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# Prospective associations between measures of gross and fine motor coordination in infants and objectively measured physical activity and sedentary behavior in childhood

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**Abstract**

One important determinant of childhood physical activity and sedentary behavior may be that of motor development in infancy. The present analyses aimed to investigate whether gross and fine motor delays in infants were associated with objective and self-reported activity in childhood. Data were from the UK Millennium Cohort Study, a prospective cohort study, involving UK children born on or around the millennium (September 2000 and January 2002). When children were 9 months old, parents reported children's fine and gross motor-coordination, and at 7 years, sports club attendance and daily TV viewing time. Children's physical activity was measured using accelerometers at 7 years. Adjusted regression models were used to examine associations between delayed motor development and accelerometry measured moderate-to-vigorous physical activity and sedentary behavior, and parent-reported sport club attendance and TV viewing time. In this sample (n = 13,021), gross motor delay in infancy was associated with less time in moderate-to-vigorous physical activity (B −5.0 95% confidence interval [CI] −6.8, −3.2) and more time sedentary (B 13.5 95% CI 9.3, 17.8) in childhood. Gross and fine motor delays during infancy were associated with a reduced risk of having high attendance at sports clubs in childhood (both relative risk [RR] 0.7, 95% CI 0.6, 0.9). Fine motor delays, but not gross delays, were also associated with an increased risk of having high TV viewing time (RR 1.3 95% CI 1.0, 1.6). Findings from the present study suggest that delays in motor development in infancy are associated with physical activity and sedentary time in childhood.

**Abbreviations:** BMI = body mass index, CI = confidence interval, MVPA = moderate-to-vigorous physical activity, RR = relative risk, TV = television.

**Keywords:** cohort, motor coordination, physical activity, sedentary

## Key Messages

- Gross motor delays at age 9 months are associated with less time in moderate-to-vigorous physical activity and more sedentary time in childhood.
- Fine motor delays at age 9 months are not associated with objectively measured activity in childhood.
- Gross and fine motor delays during infancy are associated with reduced risk of high attendance at sport clubs.

## 1. Introduction

Population levels of physical activity behavior are low and sedentary behavior (defined as any waking behavior characterized by energy expenditure below 1.5 metabolic equivalents while in a sitting or reclined posture) high in infants and children.[1] Regular participation in physical activity and low levels of sedentary behavior in childhood aid in the prevention of cardiometabolic disease risk factors and have been shown to be associated with good mental health.[2] Interventions to increase physical activity and reduce sedentary behavior in childhood have been met with little success, particularly over the long term.[3] One limitation of these interventions is that they

Editor: Hidetaka Hamasaki.

Funding: This work was supported by the Cancer Research UK under grant number C57326/A22090.

The authors have no conflicts of interest to declare.

Supplemental Digital Content is available for this article.

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Medicine (2017) 96:46(e8424)

Received: 8 September 2017 / Received in final form: 2 October 2017 / Accepted: 6 October 2017

http://dx.doi.org/10.1097/MD.0000000000008424

may not be targeted enough. Identifying correlates of physical activity can aid in the development of successful physical activity interventions, by highlighting the potentially modifiable correlates that may bring about physical activity (e.g., the physical environment), or identify characteristics of target groups most in need of intervention (e.g., those with low motor coordination). Importantly, identifying early life determinants of children's physical activity and sedentary behavior may increase physical activity across the lifespan. Indeed, previous research has shown that both physical activity and sedentary behavior in childhood are associated with such behaviors in adulthood.[4–5]

One important determinant of childhood physical activity and sedentary behavior may be that of motor development in infancy. Motor development models propose stages of motor proficiency from birth, which lead to the achievement of fundamental motor skills. Fundamental motor skills involve object control, such as grasping with the hand or striking a ball with the feet, and locomotor, such as walking and hopping. Proficiency in fundamental motor skills is key for the development of sports specific skills. Literature suggests that the development of motor coordination is related to physical activity levels in childhood.[6–7] Indeed, Stodden et al[6] have developed a theoretical model highlighting potential pathways between motor competence, physical activity, and risk of obesity.

