Human Movement Science 45 (2016) 1–6

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Associations between sensor-based physical activity behaviour features and health-related parameters

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ARTICLE INFO

Article history:
Received 15 July 2015
Revised 13 October 2015
Accepted 18 October 2015

Keywords:
Accelerometry
Physical activity
Cohort studies
Pattern recognition

ABSTRACT

Objectives: Wearable actimetry devices are used increasingly in cohort and cross-sectional studies to assess physical activity (PA) behaviour objectively. Thus far, the medical relevance of distinct PA groups, as identified by using new methods of sensor data analysis, remains unclear. The objective of this research paper is to evaluate whether such PA groups differ in commonly accepted health risk parameters.

Methods: PA sensor data and corresponding outcome data of the NHANES 2005–06 study were obtained. Data pre-processing included elimination of potential outliers, data splitting and the computation of PA parameters, including a novel regularity measure. PA groups were identified using the *x*-Means clustering algorithm, and groups were evaluated for differences in CRP, BMI and HDL.

Results: Data sets of 7334 NHANES participants were analysed, and four distinct PA groups were identified. Statistically significant group differences were found for CRP and BMI ($p < 0.001$), but not for HDL ($p = 0.67$).

Conclusions: PA groups derived from objective accelerometer mass data differ in exemplary health-related outcome parameters. The novel PA regularity measure is of particular interest and may become part of future PA assessments, especially when regarding low-intensity, short-lived PA events. Further research in pattern recognition methods and analytic algorithms for PA data from current multi-sensing devices is necessary.

1. Introduction

Along with the increasing use of wearable actimetry devices in cohort studies, the exploitation of detailed objective data has become a recent research focus. Never before has physical activity (PA) been measureable in more detail for extended periods of time (at least a week) under daily-life conditions. Having started with uniaxial accelerometers, researchers now frequently use multi-sensor devices, not only including triaxial accelerometers, but also gyroscopes, pressure sensors and magnetometers, allowing for ever more detailed activity analyses. More recently, 'lifestyle' devices such as actimetry armbands for recording activity levels or sleep rhythm, have hit the mass market. The amount data available grows steadily, but some of the semantics of these data are yet to be determined. Of particular interest to epidemiologic cohort or cross-sectional studies is the effect of different amounts of PA on health-related parameters or mortality (Leitzmann et al., 2007; Paffenbarger et al., 1993). Knowing the 'healthy dose' – as defined by PA intensity and duration – PA recommendations can be deduced for the population or sub-populations, such as the elderly (Nelson et al., 2007). Apart from the amount, however, also the type of activities (walking, cycling, running, rowing, etc.) may affect the outcome and can – with some

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http://dx.doi.org/10.1016/j.humov.2015.10.003
0167-9457/

limitations – be identified with wearable devices (e.g., Khan, Lee, Lee, & Kim, 2010). Furthermore, a recent study by Glazer et al. shows that activities of short duration – less than ten minutes – constitute a large part of overall PA, and that these have significant and independent relationships with outcome parameters such as triglycerides or high-density lipoprotein (HDL) (Glazer et al., 2013). Such brief activities are likely to evade common recall-based assessment tools, but are easily measured by the devices mentioned above.

At present, evidence is scarce whether not only the intensity and the duration – in other words the dose – have an effect in terms of health outcome, but also the *regularity* of PA events. There is some evidence that frequent PA is related to lower risk, even if the dose is similar. Lee et al. report a lower risk of mortality for the regularly active (RR = 0.64) and the so-called 'weekend warriors' (RR = 0.85) in contrast to the inactive (RR = 1.0) (Lee, Sesso, Oguma, & Paffenbarger, 2004).

Previous research has shown that distinct PA behaviour groups can be identified (Marschollek, 2014) using the three parameters *intensity*, *duration* and *regularity*, introduced as the ATLAS (*Activity Types from Long-term Accelerometric Sensor data*) index by the author (Marschollek, 2013). So far, it remains unclear if these activity groups actually differ with regard to health outcome parameters.

1.1. Related work

Other studies have identified PA patterns, but so far without taking into account the regularity or temporal distribution of activity events. Metzger et al. have used latent class analysis (LCA) on three dose parameters computed from NHANES accelerometer data ($N = 3802$) plus socio-demographic data, and found five different groups (Metzger et al., 2008). LCA was also used by Patnode et al. for a cohort of children, including accelerometer and self-reported data. Three classes were thus identified, with different distributions among girls and boys (Patnode et al., 2011). Tudor-Locke et al. have – also on the basis of NHANES data – compared activity between body-mass-index-based (BMI) sub-cohorts and report differences between BMI-based groups and gender (Tudor-Locke, Brashear, Johnson, & Katzmarzyk, 2010). In their sample, just 3.2% of the subjects met common physical activity guidelines.

The above-mentioned studies did not test whether metabolic parameters differ between groups. Such effects of physical exercise have been investigated by Stewart et al. (Stewart et al., 2007). A 12-week exercise programme induced a significant decrease in C-reactive protein (CRP) in a group of inactive persons. CRP is a marker of inflammation that, along with several cytokines, is also regarded as a potential mediator entity of PA on cardiovascular risk, in theory by lowering chronic inflammation (Kasapis & Thompson, 2005). CRP seems to be inversely associated with regular PA patterns, as shown by Kasapis and Thompson in their systematic review (Kasapis & Thompson, 2005).

1.2. Objective

With regard to the unknown health outcome for different PA behaviour groups, the objective of the research work for this paper is to evaluate whether identifiable PA behaviour groups differ significantly in commonly accepted health risk parameters.

The paper is organised as follows: the following section briefly introduces the NHANES study data sets and the methods of data pre-processing and analysis. The results section includes all findings, which are then discussed critically with regard to the aim mentioned above and their implications for current or future PA assessment and recommendations. The paper concludes with a brief summary of its main findings.

2. Methods

The *National Center for Health Statistics* (NCHS), *Centers for Disease Control and Prevention* (CDC) has published several data sets from the NHANES (*National Health and Nutrition Examination Survey*) cross-sectional study (Centers for Disease Control and Prevention (CDC), 2013). This study was approved by the NCHS Research Ethics Review Board ('Protocol #2005–06'). The author states that the retrospective study on hand complies with the Declaration of Helsinki.

The NHANES 2005–06 data include both health-related parameters, e.g., lab test results, and objective data on PA obtained with a uniaxial accelerometer (ActiGraph AM7164, http://www.actigraphcorp.com/). This set includes accelerometer data of $N = 7457$ subjects in one-minute aggregates, recorded over a duration of up to one week each. Using an outlier detection approach accounting for acceleration values that either exceed the measurement range of the accelerometer – measurement values > 32,766, of data type 'signed integer' as normally provided by the AM7164 device (Marschollek, 2014) – or may potentially be erroneous based on a recent outlier detection approach based on the median absolute deviation (MAD) (Leys, Ley, Klein, Bernard, & Licata, 2013), the author has excluded $N = 123$ subjects from the analysis, with $N = 7334$ remaining subjects. For handling matters – the accelerometer data exceed two GBytes – the data were split into single files for each NHANES subject.

Following pre-processing, each file was analysed by an algorithm that computes

- mean PA *intensity* during all PA events detected,
- mean *duration* of all PA events detected per 1000 min,