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Cycling to School and Cardiovascular Risk Factors: A Longitudinal Study

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Background: Cycling to school may potentially increase physical activity level in sedentary children. Transport to school occur twice a day and could improve cardiovascular health in children. Commuter cycling is associated with lower mortality and cardiovascular disease rate in adults, but limited evidence exists in children. ***Methods:*** Participants were 334 children (age 9.7 ± 0.5 years) who were followed up 6 years later. Mode of travel to school was investigated by questionnaire. Cardiovascular (CVD) risk factors were compared by mode of travel to school both at baseline and at follow up and for subjects who changed mode of transportation. No difference was found between walkers and passive travelers, and these groups were merged in the analysis. ***Results:*** A consistent pattern of better CVD risk factor profile in commuter cyclists compared with children using other means of transport was found. Participants, who did not cycle to school at baseline, and who had changed to cycling at follow up, were fitter, had better cholesterol/HDL ratio, better glucose metabolism, and a lower composite CVD risk factor score than those who did not cycle at either time point. ***Conclusion:*** Cycling to school may contribute to a better cardiovascular risk factor profile in young people.

Keywords: accelerometry, community-based research, fitness, youth, cardiovascular health

A decrease in habitual physical activity is suggested to be a contributor to rising levels of childhood overweight and obesity, although there are limited direct data to describe how children's physical activity has changed over recent decades.[1] Indirect evidence for a decline in overall physical activity comes from transportation surveys, which have recorded a reduction in the proportion of journeys taken by foot and an increase in car travel.[2,3] These trends are reflected in the decline in active travel to school reported in many countries. In the U.S. children's active commuting to school declined by 37% between 1977 and 1995, and current estimates suggest that approximately 5 to 10% of children aged 5 to 15 years walk to school with fewer than 2 to 4% cycling.[4,5] This decline has not happened in countries with a strong tradition of active commuting. In Denmark, cycling to school has not changed since 1983, with 63% of 16- to 19-year-olds cycling to school in 1983[6] compared with 66% of 15-year-olds in 1997[7] and 63% in 2003.[8] The potential opportunity to reverse the decline has resulted in the journey to school receiving attention as a clear target for intervention to increase young people's daily physical activity.

A number of observational studies in the U.S.,[4] Europe[9,10] and elsewhere[11,12] have used objective measurement of physical activity with accelerometers or pedometers to investigate the association between how children travel to school and total physical activity. The majority (11 of 13) of these studies have shown that children who walk or cycle to school engage in more physical activity than those who travel by other means.[13] As objectively measured physical activity has been shown to be inversely associated with fatness[14] and positively associated with a better profile of cardiovascular (CVD) risk factors in children and adolescents,[15] a number of studies have investigated whether active commuting to school may be associated with reduced levels of overweight or obesity. To date, no consistent association with body mass index (BMI) or other measures of adiposity have been reported.[13,16] In addition, no studies investigating associations between active travel and other direct health parameters that might be influenced by physical activity such as metabolic risk factors for cardiovascular disease have been reported in children.

In contrast, active commuting has been associated with CVD risk factors in adults. In a large sample of Chinese adults, daily walking or cycling to and from work was inversely associated with serum total cholesterol, low-density lipoprotein cholesterol and triglyceride concentrations among men, and positively associated

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with high-density lipoprotein cholesterol concentrations among women when compared with individuals commuting by bus.[17] The Coronary Artery Risk in Young Adults (CARDIA) study in the US explored associations between CVD risk factors and active commuting in 2364 participants.[18] Men who reported active commuting were fitter than those who did not, and active commuting was associated with a reduced likelihood of obesity (OR 0.5) and improved CVD risk factor profile though these associations disappeared after adjustment for BMI. In women, despite higher fitness in active commuters, associations with CVD risk factors were not seen. The separate effects of walking and cycling were not reported in either study, but it is likely that the physiological effects of walking and cycling differ. In adults, commuter cycling elicits a higher mean heart rate than walking, is associated with greater increases in fitness[19] and is associated with a substantial reduction in risk of all-cause mortality.[20] In young people, those who cycle to school are fitter than those who travel by foot or by motorized transport, and in observational studies a change in travel mode from noncycling at baseline to cycling 6 years later is associated with an improvement in fitness.[7,8] Since higher cardiorespiratory fitness is associated with a better CVD risk factor profile in young people[21] it is possible that the higher fitness seen in commuter cyclists may be also associated with better levels of CVD risk factors.

