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Cycling to school and adolescent fitness: A longitudinal study

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ABSTRACT

Objective. This study investigated whether a change in mode of transport to school from non-cycling to cycling was associated with change in cardio-respiratory fitness (CRF) over a six-year follow-up. *Methods.* Participants were 384 children (9.7 (0.5) yr) who participated in the Danish arm of the European Youth Heart Study in 1997 and who were followed up six years later. CRF was assessed by a maximal cycle ergometer test and travel to school was investigated by computerised questionnaire at both time points. Linear regression models were used to investigate associations between CRF and change in mode of travel to school between baseline and follow-up. *Results.* Participants who did not cycle to school at baseline, and who had changed to cycling at follow up, were significantly fitter than those who did not cycle to school at either time point (p=0.004). The difference of 0.23 $W \cdot kg^{-1}$ corresponds to a difference of 7.7% in CRF. Longitudinal regression showed that a change in travel mode from non-cycling in 1997 to cycling in 2003 was a significant predictor of CRF in 2003 (p<0.001) after adjustment for potential confounders. *Conclusion.* Cycling to school may contribute to higher cardiovascular fitness in young people.

Key words: YOUTH, ACTIVE COMMUTING, HEALTH, TRANSPORTATION, CYCLING, FITNESS, PHYSICAL ACTIVITY

INTRODUCTION

The journey to and from school presents a substantial opportunity for children to be physically active. However transport surveys show that active travel is in decline (Department for Transport, 2005). In the US, children's active commuting to school declined by 37% between 1977 and 1995, and current estimates suggest that only 5-10% of American youth walk to school and 2-4% cycle (Centers for Disease Control, 2000, Evenson et al., 2003, Sirard et al., 2005a). In the UK the proportion of secondary school-age children (11-16yrs) walking to school declined from 46% in 1991/93 to 38% in 2002 and cycling to school was negligible (1-2%) (Department for Transport, 2005). These low rates of active transportation to school have resulted in the journey to school being seen as a target for intervention to increase young peoples daily physical activity.

Studies in the U.S. (Sirard et al., 2005b), Europe (Cooper et al., 2003, Cooper et al., 2005) and elsewhere (Tudor-Locke et al., 2003) have shown that children who walk or cycle to school engage in more physical activity than those using motorised transport, and that this extra physical activity may exceed the amount due to the journey alone. Physical activity is inversely associated with fatness and with clustering of cardiovascular risk factors in children and adolescents (Andersen et al., 2006, Ekelund et al., 2004), but to date no consistent association between active commuting and body mass index (BMI) or other measures of adiposity have been described (Rosenberg et al., 2006). Similarly, no association between active commuting and metabolic risk factors has been reported. Recently, however, cycling to school has been associated with higher levels of cardio-respiratory fitness in children and adolescents (Cooper et al., 2006). Cardio-respiratory fitness (CRF) may be an important health-related outcome of higher physical activity. Habitually active children are fitter than less active children (Eiberg et al., 2005) and fitness can be increased by physical training (Baquet et al., 2003). Low fitness has been associated with clustering of metabolic risk factors in young people that may persist into adulthood, and thus modifying risk factor levels in children may be of critical importance for ameliorating future CVD risk (Andersen et al., 2003, Bao et al., 1994, Janz et al., 2003). In optimizing young peoples health, it may thus be important to understand not only how we may increase physical activity, but also to improve fitness, and cycling to school may be one way to achieve both of these aims. The purpose of the present investigation was to use a cohort of children in which commuter cycling is a common activity, and where associations between cycling and higher CRF have been demonstrated, to investigate whether these associations persist after 6 years of follow-up and to explore whether a change in mode of travel to school is associated with a change in CRF.

METHODS

Participants

This paper describes data from the Danish arm of the European Youth Heart Study. The sampling frame has been described in detail elsewhere (Riddoch et al., 2005). Briefly, in 1997 a representative sample of third grade (8-10yrs) and ninth grade (14-16 yrs) students were recruited from schools in Odense, Denmark. Schools were stratified according to location and socio-economic profile of their catchment area. In 2003 the children who were in the third grade in 1997 were followed up (longitudinal cohort). Seven hundred and seventy one third grade children from 25 different schools were invited to participate in 1997, of whom 589 (310 girls and 279 boys) consented. Six years later, 384 of these children (212 girls and 171 boys) were re-examined. The study was approved by the ethical committee of Vejle and Funen, and written consent was obtained from the parent/guardian of each participant.

