 (0.06)
Asc./Desc. stairs	6.08 (1.29)	5.41 (1.15)
Slow run	7.76 (0.96)	7.76 (0.27)

5 Conclusions

In this paper we presented a tool for real time evaluation of physical activity, supported in an inexpensive and miniaturized base hardware device. We were able to validate the METs algorithm for the calculation of physical activity estimates in real-time; experimental results on real-world data enabled us to validate our results and prove the accurate operation of the system as our results are within the confidence intervals of the reference work by Crouter for the same activities. As future work, we will implement this algorithm in Android operation system in order to improve the portability and usability of the system and take advantage of smartphone technology. Our work enables practitioners to better study the dose-response relationship in physical activity, since it allows the quantification of the activity level, and, use the collected information to better support the evaluation and prescription of exercise therapy based techniques.

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