

1 **Cross-sectional and longitudinal relationships between cardiorespiratory fitness**  
2 **and health-related quality of life in primary school children in England: the**  
3 **mediating role of psychological correlates of physical activity**

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29 **Abstract**

30 **Purpose.** The aims were (i) to analyse the cross-sectional and longitudinal associations between  
31 children's cardiorespiratory fitness (CRF) and health-related quality of life (HRQoL), and (ii) to  
32 examine whether these associations were mediated by physical activity self-efficacy and physical  
33 activity enjoyment.

34 **Methods.** This study involved 383 children ( $10.0\pm 0.5$  years) recruited from 20 primary schools  
35 in northwest England. Data were collected on two occasions 12 weeks apart. The number of laps  
36 completed in the 20m Shuttle Run Test was used as the CRF indicator. HRQoL was assessed  
37 using the KIDSCREEN-10 questionnaire. Physical activity self-efficacy and enjoyment were  
38 assessed with the social-cognitive and Physical Activity Enjoyment Scale questionnaires,  
39 respectively. Linear mixed models with random intercepts (schools) assessed associations  
40 between CRF and HRQoL cross-sectionally, and longitudinally. Boot-strapped mediation  
41 procedures were performed, and indirect effects (IE) with 95% confidence intervals (CI) not  
42 including zero considered as statistically significant. Analyses were adjusted for sex, time of the  
43 year, socioeconomic status, waist-to-height ratio, maturation and physical activity.

44 **Results.** CRF was cross-sectionally associated with HRQoL ( $\beta=0.09$ ; 95%CI=0.02, 0.16,  
45  $p=0.015$ ). In the longitudinal analysis, CRF at baseline was associated with HRQoL at 12 weeks  
46 after additionally controlling for baseline HRQoL ( $\beta=0.08$ ; 95%CI=0.002,  $p=0.15$ ,  $p=0.045$ ).  
47 Cross-sectionally, physical activity self-efficacy and enjoyment acted individually as mediators  
48 in the relationship between CRF and HRQoL (IE=0.069; 95%CI:0.038;  $p=0.105$  and IE=0.045;  
49 95%CI:0.016;  $p=0.080$ , respectively). In the longitudinal analysis physical activity self-efficacy  
50 showed a significant mediating effect (IE=0.025; 95%CI=0.004;  $p=0.054$ ).

51 **Conclusions.** Our findings highlight the influence of CRF on children's psychological correlates  
52 of physical activity and their overall HRQoL.

53

54 **Key words:** Health, physical fitness, quality of life, youth.

55

56 **1. Introduction**

57 Health-related quality of life (HRQoL) is a multidimensional concept which reflects an  
58 individual's own perception of their physical, mental, social health, and functionality.<sup>1</sup> HRQoL  
59 has been highlighted as an important health indicator<sup>2</sup> since perceived well-being and  
60 functionality are considered important components of health surveillance.<sup>3</sup> Indeed, investigating  
61 HRQoL has been nowadays considered relevant due to its relationship with both self-reported  
62 chronic diseases (e.g., diabetes, breast cancer, arthritis, and hypertension) and their risk factors  
63 (e.g., body mass index, physical inactivity, sleep patterns, diet quality, and smoking status).<sup>4</sup>  
64 Measuring HRQoL can help to determine the burden of preventable disease, injuries, and  
65 disabilities, and can provide valuable new insights into the relationships between HRQoL and risk  
66 factors.<sup>5</sup> Thus, over the past twenty-five years, HRQoL has become an important outcome in  
67 healthy children, being commonly examined by professionals, such as clinicians, caregivers,  
68 educators, or public health authorities due to a collective interest towards the subjective  
69 perception and evaluation of an individual's own life.<sup>6-8</sup> Given the importance of HRQoL,  
70 identifying factors that may contribute to improving children's HRQoL is a public health priority.

71 Among possible factors influencing children's HRQoL, previous cross-sectional studies have  
72 revealed significant positive associations with cardiorespiratory fitness (CRF). CRF represents a  
73 measure of the body's ability to deliver and use oxygen to support muscular activity during  
74 physical activity<sup>9</sup> and is considered an important health marker.<sup>10</sup> Previous research suggests that  
75 CRF may be a potentially useful strategy to enhance children's HRQoL, however evidence of this  
76 relationship is limited to cross-sectional studies.<sup>11-13</sup> For example, Andersen et al.'s study of 1129  
77 schoolchildren aged 10 years, showed that CRF was positively associated with overall HRQoL.<sup>11</sup>  
78 Another study including 415 children aged between 8 and 9 years reported a positive weak  
79 correlation between CRF and HRQoL in boys, but not in girls.<sup>12</sup> Moreover, the study of Redondo-  
80 Tébar et al., which involved 1413 younger children, aged 4 to 7 years, concluded that children  
81 with higher CRF levels had greater HRQoL.<sup>13</sup> While informative, these studies cannot explain the  
82 dynamic processes that could occur over time, neither provide a long-term perspective of the  
83 influence that CRF might have on HRQoL, which could contribute to understanding the  
84 determinants of children's health outcomes.<sup>14</sup> Thus, to strengthen the current evidence base,  
85 investigation into the longitudinal associations between CRF and HRQoL is warranted.<sup>15</sup>