The aim of this study was to use longitudinal data from the European Youth Heart Study to determine the CVD risk factor profile in children and adolescents who cycled to school compared with noncyclists, and to investigate whether the levels of risk factors change in participants who changed travel mode to school between baseline and follow-up.

Methods

Participants

This paper describes the participants from the Danish arm of the EYHS, who were 9 years old in 1997–98 and 15 years old when recontacted in 2003–04. For the original sample, all schools (n = 35) in the region of Odense, Denmark, were stratified according to location (urban, suburban, rural), and socioeconomic profile of uptake area (high, middle, low). A proportional, two-stage cluster sample of children was taken from each stratum. Twenty-five of 28 sampled schools agreed to participate. In all, 771 children were invited to participate in EYHS-I in 1997 to 98, of whom 589 (76.4%; 310 girls and 279 boys) consented. Six years later, 384 of these children (212 girls and 172 boys) were reexamined in EYHS-II. Twelve participants provided nonfasting blood samples at one of the occasions and were excluded, and another 38 participants did not reach a maximal heart rate of 185 bpm during the fitness test. There were no differences in BMI between participants excluded for an invalid fitness test and subjects with valid fitness tests in 9- or 15-year-olds. A tendency was seen for fewer cyclists among subjects excluded for invalid fitness test ($P = .1$). The sample for the current study was 187 girls and 147 boys with complete data. Written informed consent was obtained from the parent/guardian of each participant, who also gave verbal assent to taking part.

Measurements

All measurements were identical for EYHS-I and II. Completion of measurements took 2 to 3 hours. Height was measured to the nearest 1mm in bare or stockinged feet with a transportable Harpenden stadiometer and weight was measured to the nearest 0.1kg using a calibrated beam scale. BMI was calculated as weight (kg) / height^2 (m). The sum of the thickness of 4 skinfolds (biceps, triceps, subscapular, and suprailiac) was measured using a Harpenden caliper, with the mean of 3 measurements used at each site. Pubertal stage was assessed according to Tanner stages using a 5-point scale of pictures—girls according to breast development and pubic hair growth and boys according to genital development and pubic hair growth. Assessments were carried out by a trained researcher of the same gender as the participant and privacy was maintained at all times.

To investigate travel mode, participants completed a computerized questionnaire including the questions: "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*, *16 to 30 minutes*, *31 minutes to 1 hour*, *more than 1 hour*). In the current study the responses "*by car or motorcycle*, *by bus or train*" were combined into the group "passive transport," and travel mode was defined by the way the participant usually traveled to school.

Blood pressure was measured using a Dinamap pediatric/adult neonatal vital signs monitor (model XL, Critikron, Inc., Tampa, FL). Five measurements were taken at two-minute intervals with the mean of the final 3 measurements used in all analyses.

Blood samples were obtained after an overnight fast and stored at –80°C before analysis. All samples were analyzed for blood lipids, glucose, and insulin at clinical pathology accredited laboratories (Bristol and Cambridge, UK).[22] Insulin resistance was estimated according to the homoeostasis model assessment (HOMA) as the product of fasting glucose (mmol/L) and insulin (µU/mL) divided by the constant 22.5.[23]

Cardio-respiratory fitness, defined as maximal power output per kilogram ($W_{max} \cdot kg^{-1}$), was determined using a cycle ergometer test with progressively increasing workload until exhaustion, on an electronically braked cycle ergometer (Monark 839 Ergomedic). This test has been validated in both children and adolescents with a low test-retest coefficient of variation (2.5% to 4.8%) and is highly correlated ($r = .90$ in boys and $r = .95$ in girls) with directly measured VO_2max.[21] The cycle ergometer was electronically calibrated every test day and mechanically calibrated after being moved.

