

1 Six year changes in body mass index and cardiorespiratory fitness of English schoolchildren from an
2 affluent area.

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17 **Key words:** Physical Activity, Health; Exercise Physiology; Epidemiology

18 **Tables: 1**

19 **Figures: 1**

20 **References: 15**

21 **Word Count: 1459**

22

23 **ABSTRACT.**

24

25 We compared values of BMI and cardiorespiratory fitness (20 m shuttle-run test) of n=157 boys and
26 n=150 girls aged 10-11 measured in 2014 with measures from 2008 and 1998. Boys' fitness was
27 lower (d=0.68) in 2014 than 2008, despite a small (d=0.37) decline in BMI. Girl's BMI changed
28 trivially (d=0.08) but cardiorespiratory fitness was lower (d=0.47) lower in 2014 than 2008.

29 This study suggests fitness is declining at 0.95% per year, which exceeds the 0.8% rate of decline we
30 reported between 1998 and 2008 and double the global average of 0.43%. Declines in fitness were
31 independent of changes in BMI suggesting continued reductions English children's habitual physical
32 activity levels.

33 **Key words:** Exercise Physiology; Epidemiology

34

35 **INTRODUCTION**

36 Cardiorespiratory fitness is an important marker of childhood¹ and adult² health, but is declining
37 globally at 4.3% a decade³. Increases in body mass index (BMI) may explain some of the decrease in
38 fitness^{4,5} but we have reported an 8% fall between 1998 and 2008 which was largely independent of
39 changes in BMI⁶. The prevalence of overweight and obesity is static or may even be declining in
40 some English children⁷. There are, however, no comparable data regarding English children's
41 cardiorespiratory fitness, despite a call for its surveillance by the Chief Medical Officer in 2009⁸. We
42 sought to determine whether cardiorespiratory fitness has changed since 2008 via a further secular
43 comparison of data from 10-11 year olds from Chelmsford, England.

44 **METHODS**

45 **Study Design.**

46 To update the Chelmsford Children's' Fitness and Activity Survey data, we approached all (n=5)
47 schools surveyed in 2008. Four schools volunteered to participate again, including one from a more-
48 deprived area we recruited purposefully in 2008 from within this relative affluent area. As one
49 school was unable to participate, we approached a neighbouring school (surveyed in 1998) which
50 agreed to participate. Area-level deprivation was initially assessed using the English Indices of
51 Deprivation⁹ obtained from school postcodes. In participating schools we assessed deprivation by
52 the same method using pupils' home postcodes.

53 We tested children in the summer term of 2014 to reduce potential seasonal bias. As before, testing
54 was completed in school gymnasias and playgrounds. Ethical approval was granted by the Writtle
55 College Ethics Committee and we obtained school and parental consent as well as pupil assent prior
56 to assessments.

57 *Sample size calculation*

58 The primary outcome measure was cardiorespiratory fitness assessed by performance on the 20 m
59 shuttle-run test. Using extant means (\pm SD) we assumed a drop of $0.5 \text{ km}\cdot\text{h}^{-1}$ over the six-year period
60 in boys and $0.4 \text{ km}\cdot\text{h}^{-1}$ in girls. We calculated that $n=140$ boys and $n=120$ girls were needed to
61 produce statistical significance at $\alpha=0.05$ and $\beta=0.80$ for this predicted difference in test
62 performance.

63 We repeated all measures using identical protocols to those reported previously¹⁰. Stature (to the
64 nearest 0.1 cm) and mass (to 0.1 kg) were measured with participants dressed in standard physical
65 education clothing, without shoes. Body Mass Index (BMI) was calculated ($\text{kg}\cdot\text{m}^{-2}$) and converted to
66 z-scores using UK reference data¹¹ to correct for age, sex and skewness. Cardiorespiratory fitness
67 (fitness) was assessed using the 20 m shuttle-run test. After listening to recorded instructions, pupils
68 ran back and forth between cones (20 m apart) on flat, non-slip surfaces. Pupils ran in time with an
69 audible signal, the initial running speed of $8 \text{ km}\cdot\text{h}^{-1}$ increased by $1 \text{ km}\cdot\text{h}^{-1}$ at the end of the first
70 minute, then by $0.5 \text{ km}\cdot\text{h}^{-1}$ after each consequent minute. Pupils were instructed to 'run as long as
71 possible' and the test was terminated if individuals volitionally withdrew or when they could no-
72 longer reach the cones in time on two consecutive occasions. Researchers recorded the number of
73 shuttles completed which we converted to maximal running speed ($\text{km}\cdot\text{h}^{-1}$) and z-scores based on
74 global reference data³.