86 CRF has been considered a physiological component that has been reported to influence  
87 psychological correlates of physical activity.<sup>16,17</sup> This is possibly due to the impact that sufficient  
88 levels of CRF have on brain functioning (e.g., serotonin), self-worth, life satisfaction<sup>16</sup> and the  
89 reward system.<sup>17</sup> Indeed, previous literature reported that children with higher levels of CRF had  
90 stronger psychological correlates of physical activity, such as physical activity self-efficacy<sup>18</sup> and  
91 physical activity enjoyment<sup>16</sup> compared to low CRF peers. Thus, CRF seems to be an important

92 attribute positively influencing psychological correlates. On the other hand, two previous studies  
93 which implemented new school playground activities, reported positive associations between  
94 children's physical activity enjoyment and HRQoL.<sup>20,21</sup> Taken together, it is plausible that the  
95 positive association between CRF and HRQL in children is explained through the influence that  
96 CRF exerts on the psychological correlates.

97 Based on this previous research, there is a need for future studies to investigate variables  
98 influencing HRQoL, specifically focusing on CRF as a variable that could impact HRQoL as well  
99 as other physical activity correlates,<sup>22</sup> which could act as possible underlying mechanisms in that  
100 association. This will be of interest for health authorities seeking to improve children's overall  
101 HRQoL through the implementation of educational interventions at schools and the design of  
102 public health strategies. Therefore, the aims of this research were (i) to analyse the cross-sectional  
103 and longitudinal association between children's CRF and HRQoL, and (ii) to examine whether  
104 these associations were mediated by physical activity self-efficacy and physical activity  
105 enjoyment separately, as key psychological correlates of physical activity.

106

## 107 **2. Material and methods**

### 108 **2.1 Study design**

109 This observational study used baseline and follow-up data from the *Active West Lancs* primary  
110 school physical activity and wellbeing programme. The aim of this programme was to evaluate  
111 the impact of a combined educational and exercise programme designed to promote and enhance  
112 children's physical activity behaviours and knowledge, fitness, and wellbeing. The programme  
113 aligned to the UK government's Childhood Obesity Strategy recommendation for children to  
114 engage in 30 minutes of physical activity during the school day.<sup>23</sup> The programme was delivered  
115 in four clusters of five schools over four consecutive 12-week phases between 2018 and 2019. As  
116 no significant pre-post changes were observed in CRF and HRQoL outcomes over the 12-weeks,  
117 for this study the baseline data were treated as cross-sectional, and the combined 12-week follow-  
118 up longitudinal data were treated as longitudinal.

### 119 **2.2 Participants**

120 The 20 schools were situated in West Lancashire, northwest England. All year 5 children (age 9-  
121 10 years) in the schools were informed about the project and received an information pack to  
122 share with their parents/carers. Written informed consent and assent were required from  
123 parents/carers and children respectively, before children could participate in the project in  
124 accordance with the project approvals granted by the University Research Ethics Committee  
125 (#SPA-REC-2015-182). Children were included if they provided the required informed parental

126 consent, assent, and medical screening forms, which indicated an absence of any medical  
127 conditions or disabilities preventing participation in the data collection and/or regular physical  
128 education lessons. The analytical sample consisted of 383 children (44.4% girls) at baseline and  
129 272 children (43.4% girls) at 12-week follow-up. The participants' drop-out at follow-up was  
130 primarily due to absence from school on data collection days. This study used participants' valid  
131 data for CRF at baseline and HRQoL at baseline and at 12-weeks follow-up.

### 132 **2.3 Active West Lancs Programme**

133 The Active West Lancs programme consisted of classroom-based healthy lifestyle education  
134 lessons based on the 'Dr Feelwell' concept developed by MerseyCare National Health Service  
135 Foundation Trust (<https://www.merseycare.nhs.uk/>), and structured 'Born to Move' physical  
136 activity lessons (<https://www.lesmills.com/borntomove/>). Both were taught once per week for 45-  
137 60 minutes by physical activity specialists from an organisation which delivers physical  
138 education, physical activity, health, and wellbeing sessions in West Lancashire primary schools.  
139 The lessons complemented the regular curriculum and did not replace mandatory subjects that  
140 cover physical activity, health, and wellbeing concepts (e.g., physical education). The data  
141 reported in the present study are from the 20 schools involved in the four phases of the programme  
142 (January-April, April-July, September-December 2018, and January-April 2019) (supplementary  
143 figure 1).

### 144 **2.4 Measures**

#### 145 *2.2.4.1 Cardiorespiratory fitness*

146 The 20-m multistage shuttle run test (20mSRT)<sup>24</sup> was conducted to provide an estimate of CRF.  
147 This test has been used extensively with participants of a similar age to those in the current study.<sup>25</sup>  
148 Prior research showed its validity (corrected mean  $r$  at the population level [95% CI]:  $r_p = 0.78$   
149 [0.72-0.85]) and reliability (intra-class correlation coefficients ranging from 0.78 to 0.93) in  
150 children.<sup>26</sup> Participants were encouraged to run for as long as possible until exhaustion or until  
151 they had reached their maximal effort. Otherwise, the test ended if the participant failed to reach  
152 within 2m of the marked line on two consecutive occasions. The 20mSRT was administered by  
153 the research team on a flat, clean surface indoors (e.g., sports/assembly hall) or outdoors (e.g.,  
154 school playground) depending on available facilities and was completed in groups of up to 10  
155 children. The total number of completed laps (shuttles) was used as a proxy indicator of CRF.