Measurements

Body composition

Height was measured to the nearest 1mm with a transportable Harpenden stadiometer and weight was measured to the nearest 0.1kg using a calibrated beam scale. Body mass index (BMI) was calculated as weight (kg)/height^2 (m). The sum of the thickness of four skinfolds (biceps, triceps, subscapular and suprailiac) was measured using a Harpenden caliper, with the mean of three measurements used at each site. Pubertal stage was assessed according to Tanner stages.

Travel mode

A computerised questionnaire assessed travel mode: “How do you usually travel to school?” (response options: *by car or motorcycle, by bus or train, by bicycle, by foot*) with a similar question for travel home, and “How long does it usually take you to travel to school from your home?” (response options: *less than 5 minutes, 5 to 15 minutes, 15 to 30 minutes, 30 minutes to 1 hour, more than 1 hour*). In this paper travel mode was defined by the way the participant usually travelled to school.

Cardio-respiratory fitness (CRF)

CRF (maximal power output per kilogram; $W_{max}{\cdot}kg^{-1}$) was determined using a validated test (Riddoch et al., 2005) on an electronically braked cycle ergometer (Monark 839 Ergomedic). After 3 minutes warm up participants pedalled at a self-selected rate between 60-80 rpm. The workload was increased every third minute until exhaustion. Initial and incremental workloads were 20 W for children weighing less than 30 kg and 25 W for children weighing 30 kg or more. For 15-year-old girls and boys the initial and incremental workloads were 40 W and 50 W, respectively. Heart rate was recorded continuously throughout the test using a heart rate monitor (Polar Vantage, Polar Electro, Kempele, Finland). Criteria for exhaustion were a heart rate >185 beats per minute, failure to maintain a pedaling frequency of at least 30 rpm or a subjective judgment by the observer that the individual could no longer continue, even after encouragement. The maximal power output was calculated for each individual according to the formula $W_l + (W_i \times T/180)$ where Wl = workload (in watts) at the last completed stage, Wi = the workload increment (in watts) at the final incomplete stage, and T = time (in seconds) at the final incomplete stage.

Physical activity

Physical activity was measured using an accelerometer (ActiGraph 7164, Manufacturing Technologies Inc.) set to store data each minute (counts per minute; cpm). The accelerometer was worn on an elastic belt around the waist, positioned above the right hip, for at least four days (including 2 weekend days), except when swimming, bathing and sleeping. Periods of 10 minutes or longer where zero counts were recorded were interpreted as the accelerometer not being worn, and were removed from the summation of activity. To provide a representative picture of physical activity, participants were required to record at least ten hours of measurement each day for three or more days. The mean number of minutes engaged in activity that resulted in ≥3000 cpm (interpreted as mean minutes of moderate to vigorous physical activity (MVPA) (Schmitz et al., 2005)) was calculated for each participant. To account for differences in the time that the monitors were worn minutes ≥3000 cpm were multiplied by the inverse of the percent time reported (Jago et al., 2004).

Statistical analyses

Descriptive statistics were calculated for all variables. One-way analysis of variance tests (ANOVA) were used to investigate whether participant characteristics (height, weight, BMI, skinfolds) or CRF differed by travel modes. Hierarchical linear regression models in which participants were clustered in schools were used to examine the cross-sectional and longitudinal associations of CRF with travel mode using the xtreg procedure in STATA (Version 9.2). Models were adjusted for gender, age, body composition (skinfolds), pubertal status, and physical activity (MVPA). To examine longitudinal associations the models were then re-run with 2003 values as outcomes and baseline CRF as a covariate.