Before testing, participants were checked for any upper respiratory tract infection or asthmatic condition that might contraindicate participation. No participants were excluded at this point. The ergometer saddle height was adjusted for each individual, and after warming up for 3 minutes participants pedaled at a self-selected rate between 60 to 80 revolutions per minute (rpm). 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. The workload was increased every third minute until exhaustion. Heart rate (HR) 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: $Wl + (W_i \times T/180)$; 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 was assessed using the MTI accelerometer, Actigraph model 7164 (Manufacturing Technology Inc., Fort Walton Beach, FL). The MTI accelerometer measures the vertical acceleration of body movement. There is almost no counts during cycling. Physical activity was monitored for 4 consecutive days—2 weekdays and 2 weekend days. Instruments were attached tightly at the hip. Minute-by-minute data were stored in memory and subsequently downloaded to a computer. Data were reduced to derivative variables using customized macros. Counts-per-minute was used as main variable.

Statistical Analyses

Descriptive statistics were calculated for all variables. Analysis of variance was used to investigate whether participant characteristics differed by travel modes.

Clustered CVD risk was calculated as the sum of z-scores for sum of skinfolds, systolic BP, total cholesterol (TC)/HDL ratio, triglycerides, HOMA, and reverse of fitness. All z-score were computed by sex. Skinfold, triglyceride (TG) and HOMA were skewed and log-transformed before z-scores were computed.

Generalized linear mixed models were used to examine the cross-sectional and longitudinal associations of clustered CVD risk with travel mode using id number and the sampling unit schools as random effects parameters. For the longitudinal analysis baseline values of risk factors were included as covariates, and we further adjusted for time of baseline measurement.

The statistical package for social sciences (SPSS version 17) and STATA version 11 were used for all analyses.

Results

We first analyzed CVD risk factors by sex between 3 traveling groups (passive, walking, and cycling) in relation to demographics and CVD risk factors in the 2 cross sectional samples. There was no difference between passive travelers and walkers in any variable either in 1997 (insulin and HOMA were borderline, $P = .070$) or in 2003 with the exception of passive travelers, who had slightly better cholesterol/HDL ratio than walkers in 2003 ($P = .047$). We therefore decided to merge passive travelers and walkers in our analysis of traveling mode.

Demographics and risk factor levels of the population in 1997 and in 2003 are described in Table 1. The number and percentage of children using the 3 travel modes is described in Table 2.

Differences in the levels of CVD risk factors between cyclist and noncyclists were first investigated separately for 9-year-olds (1997) and 15-year-olds (2003), after adjustment for sex (Table 3). In the 9-year-olds, only fitness level differed between cyclists and noncyclists, but in 15-year-olds differences were found in fitness, TG, TC/HDL, fasting glucose, HOMA, and sum of z-scores (all $P < .05$). In addition, differences in waist circumference and fasting insulin between cyclists and noncyclists were of borderline statistical significance. We further analyzed the association between journey time between home and school and fitness in cyclists and noncyclists separately (regression), since children who cycled further might be expected to have higher fitness. Very few participants cycled more than 15 minutes each way (Table 4), and there was no association between journey time and fitness in participants using passive transport or walking. However in those who cycled to school we found a positive association between fitness and time spent on the journey among adolescents after adjustment for sex ($P = .025$). There was no difference between cyclists and noncyclists in other physical activity assessed objectively by accelerometry. However, we did find interaction between sex and physical activity level in the cross sectional analyses. In 9-year-olds, boys who cycled were more active and a tendency toward less activity in cycling girls was observed (Table 3). In 15-year-olds the opposite was found; cycling girls were more active and a tendency toward less active cycling boys.