#### 156 *2.2.4.2 Health-related quality of life*

157 The KIDSCREEN-10 Index questionnaire was used as a measure of global HRQoL<sup>3</sup>.  
158 KIDSCREEN-10 is a 10-item questionnaire, which asks participants how they felt in the last  
159 week. Items reflect the factors of physical well-being, psychological well-being, autonomy,

160 parent relations, peers and social support, and school environment, which are derived from the  
161 27-item version of KIDSCREEN and are presented using a 1-5 Likert scale (i.e., 1 = “nothing”  
162 and 5 = “very much”).<sup>1</sup> Cronbach’s alphas are 0.82 and test–retest reliability was also generally  
163 satisfactory with internal consistent coefficients (ICCs) ranging from 0.61 to 0.70.<sup>27</sup> The  
164 Cronbach’s alpha for internal consistency of this questionnaire was 0.73 and 0.71 for the cross-  
165 sectional and longitudinal samples, respectively. Raw scores were converted to T-scores using  
166 the methodology described in the KIDSCREEN administration manual.<sup>3</sup> The questionnaire was  
167 completed in classrooms following instructions from the research team and in the presence of the  
168 class teachers.

#### 169 *2.2.4.3 Socioeconomic status*

170 Neighbourhood-level socioeconomic status (SES) was calculated for each child using the 2019  
171 Indices of Multiple Deprivation (IMD).<sup>28</sup> The IMD is a UK government-produced deprivation  
172 measure for England comprising income, employment, health, education, housing, environment,  
173 and crime.<sup>28</sup> IMD rank scores were generated from parent-reported home postcodes using the  
174 National Statistics Postcode Directory database. Every neighbourhood in England is ranked from  
175 one (most deprived area) to 32,844 (least deprived area).<sup>28</sup>

#### 176 *2.2.4.4. Anthropometric variables*

177 Height was measured using a portable stadiometer (Leicester Height Measure, Seca, Birmingham,  
178 UK), and body mass was measured using calibrated scales (813 model, Seca). Body mass index  
179 (BMI) was calculated for each participant, BMI z-scores were assigned,<sup>29</sup> and International  
180 Obesity Task Force BMI cut-points applied to classify the participants as underweight, normal  
181 weight or overweight/obese.<sup>30</sup> Waist circumference was measured, using an anthropometric tape  
182 measure from the minimal waist site to the nearest millimetre, with participants in the standing  
183 position and at the end of expiration. Waist-to-height ratio (WHtR) was calculated as a measure  
184 of central obesity.<sup>31</sup> Age at peak height velocity (APHV) was used as a proxy somatic measure of  
185 biological maturation. This method is based on anthropometric variables to predict APHV, which  
186 is a commonly used indicator of biological maturity.<sup>32</sup> The method employs validated sex-specific  
187 regression equations which include participants’ chronological age and height.<sup>32</sup> All the  
188 measurements were undertaken by trained researchers. To ensure accurate and standardised  
189 measurements all researchers firstly completed a six-hour training and supervised practice session  
190 using the assessment protocols. In addition, in order to avoid interindividual variability each  
191 researcher was responsible for administering the same measures during baseline and follow up  
192 assessment periods.

#### 193 *2.2.4.5. Moderate-to-vigorous physical activity*

194 Self-reported moderate-to-vigorous physical activity (MVPA) data were collected using the  
195 Youth Activity Profile (YAP) English version.<sup>33</sup> The YAP is a 15-item questionnaire comprised  
196 of three sections (school-day MVPA, out-of-school MVPA, and sedentary behaviour), with five  
197 questions per section. Participants are asked to recall their MVPA and sedentary behaviour over  
198 the past 7 days during context-specific time segments (e.g., active travel to and from school, break  
199 time, etc.). The out-of-school segment refers to activity levels before school, immediately after  
200 school, evening, and at weekends. All questions were structured using a 5-point Likert scale (e.g.,  
201 for active travel to school, a score of 1 indicated 0 days per week of active travel, whereas a score  
202 of 5 indicated 4–5 days per week). For this study, only data from the school-day and out-of-school  
203 MVPA questions were used. For each child, mean values for school-day and out-of-school  
204 MVPA were calculated and averaged resulting in a score for overall MVPA (1=low, 5=high). The  
205 YAP was completed in classrooms following instructions from the research team and in the  
206 presence of the class teachers.

#### 207 2.2.4.6. *Psychological correlates of physical activity: self-efficacy and enjoyment*

208 Self-efficacy was measured using a valid and reliable questionnaire which contained 8 items  
209 related to the child's ability to be physically active.<sup>34</sup> The items were rated on a 5-point Likert  
210 scale ranging from 1 (very easy / disagree a lot) to 5 (very difficult / agree a lot). The Cronbach's  
211 alpha for the internal consistency of the cross-sectional sample was 0.77 and 0.78 for the  
212 longitudinal sample. Enjoyment was assessed through the Physical Activity Enjoyment Scale  
213 (PACES) for children.<sup>35</sup> A 5-point Likert-type scale (1 = "disagree a lot" to 5 = "agree a lot") is  
214 used to answer 16 statements. The average of the answers assigned to the 16 items is the final  
215 score. The Cronbach's alpha for the internal consistency of the sample was 0.87 and 0.88 for the  
216 cross-sectional and longitudinal samples, respectively.