RESULTS

The 384 participants in the longitudinal cohort did not differ at baseline from the rest of the 1997 cohort in age, height, weight or physical activity, although fitness was significantly higher in both girls and boys (Girls: 2.87 $\pm$ 0.52 vs 2.71 $\pm$ 0.46 $W_{max} \cdot kg^{-1}$, F (1,281) = 6.464, *p*=0.012; Boys: 3.28 $\pm$ 0.51 vs 3.03 $\pm$ 0.65 $W_{max} \cdot kg^{-1}$, F (1,256) = 11.790, *p*=0.001). This difference may be explained by the higher proportion of children cycling to school in the longitudinal sample (41.0% vs 31.7%). Demographics of the longitudinal cohort are shown in table 1. Cycling was the most common form of travel to school, with the proportion of participants cycling to school increasing from 41.0% in grade 3 to 63.1% in grade 9 at the expense of car travel. There were no significant differences in demographics (including BMI and skinfold thickness) between participants using different travel modes. Participants using motorised transport (car/bus/train) were merged into a single category ("Passive") for further analyses to increase statistical power. MVPA was highest in walkers and lowest in those using passive transport, but differences were not statistically significant (1997: *p*=0.058; 2003: *p*=0.564). Values for cyclists MVPA were inconsistent but generally in between those of walkers and passive travellers. Journey times to school were similar for walkers and cyclists, with 88% of walkers and 95.5% of cyclists reporting a journey time of 15minutes or less in 1997 (98.7% and 88.8% respectively in 2003). Those using passive transport had longer journey times, particularly in adolescence, where 64.6% reported a journey to school of over 15 minutes (22.9% in 1997).

Fitness of the participants by travel mode is shown in Table 2. Travel mode was significantly associated with CRF (1997: F (2,338) = 7.914, $p < 0.001$; 2003: F (2,349) = 7.675, $p < 0.001$). CRF was higher in participants cycling to school in both genders and at both time points. Participants walking to school or using passive transport did not significantly differ in fitness and were combined ("non-cycling") for regression analyses. The cross-sectional regression models are shown in table 3. At both time points cycling to school and gender were independently associated with CRF (1997 and 2003: $p < 0.001$) and adiposity (skinfolds) was negatively associated (1997 and 2003: $p < 0.001$). Age was a significant predictor of CRF only in 1997 (p=0.01). Physical activity was not a significant predictor of CRF. The models explained 49.2% (1997) and 71.4% (2003) of the overall variance in CRF.

The longitudinal association between commuting mode and fitness was investigated in 322 participants who provided fitness and travel data at both measurements (Table 4). Participants who cycled at both time points had the highest fitness values in 2003, though these were almost identical to those of participants who did not cycle at baseline but had switched to cycling at follow up. CRF was significantly higher (0.23 $W \cdot kg^{-1}$; p=0.004) in those who cycled than in those who did not, corresponding to a difference of 7.7% compared with participants who did not cycle to school at either time point. Longitudinal regression showed that a change in travel mode from non-cycling in 1997 to cycling in 2003 was a significant predictor of CRF in 2003 (p<0.001; Table 4), as was cycling at both time points (p<0.001). Participants who had stopped cycling to school did not differ from those who had never cycled. The model explained 75.7% of the overall variance in CRF. Models were essentially unchanged when run with and without age, pubertal status and physical activity.

DISCUSSION

A strong cross-sectional association between cycling to school and CRF was seen in a cohort of children at baseline and when followed up 6 years later, strengthening previous findings that cycling to school is associated with increased CRF in young people. In cross-sectional analyses it is possible that genetically fitter children find cycling easier than those less fit and thus choose to cycle to school. The new data in this paper provides evidence that this is not the case, since fitness was increased in children who had changed travel mode to become cyclists but not in those who had remained non-cyclists. These data suggest that commuter cycling *per se* may be sufficient to improve fitness, and to our knowledge is the first study to describe how change in travel behaviour over time may be associated with a change in fitness in children.

The higher CRF associated with cycling is likely to be due to an increased volume and/or intensity of physical activity over other forms of transport. It is possible that the journey to school may provide sufficient stimulus to elicit the increased fitness that we report. In adults, commuter cycling has been shown to elicit a heart rate equivalent to 62-65% VO_{2max} and to improve fitness by up to 6% over a relatively short time (Hendriksen et al., 2000, Vuori et al., 1994). There are, to our knowledge, no data describing the intensity of, or heart rate response to, commuter cycling in children or adolescents. However interval training studies, which may represent commuter cycling due to their stop-start nature, have demonstrated that repeated short bouts of 10 or 20 seconds of exercise at 80-95% HR_{max} can significantly increase peak VO_2 (Baquet et al., 2002). If the intensity of commuter cycling in children approaches this level, even for short bouts, this could explain why cycling to school might improve cardio respiratory fitness in children when carried out daily.