75 *Data analysis.*

76 We analysed data from boys and girls separately using ANOVA to examine differences in BMI and
77 fitness (z-scores). When analysing running speed, we checked data were normally distributed and
78 then controlled for decimal age using Analysis of Covariance [ANCOVA] with Bonferroni *post hoc*
79 tests). We calculated the intraclass correlation coefficient ($\text{ICC} = \text{between-school}$
80 $\text{variance}/(\text{between-school variance} + \text{within-school variance})$) to assess whether outcomes clustered
81 within schools (low ICC (close to 0)=no/little clustering; high ICC (close to 1) =most/all variance is
82 explained by clustering). We calculated standardised effect sizes (Cohen's d) to describe the
83 magnitude of differences between values obtained in 2008 and 2014; assuming a minimum

84 important effect size of $d=0.2$ ¹². All analyses were performed in SPSS version 20 (SPSS Inc. An IBM
85 Company, Chicago, Il.)

86 **RESULTS.**

87 Table 1 shows BMI and fitness values from: 1998, 2008 and 2014. As differences between 1998 and
88 2008 have been reported previously, the following results focus on differences between 2008 and
89 2014.

90 *Changes in BMI and Fitness: Boys.*

91 ANOVA showed no statistically significant main effect of time for boy's BMI which was lower ($z=-$
92 0.50 , 95%CI:-1.2 to 0.24) in 2014 than in 2008 ($d=0.38$). ANCOVA showed a main effect for time on
93 boys' running speed and significant *post hoc* differences between all cohorts. There was a moderate
94 ($d=0.68$) difference in boys' running speed which was -0.87 (95%CI:-0.57 to -1.12) $\text{km}\cdot\text{h}^{-1}$ slower in
95 2008 than 2014. There was a main effect of time for fitness (z-score) in boys, (Figure 1). Boy's fitness
96 was $z=-0.67$ (95%CI: -0.82 to -0.46) lower in 2008 than 2014 ($d=0.64$).

97 *Changes BMI and Fitness: Girls.*

98 There was no significant main effect for time on girls' BMI (z-score) and a trivial ($d=0.08$) difference
99 in mean values between 2008 and 2014. There was, however, a significant main effect for time on
100 girls' running speed, which declined by -0.34 , (95%CI:-0.56 to -0.13) $\text{km}\cdot\text{h}^{-1}$ from 2008 to 2014
101 ($d=0.47$). Girls' fitness (z-score) was also ($z=-0.51$, 95%CI: -0.43 to -0.28) lower in 2014 than 2008
102 ($d=0.57$)

103 *Subgroup Analysis: Changes BMI and Fitness in Children from More-Deprived School*

104 There was some evidence between-school clustering of fitness in 2008. Boys' and girls' fitness (z-
105 scores) were lower in 2008, but between 2008 and 2014 the change in deprived boys; fitness was
106 smaller ($d=0.20$) and there was a trivial increase ($d=0.14$) in deprived girls' fitness.

107 **DISCUSSION.**

108 We reported annual declines of 0.7% and 0.9% in the cardiorespiratory fitness of boys and girls
109 (respectively) in children from this area between 1998 and 2008⁶. Chelmsford, like other affluent
110 areas,¹³ did not witness overt increases in children's BMI, despite reports of a 'national' an obesity
111 epidemic. As our primary aim was to provide an update from to our 2008 findings, this discussion is
112 limited to the differences in measures of BMI and fitness from 2008 to 2014.