## 217 **2.5 Statistical analyses**

218 Preliminary analyses involved checking all variables for normality using normal probability plots  
219 and Kolmogorov–Smirnov tests. The data assumed a normal distribution and descriptive statistics  
220 were calculated for all continuous measures using means (SD) and percentages for categorical  
221 variables. As exploratory analyses did not show a significant interaction of sex and CRF in  
222 relation to HRQoL ( $p > 0.05$ ), the main analyses were performed with the total mixed-sex sample.

223 For study aim (i), mixed linear models examined the cross-sectional association between CRF  
224 and HRQoL with adjustment for sex, time of year, SES, WHtR, APHV, and MVPA; and the  
225 longitudinal association between CRF at baseline and HRQoL 12-weeks later adjusted for sex,  
226 time of year, SES, WHtR, APHV, MVPA, and HRQoL at baseline. Schools were included as  
227 random intercepts for aim (i) analysis. For study aim (ii), mediation analyses were conducted to  
228 assess the mediating role of each psychological correlate of physical activity (i.e., physical

229 activity self-efficacy and physical activity enjoyment) on the association between CRF and  
230 HRQoL with adjustment for sex, time of year, SES, WHtR, APHV, MVPA and schools. Cross-  
231 sectional mediation analyses were performed with CRF as the independent variable, HRQoL as  
232 the dependent variable and physical activity self-efficacy, and physical activity enjoyment  
233 individually introduced as mediator variables, with adjustment for the covariates. Further,  
234 longitudinal mediation analyses were performed with CRF at baseline as the independent  
235 variable, HRQoL at 12-week follow-up as the dependent variable and each psychological  
236 correlate individually introduced as mediator variables, with adjustment for the same covariates,  
237 with the addition of HRQoL at baseline. Effect sizes (Cohen's  $d$ ) were calculated for both cross-  
238 sectional and longitudinal linear mixed models as suggested by Brysbaert and Stevens<sup>36</sup> and  
239 defined as: small ( $<0.2$ ), medium ( $0.2-0.5$ ), and large ( $0.5-0.8$ ). For the mediation analyses effect  
240 sizes,  $R^2$  was used to calculate  $f^2$  ranges, carried out as proposed by Cohen<sup>37</sup> and defined as small  
241 ( $<0.02$ ), medium ( $0.02-0.15$ ), and large ( $0.15-0.35$ ). The PROCESS SPSS Macro version 2.16.3,  
242 model 4, with 5000 bias-corrected boot-strap samples and 95% confidence intervals (CIs) was  
243 used for these analyses<sup>38</sup>. Mediation was assessed by the indirect effect of CRF (independent  
244 variable) on HRQoL (dependent variable) through (i) self-efficacy, and (ii) enjoyment  
245 (mediators). Indirect effects ( $a*b$  paths) with confidence intervals not including zero were  
246 considered significant. Mediation percentage ( $P_M$ ) indicates how much of the association between  
247 CRF and HRQoL was explained by the mediator variables.<sup>38</sup> We performed post-hoc power  
248 statistical analyses to examine the impact of the changes from 383 to 272 on the results presented.  
249 Statistical significance was set at  $p<.05$  for all analyses which were performed using IBM SPSS  
250 Statistics version 23 (IBM, Armonk, NY).

251

### 252 3. Results

253 Participants' baseline characteristics are presented in Table 1. The percentage of children at  
254 baseline and 12-week follow-up in the normal weight group was 78.1% and 82.7%, respectively.  
255 The drop-out from overweight and obese participants from baseline to follow up was 21.9% and  
256 17.3%, respectively. On average, for the 20mSRT test, children performed 32.5 shuttles at  
257 baseline and 36.3 at 12-week follow-up. Mean HRQoL scores were 50.4 at baseline and 50.3 at  
258 12-week follow-up. The psychological correlates of physical activity showed the same values at  
259 baseline and at 12-week follow-up.

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**Table 1.** Characteristics of the participants at baseline and at 12-weeks follow-up. 263

	Baseline (n = 383)	Follow-up (n = 264)
<b>Variable</b>	<b>Mean (SD) or frequency (%)</b>	
Sex		265
Boys	213 (55.6%)	154 (56.6%) <sup>266</sup>
Girls	170 (44.4%)	118 (43.4%) <sup>267</sup>
Age (y)	10.0 (0.5)	10.2 (0.4) <sup>268</sup>
SES (IMD rank)	15902.2 (10201.5)	16513.47 (9911.7)
WHtR	0.5 (0.1)	0.5 (0.1) <sup>269</sup>
APHV (years)	-2.5 (0.7)	-2.3 (0.7) <sup>270</sup>
Height (cm)	139.8 (6.4)	140.8 (6.4) <sup>271</sup>
Mass (kg)	35.4 (7.8)	35.9 (7.6)
BMI (kg·m <sup>-2</sup> )	18.0 (3.0)	18.0 (2.9) <sup>272</sup>
Weight status		273
Under Weight	24 (6.2%)	17 (6.3%) <sup>274</sup>
Normal Weight	275 (71.8%)	203 (74.6%)
Overweight/Obese	84 (21.9%)	52 (19.1%) <sup>275</sup>
Waist circumference (cm)	65.3 (8.0)	65.7 (8.8) <sup>276</sup>
YAP MVPA score	3.4 (0.8)	3.7 (0.8) <sup>277</sup>
CRF (shuttles)	32.5 (16.0)	36.3 (17.1)
HRQoL	50.4 (9.7)	50.3 (10.0) <sup>278</sup>
Physical activity self-efficacy	3.6 (0.7)	3.6 (0.8) <sup>279</sup>
Physical activity enjoyment	4.3 (0.6)	4.3 (0.7) <sup>280</sup>
Data are presented as mean ( $\pm$ SD) or frequencies (percentages). Differences between baseline and follow-up were examined by paired <i>t</i> -test ( $p < 0.05$ ). SD: standard deviation; %: percentage; SES: socioeconomic status; IMD: indices of multiple deprivation; WHtR: waist to height ratio; APHV: peak height velocity; BMI: body mass index; YAP: youth activity profile; MVPA: moderate to vigorous physical activity; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.		

