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Methods for objective measure, quantification and analysis of sedentary behaviour and inactivity

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ABSTRACT

The purpose of this study was to develop and test a generic technique to robustly quantify the pattern of sedentary behaviour from objective records.

The technique was applied to four groups of subjects: a healthy group with an active occupation ($N = 54$), a healthy group with a sedentary occupation ($N = 53$), a group of subjects with chronic low back pain ($N = 5$) and a group of subjects with chronic fatigue syndrome ($N = 14$).

This study presents the first evidence that bouts of sedentary activity are power law distributed.

Results showed that there was no significant difference in total sedentary time between the groups, however, the patterns of accumulation of sedentary time were significantly different for the groups. Sedentary groups accumulated their total sedentary time from a small number of longer sedentary bouts. Active groups tended to break their sedentary time into a greater number of shorter bouts. This suggests that the power law exponent α and the GINI index G, used to describe the pattern of accumulation of sedentary time, could be used to evaluate and quantify sedentary behaviour.

1. Introduction

Sedentary behaviour is associated with a range of poor health outcomes, typically high levels of body fat/obesity, blood glucose levels and type 2 diabetes and cardiovascular problems [1]. Western lifestyle is becoming increasingly sedentary, at home, work and during leisure time [2]. This has driven global efforts to quantify physical. Consequently sedentary behaviour has generally been inferred from studies of physical activity where sedentary behaviour has been considered as the bottom end of a physical activity continuum. However, there is now mounting evidence, [1,3–7] that sedentary behaviour per se rather than just low level of physical activity, is an independent risk factor for chronic disease and poor health outcomes. This evidence has shown that there is a need to study and quantify sedentary behaviour.

Early studies of sedentary behaviour relied on self-reported methods, often using television viewing time as a proxy marker for sedentary time [8–13]. These subjective methods have the obvious caveats, with any self-report methods, that they tend to under report sedentary behaviour [14]. However, using these methods, associations between subjectively recorded total sedentary time and obesity [8], abnormal glucose metabolism [10] and the metabolic syndrome [11] have been reported, and it has been suggested that there is a need for more precise objective measures of sedentary behaviour [10].

Several studies [15–19] have used objective measures of energy expenditures, recorded by accelerometry. These studies have reported relationship between total sedentary time and abnormal glucose metabolism [16], metabolic risks [17] and obesity markers [18].

These findings do not provide insight into the drivers for adopting a sedentary lifestyle which are also poorly understood [20]. In order to investigate these, global measures of total sedentary time is not sufficient. Dietz [4] suggested that the study of "sedentarism" as a behaviour, rather than accounts of energy spent in sedentary pursuit might offer richer insight and assessment of factors that contribute to obesity and other diseases. Recent studies [5,6] highlight the fact that the pattern of inactivity has important physiological impact on muscles, cardiovascular health and metabolism.

Devices have been developed which enable long term recording of accelerometer signals. This technology offers the possibility to explore the temporal patterns sedentary behaviour. A recent study by Healy et al. [21] found a relationship between the number of breaks in sedentary periods and metabolic markers. This study illustrated the potential importance for studying patterns of sedentary periods.

The aim of this study was to develop a novel generic method for analysing and quantifying patterns of sedentary behaviour based on an objective monitoring technique and to test this to