A recent review identified 3 studies investigating the longitudinal association between motor coordination in infancy and physical activity behavior in childhood.[8] These studies found mixed results. One study using objective measures of physical activity found that motor coordination at 6 months had a modest association with physical activity (accelerometer counts per minute) in children aged 11 to 12 years residing in the UK (n = 4452)[9] whereas the only other study using an objective measure of physical activity found no association in 347 children residing in the Netherlands.[10] One study using a subjective outcome found that age at walking supported (months) was inversely associated with a higher frequency of sport participation in 14-year olds (n = 9009) residing in Finland.[11] All the aforementioned studies investigated a few gross motor coordination mile stones only (not fine) and did not investigate the association between motor coordination and sedentary behavior. Moreover, these studies have utilized self-reported measures of motor coordination and thus may be subject to self-report bias.

In childhood physical activity can be achieved by participating in 3 key domains: sport, active travel, and active play; it is likely that fine motor coordination is associated with sport participation, owing to the nature of "fine" movements required in the fingers and wrists in many sports (e.g., table tennis, cricket, netball). It is plausible to assume that for children with poor gross and fine motor coordination sedentary activities (i.e., television [TV] viewing and computing gaming) may be more enjoyable options. Indeed, the present authors' have previously shown that lower levels of gross motor coordination in childhood are associated with higher TV viewing in adolescents and adulthood.

The present analyses aimed to investigate whether gross and fine motor delays in infants (aged 9 months) were associated with objective and self-reported activity levels later in childhood (aged 7 years). We hypothesize that those children with high levels of gross and/or fine motor coordination in infancy will exhibit higher levels of physical activity and lower levels of sedentary behavior in childhood.

## 2. Methods

Data were drawn from the Millennium Cohort Study, a prospective cohort study, involving UK children born on or around the millennium (September 2000 and January 2002). Eligible children were identified from the record of child benefit. Information was collected on 18,818 children at 9 months of age from 1 parent (usually the child's mother). Further surveys were administered at ages 3, 5, and 7 years. All measures were collected in the child's home. The present analyses utilized data from the age 9 months and 7 years' survey. Physical activity was objectively measured using waist worn accelerometers (Actigraph GT1M, Pensacola, FL). Ethical approval was granted by the South West and London Multi-Centre Research Ethics Committees.

### 2.1. Exposure variable

Parents/carers (usually mothers) reported gross and fine motor-coordination for their child (ren) at 9 months of age. The items used in the survey were adapted from the Denver Developmental Screening Test. Delay in the developmental milestones were determined when an infant had not reached a milestone (see S1 for list of milestones, http://links.lww.com/MD/B964) that 90% of infants had reached. If ≥1 gross motor milestone was delayed, then an infant was categorized as having delayed gross motor-coordination. The same approach was applied to categorize delayed fine motor-coordination. This method of categorizing delayed motor coordination has been previously used in this population.[12]

### 2.2. Outcome variable

Free-living physical activity and sedentary behavior were measured using Actigraph GT1M accelerometers when participants were 7 years of age (between May 2008 and August 2009). Full details on the accelerometry procedures have been published previously.[13] Accelerometers were programmed to record data at 15-second intervals (15-second epoch length). Accelerometers were worn around participants' waists during waking hours for 7 consecutive days, but were removed during water-based activities. A total of 6675 children (3176 boys) met the inclusion criteria of having at least 2 days with ≥10 hours of wear time. Time spent engaging in physical activities of varying intensities was derived using cutpoints generated from a prior calibration study in 7-year-old children. Time sedentary was classified as <100 counts per minute, and time in moderate-to-vigorous physical activity (MVPA) was classified as >2241 counts per minute.

When children were 7 years old, parents/carers (mainly mothers) were asked to report how often their child (ren) participated in clubs or classes involving sports or other physical activities outside of school lessons, such as gymnastics or football. Response options for this question were not at all, less often than once per week, 1 day per week, 2 days per week, 3 days per week, 4 days per week, or ≥5 days per week. High attendance was categorized as ≥2 days per week, moderate attendance as 1 day per week, and low attendance as <1 day per week/not at all. Mothers were also asked about their children's participation in a variety of sedentary behaviors, including the number of hours spent watching television/videos/DVDs (none, less than an hour, 1 hour to <3 hours, 3 hours to <5 hours, 5 hours to <7 hours, or ≥7 hours). High TV viewing was categorized as (≥3 h/d), moderate as 1 to 3 h/d, and low as <1 h/d.

