Abstract:

2016 has been an exciting year for research in physical activity, inactivity and health. Recognition of the importance of all physical behaviours (physical activity, sedentary time and sleep) across the 24 h day continues to grow. Notable advances have included: applications of recent methodological innovations that account for the co-dependence of the behaviours in the finite 24 h period showing that the balance of these behaviours is associated with health; methodological innovations focussing on the classification of behaviours and/or quantification of the 24 h diurnal activity pattern; and a series of systematic reviews that helped provide the evidence base for the release of the innovative 24 h movement guidelines earlier this year. This commentary focuses on just two of these papers: the first by Goldsmith and colleagues who demonstrate a new statistical method that exploits the time series nature of accelerometer data facilitating new insights into time-specific determinants of children’s activity patterns and associations with health; the second by Tremblay and colleagues who describe the evidence base for associations between each physical behaviour and children’s health, the emerging evidence base for associations between the balance of behaviours and health, and development of the world’s first 24 h movement guidelines.

Novel insights into activity patterns in children, found using functional data analyses

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Abstract: Introduction/Purpose: Continuous monitoring of activity using accelerometers and other wearable devices provides objective, unbiased measurement of physical activity in minute-by-minute or finer resolutions. Accelerometers have already been widely deployed in studies of healthy aging, recovery of function after heart surgery, and other outcomes. Although common analyses of accelerometer data focus on single summary variables, such as the total or average activity count, there is growing interest in the determinants of diurnal profiles of activity. Methods: We use tools from functional data analysis (FDA), an area with an established statistical literature, to treat complete 24-h diurnal profiles as outcomes in a regression model. We illustrate the use of such models by analyzing data collected in New York City from 420 children participating in a Head Start program. Covariates of interest include season, sex, body mass index z-score, presence of an asthma diagnosis, and mother’s birthplace. Results: The FDA model finds several meaningful associations between several covariates and diurnal profiles of activity. In some cases, including shifted activity patterns for children of foreign-born mothers and time-specific effects of asthma on activity, these associations exist for covariates that are not associated with average activity count. Conclusion: FDA provides a useful statistical framework for settings in which the effect of covariates on the timing of activity is of interest. The use of similar models in other applications should be considered, and we make code public to facilitate this process.


Commentary:

Since the first time-stamped accelerometry-based activity monitors were used to objectively assess physical activity back in the 1990s, it has been possible to generate extremely rich pictures of the pattern of physical activity. For example, in Figure 1a taken from data published in 1999 (8), the pattern of a child’s school day can be clearly seen with spikes in activity before school, morning recess, lunchtime, afternoon recess and following school. Without the constraints of school, the
waking daytime activity pattern of this highly active child is quite different (Figure 1b). Increasingly these monitors are worn day and night (e.g. International Study of Childhood, Obesity, Lifestyle and the Environment (ISCOLE, 3); National Health and Nutrition Examination Survey (NHANES, 2)), facilitating capture of the entire 24 h period of a day and examination of the diurnal activity pattern.

Despite this richness of physical activity data that has been available for the past couple of decades, most commonly data are simply reduced into aggregate measures of overall activity, moderate-to-vigorous physical activity (MVPA) and sedentary time. Recently, rapid progress has led to innovative methodological developments towards the classification of activity types (e.g. 10), identification of physical activity phenotypes (e.g. 5) and examination of physical behaviours (physical activity, sedentary time and sleep) using a compositional approach that takes into account the co-dependence of these behaviours in the finite 24 h period (1). However, less attention has been paid to exploiting the time series nature of accelerometer data to examine diurnal profiles. To do this, it is necessary to take into account the correlation between consecutive data-points; i.e. the activity level at one minute (or other sampling interval) is related to the activity level at the next minute or, to put it more simply, people do not generally go from very high activity one minute to nothing the next and vice versa.