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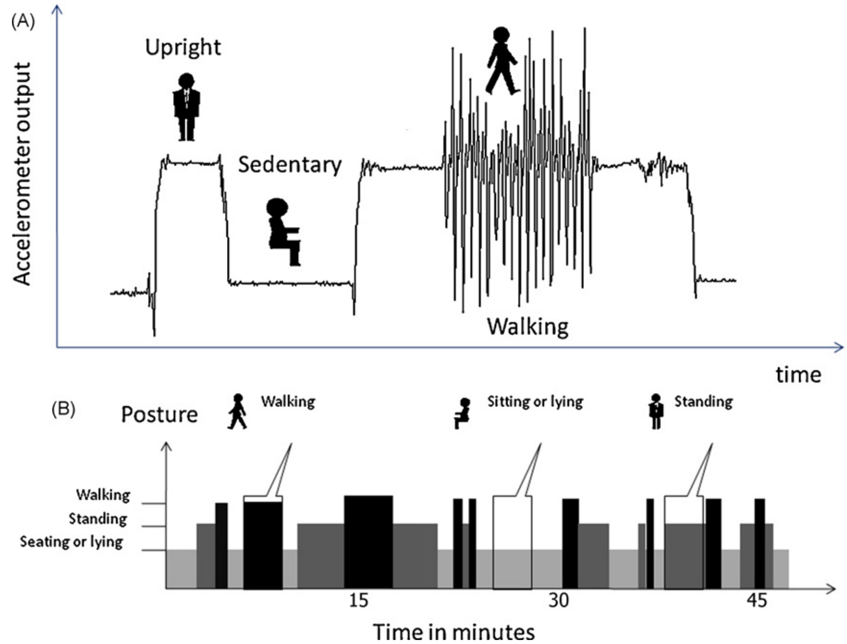

Fig. 1. (A) Typical signal from a thigh mounted activPAL depending on posture. (B) Pattern of activity derived from the accelerometer signal by the propreitory activPAL software (A).

explore how sedentary behaviour is modified by occupation and disease.

2. Objective measures of sedentary behaviour

2.1. Definition

A major difficulty in monitoring sedentary behaviour is finding a practical and accepted definition of sedentary activity [22]. A review by Bennett et al. [23] revealed that most studies of "sedentarism" define sedentary behaviour as a low level of physical activity. Owen et al. [20] proposed that sedentary behaviour is identified by an energy expenditure threshold. Using an energy threshold leads to large uncertainty about the sedentary data recorded, first of all because estimating energy expenditure from accelerometer data is not robust [24] and the length of sedentary period extracted will be very sensitive to the to the metabolic equivalent of task (MET) cut-off point chosen [2].

Secondly a MET threshold of 1.5 MET as defined by Owen et al. [20] can also include periods of quiet standing [25]. Hamilton et al. [6] showed that seating and quiet standing are fundamentally different physiologically and that it is important to makes a clear distinction between sedentary activity and low energy standing activity. This study introduces the concept that postural allocation is a direct reflection of sedentary behaviour.

Classifying sedentary behaviour as "non-upright" activities provides an unequivocal and robust definition supported by physiological and epidemiological studies. Matthews et al. [2] argue for a more direct measurement of sedentary behaviour by the recording of body posture.

2.2. Monitoring postural allocation

There have been various techniques for the classification of body posture from accelerometry data [26,27]. Various multi-sensor systems have been developed but accurate detection of seated and lying activity can be achieved using a single thigh mounted accelerometer [27]. In this position the accelerometer can act as inclinometers when the background acceleration is low. This creates a clear distinction between upright posture where the thigh is vertical and seated/lying activities where the thigh is near horizontal. This enables accurate detection of "non-upright" periods (Fig. 1).

3. Methodology

3.1. Design

This was a cross-sectional study of sedentary behaviour of four different groups. This study was approved by the ethic committee of the School of Health and Social care of Glasgow Caledonian University.

The demographics for these groups are presented in Table 1. The first group were healthy postal workers (Ha) whose occupation is by nature active involving mail delivery on foot. The second group were healthy office based postal workers (Hs), whose daily work activity was sedentary [35]. The third group were people diagnosed with chronic fatigue syndrome (CFS). The last group were people with chronic low back pain (LBP).

Posture recognition has been incorporated in the activPAL (PAL Technologies, Glasgow, UK) [28] activity monitor, which has been shown to accurately detect sedentary postures [29]. Participants wore an activPAL monitor continuously for 3–7 days. The monitors were then retrieved and data downloaded to a computer for further analysis.

Table 1
Groups demographics data. F = number of female, M = number of male.

Group	Number	Age range (years)	Mean age (years)
Healthy active (Ha)	53 (F 5, M 48)	23–59	39.2
Healthy sedentary (Hs)	54 (F 10, M 44)	22–60	39.9
Chronic fatigue syndrome (CFS)	14 (F 11, M 3)	34–63	48.3
Chronic low back pain (LBP)	5 (F 3, M 2)	40–51	45