283

284 The results of the linear mixed model showing the cross-sectional associations between CRF and  
285 HRQoL are presented in Table 2. A positive association was observed between CRF and HRQoL  
286 ( $p=0.015$ ) after adjusting for sex, time of year, SES, WHtR, APHV, and MVPA. A medium effect  
287 size ( $d = 0.26$ ) was found for this model. The unadjusted cross-sectional linear mixed model  
288 showing the association between CRF and HRQoL is presented in supplementary table 1. Table  
289 3 presents the linear mixed model outcome analysing the longitudinal associations between CRF  
290 and HRQoL. The analysis revealed a positive association between CRF at baseline and HRQoL  
291 at 12-week follow-up ( $p=0.045$ ) after adjusting for covariates including HRQoL at baseline. A  
292 medium effect size ( $d = 0.35$ ) was found for this model. The unadjusted longitudinal linear mixed

293 model showing the association between CRF at baseline and HRQoL at 12-week follow-up is  
 294 presented in supplementary table 2.

**Table 2.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	57.67	44.43 – 70.90	<b>&lt;0.001</b>
Sex	2.80	-0.54 – 6.14	0.100
Project phase	-0.71	-1.75 – 0.32	0.158
SES	5.31	-5.41 – 0.00	0.324
WHtR	-18.24	-39.04 – 2.56	0.086
APHV	-0.09	-2.45 – 2.27	0.941
YAP MVPA	0.16	-1.09 – 1.40	0.806
Cardiorespiratory fitness	0.09	0.02 – 0.16	<b>0.015</b>

Model 1: adjusted for the fixed effects of sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity and moderate to vigorous physical activity. Clustering for analysis was schools. Health related quality of life was measured using KIDSCREEN-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold. HRQoL: health-related quality of life; SES: socioeconomic status; WHtR: waist to height ratio; APHV: peak height velocity; YAP: youth activity profile; MVPA: moderate to vigorous physical activity.

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**Table 3.** Longitudinal associations between cardiorespiratory fitness at baseline and HRQoL at 12-weeks follow-up (n= 272).

	Model 2		
	$\beta$	95% CI	<i>p</i> -value
Intercept	21.46	6.7 – 36.22	<b>0.005</b>
Baseline HRQoL	0.52	0.42 – 0.63	<b>&lt;0.001</b>
Sex	3.41	0.04 – 6.78	0.47
SES	1.53	-8.52 – 0.00	0.764
Project phase	-0.63	-1.91 – 0.65	0.337
WHtR	0.50	-21.83 – 22.82	0.965
APHV	-0.58	-2.82 – 1.67	0.615
YAP MVPA	-0.05	-1.28 – 1.18	0.940
Cardiorespiratory fitness	0.08	0.02 – 0.15	<b>0.045</b>

Model 2: adjusted for the fixed effects of sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity and baseline HRQoL. Clustering for analysis was schools. Health related quality of life was measured using KIDSCREEN-10.

Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold. HRQoL: health-related quality of life; SES:

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socioeconomic status; WHtR: waist to height ratio; APHV: peak height velocity; YAP: youth activity profile; MVPA: moderate to vigorous physical activity.

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297 Figure 1 shows the adjusted cross-sectional mediating effect of self-efficacy and enjoyment in the  
298 association between CRF and HRQoL. There was a significant indirect effect (path  $a*b$ ) between  
299 CRF and HRQoL when each psychological correlate of physical activity was individually  
300 included in the analyses. CRF was positively associated with both single psychological correlates  
301 ( $a$  path; all  $p<0.001$ ), which were also positively associated with HRQoL ( $b$  path; all  $p<0.001$ ).  
302 However, in each model the direct effect between CRF and HRQoL was not significant ( $c'$  path;  
303 all  $p>0.05$ ). The outcome of these cross-sectional mediation analyses suggested that CRF could  
304 indirectly influence HRQoL through its effects on children's physical activity self-efficacy  
305 ( $P_M=82.7\%$ ) and enjoyment ( $P_M=54.1\%$ ). Mediation analyses effect sizes were medium to large,  
306 with  $R^2$  ranging from 0.07 to 0.19 for enjoyment and from 0.09 to 0.22 for self-efficacy. For the  
307 cross-sectional mediation models the post-hoc power of the regressions included ranged from  
308 99.7% to 100%.