An alternative explanation may be that cycling to school is an indicator of a child who also cycles more in their free time and/or was more physically active in general than non-cyclists. Data describing habitual levels of cycling were not collected in this study, and although the participants spend much of their day at school where they will not be cycling, higher levels of cycling in the evenings and at weekends cannot be ruled out. We have previously shown in this cohort that the overall physical activity of children who walk to school is higher than those who travel by car, but that their CRF is no higher, and in contrast the physical activity of cyclists is generally intermediate between that of passive travellers and walkers, yet cyclists are consistently fitter than these other groups (Cooper et al., 2005, Cooper et al., 2006). These data suggest that it is not higher levels of overall physical activity that account for the higher CRF of cyclists.

In the current analysis, moderate to vigorous physical activity (MVPA) was not a significant predictor of CRF in regression models, indicating that activity of greater intensity of activity is not associated with higher CRF. Similarly cyclists did not record more MVPA than non-cyclists. However, a limitation of using accelerometers to measure physical activity is that they may poorly record physical activity when cycling. Uni-axial accelerometers, such as the ActiGraph, measure vertical accelerations of the body. During cycling, accelerations of the upper body are small and the counts recorded by the accelerometer are an underestimate of the true volume and intensity of the activity (Freedson et al., 2005). This limitation means that we cannot estimate the contribution to overall activity and, importantly for development of CRF, to activity of a higher intensity made by cycling to school or other recreational cycling. It is thus possible, but cannot be confirmed, that the overall volume and/or intensity of physical activity carried out by cyclists was greater than indicated by the accelerometer and may explain the observed differences in fitness.

CONCLUSIONS

There is a consistent association between cycling and higher CRF in young people. Whether the differences in fitness between cyclists and non-cyclists that we observed are due only to active commuting remains to be established. Nonetheless, these data support programmes that encourage active travel to school, and in particular cycling, for young people. Active travel to school is associated with increased levels of overall physical activity and this study suggests that whilst promotion of walking may have a benefit in terms of increasing levels of moderate activity, the benefits may be greater in terms of fitness if children and adolescents cycle rather than walk.

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Tables

Table 1. Characterisitics of Danish participants in the longitudinal cohort at baseline in 1997 and follow-up in 2003 (mean (SD) unless otherwise stated).

	Baseline (1997)			**Follow-up (2003)**		
	All n=384	**Girls n=213**	**Boys n=171**	**All n=384**	**Girls n=213**	**Boys n=171**
Age (years)	9.7 (0.5)	9.6 (0.6)	9.7 (0.4)	15.7 (0.4)	15.7 (0.4)	15.8 (0.3)
Height (m)	1.39 (0.06)	1.38 (0.06)	1.40 (0.06)	1.70 (0.09)	1.65 (0.07)	1.76 (0.07)
Weight (kg)	33.3 (6.0)	33.0 (6.2)	33.6 (5.7)	61.6 (10.8)	58.4 (9.7)	65.6 (11.0)
BMI (kg/m^2)	17.1 (2.2)	17.2 (2.5)	17.1 (2.0)	21.2 (3.0)	21.4 (3.1)	21.0 (2.9)
Skinfolds (mm)	36.1 (16.7)	38.7 (17.4)	32.8 (15.2)	44.7 (21.1)	52.5 (17.6)	35.0 (21.2)
Pubertal stage (1/2/3)*	321/61/0	150/61/0	171/0/0	0/340/42	0/171/42	0/171/0
Commuting mode (% (n))#						
Bus/train	10.4 (39)	10.6 (22)	10.1 (17)	10.7 (41)	10.4 (22)	11.2 (19)
Car	24.2 (91)	24.0 (50)	24.4 (41)	6.0 (23)	4.2 (9)	8.2 (14)
Walk	24.5 (92)	24.0 (50)	25.0 (42)	20.2 (77)	19.3 (41)	21.2 (36)
Cycle	41.0 (154)	41.3 (86)	40.5 (68)	63.1 (241)	66.0 (140)	59.4 (101)

* 1 = pre-pubertal, 2 = early/mid puberty (Tanner stages 2, 3, 4), 3 = late/post puberty

Eight participants did not provide travel data in 1997, two did not provided data in 2003

Table 2. Cardiovascular fitness by mode of travel to school of Danish participants in the longitudinal cohort at baseline in 1997 and follow-up in 2003 (Mean (SD) (95%CI)).