Finally, we investigated whether a change in travel mode to school between 1997 and 2003 was associated with a change in CVD risk factors (Table 5). Compared with those who remained noncyclists, adolescents who did not cycle at the age of 9 years, but had changed to cycling by age 15 years were significantly fitter and had significantly lower waist circumference, glucose, insulin, HOMA, and TC/HDL values, and also significantly lower clustered risk scores. The opposite analysis of children who stopped cycling between 1997 and 2003 was also done (Table 5) where a significant difference was seen only for TG. For many of the risk factors that were not significantly different between the groups, values pointed

Table 1 Demographics and Risk Factors of Danish Participants in the European Youth Heart Study Who Were Measured in 1997 and at Follow-Up in 2003 (Mean ± SD)

	1997			2003		
	Girls	Boys		Girls	Boys	
	Mean (SD)	Mean (SD)	*P* for sex	Mean (SD)	Mean (SD)	*P* for sex
Age at examination (yr)	9.6 (0.4)	9.7 (0.4)	0.05	15.7 (0.4)	15.8 (0.3)	0.05
Height (cm)	138.2 (6.6)	139.7 (6.3)	0.05	165.0 (6.7)	176.4 (7.3)	0.001
Weight (kg)	33.0 (6.2)	33.6 (5.8)	Ns	57.9 (9.2)	65.5 (11.1)	0.001
BMI (kg/m2)	17.2 (2.5)	17.1 (2.1)	Ns	21.2 (3.0)	21.0 (2.9)	Ns
Sum of 4 skinfolds (mm)	39.0 (17.8)	33.3 (16.0)	0.001	51.8 (17.0)	34.8 (20.9)	0.001
Waist circumference (cm)	58.0 (5.7)	58.2 (5.3)	Ns	72.6 (6.8)	75.9 (8.3)	0.001
Physical activity (cpm)	604 (238)	708 (240)	0.01	396 (130)	486 (177)	0.001
Fitness (watt/kg)	2.88 (0.51)	3.26 (0.51)	0.001	3.00 (0.44)	3.76 (0.55)	0.001
Diastolic BP (mm/hg)	63.1 (5.4)	63.8 (5.5)	Ns	61.2 (5.5)	59.2 (6.3)	0.001
Systolic BP (mm/hg)	105.0 (7.3)	105.6 (7.5)	Ns	105.5 (7.7)	110.7 (9.6)	0.001
Total cholesterol (mmol/l)	4.59 (0.67)	4.51 (0.75)	Ns	4.05 (0.81)	3.64 (0.62)	0.001
HDL (mmol/l)	1.48 (0.27)	1.54 (0.31)	0.05	1.53 (0.34)	1.34 (0.29)	0.001
Triglyceride (mmol/l)	0.90 (0.35)	0.80 (0.32)	0.01	0.82 (0.37)	0.78 (0.40)	Ns
Glucose (mmol/l)	5.06 (0.37)	5.18 (0.37)	0.001	4.89 (0.40)	5.16 (0.36)	0.001
Insulin (pmol/l)	51.7 (26.0)	46.9 (24.3)	0.05	61.7 (24.5)	58.3 (28.9)	Ns
HOMA	11.8 (6.4)	10.9 (6.0)	0.01	13.5 (5.6)	13.6 (7.5)	Ns
Sum of Z-scores	0.94 (5.17)	–0.64 (4.24)	0.01	–0.01 (4.52)	0.03 (4.94)	Ns

Table 2 Numbers of Children, N (%), in 1997 and 2003 Using the Different Traveling Modes; 7 Children did not Report Travel Mode in 1997 and 1 Adolescent did not Report Travel Mode in 2003

	Travel mode 1997		Travel mode 2003	
	Girls	Boys	Girls	Boys
Passive	59 (32.2%)	50 (34.7%)	24 (13.0%)	27 (18.4%)
Walking	43 (23.5%)	35 (24.3%)	35 (18.8%)	30 (20.4%)
Biking	81 (44.3%)	59 (41.0%)	127 (68.3%)	90 (61.2%)
Total (N)	183	144	186	147