113 The lower mean value for BMI (z-scores) observed in boys measured in 2014 than in 2008 ($d=0.37$)
114 indicates reduced adiposity; which is commonly associated with better performance on weight-
115 bearing fitness tests like the 20 m shuttle-run⁴. Despite potentially favourable changes in body
116 composition, boys' running speed was 8.3% lower in 2014 than in 2008; equivalent to a decline of
117 1.4% per year. This annual decline is double the figure reported between 1998 and 2008 (0.7%)
118 which did coincide with a small increase in BMI⁶. There was little change in girls' BMI values, but
119 their maximum running speed was 3.9% lower in 2014 than in 2008. This 0.65% annual rate of
120 decline is lower than the 0.9% reported between 1998 and 2008.

121 The global rate of decline in fitness based on maximum running speed of both sexes is 0.43%, but we
122 reported a much higher (0.8%) annual rate between 1998 and 2008. Combining data for both sexes
123 suggests the rate of decline between 2008 and 2014 was 0.95% per year; higher still than over the
124 previous 10-years and more than double the global average. Levels and changes in fitness differed
125 greatly between sexes and to a lesser extent, between schools.

126 Inspection of mean values by school showed modest clustering of fitness ($ICC=0.13$) was partly due
127 to more-deprived children's lower fitness (Table 1). Such clustering was less obvious in 2014
128 ($ICC=0.016$). The change in more-deprived boys' fitness was much smaller ($d=0.20$) than in the
129 remaining population ($d=0.96$). The (albeit trivial, $d=0.14$) increase in fitness of more-deprived girls)
130 was greatly at odds with the larger ($d=0.69$) decrease in fitness of the girls from less-deprived
131 schools. While intriguing, these findings should be interpreted with caution as this was an unplanned
132 analysis in a small sample.

133 Historical declines in fitness may indeed have been partly due to concomitant increases in body
134 mass^{4, 5, 14}. Support for this hypothesis was elegantly provided in the Fitlinx project⁴ which reported
135 declines in shuttle-run performance concurrent with increases in BMI. The current study is
136 comparable to Fitlinx in design, but the findings differ greatly. Girls' BMI (z-scores) changed little
137 ($d=0.08$) but boys' BMI was actually lower ($d=0.37$) in 2014 than 2008. Despite such potentially
138 favourable changes in BMI, both boys and girls measured in 2014 performed less well on our weight-
139 bearing fitness test compared with our age-matched sample from 2008.

140 The lower mean values for BMI are welcome and concur with national data showing a plateau⁶ or
141 small decrease in the adiposity of children, from more-affluent areas at least⁷. Our findings cannot
142 explain the changes in BMI, but the lower fitness of children measured in 2014 than 2008 suggests
143 continuing declines in their habitual physical activity. This theory is also supported by national survey
144 data showing continued declines in calorie consumption¹⁵.

145 Childhood fitness is a predictor of adult health status independent of BMI², yet national-level health
146 surveillance of English children is limited solely to measurement of BMI⁸. Following our 2009 report¹⁰
147 on declining fitness, the Chief Medical Officer⁸ suggested the need for systematic evaluation of
148 children's fitness. No action has, as yet, been taken following this recommendation despite
149 publication of expert guidance¹⁴ and examples of cost-effective, safe and successful localised fitness
150 surveillance projects^{4,10}.

151 **Study limitations**

152 Given the lack of systematic surveillance of English children's fitness, these data are necessarily
153 opportunistic. Our sample of schools was, however, carefully matched area-level deprivation. There
154 was some between-school clustering of fitness in 2008 but this was less-obvious in 2014. Our
155 subsample analysis of more-deprived children was of limited sample size but the somewhat
156 intriguing findings warrant further investigation through studies including data from larger, more
157 diverse samples the use of multilevel modelling.