Examination of the diurnal activity profile is desirable as it facilitates identification of determinants of physical activity that may impact only at particular times of the day, or affect groups differentially at distinct times. In this paper, Dr Jeff Goldsmith and colleagues introduce Functional Data Analysis (FDA), demonstrate its application to accelerometer data collected on a sample of 420 children in New York City and highlight the novel insights that FDA provides. Crucially, FDA treats the complete observed profile (i.e. the diurnal activity pattern measured by accelerometry) as a single unit of observation. This maintains the richness of the accelerometer data, while taking into account the correlation of the data points over time. Goldsmith et al. demonstrate this technique by using it to
examine the impact of co-variates (season, sex, body mass index, asthma diagnosis, whether the mother worked and mother’s birthplace) on a child’s diurnal activity profile. They compare the results with those found using aggregate measures of physical activity to highlight whether time specific associations occur. The authors present plots that show the diurnal activity patterns of groups of children (split by a co-variate, e.g. mother works or does not work) and an accompanying plot with the same 24 h x-axis showing how the coefficient function and 95% confidence interval vary across the 24 h profile. These informative plots clearly display, in a continuous fashion, the times of day when the co-variate does and does not have a significant effect.

Examples of the time-specific associations reported include children with asthma exhibiting lower levels of activity levels in the afternoon relative to children without asthma, despite similar overall activity levels. The authors speculate that this may be due to ground level ozone levels that are known to peak in the afternoon (4, 9), pollen or other ecological factors. The authors also show that, despite similar aggregate activity levels, children born to US mothers were less active in the morning and more active in the afternoon than children of mothers born elsewhere. This type of information could be crucial for tailoring interventions, but also potentially for linking activity and health outcomes. It is becoming increasingly clear that the timing of physical behaviours can be important for health, e.g. it appears that your preferred sleep timing, that is whether you are a ‘morning’ or ‘evening’ person (your chronotype), is linked to your cardiometabolic health even after accounting for sleep duration (6).

Total physical activity and time spent in MVPA are important outcome measures that are associated with a range of health outcomes (7). New statistical and/or mathematical approaches that can supplement these aggregate measures of physical activity have the potential to add significantly to our knowledge on physical activity and health in children. Barriers to adoption of new methods are lack of awareness and the complexity of the methods. Papers such as this one, presenting recently developed statistical models that have clear applications to accelerometry data and making the
codes necessary to run the analyses publically available, will hopefully facilitate adoption and lead to new insights into children's physical activity, the determinants of their activity and associations with health.

References


**Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep.**


**Abstract:** Leaders from the Canadian Society for Exercise Physiology convened representatives of national organizations, content experts, methodologists, stakeholders, and end-users who followed rigorous and transparent guideline development procedures to create the Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. These novel guidelines for children and youth aged 5-17 years respect the natural and intuitive integration of movement behaviours across the whole day (24-h period). The development process was guided by the Appraisal of Guidelines for Research Evaluation (AGREE) II instrument and systematic reviews of evidence informing the guidelines were assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. Four systematic reviews (physical activity, sedentary behaviour, sleep, integrated behaviours) examining the relationships between and among movement behaviours and several health indicators were
completed and interpreted by expert consensus. Complementary compositional analyses were performed using Canadian Health Measures Survey data to examine the relationships between movement behaviours and health indicators. A stakeholder survey was employed (n = 590) and 28 focus groups/stakeholder interviews (n = 104) were completed to gather feedback on draft guidelines. Following an introductory preamble, the guidelines provide evidence-informed recommendations for a healthy day (24 h), comprising a combination of sleep, sedentary behaviours, light-, moderate-, and vigorous-intensity physical activity. Proactive dissemination, promotion, implementation, and evaluation plans have been prepared in an effort to optimize uptake and activation of the new guidelines. Future research should consider the integrated relationships among movement behaviours, and similar integrated guidelines for other age groups should be developed.