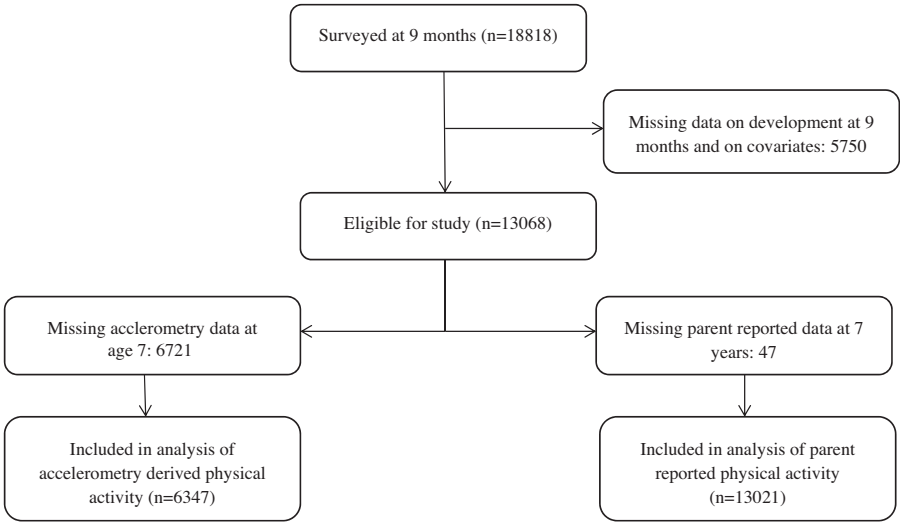


**Figure 1.** Flow chart to illustrate phases of the study and arrival of final samples.

### 2.3. Covariates

Covariates were selected a priori based on the availability of data and existing research suggesting independent associations with outcomes and exposures. Trained interviewers measured children's height and weight from which body mass index (BMI) was calculated using standard formulae from which children were categorized as overweight/obese. Parents/carers (usually mothers) reported child (ren)'s sex, age, ethnicity (classified as White British or Other), and income (classified as above or in poverty). Total actigraph wear time across the week was also recorded.

### 2.4. Analyses

Characteristics of the study population were described using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Characteristics of the final sample and those excluded from the analysis were compared using the chi-squared test. Linear regression models, adjusted for prespecified covariates were run to investigate associations between delayed gross motor-coordination development (at age 9 months) and objectively measured time spent in MVPA and sedentary behavior (at age 7 years). Models were then repeated with delayed fine motor-coordination development as the exposure. MVPA and sedentary time were checked for normality prior to analysis. For each analysis, we also verified that the assumptions for normally distributed residuals and homoscedasticity were met. Next, adjusted (for prespecified covariates) multinomial logistic regression models were run to investigate associations between delayed gross motor-coordination development, parent-reported participation in sports/physical activity clubs, and TV viewing time. Models were then repeated with delayed fine motor-coordination development as the exposure. All analyses were performed in STATA version 14 (College Station, TX: StataCorp LLC).

## 3. Results

The final sample consisted of 13,021 children with complete parent-reported data on motor coordination at 9 months accompanied by complete parent-reported data on attendance at sports clubs and TV viewing at age 7 (Fig. 1). A total of 6347 children also had valid accelerometry data at age 7. Compared with the accelerometry sample, children who were excluded from this part of the analysis (n = 6681) spent more time watching TV (proportion classified as high TV viewers: 14.5% vs 16.9%, $P < .001$), attended fewer sports/PA clubs (proportion classified as high attendees: 48.5% vs 34.7%, $P < .001$), were more likely to be male (48.7% vs 52.1%), were more likely to be in poverty (22.0% vs 36.2%, $P < .001$), were less likely to be White British (88.5% vs 80.9%, $P < .001$) and were more likely to have a fine motor delay (5.8% vs 7.6%, $P < .001$) but not a gross motor delay ($P = .4$).

Sample characteristics are displayed in Table 1. In the full sample (n = 13,021), 41.5% of children had high attendance at sports/physical activity clubs (≥2 d/wk) and 15.7% had high TV viewing time (≥3 h/d). In the accelerometry sample, mean time spent sedentary and in MVPA was 393 min/d and 62 min/d, respectively. In the accelerometry analysis, gross motor delay was associated with less time spent in MVPA (B −5.0 95% CI −6.8, −3.2; Table 2) and more time sedentary (B 13.5 95% CI 9.3, 17.8; Table 2). No associations were observed between fine motor delay and objectively measured activity levels. Gross and fine motor delays during infancy were associated with a reduced