158 **CONCLUSIONS**

159 Cardiorespiratory fitness is a independent marker of children's health-status. Any evidence of a
160 decline in fitness is worrying, regardless of any concurrent changes in BMI. Continued reliance on
161 BMI as the lone population-level measurement of children's health status is insufficient. There is
162 urgent need for interventions to increase physical activity in English youth, the efficacy of which
163 could be evidenced via systematic assessment of changes in physical fitness.

164

165 **Conflict of interest:** The authors have no conflicts of interest to report.

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223 **Table and Figure Legends.**

224

225 **Table 1. Sample characteristics, Body Mass Index and Cardiorespiratory Fitness (20 m shuttle-run**
226 **test) for 10-11 year old schoolchildren: 1998, 2008 and 2014.**

227 **Legend:** All values are unadjusted means (SD) unless stated. Area-level deprivation calculated from
228 pupils' home postcode using the English Indices of Deprivation⁹ (values not available for 1998). BMI
229 – body mass index, z-score calculated using UK1990 Growth Reference Data¹¹; 20mSRT – 20 m
230 shuttle run test, z-score calculated based on final running speed at last level completed using Global
231 Reference data⁵.

232 1998 Data drawn from 7 schools, 2008 data from 5 schools (including 1 from 1998 cohort), 2014
233 data from 5 schools including (4 from 2008 and 1 from 1998 cohort). Two schools from 1998 had
234 amalgamated, one had closed. Participation rate was 92%, 2% of pupils had missing data, 2% were
235 absent on day of assessment, 3% did not give consent and 1% were injured or without the PE kit
236 needed to safely complete tests.

237

238 ^aSignificantly different from 1998 value ($p < 0.05$, Bonferroni *post hoc* test); ^b Significantly different
239 from 1998 and 2008 value ($p < 0.05$, Bonferroni *post hoc* test); ^cBased on estimated marginal means
240 from ANCOVA controlling for participant age (10.3 years); Effect size is Cohen's d calculated to
241 describe the magnitude of differences in marginal mean values between 2008 and 2014.

242 Clustering of outcomes between schools by round (ICC – Intraclass Correlation Coefficient).

243 BMI (z-score) 1998: ICC = 0.061, 2008: ICC = 0.057, 2014: ICC = 0.045

244 Fitness (z-score) 1998: ICC = 0.11, 2008: ICC = 0.13, 2014: ICC = 0.016

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246

247 **Figure 1. Body Mass Index and Cardiorespiratory Fitness (20 m shuttle-run test) of 10-11 year old**
248 **schoolchildren: 1998, 2008 and 2014.**

249 Legend:

250 All values are age- and sex-normalised z-scores. BMI – body mass index, z-scores calculated using the
251 1990 UK Growth Reference. Fitness – cardiorespiratory fitness assessed as maximal running speed
252 achieved on the 20 m shuttle run test and converted to z-scores using global reference data.⁵

