Preventive Medicine Reports 11 (2018) 254–261

Contents lists available at ScienceDirect

Preventive Medicine Reports

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

Adiposity, fitness, health-related quality of life and the reallocation of time between children's school day activity behaviours: A compositional data analysis

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ARTICLE INFO

Keywords:
Time-use epidemiology
Physical activity
Sedentary behaviour
Accelerometer
Schools
Children
Health
CoDA

ABSTRACT

Sedentary time (ST), light (LPA), and moderate-to-vigorous physical activity (MVPA) constitute the range of school day activity behaviours. This study investigated whether the composition of school activity behaviours was associated with health indicators, and the predicted changes in health when time was reallocated between activity behaviours. Accelerometers were worn for 7-days between October and December 2010 by 318 UK children aged 10–11, to provide estimates of school day ST, LPA, and MVPA. BMI z-scores and percent waist-to-height ratio were calculated as indicators of adiposity. Cardiorespiratory fitness (CRF) was assessed using the 20-m shuttle run test. The PedsQL™ questionnaire was completed to assess psychosocial and physical health-related quality of life (HRQL). Log-ratio multiple linear regression models predicted health indicators for the mean school day activity composition, and for new compositions where fixed durations of time were reallocated from one activity behaviour to another, while the remaining behaviours were unchanged. The school day activity composition significantly predicted adiposity and CRF (p = 0.04–0.002), but not HRQL. Replacing MVPA with ST or LPA around the mean activity composition predicted higher adiposity and lower CRF. When ST or LPA were substituted with MVPA, the relationships with adiposity and CRF were asymmetrical with favourable, but smaller predicted changes in adiposity and CRF than when MVPA was replaced. Predicted changes in HRQL were negligible. The school day activity composition significantly predicted adiposity and CRF but not HRQL. Reallocating time from ST and LPA to MVPA is advocated through comprehensive school physical activity promotion approaches.
Trial registration: ISRCTN03863885.

1. Introduction

Schools are key settings for initiatives to engineer moderate-to-vigorous physical activity (PA) (MVPA) into children's daily routines, through expansion, extension, and enhancement of existing school day activity opportunities (Beets et al., 2016). Children spend a significant proportion of waking hours in schools, which have the physical and curriculum infrastructures, and personnel to promote health and well-being. Further, schools can positively influence children's PA irrespective of socio-demographic characteristics, which drive health

Abbreviations: CRF, cardiorespiratory fitness; HRQL, health-related quality of life; IMD, indices of multiple deprivation; SRT, shuttle run test

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https://doi.org/10.1016/j.pmedr.2018.07.011
Received 16 April 2018; Received in revised form 22 June 2018; Accepted 21 July 2018
Available online 24 July 2018
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inequalities (Morton et al., 2016). However, while schools provide various opportunities for PA engagement, they are also environments where children are sedentary for long periods (Stralen et al., 2014).

The increased attention given to the role of PA in positively influencing children's academic performance (Santana et al., 2017; Martin and Murtagh, 2017; Marques et al., 2017) has led to PA beyond physical education classes being advocated as a regular element of the school day (Department of Health, 2016; Institute of Medicine, 2013). For example, in the US and UK it is recommended that children accrue at least 30 minute MVPA during the school day (Department of Health, 2016; Institute of Medicine, 2013). Such advocacy reflects the increased awareness of the influence of PA on child health and wellbeing, which is demonstrated by the volume and range of school-based PA initiatives and interventions reported over the last decade (Owen et al., 2017; Hollis et al., 2017; Rafferty et al., 2016; Minatto et al., 2016; Mears and Jago, 2016). Such interventions require using a finite amount of time in the school day for one activity behaviour at the expense of another, which makes the proportions of time spent in these activity behaviours perfectly collinear (Pedisic et al., 2017). For example, the TAKE 10! Programme (Kibbe et al., 2011) involves swapping 10 min of classroom sedentary activity with MVPA. This means that every change in time spent sitting is intended to result in a corresponding opposite change in time spent in MVPA. Data on children's activity behaviours at school are therefore constrained, or *compositional data* (Dumuid et al., 2017a), made up of mutually exclusive parts of a whole (Aitchison, 1982). The sample space of compositional data differs from real space associated with unconstrained vectors (Aitchison, 1982), and therefore the mathematical properties of compositional vectors should be accounted for when analysing time-use data (Pedisic et al., 2017). Recently, studies have applied this *time-use epidemiology* concept (Pedisic et al., 2017) by treating activity behaviour data as compositional data (Carson et al., 2016; Chastin et al., 2015; Fairclough et al., 2017; Dumuid et al., 2017b,c, 2018a,b) to properly understand the relationships between health and activity (Pedisic et al., 2017). School day activity behaviours (i.e., sedentary time (ST), light PA (LPA), and MVPA) collectively constitute the range of activity behaviours that children engage in during this period. Associations between children's ST (Tremblay et al., 2011), LPA (Carson et al., 2013), and MVPA (Janssen and Leblanc, 2010) and various health outcomes have been reported, but rarely have these individual exposure variables been analysed relative to the other activity behaviours which help compose the full period of time under examination (Pedisic et al., 2017). Furthermore, it is unclear what the potential health effects are of substituting one school day behaviour, such as ST, for another, such as MVPA. Considering the importance placed on schools promoting child health and wellbeing and the range of school-based interventions that are advocated, the aims of this study were to (1) examine whether the school day activity composition was associated with indicators of physical health and health-related quality of life, which is increasingly used as an indicator of general health and wellbeing in epidemiological studies (Dumuid et al., 2018a), and (2) investigate predicted differences among these health indicators when a fixed duration of time was reallocated from one activity behaviour to another.

