Preventive Medicine Reports 2 (2015) 548–553

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Review

Are children's activity levels determined by their genes or environment? A systematic review of twin studies☆

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ARTICLE INFO

Available online 16 June 2015

Keywords:
Twin
Child
Activity
Genetic
Environment

ABSTRACT

Context. The importance of physical activity to paediatric health warrants investigation into its determinants. Objective measurement allows a robust examination of genetic and environmental influences on physical activity.

Objective. To systematically review the evidence on the extent of genetic and environmental influence on children's objectively-measured activity levels from twin studies.

Data sources and search terms. Medline, EMBASE, PsycINFO, Health and Psychosocial Instruments and all Ovid Databases. Search terms: "accelerometer" OR "actometer" OR "motion sensor" OR "heart rate monitor" OR "physical activity energy expenditure" AND "twin". Limited to Human, English language and children (0–18 years).

Results. Seven sets of analyses were included in the review. Six analyses examined children's daily-life activity and found that the shared environment had a strong influence on activity levels (weighted mean 60%), with a smaller contribution from genetic factors (weighted mean 21%). Two analyses examined short-term, self-directed activity in a standard environment and found a smaller shared environment effect (weighted mean 25%) and a larger genetic estimate (weighted mean 45%).

Conclusions. Although genetic influences may be expressed when children have brief opportunities for autonomous activity, activity levels in daily-life are predominantly explained by environmental factors. Future research should aim to identify key environmental drivers of childhood activity.

Contents

Introduction

Regular participation in physical activity is protective against many chronic diseases including cardiovascular disease, some cancers, and diabetes (Booth et al., 2002; Cooper et al., 2005, 2006). There is evidence

☆ *Funding source*: Cancer research UK.

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http://dx.doi.org/10.1016/j.pmedr.2015.06.011

that activity 'tracks' from childhood into adult life, with active children being more likely to become active adults (Craigie et al., 2011; Telama et al., 2005). Childhood physical activity is therefore important for health over the life-course. However, surprisingly little is known about the causes of variation between children's levels of physical activity.

Several studies have demonstrated that physical activity levels aggregate within families (Craig et al., 2013; Freedson and Evenson, 1991; Jago et al., 2010; Moore et al., 1991; Spinath et al., 2002). Most have depended on self-report or parent-report measures. The three studies that used objective measures of free-living activity found inconsistent effects. One study found that 4–7 year olds with two active parents were around six times more likely to be sufficiently active than those whose parents were sedentary (Moore et al., 1991). Similarly, a large study of 539 parent–child pairs found that children with more active mothers or fathers were more likely to be active themselves (Craig et al., 2013). However, another study measuring activity over 3 days found no parent–child correlations for activity levels (Jago et al., 2010); it is possible that a shorter measurement period (compared with 7 + days in the former studies) reduced the reliability of these results.

Studies of parent–child resemblance cannot distinguish between genetic interpretations (e.g. activity level is a heritable trait) and environmental interpretations (e.g. children's activity is influenced by parental modelling). However, twin studies make it possible to estimate the relative extent of genetic and environmental influence by comparing the similarity between genetically identical pairs (monozygotic; MZ) and fraternal pairs (dizygotic; DZ) who share on average, half of their segregating genes (Plomin et al., 2008). In addition, by assessing the extent to which twin similarity exceeds the correlation expected by the heritability of the trait, it is possible to divide the environmental component into the shared environment effect (which makes twins reared in the same home more similar) and the non-shared (or unique) environment effect (which makes the children different from one another).

Most twin studies on physical activity have used data from adult twin cohorts and have relied on self-reported measures of physical activity. This literature was reviewed by Beunen and Thomas (1999) who concluded that heritability of self-reported sports participation ranged from 35 to 85%, while the heritability of self-reported daily physical activity was slightly lower, at 29–62%. Two large twin studies published since this review have supported the conclusion that there is a moderate-to-strong genetic influence on adult physical activity (Stubbe et al., 2005, 2006), although one study that used the criterion of meeting adult guidelines for physical activity (≥150 min per week) found that the environmental effect predominated and the genetic effect was non-significant (Duncan et al., 2008).

Fewer adult studies have used objective measures of physical activity. A small exploratory study using accelerometers in 20 twin pairs suggested strong genetic influence of 78% (57–87%) on free-living daily physical activity (Joosen et al., 2005). A larger study involving 225 twin pairs, which measured activity over a 6 hour period in a controlled setting in which participants carried out a variety of tasks, such as psychological testing, role playing and giving presentations, found that the genetic effect explained almost half of the variation (Spinath et al., 2002).

In infants and young children there are a number of studies using parent-reported activity (often from activity subscales on temperament questionnaires), which generally suggest a slightly lower genetic influence (in the region of 19–40%, as reviewed in Hwang and Rothbart, 2003). However, parent-reported child activity can be unreliable (Corder et al., 2009), and a particular critique of its use in twin studies is the possibility of 'contrast bias' where parents over-report the differences between their DZ twins, or 'assimilation bias', whereby parents over-report the similarity of their MZ twins (Neale and Stevenson, 1989; Saudino, 2003; Saudino et al., 2000). These biases are indicated when DZ correlations are less than half of the MZ correlations and they generate inflated heritability estimates (Neale and Stevenson, 1989; Saudino, 2003; Saudino et al., 2000).

Objective measurements of physical activity avoid contrast or assimilation bias and provide more robust estimates of genetic and environmental effects. This paper systematically reviews paediatric twin studies that have used objective measures to quantify the extent of genetic and environmental influences on physical activity.

Materials and methods

Literature search

The following databases were searched simultaneously for peer-reviewed journals; Medline, PsycINFO, EMBASE, Health and Psychosocial Instruments and all OVID Databases in April 2015. Results were limited to human, English language and "all child" (0 to 18 years). Searched terms used were "twin" AND "accelerometer" OR "actometer" OR "heart rate monitor" OR "physical activity energy expenditure" OR "motion sensor." A total of 3134 papers were identified. Titles and abstracts were scanned for relevance by three reviewers (AF, AS, LS), after removing papers based on title 74 were carried forward to abstract screening. Seven potentially eligible papers were identified. References lists of these papers were searched for relevant articles and reference lists of those papers and so on until no more articles could be identified. Four additional papers were included. Eleven papers were taken forward to full text review (Fig. 1).

We identified eleven papers that provided heritability estimates of objectively-measured activity in children, but two sets of reports used the same twin sample with data examined in different ways. One set reported analyses of accelerometer data in one paper (Wood et al., 2007) and analyses of a composite index of accelerometer plus subjective measures in another (Wood et al., 2008). The other set reported

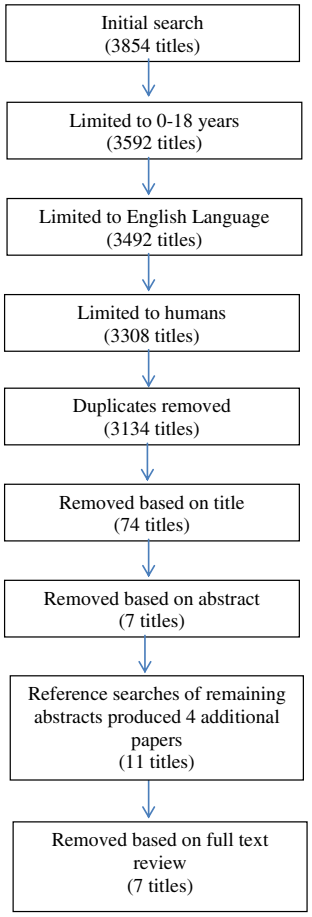

Fig. 1. Flow of citations.