Mental Health and Physical Activity 6 (2013) 212–219

Contents lists available at ScienceDirect

Mental Health and Physical Activity

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

Associations between executive attention and objectively measured physical activity in adolescence: Findings from ALSPAC, a UK cohort

J.N. Booth [a,*], P.D. Tomporowski [b], J.M. Boyle [a], A.R. Ness [c], C. Joinson [d], S.D. Leary [c], J.J. Reilly [a]

[a] School of Psychological Sciences and Health, University of Strathclyde, Glasgow G1 1QE, UK
[b] University of Georgia, Athens, GA 30602, USA
[c] School of Oral and Dental Sciences, University of Bristol, Bristol Dental School, Lower Maudlin Street, Bristol BS1 2LY, UK
[d] School of Social and Community Medicine, University of Bristol, Canynge Hall, 39 Whatley Road, Bristol BS8 2PS, UK

ARTICLE INFO

Article history:
Received 29 April 2013
Received in revised form
9 September 2013
Accepted 9 September 2013

Keywords:
ALSPAC
Physical activity
Executive function
Adolescents

ABSTRACT

Studies of relationships between physical activity and children's attention skills are often constrained by small samples, lack of objective measurements and lack of control for confounders. The present study explores the relationship using objective measures of physical activity from a large birth cohort which permits both longitudinal and cross-sectional analyses. Data from 4755 participants (45% male) with valid measurement of physical activity (total volume and intensity) by accelerometry at age 11 from the Avon Longitudinal Study of Parents and Children (UK) were analysed. Attention was evaluated by the Test of Everyday Attention for Children (TEA-Ch) at 11 years and by the Cognitive Drug Research (CDR) computerised cognitive assessment system at 13 years. Males engaged in an average of 29 min (SD 17) of daily moderate-to-vigorous physical activity (MVPA) at age 11 years compared with 18 min (SD 12) among females. In unadjusted models, higher total volume of physical activity was associated with lower performance across attention tasks. When total volume of physical activity and potential confounding variables were controlled for, higher MVPA was associated with better performance at both 11 and 13 years. Correction for regression dilution approximately doubled the standardised β coefficients. We observed complex associations but results suggest that MVPA may be beneficial for attention processes in adolescence, especially in males. This has implications for interventions aimed at improving executive attention but may also be supportive of the benefits of physical activity for educational and mental health outcomes.

Low levels of physical activity are common in adults and children, so much so, that there has recently been a call for action on the "pandemic of physical inactivity" (Kohl et al., 2012). Engaging in physical activity is well known to be beneficial for physical health. However evidence also suggests that it is related to mental health, including cognitive function (Callaghan, 2004), in populations with and without psychological difficulties and that it can be beneficial for cognitive decline in older adults (see Physical Activity Guidelines Advisory Committee, 2008, for a review). In addition, there is evidence that increased physical activity (PA) leads to improvements in cognition in adults (Colcombe & Kramer, 2003) and children (Hillman, Kamijo, & Scudder, 2011; Sibley & Etnier, 2003; Tomporowski, Naglieri, & Lambourne, 2012), particularly in the area of executive function (Tomporowski, Davis, Miller, & Naglieri, 2008; Tomporowski, Lambourne, & Okumura, 2011).

Executive functions are the higher order processes which direct thought and action. They are generally thought of as an umbrella term which comprises distinct but related processes such as working memory, inhibition and attentional shifting (Miyake et al., 2000; Steele, Karmiloff-Smith, Cornish, & Scerif, 2012). Controversies exist in the literature about the exact relationship between different executive functions and the terms used to refer to them. For example, Diamond (2013) suggests that inhibitory control subsumes processes such as interference control and attention. However, recent investigation of attentional processes in children

* Corresponding author. Present address: School of Psychology, University of Dundee, Dundee DD1 4HN, UK. Tel.: +44 1382 384187.
E-mail address: j.booth@dundee.ac.uk (J.N. Booth).

1755-2966
http://dx.doi.org/10.1016/j.mhpa.2013.09.002

has pointed to two distinct but related aspects: selective/sustained attention and executive attention (i.e. attentional shifting) (Steele et al., 2012). A full review of the current controversies is beyond the scope of this paper, however a growing body of research points to the wide reaching importance of executive functions, even with the differing terminologies. For example, a strong relationship has been identified between executive function performance and cognitive reserve in older adults (Roldán-Tapia, García, Cánovas, & León, 2012) and these two closely related constructs of attention and executive function have been implicated in children's mental health (Micco et al., 2009) and in many areas of children's learning (Bull & Scerif, 2001; Christopher et al., 2012; St Clair-Thompson & Gathercole, 2006) with deficiencies identified across a number of developmental difficulties, for example, reading difficulties, ADHD and Autism (c.f. Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008, for a review). A recent review concluded that making any substantial change to executive function through traditional training programmes is extremely difficult though (Wass, Scerif, & Johnson, 2012). Physical activity interventions, however, have been suggested to be the most promising, in adults at least (Hertzog, Kramer, Wilson, & Lindenberger, 2008). Therefore evidence suggesting whether physical activity can lead to improvements in these areas is of particular importance, especially in young populations where executive functions are still developing (c.f. Diamond, 2012).