**Table 1**

**Sample characteristics.**

| Characteristic | No. | % | Mean (SD) |
|---|---|---|---|
| Total sample | 13,021 | | |
| Age | | | 7.2 (0.3) |
| White British race/ethnicity | 11,014 | 84.6 | |
| Male sex | 6571 | 50.5 | |
| Poverty-level income | 3814 | 29.3 | |
| Fine motor delay at 9 mo | 877 | 6.7 | |
| Gross motor delay at 9 mo | 1165 | 9.0 | |
| High sport participation | 5395 | 41.4 | |
| High TV viewing | 2050 | 15.7 | |
| | | | |
| Accelerometry sample | 6340 | | |
| Sedentary time, min/d | | | 393.2 (67.3) |
| MVPA, min/d | | | 62.3 (22.4) |
| Wear time, min/d | | | 736.3 (62.5) |

MVPA = moderate-to-vigorous physical activity, SD = standard deviation.

**Table 2**

**Association between gross and fine motor delay at 9 months with objectively measured activity levels at 7 years of age, n = 6340.**

| | Sedentary time | | | | MVPA | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1* | | Model 2† | | Model 1* | | Model 2† | |
| | B | 95% CI | B | 95% CI | B | 95% CI | B | 95% CI |
| No gross motor delay | Referent | | | | Referent | | | |
| Gross motor delay | 13.5 | 9.1, 17.8 | 13.5 | 9.3, 17.8 | –5.1 | –7.0, –3.1 | –5.0 | –6.8, –3.2 |
| No fine motor delay | Referent | | | | Referent | | | |
| Fine motor delay | 1.9 | –3.3, 7.17 | 2.6 | –2.6, 7.8 | –0.2 | –2.5, 2.2 | –0.6 | –2.8, 1.6 |

CI = confidence interval, MVPA = moderate-to-vigorous physical activity.
* Unadjusted for age, sex, ethnicity, poverty status, body mass index, and accelerometer wear time.
† Adjusted for age, sex, ethnicity, poverty status, body mass index, and accelerometer wear time.

**Table 3**

**Association between gross and fine motor delay at 9 months with parent-reported sport and TV time among children aged 7 years of age, n = 13,021.**

| | Sports clubs attendance | | | TV time | | |
|---|---|---|---|---|---|---|
| | Low | Moderate | High | Low | Moderate | High |
| | RR 95% CI | RR 95% CI | RR 95% CI | RR 95% CI | RR 95% CI | RR 95% CI |
| Model 1* | | | | | | |
| Gross motor delay† | 1.00 | 0.8 (0.7, 0.9) | 0.7 (0.6, 0.8) | 1.00 | 1.0 (0.9, 1.2) | 1.0 (0.8, 1.2) |
| Fine motor delay† | 1.00 | 0.8 (0.7, 0.9) | 0.6 (0.5, 0.7) | 1.00 | 1.1 (0.9, 1.3) | 1.4 (1.1, 1.7) |
| Model 2‡ | | | | | | |
| Gross motor delay† | 1.00 | 0.8 (0.7, 0.9) | 0.7 (0.6, 0.9) | 1.00 | 1.0 (0.9, 1.2) | 1.0 (0.8, 1.2) |
| Fine motor delay† | 1.00 | 0.9 (0.7, 1.1) | 0.7 (0.6, 0.9) | 1.00 | 1.1 (0.9, 1.3) | 1.3 (1.0, 1.6) |

CI = confidence interval, RR = relative risk.
* Unadjusted for age, sex, ethnicity, poverty status, and body mass index.
† Reference groups were children with no gross or no fine developmental delays, respectively.
‡ Adjusted for age, sex, ethnicity, poverty status and body mass index.

risk of having high attendance at sports clubs at age 7 (both relative risk [RR] 0.7, 95% confidence interval [CI] 0.6, 0.9; Table 3) after adjusting for sociodemographic and health variables. Fine motor delays, but not gross delays, were also associated with an increased risk of having high TV viewing time (RR 1.3 95% CI 1.0, 1.6; Table 3).

## 4. Discussion

This is the first study to investigate the longitudinal association between delayed fine and gross motor coordination development in infancy and physical activity and sedentary behavior in childhood. This study found in a large representative sample of children residing in the UK that delays in gross (but not fine) motor-coordination development in infancy were inversely associated with MVPA and positively associated with sedentary time in childhood. Interestingly, the present study also found that both delayed gross and fine motor-coordination development in infancy were associated with lower sport club attendance and higher TV viewing time in childhood.