309 The results of the adjusted longitudinal mediating effects of both physical activity self-efficacy  
310 and enjoyment on the association between CRF at baseline and HRQoL at 12-week follow-up are  
311 shown in Figure 2. There was a significant indirect effect of baseline self-efficacy in the  
312 longitudinal association between baseline CRF and HRQoL at 12-week follow-up (path  $a*b$ ), but  
313 not for enjoyment. Moreover, baseline CRF was significantly associated with baseline self-  
314 efficacy ( $a$  path;  $p<0.01$ ), whereas a non-significant association was found with baseline  
315 enjoyment ( $a$  path;  $p>0.05$ ). Baseline self-efficacy and enjoyment were positively associated with  
316 HRQoL at 12-week follow-up ( $b$  path; all  $p<0.01$ ). Finally, the direct effect between baseline  
317 CRF and HRQoL at 12-week follow-up was non-significant ( $c'$  path; all  $p>0.05$ ). The results of  
318 the longitudinal mediation analyses suggested that baseline CRF could indirectly influence  
319 HRQoL 12 weeks later through its effects on children's baseline physical activity self-efficacy  
320 ( $P_M=29.4\%$ ) and enjoyment ( $P_M=15.8\%$ ), separately.  $R^2$  ranged from 0.10 to 0.20 for enjoyment,  
321 and from 0.09 to 0.25 for self-efficacy (i.e., medium to large effects). For the longitudinal  
322 mediation models the post-hoc power of the regressions included was 100%.

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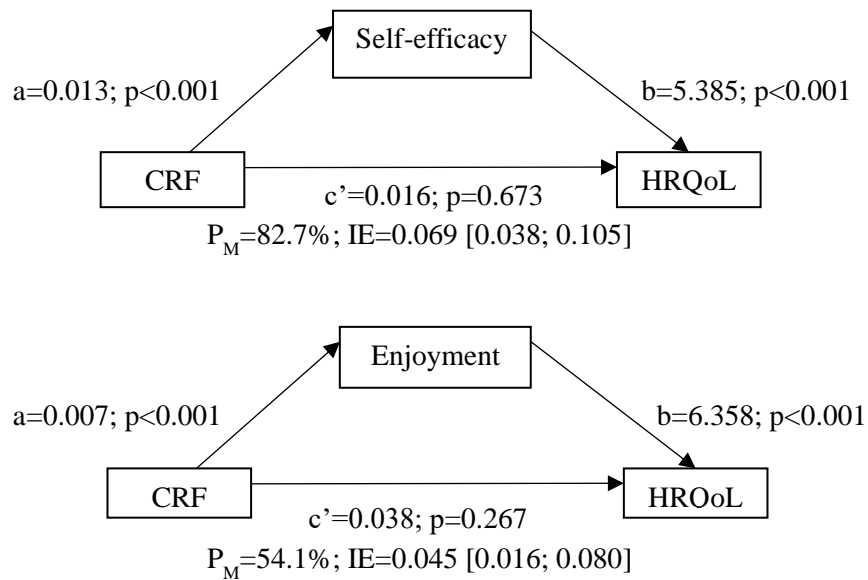
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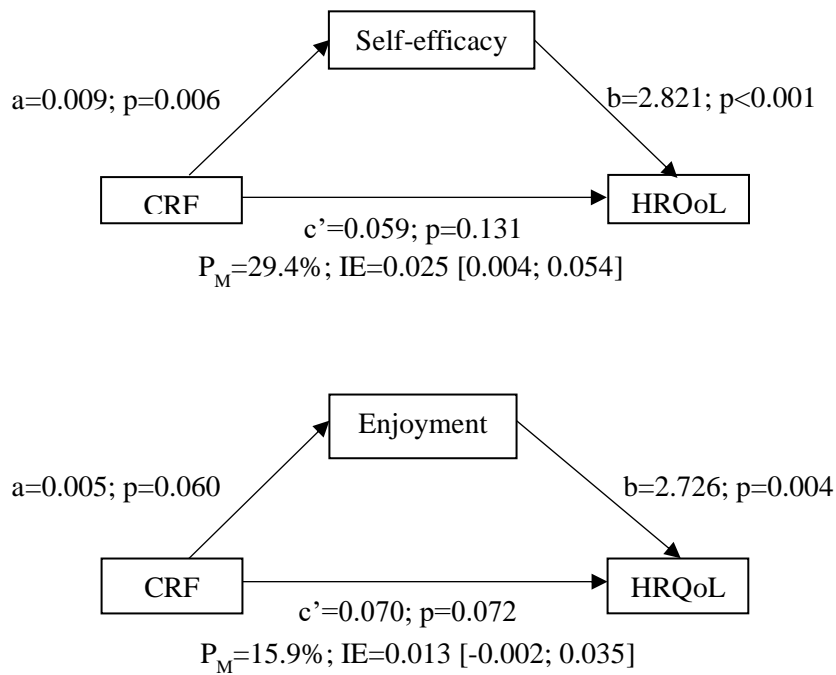
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**Figure 1.** Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) mediation models of the cross-sectional relationship between CRF and HRQoL, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity and schools (n = 383). Results are showed as unstandardized regression coefficients; *p*-value. IE = indirect effect [lower and upper levels for 95% confidence interval of the indirect effect between CRF and HRQoL]. P<sub>M</sub>: percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