Randomised controlled trials have found that increases in moderate to vigorous intensity PA in particular can lead to improvements in certain aspects of executive function in young children (Fisher et al., 2011) and children who are overweight, with evidence for a dose response effect (Davis et al., 2011). Indeed a recent review suggested that the greatest benefits of physical activity for children have been found for working memory, selective attention and inhibition tasks (Guiney & Machado, 2013). However, studies are often constrained by cross-sectional designs, small samples, lack of objective measurement of physical activity, and failure to control for confounders (Biddle & Asare, 2011; Etnier & Chang, 2009; Tomporowski et al., 2012) and so further work aimed at addressing these issues is required, with a particular need for longitudinal studies which can assess the effects of PA over time.

If higher levels of habitual PA can lead to improvements in attention, including executive attention, this would have implications for improvements in academic attainment and potentially inform interventions for those with less efficient executive functions (e.g. those with developmental or psychological difficulties). In addition there are also implications for mental health given the evidence which suggests executive functions are an important factor in young people (e.g. Micco et al., 2009). The present study therefore aims to explore whether objectively measured physical activity at 11 years old is associated with attention and executive function cross-sectionally and longitudinally.

1. Method

1.1. Study cohort

The sample comprised participants from the Avon Longitudinal Study of Parents and Children (Golding, Pembrey, Jones, & ALSPAC, 2001). ALSPAC is an on-going population-based study investigating influences on health and development of children. Ethical approval for the study was obtained from the ALSPAC Law and Ethics Committee and the Local Research Ethics Committees. The phases of enrolment are described in detail in Supplementary material and in the cohort profile paper. Pregnant women resident in the former Avon Health Authority in south-west England, having an estimated date of delivery between 1/4/91 and 31/12/92 were invited to take part, resulting in a cohort of 14,541 pregnancies and 13,988 children alive at 12 months. When the oldest children were aged 7 years, an attempt was made to increase the size of the initial sample with eligible cases that did not join the cohort at the outset. The phases of enrolment are described in more detail in the cohort profile paper (Boyd et al., 2012).

1.2. Study design and procedures

The present study investigates associations between objectively measured total volume of PA and moderate–vigorous intensity PA (MVPA) at an ALSPAC research clinic attended at age 11 years, and attention and executive attention at ages 11 and 13.

1.3. Exposure, outcome measures and covariates

1.3.1. Physical activity measurement

The Actigraph AM 7164 2.2 accelerometer (Fort Walton Beach, Florida) objectively measures free-living PA. The Actigraph has acceptable reliability, high criterion validity, and low reactivity for measurement of physical activity in adolescents (DeVries et al., 2009) and provides greater power to detect associations than measurement which is not objective (Janz, 2006; Reilly et al., 2008).

The Actigraph used is described in detail elsewhere (Mattocks et al., 2008; Ness et al., 2007) with participants requested to wear the accelerometer for 7 consecutive days during waking hours. A monitoring period of at least 3 days and 10 h of wear time per day was required (Mattocks et al., 2007a; Penpraze et al., 2006) with strings of consecutive zero's lasting ten minutes or more removed to account for non-wear time. In order to quantify MVPA from accelerometry output we applied the cut-point of 3600 cpm derived from the validation and calibration study conducted in a sub-sample of ALSPAC participants at 11 years (Mattocks et al., 2007b).

1.3.2. Attention and executive attention tasks

The outcome measures for the present analyses were from the Test of Everyday Attention for Children (TEA-Ch) (Manly, Robertson, Anderson, & Nimmo-Smith, 1998) at 11 years and the Cognitive Drug Research (CDR) computerised cognitive assessment system (United BioSource Corporation) at 13 years (c.f. Wesnes, 2008). Three tasks were selected from the TEA-Ch, each found to load on a different aspect of attention in factor analytic studies: the Sky search task; the sky search dual task; and the opposite-worlds task. The Sky search task has been found to load on selective attention factors in previous research (e.g. Manly et al., 2001). Participants are required to identify pairs of identical "spacecraft" from a page of visually similar stimuli whilst ignoring all distracting stimuli and to circle each pair of identical spaceships. Twenty pairs of spacecraft were identical from 49 displayed. Time and accuracy were recorded and a motor control condition was also performed. An age-corrected normative score was calculated based on the manual instructions, which was also adjusted for motor control. The sky search dual task has been found to load on sustained attention factors (Manly et al., 2001) and followed the same procedure as the sky search task but with the addition of simultaneously presented auditory stimuli which participants had to count whilst performing the sky search task. Normative scores based on time and errors were calculated. In previous research (Manly et al., 2001) the opposite-worlds task has loaded on a factor which was labelled attentional control/switching. It involves two conditions: in the first, participants followed digits (1 and 2 only) printed on a hand out stating the number out loud; in the second condition, participants had to inhibit the prepotent response and this time state "one" when presented with the digit 2, and "two" when