These findings support and add to previous literature. Two out of 3 previous studies have found that gross motor-coordination in infancy is associated with physical activity in childhood.[9,11] This association is likely to be explained by children with better gross motor-coordination finding physical activity more enjoyable as it is easier for them (sport participation, active play, e.g., catch, tag, etc.). One study, however, did not find such an association.[10] One plausible explanation is that this study consisted of a small sample (n = 347) and thus may be underpowered to detect significant effects.

The present study is the first to investigate the association between delayed motor development in infancy and sedentary behavior in childhood. This study found that delayed gross-motor coordination in infancy was associated with an additional 13.5 minutes of sedentary time a day when compared with those who did not experience such a delay. One plausible explanation is that children with poor motor coordination may find physical activity less enjoyable as it may be more challenging for them, and thus may prefer more passive sedentary activities (e.g., TV viewing). However, to date this hypothesis has not been tested and further research is thus required.

The present study is also the first to investigate the longitudinal association between delayed fine motor-coordination and free-living activity, sport club attendance, and TV viewing time. Interestingly, delayed fine motor-coordination was not associated with overall levels of activity but was inversely associated with sports club attendance and positively associated with TV viewing time. High levels of fine motor coordination are a likely requirement for success in specific sports (cricket, netball, tennis etc.). Therefore, those with high levels of fine motor-coordination are likely to participate in such sports whereas those with low levels are not. Those with low levels of fine motor-coordination may spend this discretionary time in TV viewing. However, it is important to note again that delayed fine-motor coordination was not associated with free-living MVPA or sedentary behavior. Therefore, children with low levels of fine motor-coordination likely achieve physical activity via other domains such as certain active play activities and/or active travel.

Clear strengths of the present study are the large representative UK sample and the longitudinal nature of the analyses. A

limitation is that accelerometers only provided data on a single week, which may not be a true reflection of typical behavior. Owing to limitations of the Actigraph accelerometer to detect ambulatory activity it is likely that certain activities such as jumping, catching, and cycling would not have been accurately recorded. However, Actigraph accelerometers are a valid and reliable way to measure physical activity in young people. It should be noted that parents reported motor skills, sports club attendance, and TV viewing time, this may have introduced bias. For example, parents may under-report TV viewing but over report sports club attendance and motor coordination development as they wish to be seen as "good parents."

## 5. Conclusions

Delays in gross motor development in infancy are inversely associated with moderate-to-vigorous physical activity and positively associated with sedentary time in childhood. Improving infants' gross motor skills may be an appropriate target for promoting overall physical activity levels; however, both gross and fine motor development may be important for promoting engagement in specific domains of physical activity, such as sport.

## References

[1] British Heart Foundation. Physical Activity Statistics; 2015.
[2] Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. J Paediatr 2005;146:732–7.
[3] Van Slujis E, McMinn A, Griffin S. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ 2007;335:703.
[4] Smith L, Gardner B, Hamer M. Childhood correlates of adult TV viewing time: a 32-year follow-up of the 1970 British Cohort Study. J Epidemiol Community Health 2015;69:309–13.
[5] Smith L, Gardner B, Aggio D, et al. Association between participation in outdoor play and sport at 10 years old with physical activity in adulthood. Prev Med 2015;74:31–5.
[6] Stodden D, Goodway J, Langendorfer S, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. Quest 2008;60:290–306.
[7] Barnett L, van Beurden E, Morgan P, et al. Childhood motor skill proficiency as a predictor of adolescent physical activity. J Adolescent Health 2009;44:254–9.
[8] Øglund G, Hildebrand M, Ekelund U. Are birth weight, early growth, and motor development determinants of physical activity in children and youth? A systematic review and meta-analysis. Paediatr Exerc Sci 2015;27:441–53.
[9] Mattocks C, Deere K, Leary S, et al. Early life determinants of physical activity in 11 to 12 year olds: cohort study. Br J Sports Med 2008;42:721–4.
[10] Wijtzes AIM, Kooijman MNM, Kiefte-de Jong JCP, et al. Correlates of physical activity in 2-year-old toddlers: the Generation R Study. J Pediatr 2013;163:791.e1–9.e2.
[11] Ridgway C, Ong K, Tammelin T, et al. Infant motor development predicts sports participation at age 14 years: Northern Finland birth cohort of 1966. PLoS One 2009;4:e6837.
[12] Sacker A, Quigey M, Kelly Y. Breastfeeding and developmental delay: findings from the millennium cohort study. Paediatrics 2006;118:682–9.
[13] Griffiths L, Cortina-Borja M, Sera F, et al. How active are our children? Findings from the Millennium CohortStudy. BMJ Open 2013;3:e002893.