Table 3 CVD Risk Factors in Cyclists and Noncyclists Measured as 9-Year-Olds in 1997 and 15-Year-Olds in 2003; Statistics Were Calculated With Adjustment for Sex

	9-year-olds in 1997			15-year-olds in 2003		
	Noncycle	Cycle	*P* for cycling	Noncycle	Cycle	*P* for cycling
CVD risk factors	**Mean (SD)**	**Mean (SD)**	***P* <**	**Mean (SD)**	**Mean (SD)**	***P* <**
BMI (kg/m^{-2})	17.2 (2.3)	17.0 (2.1)	Ns	21.5 (3.3)	21.1 (2.8)	Ns
Sum of 4 skinfolds (mm)	35.8 (17.0)	36.1 (16.1)	Ns	45.2 (23.5)	44.5 (19.6)	Ns
Waist circumference (cm)	58.4 (5.5)	57.7 (5.2)	Ns	75.3 (9.1)	73.7 (6.7)	*P* = .07
Physical activity (cpm)	649 (236)	656 (258)	*	439 (176)	441 (159)	**
Fitness (ml/m^{-1}/kg^{-1})	46.2 (7.1)	49.2 (7.7)	0.001	44.7 (8.5)	47.2 (7.8)	0.001
Diastolic BP (mmHg)	63.1 (5.5)	63.6 (5.3)	Ns	60.1 (6.1)	60.3 (5.7)	Ns
Systolic BP (mmHg)	104.4 (7.7)	105.1 (6.7)	Ns	107.1 (9.0)	107.9 (8.9)	Ns
Total cholesterol (mmol/l^{-1})	4.50 (0.69)	4.55 (0.70)	Ns	3.94 (0.80)	3.83 (0.74)	Ns
HDL (mmol/l^{-1})	1.47 (0.28)	1.51 (0.30)	Ns	1.42 (0.36)	1.44 (0.33)	Ns
LDL (mmol/l^{-1})	2.64 (0.62)	2.66 (0.60)	Ns	2.12 (0.59)	2.04 (0.55)	Ns
Triglyceride (mmol/l^{-1})	0.84 (0.32)	0.85 (0.35)	Ns	0.89 (0.44)	0.76 (0.36)	0.01
Glucose (mmol/l^{-1})	5.13 (0.40)	5.08 (0.34)	Ns	5.07 (0.40)	4.98 (0.40)	0.05
Insulin (pmol/l^{-1})	51.1 (26.4)	46.4 (22.8)	Ns	64.3 (26.7)	58.6 (26.4)	0. 05
HOMA	1.91 (1.04)	1.71 (0.89)	*P* = .07	2.36 (1.05)	2.11 (1.03)	0.05
TC/HDL	3.13 (0.61)	3.10 (0.59)	Ns	2.88 (0.62)	2.73 (0.58)	0.05
Sum of z-scores	0.32 (4.95)	0.00 (4.55)	Ns	1.06 (4.98)	–0.52 (4.85)	0.01

* There was interaction between sex and cycling (*P* = .02). In girls, there was a tendency for cyclists being less active (*P* = .18), and in boys cyclist were more active than noncyclist (*P* = .04).

** There was interaction between sex and cycling (*P* = .04). In girls, cyclist were more active (*P* = .04), and in boys there was a tendency for cyclist to be less active than noncyclist (*P* = .32).