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**Figure 2.** Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) of the longitudinal relationship between CRF at baseline and HRQoL at 12-week follow-up, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity, schools, and HRQoL at baseline (n = 272). Results are showed as unstandardized regression coefficients; *p*-value. IE = indirect effect [lower and upper levels for 95% confidence interval of the indirect effect between CRF at baseline and HRQoL at 12-week follow-up]. P<sub>M</sub>: percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

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#### 360 4. Discussion

361 The results of our cross-sectional and longitudinal analyses showed that among northwest  
362 England primary school children (i) CRF was positively associated with HRQoL and (ii) this  
363 association was mediated by self-efficacy and enjoyment as psychological correlates of physical  
364 activity. Our findings expand prior knowledge about the association between CRF and HRQoL  
365 in children and reveal for the first time potential underlying mechanisms involved in the  
366 association between CRF and HRQoL, highlighting the significant roles of single physical  
367 activity correlates such as self-efficacy and enjoyment.

368 Our cross-sectional results showed a positive association between CRF and HRQoL. Similar  
369 findings were found in previous studies,<sup>11-13,39</sup> which reported that children with higher levels of  
370 CRF had better HRQoL. For instance, a study in Norwegian 10-year-olds revealed that CRF had  
371 a small to medium effect size ( $R^2$  ranging from 0.17 to 0.5) in its positive association with all  
372 HRQoL domains (i.e., physical and psychological well-being, autonomy and parents, social  
373 support and school environment).<sup>11</sup> Also, Redondo et al. reported a small (all  $R^2 < 0.5$ ) positive  
374 association between CRF and HRQoL among children aged 4 to 7 years.<sup>12</sup> Regarding longitudinal  
375 associations between CRF and HRQoL, our novel findings revealed a positive association  
376 between CRF at baseline and children's HRQoL at 12-week follow-up after adjusting for  
377 confounders. This outcome is partially supported by previous longitudinal research in different  
378 age groups by confirming the individual positive small association of CRF at baseline on HRQoL  
379 over a 2-year period follow-up ( $R^2 < 0.5$ ).<sup>40</sup> These findings might be somewhat explained by the  
380 positive influence that CRF has on both physical and mental dimensions of health in children<sup>2</sup>  
381 over time,<sup>41,42</sup> which may positively impact children's HRQoL. We hypothesise that the similarity  
382 between our study's effect sizes and the ones of previous evidence might be due to the several  
383 dimensions of HRQoL which could not be fully influenced by CRF.

384 Since mediation analysis assumes that the independent variable influences the mediator, our  
385 cross-sectional and longitudinal results suggest that CRF at baseline influenced the psychological

386 variables, which, in turn, may affect HRQoL at baseline and 12-weeks later. With respect to path  
387 *a*, our findings could be partially supported by a previous cross-sectional study which reported  
388 that children with higher CRF levels had higher physical self-efficacy and physical activity  
389 enjoyment than their peers with low CRF.<sup>18</sup> Regarding our longitudinal results, we were not able  
390 to make comparisons since no evidence relating CRF and physical activity self-efficacy over time  
391 was found. We hypothesise that it is plausible that CRF influenced physical activity self-efficacy  
392 and enjoyment through motor skill development/proficiency and sport experiences. Children's  
393 CRF levels are associated with increased motor competence,<sup>43</sup> positive sport and physical activity  
394 experiences,<sup>44,45</sup> which in turn may affect several domains of their HRQoL. However, there is  
395 paucity of evidence in this area and further research is warranted. With respect to path *b*, our  
396 findings are in line with previous cross-sectional<sup>21</sup> and interventional<sup>20</sup> studies which reported a  
397 positive association of children's physical activity enjoyment and their HRQoL. However, no  
398 previous studies have examined the cross-sectional and longitudinal associations between  
399 children's physical activity self-efficacy and their HRQoL. The association found in our study  
400 between both psychological correlates and HRQoL may be related to the mental domain of the  
401 construct, predisposing children to higher scores of psychological well-being.<sup>21,46</sup>

402 The results obtained in the present study through mediation analyses, a powerful statistical  
403 technique that can be used to clarify the process underlying the relationship between two  
404 variables,<sup>38</sup> add support for the psychological correlates of physical activity being an intermediate  
405 step on the causal pathway between CRF and children's HRQoL. Thus, our findings are consistent  
406 with the idea that the promotion of children's physical activity self-efficacy and physical activity  
407 enjoyment may be of importance to improve their HRQoL.

408 Our mediation results are partially supported by only one previous cross-sectional study. This  
409 involved overweight adolescents, and showed the mediating role that motivational variables (i.e.,  
410 self-determined motivation) have in the association between CRF and HRQoL.<sup>47</sup> However, the  
411 mediating roles of physical activity self-efficacy and enjoyment in children have not been  
412 previously investigated. Yet, based on prior cross-sectional research in other populations framed  
413 by self-determined motivation, being more physically fit leads to the need for more autonomy and  
414 competence during physical activity practice and, therefore, the development of more  
415 autonomous forms of self-regulations, which might benefit persistence and mental well-being<sup>47,48</sup>  
416 with a positive impact on their HRQoL.

