Feasibility of Calibrating Smartphone to Access Physical Activity

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Abstract

The purpose of the study was to develop algorithms to predict energy expenditure (EE) and to evaluate their utility compared to existing accelerometer technology. Forty-four participants wore an Actigraph GT3X (AG3X) and the Samsung Galaxy S2 Smartphone (SP) over a 69 min period. Oxygen consumption (VO2) was simultaneously measured by a portable indirect calorimetry system. EE prediction equations for the SP were developed from the walking and running activities using standard regression methods. The equation was then cross-validated on a separate holdout sample (n=22) using equivalence testing to evaluate accuracy. The overall mean absolute percentage errors were large for both the SP algorithm (42.4%) and the Freedson’s AG3X algorithm (38.2%). However, the estimated METs from the SP was statistically equivalent to the measured METs for the two activities used in calibration: walking (90% CI: 2.85, 3.50 kcal·min⁻¹) and running (90% CI: 7.64, 8.25 kcal·min⁻¹). Other activities were not accurately assessed with the SP but none of the estimates from the AG3X met the statistical criteria for equivalency. The study demonstrates that data from SP can be easily calibrated to estimate EE and that accuracy is comparable to the common research-grade monitors.

Keywords: Physical activity, Accelerometer, Smartphone

I. Introduction

Accurate and objective assessments of physical activity patterns and energy expenditures (EE) are required to understand dose-response relationships between physical activity (PA) and health benefits (Brown et al., 2003; Haskell et al., 2007). Accelerometry-based PA devices have been wide-
ly employed as objective tools to assess physical activity behavior in free-living settings (Calabro et al., 2009). These devices provide individual’s daily PA patterns (i.e., moderate-to-vigorous physical activity; MVPA), duration, and predicted EE. However, there are also a number of well-documented limitations (Strath, et al, 2012). The limitations include no consensus on the best approach for detecting non-wear time (Choi et al, 2012), handling missing data (Alhassan et al, 2008), and for classifying intensities of PA (Kim, et al, 2012), altered PA patterns (Sirard et al, 2009), and high cost (i.e. approximately $400 per monitor) (Lamonte et al, 2001). While considerable advances have been made, there is still a need for low-cost, user-friendly PA monitoring devices that can accurately capture PA patterns.

There are numerous advantages of smartphones (i.e. ubiquitous use, increasing popularity, ease-of-use and low cost) and this provides enormous potential for developing innovative ways of estimating PA and EE levels. Current estimates suggest that, worldwide, more than 6.2 billion people carry a smartphone throughout the day. In the United States, 114 million Americans were estimated using smartphones (as of July 2012) (Blodget 2012, September 13). Most contemporary smartphones have an array of sensors including acceleration sensors (i.e., accelerometer), gyroscope, GPS sensors, vision sensors (i.e., cameras), audio sensors (i.e., microphones), light sensors, temperature sensors, and direction sensors (i.e., magnetic compasses). The multi-sensor nature make them perhaps better equipped than standard activity monitors for detecting and quantifying PA behavior. With calibration and development, these sensors could potentially be used to identify an individual’s PA and EE level as well as its context, and situation.

The sensors with the most direct utility for PA assessment are the built-in accelerometer and gyroscope. Most smartphones utilize Micro-Electro-Mechanical Systems (MEMS) that record acceleration at three axes, perpendicular to each other, and provide three real time values – X, Y, and Z. In contrast to commercially available activity monitoring devices, smartphones also have a gyroscope sensor to record the speed of movements, the acceleration of rotation, and three real time values that indicate acceleration of rolling, whirling, and rotation. This sensor could be used to evaluate relative location, direction, and angle of the smartphone.

The utility of accelerometer-based smartphone applications has been examined in a variety of settings: testing cognitive function for older adults (Brouillette et al., 2013), examining movement economy in simulated neurosurgical tasks (Ang et al., 2014), evaluating abnormal gain for patients with rheumatoid arthritis (Yamada et al., 2012), and developing real-time disease surveillance tools (Michael et al., 2013). Moreover, previous studies (Allen et al., 2013; Glynn et al., 2013; Kirwan et al, Duncan, 2013), reported the efficacy of smartphones for physical activity intervention studies aimed at improving health. A recent study (Wu et al., 2012) demonstrated high classification of both the accelerometer and gyroscope found in a smartphone (i.e. Apple iPod Touch) in identifying 13 simulated activities on a sample of 16 participants. However, to date, no calibration studies have been carried out to spe-