253

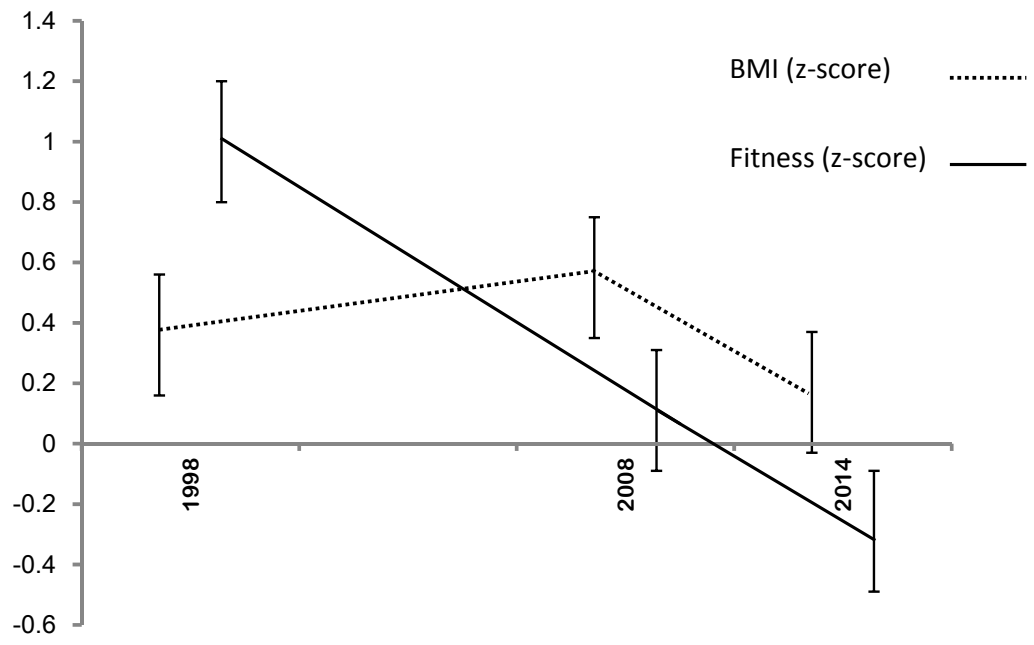


Figure 1.

Table 1.

	Boys			Main Effect ANOVA or ANCOVA	Effect Size: 2008 - 2014	Girls			Main Effect	Effect Size: 2008 - 2014
	1998	2008	2014			1998	2008	2014		
Sample Size	<i>n</i> =158	<i>n</i> =145	<i>n</i> =157			<i>n</i> =158	<i>n</i> =157	<i>n</i> =150		
IMD	-	9.8 (6.4)	10.1 (8.9)			-	8.1 (6.2)	7.9 (6.6)		
Age (years)	10.4 (0.3)	10.4 (0.3)	10.8 (0.4)			10.4 (0.3)	10.4 (0.3)	10.8 (0.4)		
BMI (kg·m⁻²)	17.6 (3.0)	18.3 (3.2)	17.9 (3.5)			18.6 (3.5)	18.4 (2.4)	18.6 (3.4)		
BMI (z-score)	0.32 (1.2)	0.64 (1.2)	0.14 (1.5)	F=2.88, p=0.06	d=0.37	0.48 (1.2)	0.37 (1.0)	0.27 (1.4)	F=0.43, p=0.655	d=0.08
Median (IQR) Shuttles completed	60 (43-75)	40 (23-58)	33 (19-50)			46 (37-46)	29 (21-43)	27 (20-34)		
20mSRT (km·h⁻¹)	11.6 (0.9)	10.8 ^a (1.2)	9.9 ^{a,b} (1.1)	F=39.2 ^c , p<0.001	d=0.68	11.0 (0.7)	10.2 ^a (0.9)	9.8 ^a (0.8)	F=54.8, p<0.001	d=0.47
20mSRT (z-score)	1.02 (0.83)	0.16 ^a (1.41)	-0.64 ^{a,b} (0.92)	F=60.2, p<0.001	d=0.67	1.17 (0.76)	0.22 ^a (0.95)	-0.28 ^{a,b} (0.78)	F=79.1, p<0.001	d=0.57
Subgroup: Children from school in more-deprived area		<i>n</i> =25	<i>n</i> =27				<i>n</i> =21	<i>n</i> =19		
IMD		21.0 (9.4)	20.9 (10.3)				20.8 (10.2)	20.3 (12.1)		
BMI (z-score)	More Deprived	0.84 (1.14)	0.28 (1.13)		d=0.50		0.16 (1.09)	-0.03 (1.14)		d=0.22
20mSRT (z-score)	More Deprived	-0.40 (0.76)	-0.86 (0.64)		d=0.20		-0.17 (0.94)	-0.05 (0.71)		d=0.14
Subgroup: Children from schools in less-deprived areas		<i>n</i> =120	<i>n</i> =130				<i>n</i> =136	<i>n</i> =131		
BMI (z-score)	Less Deprived	0.60 (1.16)	0.09 (1.52)		d=0.38		0.43 (1.01)	0.31 (1.23)		d=0.11
20mSRT (z-score)	Less Deprived	0.35 (1.0)	-0.60 (0.97)		d=0.96		0.28 (0.95)	-0.32 (0.79)		d=0.69