417 Given the need of further research on correlates of physical activity due to its influence on  
418 behavioural change<sup>17</sup> and the temporal trends in physical fitness reporting a global declining  
419 tendency over the years,<sup>49</sup> our data may have significant implications for HRQoL improvement.  
420 Indeed, maintaining children's HRQoL is important for current health, as well as, has transferable  
421 value for future societal health. Our findings are of interest to educators and policy makers, to

422 raise the importance of CRF for improving children’s psychological correlates of physical activity  
423 and their HRQoL.

424 Strengths of this study include the homogeneous age-matched and relatively large sample of  
425 children. The multilevel analyses accounted for school-level variance and adjusted for important  
426 fixed effects confounders. Furthermore, the mediation models added significant novelty to  
427 provide improved insights into the CRF-HRQoL relationships. There are also limitations which  
428 warrant consideration. The findings obtained from the cross-sectional elements of the study  
429 preclude claims of causal inferences and directionality between CRF and HRQoL, whereas there  
430 is more confidence about causality in those from the longitudinal aspects which controlled for  
431 baseline HRQoL and confounders. The 12-weeks duration of the follow-up is short which limits  
432 the significance of the longitudinal results. Moreover, the sample was drawn from one  
433 geographical region of northwest England, therefore the results may not be generalizable to  
434 populations elsewhere. MVPA was assessed using a self-report instrument which is open to recall  
435 and social desirability biases; however, the YAP is a validated method that was administered in  
436 the same way at both time points, thus limiting variation in responses between baseline and  
437 follow-up. Lastly, we acknowledge that more accurate estimates of CRF could have been obtained  
438 using a laboratory-based physiological direct measure. However, such measures were not feasible  
439 within our study, and the 20mSRT is the most widely used field-based test of CRF in children,  
440 which demonstrates criterion validity against gas-analyzed peakVO<sub>2</sub>, and has strong ecological  
441 validity and feasibility in school settings.

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## 443 **5. Conclusion**

444 The results of the current study showed that CRF was cross-sectionally and longitudinally  
445 associated with HRQoL in primary school children in England. Furthermore, self-efficacy and  
446 enjoyment as psychological correlates of physical activity act separately as mediators in the  
447 positive association between CRF and HRQoL. Therefore, we contribute to the comprehension  
448 of the relationship between these key factors, suggesting that both optimal CRF levels and better  
449 psychological correlates of physical activity are important for children’s HRQoL. Our findings  
450 should be considered when designing education and public health interventions and strategies  
451 aiming to improve HRQoL during childhood.

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588 **Supplementary material**

**Supplementary table 1.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	57.30	44.94 – 49.66	<b>&lt;0.001</b>
Cardiorespiratory fitness	0.09	0.04 – 0.16	<b>0.002</b>

Model 1: Unadjusted. Health related quality of life was measured using Kidscreen-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold.

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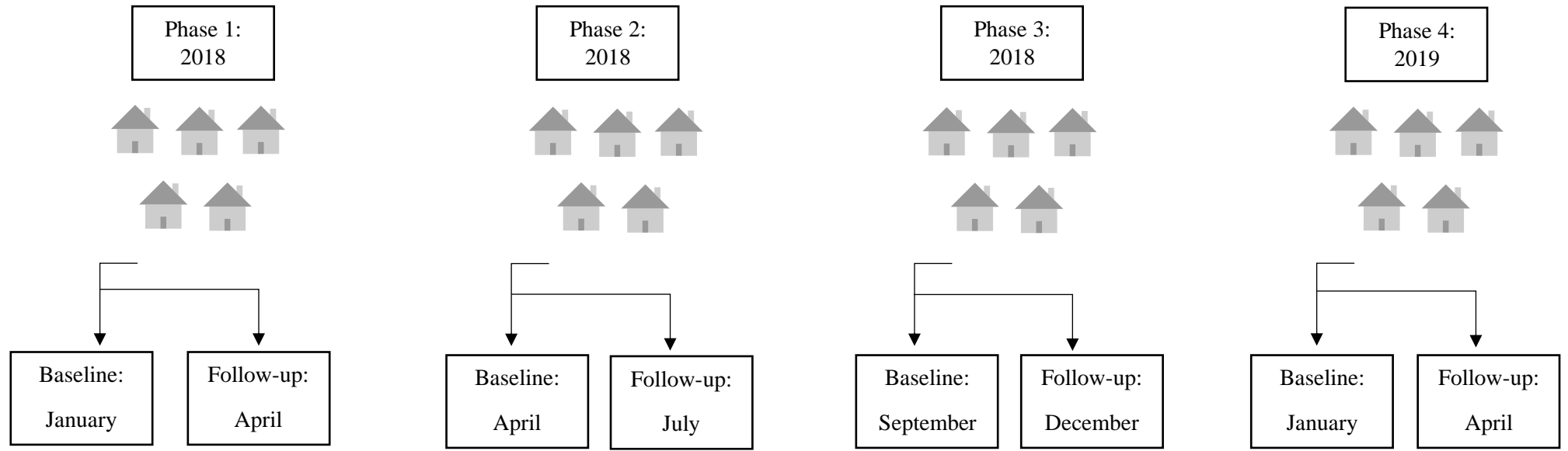
**Supplementary table 2.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	47.75	44.06 – 49.43	<b>&lt;0.001</b>
Cardiorespiratory fitness	0.11	0.03 – 0.18	<b>0.004</b>

Model 1: Unadjusted. Health related quality of life was measured using Kidscreen-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold.

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**Supplementary figure 1.** Active West Lancs Programme phases of data collection.