Table 4 Cardiorespiratory Fitness in Relation to Duration of the Journey to School; Fitness Is ml/min^{-1}/kg^{-1}, and (%) Is Percentage of Total Within the Sex

	9-year-olds, 1997			
	Noncycle		Cycle	
	Boys	Girls	Boys	Girls
< 5 min	47.2 (19.4%)	43.5 (18.6%)	53.6 (20.1%)	44.6 (10.4%)
5–15 min	49.7 (29.9%)	44.2 (25.1%)	51.0 (19.4%)	46.6 (31.1%)
15+ min	47.0 (9.7%)	45.7 (12.0%)	56.9 (1.4%)	46.6 (2.7%)
	15-year-olds, 2003			
	Noncycle		**Cycle***	
	Boys	**Girls**	**Boys**	**Girls***
< 5 min	49.7 (13.6%)	40.0 (10.8%)	53.4 (20.4%)	40.8 (24.7%)
5–15 min	49.0 (13.6%)	38.2 (12.4%)	52.9 (33.3%)	44.1 (36.0%)
15+ min	51.5 (12.2%)	40.4 (9.7%)	56.0 (6.8%)	43.0 (16.1%)

* There was interaction between time of journey and sex among 15-year-old cyclists. An analysis stratified for sex showed that longer journey time in cyclists was associated with higher fitness in girls but not in boys. There was no association between fitness and journey time in noncyclists.

in a direction which was beneficial for cyclists. To illustrate the change we computed the difference in 6-year change in z-score of all the risk factors (inverse of physical fitness and HDL) between cyclists minus noncyclists in 2003 (Figure 1). A negative value means that cyclists had a more favorable change. When all risk factors were combined by summing the z-scores (inverse of fitness and HDL), cycling in 2003 was highly significantly associated with better metabolic profile after adjustment for travel mode in 1997 and time of measurement (*P* = .006, coefficient: –2.2, variance for random intercept 26.4 and for random coefficient 0.28).

Discussion

The current study analyzed the association between CVD risk factors and traveling mode in 2 cross sectional samples and longitudinally after 6 years of follow up. To our knowledge the current study is the first longitudinal population study to analyze the association between cycling to school and CVD risk factors. There were no differences in CVD risk factors between passive travelers and walkers, but children cycling to school showed consistently better risk factor levels even if not all differences in single risk factors reached statistical significance. Differences between cyclists and noncyclists were larger in adolescents than in 9-year-old children. Change from noncycling as 9-year-olds to cycling at the age of 15 years was associated with a better composite risk factor score than remaining a noncyclist, and the opposite change (stopping cycling) was associated with a worse score.

Earlier studies have reported higher physical activity levels in active commuters,[9] and cycling has been associated with higher fitness level both in cross sectional and in longitudinal studies.[6–8] The difference in fitness level between traveling modes in cross sectional studies could be attributed to selection, and commuter cycling could affect work efficiency during the fitness test, which could explain the higher work capacity. However, the study in adolescents of Andersen et al showed no difference in submaximal oxygen uptake at a given work load and only showed differences in types of fitness which could be expected to be affected by cycling such as aerobic fitness and muscle endurance, and this may indicate that the higher fitness is a result of cycling.[6] The longitudinal study of Cooper et al showed that changes in cycling habits were associated with changes in aerobic fitness, which could indicate that the higher fitness level in cyclists may not be attributed to selection.[8] In the current study other physical activity than cycling was assessed by accelerometry, and the more beneficial CVD risk factor

Table 5 Longitudinal Associations in CVD Risk Factors: to the Left Is a Comparison of CVD Risk Factors in 2003 Among Children Who did not Cycle in 1997, and to the Right Those Who Cycled in 1997; *P*-Values Below 0.1 Are Shown, *P*-Values Are Adjusted for Sex