**Commentary:**

The concept that “the whole day matters” underlies the production of the first 24-hour movement guidelines by Professor Mark Tremblay and colleagues. These innovative guidelines reflect the growing recognition of the importance and co-dependence of all movement behaviours (physical activity, sedentary behaviour and sleep; also collectively referred to as ‘physical behaviours’) over the 24 h day for health (2). They are the culmination of a stringent two-year development process including completion of four systematic reviews and expert consensus as well as extensive stakeholder and focus group engagement. Three of the systematic reviews focussed on the association between health and each of the physical behaviours in isolation, and the final systematic review on associations between health and combinations of multiple movement behaviours. Additionally children’s data from the first three cycles of the Canadian Health Measures Survey (5)
were re-analysed using the compositional approach described by Chastin et al. (2) that takes into account the co-dependence of these behaviours in the finite 24 h period; that is if a behaviour, e.g. moderate-to-vigorous physical activity (MVPA), changes in the finite 24 h period, something else (e.g. sleep, sedentary time or light physical activity) will have to change to accommodate it. Thus, the evidence base for the guidelines was as up-to-date and comprehensive as possible.

The resulting guidelines represent a “healthy 24 hours” and have a striking logo covering the four behaviours branded as: SWEAT, STEP, SLEEP and SIT. Sweat refers to MVPA with a daily dose of at least 60 minutes recommended; STEP refers to light physical activity with several hours recommended; 9-11 h of uninterrupted SLEEP is recommended for 5-13 y olds and 8-10 h for 14-17 y olds; finally no more than 2 h of recreational screen SIT time with limited sitting for prolonged periods is advised.

Eagle eyed readers will note that it is not possible to sum these recommendations to make a specific prescription for time allocation to each behaviour across the 24 h period. This is a deliberate move on the part of the authors with recommendations for minimum MVPA, maximum screen time, a range for sleep and more general guidance for light activity. This recognizes normal day-to-day variability of behaviours and also reflects the stronger evidence base for MVPA, screen time and sleep. Further the authors recommend that adherence to these guidelines is assessed using average weekly behaviours. This is primarily because most of the evidence comes from studies that used the average of daily behaviours and also because, again, this allows for day-to-day variability. This is an important point as previous guidelines for behaviours (MVPA and screen time, individually and combined) have been implemented in a variety of ways that can impact considerably on prevalence estimates (3); consistency in implementation is essential and addressing it up front should help ensure this happens.
Despite only being released in June this year, research has already been published that supports the value of the integrated 24 h movement guidelines. Roman-Vinás et al. (4) assessed the adherence to the guidelines in participants from the 12-country International Study of Childhood Obesity Lifestyle and the Environment (ISCOLE). While prevalence of meeting all three components of the guidelines was low (7%), children meeting them were 72% less likely to be obese than children who did not meet the guidelines; those who met two recommendations were less likely to be obese than those who met one recommendation, who in turn were less likely to be obese than those who met none of the recommendations. This was a cross-sectional analysis, but with time research will be able to employ longitudinal designs to assess causal associations between adherence to the 24 h movement guidelines and health outcomes.

As the authors state, this integration of the physical activity, sedentary time and sleep guidelines into one “healthy 24 hours” message represents a paradigm shift in thinking. But it is a logical shift that follows on from the focus on vigorous physical activity and physical fitness in the 1970s, through recognition of the value of moderate intensity activity for health in the 1990s and the more recent focus on how sedentary time and light intensity activity impact on health. It is time to consider the balance of movement behaviours across the intensity spectrum and the impact of changes in the balance of behaviours, a need that is backed up both by evidence for the impact of individual behaviours on health and an emerging evidence base on associations between the composition of movement behaviours and health (1). This fundamental change in approach will be greatly enhanced by this pioneering development and dissemination of these 24 h movement guidelines.

References


List of figures

Figure 1: Accelerometer trace showing the waking daytime activity pattern for a highly active child on a) a school day and b) a free day.

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