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Physical activity event regularity and health outcome – 'Undiscovered country' in cohort accelerometer data

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Abstract. The increasing use of wearable devices for measuring long-term activity data allows for detailed analyses of real-life behavioral patterns and for the identification of new parameters such as activity event regularity. Thus far, the medical relevance of this new regularity parameter is unknown. The objective of the research work for this paper is to investigate associations between activity regularity and resting systolic blood pressure, as an exemplary well-established cardiovascular risk factor. Using accelerometer and blood pressure data of N=5695 subjects from the NHANES 2005-6 cohort study, three characteristic physical activity parameters (regularity, duration and intensity) were computed and compared for the upper and lower quartiles of subjects with regard to their blood pressure values. Results show statistically significant differences in the parameters regularity ($p<0.001$) and duration ($p=0.008$) of physical activity events, but not in intensity ($p=0.889$). Results confirm that subjects with low resting systolic blood pressure not only are active for longer periods of time, but also are more *regularly* active. It also shows that low-intensity, short-lived physical activity (< 10 min.) is associated with health-related outcome parameters. More research is necessary to make full use of detailed activity behavior data, and in particular to uncover relations between physical activity patterns and health outcome.

Keywords. Motor Activity, Health Behavior, Cohort Analysis, Epidemiologic Methods

Introduction

Wearable sensors are not only used increasingly in large-scale epidemiologic studies, but also progressively enter the market of lifestyle devices (e.g. *FitBit* and *Polar Loop*[2]). While much research work has been invested in detecting and classifying physical activities (PA) or in estimating active energy expenditure from wearable sensor data (e.g. [9]), with results partly embedded in new devices, some major challenges remain. Data size easily exceeds the gigabyte threshold for one-week data sets of an individual. This challenges algorithmic optimization [8]. Furthermore, while motivational benefits are often stressed, relevance and validity of identified physical activity parameters, and especially of activity behavior patterns, often remain unclear. Current PA recommendations such as those of the WHO include the overall PA duration of aerobic

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activity lasting for more than ten minutes [7]. Recent literature, however, shows that most of our daily activities last less than ten minutes, and that these are independently associated with relevant health-related outcome parameters or risk factors such as HDL cholesterol or waist circumference [2]. While most recommendations state that persons should be 'regularly' active, there is no evidence with regard to which *degree* of regularity is more or less healthy. In other words, what is a 'healthy' activity pattern in terms of PA event distribution? The objective of this research paper is to evaluate if activity event distribution, respectively *regularity*, is associated with an exemplary, well-established disease risk parameter, resting systolic blood pressure (RSBP). Apart from this, the methodical approach for analyzing large cohort accelerometer data sets to extract three characteristic parameters is described briefly.

1. Methods

An openly-available PA data set was chosen (*National Health and Nutrition Examination Survey* 2005-6, NHANES [1]), containing one-week accelerometer data of more than 7000 subjects. Following the methodical approach as described by the author in [5], the ATLAS (*Activity Types from Long-term Accelerometric Sensor data*) dimensions *regularity*, *duration* and *intensity* of detected PA events were computed for each subject. The following processing steps were performed:

- outlier detection of exceeding accelerometer values (as described in [4]), exclusion of outlier data sets (1.7%)
- detection and flagging of all PA events with a minimum duration of five minutes and an activity intensity higher than the 2nd decile of all PA intensities of all subjects in the cohort
- for each subject, the following parameters are computed
    - regularity: variance of all time differences between PA event starts
    - mean duration of all PA events per 1000 minutes
    - mean intensity of all detected events (unit: proprietary 'counts')

For a detailed description of this procedure, please refer to [5]. Due to the amount of data and the computational complexity of the above-mentioned processing steps, computing took several weeks despite the use of powerful hardware. The author chose *resting systolic blood pressure* (RSBP) as an adequate exemplary medical reference parameter, as it is associated with cardiovascular risk. Merging the NHANES parameter data sets of subjects with both the accelerometer data and RSBP values, a data set of N=5695 subjects remained for analysis. To assess the relevance of extracted PA parameters *regularity*, *duration* and *intensity*, the cohort's upper and lower quartiles according to their RSBP values were compared for these parameters using a Welch t-test.

2. Results

Subjects with RSBP values in the upper (>= 126 mmHg) and lower quartile (< 106 mmHg) showed statistically significant differences in two out of three parameters extracted from their sensor data: duration of PA events (76.9 vs. 81.9/1000 minutes; $p=0.009$), regularity (653,640 vs. 392,675; $p<0.001$). The intensity level of PA events showed no differences (7.0 vs 7.1; $p=0.889$).

3. Discussion

PA parameters extracted exclusively from objective sensor data are related to health outcome. They may serve to describe real-life physical activity behavior patterns in detail, and to identify high-risk subgroups within a population. The exemplary analysis shows that subjects with a high RSBP – which is associated with increased cardiovascular risk – are not only *less* active than those with a low RSBP, but also much more *irregularly*. The computed measure for PA regularity is a novel concept, which may prove useful to identify PA patterns associated with other health-related outcome parameters, or health risk in general. It may therefore be worthwhile to investigate the influence of distinct PA patterns ([6]) on long-term outcome. The computational approach is – due to its straightforwardness – easily transferrable to other data sets, even if the contain data obtained with different devices and aggregation levels [5]. More research is necessary to uncover the relationships between physical activity behavior patterns and health risk. This should include longitudinal studies which investigate morbidity and mortality associated with different PA behavior (e.g. [3]). The amount of detailed PA data, available from studies using wearable monitoring devices, provides a yet unparalleled insight, and therefore deserves a 'closer look'.

4. Conclusion

Objective PA measurement with wearable sensors has the potential to provide accurate information about real-life behavior. To tap its full potential, innovative algorithms are necessary to cope with the sheer amount of data and to identify novel entities such as PA event regularity. It could be shown that this new parameter is associated with an exemplary health outcome parameter, resting systolic blood pressure.

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