	1997			**2003**		
Fitness (W_{max}/kg)	**All (n=341)***	**Girls (n=189)**	**Boys (n=152)**	**All (n=352)***	**Girls (n=193)**	**Boys (n=159)**
All	3.05 (0.55) (2.99, 3.11)	2.87 (0.52) (2.80, 2.95)	3.28 (0.51) (3.20, 3.36)	3.33 (0.62) (3.27, 3.40)	2.99 (0.45) (2.92, 3.05)	3.75 (0.54) (3.67, 3.84)
Passive	2.94 (0.51) (2.85, 3.03)	2.81 (0.50) (2.70, 2.93)	3.11 (0.47) (2.98, 3.24)	3.31 (0.63) (3.14, 3.47)	2.91 (0.41) (2.74, 3.08)	3.65 (0.58) (3.43, 3.87)
Walk	2.97 (0.53) (2.85, 3.09)	2.81 (0.50) (2.65, 2.96)	3.15 (0.51) (2.98, 3.32)	3.09 (0.66) (2.93, 3.24)	2.67 (0.43) (2.52, 2.82)	3.51 (0.57) (3.31, 3.71)
Cycle	3.19 (0.58) (3.09, 3.28)	2.95 (0.54) (2.83, 3.07)	3.50 (0.47) (3.38, 3.61)	3.41 (0.59) (3.34, 3.49)	3.08 (0.42) (3.01, 3.16)	3.89 (0.49) (3.77, 3.97)

*The fitness test was not completed by 43 participants at baseline and by 32 at follow-up.

Table 3. Cross-sectional associations of travel mode (cycle/non-cycle) and demographic factors and physical activity with cardiorespiratory fitness in Danish participants in the longitudinal cohort at baseline in 1997 and follow-up in 2003 (W_{max}/kg).

	1997			2003		
	Beta (95% CI)	**z**	***p***	**Beta (95% CI)**	**z**	***p***
Travel*	0.192 (0.101, 0.284)	4.12	<0.001	0.293 (0.209, 0.378)	6.81	<0.001
Gender	0.253 (0.148, 0.359)	4.69	<0.001	0.470 (0.380, 0.560)	10.22	<0.001
Age	0.154 (0.037, 0.272)	2.58	0.010	0.008 (-0.107, 0.124)	0.14	0.889
Skinfolds	-0.018 (-0.021, -0.015)	-11.60	<0.001	-0.017 (-0.019, -0.015)	-16.94	<0.001
Tanner stage	-0.048 (-0.182, 0.087)	-0.70	0.486	0.010 (-0.099, 0.119)	0.18	0.859
Physical activity	0.001 (-0.000, 0.003)	1.60	0.109	0.002 (-0.000, 0.003)	1.69	0.091

*Reference group = non-cycle.

Table 4. Longitudinal associations of change in travel mode between 1997 and 2003 with cardiorespiratory fitness (W_{max}/kg) in 2003 in Danish participants in the longitudinal cohort.

Travel mode 1997	Travel mode 2003	Participants n (F, M)	CRF (Mean (SD)) (95% CI)) 1997	CRF (Mean (SD)) (95% CI)) 2003	Beta (95% CI)*	z	*p*
Non cycle	Non cycle	76 (34, 42)	2.95 (0.55) (2.82, 3.07)	3.19 (0.65) (3.04, 3.34)			
Non cycle	Cycle	108 (63, 45)	3.01 (0.47) (2.92, 3.10)	3.41 (0.60) (3.29, 3.52)	0.292 (0.190, 0.362)	5.62	<0.001
Cycle	Non cycle	36 (19, 17)	3.22 (0.56) (3.03, 3.41)	3.27 (0.63) (3.06, 3.48)	0.059 (-0.081, 0.200)	0.83	0.409
Cycle	Cycle	102 (59, 43)	3.16 (0.58) (3.05, 3.28)	3.44 (0.56) (3.33, 3.55)	0.267 (0.160, 0.373)	4.89	<0.001

Non cycle = walking and passive transport combined.
*Model adjusted for baseline CRF, gender, skinfolds and physical activity. Reference group = non-cycle – non-cycle.

Precis

Cycling to school was associated with higher cardio-respiratory fitness in 384 Danish youth at baseline and after 6 years follow up. Fitness was higher in participants who had become cyclists.

*** Reviewer Suggestions**

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