Z-score of CVD risk factor level in 2003	Noncyclist in 1997			Cyclists in 1997		
	Noncycle in 2003	Cycle in 2003		Noncycle in 2003	Cycle in 2003	
	Mean (SD)	Mean (SD)	*P* <	Mean (SD)	Mean (SD)	*P* <
BMI (kg/m^{-2})	21.7 (3.5)	21.1 (2.8)		21.0 (3.1)	21.1 (2.7)	
Sum of 4 skinfold (mm)	45.9 (23.7)	45.3 (20.9)		43.5 (24.1)	43.4 (18.2)	
Waist (cm)	76.1 (9.5)	74.1 (7.0)	0.082	73.9 (8.4)	73.1 (6.2)	
Physical activity (cpm)	454 (190)	445 (164)		415 (149)	437 (152)	
Fitness (ml/m^{-1}/kg^{-1})	44.5 (8.5)	47.0 (8.1)	0.005	45.2 (8.7)	47.4 (7.5)	
Diastolic BP (mmHg)	59.9 (6.3)	60.5 (5.7)		60.4 (5.8)	60.1 (5.8)	
Systolic BP (mmHg)	107.1 (9.3)	108.4 (9.8)		106.7 (8.3)	107.3 (7.9)	
Cholesterol (mmol/l^{-1})	3.89 (0.76)	3.83 (0.77)		4.03 (0.88)	3.81 (0.70)	0.079
HDL (mmol/l^{-1})	1.40 (0.35)	1.46 (0.34)		1.41 (0.34)	1.42 (0.30)	
LDL (mmol/l^{-1})	2.10 (0.59)	2.01 (0.56)		2.18 (0.63)	2.07 (0.53)	
TG (mmol/l^{-1})	0.86 (0.44)	0.79 (0.40)		0.98 (0.45)	0.72 (0.29)	0.001
Glucose (mmol/l^{-1})	5.13 (0.41)	5.00 (0.42)	0.021	4.98 (3.39)	4.95 (0.38)	
Insulin (pmol/l^{-1})	65.7 (28.0)	59.5 (22.4)	0.044	61.3 (25.2)	56.6 (28.3)	
HOMA	2.43 (1.09)	2.14 (0.85)	0.019	2.22 (1.00)	2.03 (1.11)	
Cholesterol/HDL ratio	2.90 (0.67)	2.71 (0.59)	0.036	2.92 (0.50)	2.75 (0.57)	
Sum of z-score	1.21 (5.20)	-0.37 (4.88)	0.044	0.76 (4.69)	-0.82 (4.68)	0.054