2. Methods

2.1. Participants

This cross-sectional study was a secondary analysis of baseline data from the Children's Health, Activity, Nutrition: Get Educated! (CHANGE!) intervention (ISRCTN03863885). The methods have previously been reported (Fairclough et al., 2013), but are described briefly here. Four-hundred and twenty children aged 10–11 years from 12 UK primary schools were invited to participate. Schools were located in Wigan, northwest England, which is an area of high deprivation and health inequalities. Parental consent and child assent were obtained for 318 children (75.7% participation rate), approximately 95% of whom were of white British ethnicity which was representative of the local school age population (Public Health England, 2017). Ethical approval was obtained from the Liverpool John Moores University Research Ethics Committee (10/ECL/039). Data were collected between October and December 2010.

2.2. Anthropometric and fitness measures

Stature to the nearest 0.1 cm (Seca Ltd. Birmingham, UK), body mass to the nearest 0.1 kg (Seca Ltd. Birmingham, UK), and waist circumference to the nearest 0.1 cm were measured using standard techniques (Lohman et al., 1991). BMI was calculated and BMI z-scores (zBMI) were assigned to each participant (Cole et al., 1995). Percentage waist-to-height ratio (%WHtR) was used as an indicator of central obesity (Mokha et al., 2010). Children completed the 20-m shuttle run test (20-m SRT) to provide an estimate of cardiorespiratory fitness (CRF) (Boddy et al., 2010; Tomkinson et al., 2016). The running speed at the last completed lap was used to estimate peak oxygen uptake (VO_2 peak; ml·kg·min^{-1}) (Tomkinson et al., 2016).

2.3. Demographic measures

Decimal age was calculated from dates of birth and dates of data collection. Neighbourhood-level socio-economic status (SES) was calculated from home postcodes to generate indices of multiple deprivation (IMD) scores, with higher scores representing higher degrees of deprivation (Department for Communities and Local Government, 2008).

2.4. Psychosocial and physical health-related quality of life (HRQL)

Each child completed the Pediatric Quality of Life Inventory (PedsQL™) generic core scales (Varni et al., 2006) supervised by the research team. The PedsQL™ consists of four scales measuring physical functioning (8 items), emotional functioning (5 items), social functioning (5 items), and school functioning (5 items) on 5-point Likert scales. Item scores are reversed and transformed to a 0–100 scale, with higher scores representing better wellbeing. The psychosocial HRQL score was computed as the mean of the scores in the emotional, social, and school functioning scales. The physical HRQL score was represented by the physical functioning score.

2.5. Activity behaviours: physical activity and sedentary time

Each child wore a waist-mounted ActiGraph GT1M accelerometer for 7 consecutive days. Children were asked to wear the monitor during waking hours only and to only remove it during water-based activities or contact sports where it might cause injury or get damaged. Monitors were set to record using 5 second epochs (Edwardson and Gorely, 2010) and consecutive 20 minute periods of zero counts were considered non-wear time (Catellier et al., 2005). Data were analysed in agd format using ActiLife v.6.11.5 (ActiGraph, Pensacola, FL). Each school day commenced at 09:00 and ended at 15:30 (i.e., 390 minute school day duration). Children were included in the data analysis if they wore the monitor for at least 70% of the school day on at least 3 days (Saint-Maurice and Welk, 2015). The cutpoints of Evenson et al. (2008) were used to define ST, LPA, and MVPA, which were the exposure variables used to form the school day activity composition. These cutpoints have previously been shown to demonstrate strong classification accuracy across a range of intensities (Trost et al., 2011).

2.6. Statistical analyses

Exploratory and descriptive analyses were undertaken using IBM SPSS Statistics Version 24 (IBM Corp., Armonk, NY). To account for

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