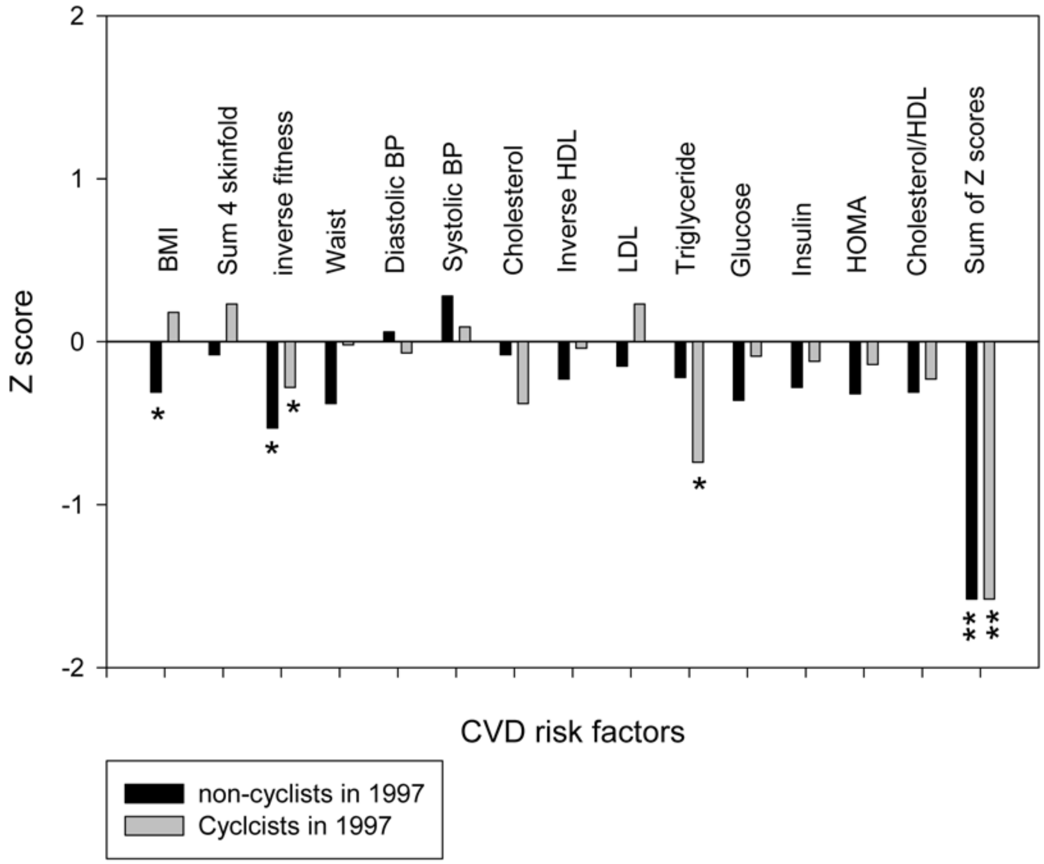

Figure 1 — Differences in 6-year change in CVD risk factor z-scores between cyclists minus noncyclists in 2003 are shown (except for fitness and HDL where inverse z-score was used). Black columns are subjects who did not cycle in 1997 and gray columns subjects who cycled in 1997. Sum of z scores includes all the other variables. Values below 0 mean that risk factor level is more beneficial in cyclists in 2003.

profile could not be explained by differences in other physical activity habits.

Cycling to school has decreased in many countries in recent decades. However in previous studies in Denmark we have found no decrease in cycling to school among adolescents between 1983 and 2003,[6,8] indicating that it is possible on a population basis to maintain high levels of commuter cycling to school through implementation of infrastructural changes supported by procycling legislation There is little doubt that other countries, which may try to promote cycling to school, will need to invest in safe cycle routes, and the Danish cycle culture is a result of a focused strategy over many decades. However, if the CVD risk factor profile can be improved as a result of commuter cycling the potential public health benefits may make it worth the investment. We have earlier shown that adult commuter cyclists have a relative risk of all cause mortality of 0.72 after adjustment for traditional CVD risk factors and leisure physical activity.[20] The Danish National Statistics Bureau makes traffic counts at 28 different places in the country every month, and during the 1990s cycling decreased 30% resulting in 4.8% more deaths based on the observed difference in death rates after adjustment for other leisure physical activities and other confounders.[24] However, in recent years cycling in Denmark is almost back to the level from 1984, and as noted earlier no decline is seen in cycling to school in adolescents. We cannot exclude that a selection of healthier subjects choose cycling to school as their means of transportation, but changes in cycling habits result in changes in CVD risk factors in a consistent way even if only some of the changes in single risk factors are significant. It is therefore likely that risk factor improvements are a result of cycling, although these observations remain to be confirmed in a randomized controlled trial. Such a trial may be difficult to conduct in children in many countries because of safety concerns. In countries where cycling is highly prevalent, such as Denmark and Holland, such studies may be possible due to networks of safe cycle routes and a culture where cyclists are protected by legislation although a potential difficulty in conducting such a study would be to find enough children who are not cycling.

We did not find difference between walking and passive travel, but this does not mean that there is no health benefit of walking. The self-selected intensity of walking is lower compared with cycling,[19] and may therefore elicit a smaller physiological response. The current study did not have sufficient statistical power to show smaller effects than we found in cycling. In fact, the difference between cyclists and others were borderline in many of the variables, and we could not conclude which specific risk factor was associated with cycling. We did not make Bonferroni correction, which would have made some of the differences insignificant, because we believe it is more important to show a general benefit and beneficial consistent pattern than to show which specific CVD risk factor was related to cycling not just by chance. It is unlikely that all significant associations could be type I statistical error, because we would only expect one type I error in 20 tests, and we would not expect a consistent pattern in the remaining analyses.

In conclusion, we found a consistently better CVD risk factor profile in cyclists compared with noncyclists. However, most differences were rather small, but pointed in the same direction, and in aerobic fitness we found both cross sectional and longitudinal differences of about 9%, which may translate into a substantial health benefit over time.

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