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

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Abstract

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

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

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

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

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

1. Introduction

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

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

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

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

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

2. Material and methods

2.1 Study design

This observational study used baseline and follow-up data from the *Active West Lancs* primary school physical activity and wellbeing programme. The aim of this programme was to evaluate the impact of a combined educational and exercise programme designed to promote and enhance children's physical activity behaviours and knowledge, fitness, and wellbeing. The programme aligned to the UK government's Childhood Obesity Strategy recommendation for children to engage in 30 minutes of physical activity during the school day.[23] The programme was delivered in four clusters of five schools over four consecutive12-week phases between 2018 and 2019. As no significant pre-post changes were observed in CRF and HRQoL outcomes over the 12-weeks, for this study the baseline data were treated as cross-sectional, and the combined 12-week follow-up longitudinal data were treated as longitudinal.

2.2 Participants

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

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

2.3 Active West Lancs Programme

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

2.4 Measures

2.2.4.1 Cardiorespiratory fitness

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

2.2.4.2 Health-related quality of life

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

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

2.2.4.3 Socioeconomic status

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

2.2.4.4. Anthropometric variables

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

2.2.4.5. Moderate-to-vigorous physical activity

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

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

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

2.5 Statistical analyses

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

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

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

3. Results

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

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

	Baseline (n = 383)	Follow-up (n = 272)
Variable	**Mean (SD) or frequency (%)**	
Sex		
Boys	213 (55.6%)	154 (56.6%)
Girls	170 (44.4%)	118 (43.4%)
Age (y)	10.0 (0.5)	10.2 (0.4)
SES (IMD rank)	15902.2 (10201.5)	16513.47 (9911.7)
WHtR	0.5 (0.1)	0.5 (0.1)
APHV (years)	-2.5 (0.7)	-2.3 (0.7)
Height (cm)	139.8 (6.4)	140.8 (6.4)
Mass (kg)	35.4 (7.8)	35.9 (7.6)
BMI ($kg \cdot m^{-2}$)	18.0 (3.0)	18.0 (2.9)
Weight status		
Under Weight	24 (6.2%)	17 (6.3%)
Normal Weight	275 (71.8%)	203 (74.6%)
Overweight/Obese	84 (21.9%)	52 (19.1%)
Waist circumference (cm)	65.3 (8.0)	65.7 (8.8)
YAP MVPA score	3.4 (0.8)	3.7 (0.8)
CRF (shuttles)	32.5 (16.0)	36.3 (17.1)
HRQoL	50.4 (9.7)	50.3 (10.0)
Physical activity self-efficacy	3.6 (0.7)	3.6 (0.8)
Physical activity enjoyment	4.3 (0.6)	4.3 (0.7)

Data are presented as mean (± SD) or frequencies (percentages). Differences between baseline and follow-up were examined by paired *t*-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.

The results of the linear mixed model showing the cross-sectional associations between CRF and HRQoL are presented in Table 2. A positive association was observed between CRF and HRQoL (p=0.015) after adjusting for sex, time of year, SES, WHtR, APHV, and MVPA. A medium effect size (d = 0.26) was found for this model. The unadjusted cross-sectional linear mixed model showing the association between CRF and HRQoL is presented in supplementary table 1. Table 3 presents the linear mixed model outcome analysing the longitudinal associations between CRF and HRQoL. The analysis revealed a positive association between CRF at baseline and HRQoL at 12-week follow-up (p=0.045) after adjusting for covariates including HRQoL at baseline. A 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		
	β	**95% CI**	***p***
Intercept	57.67	44.43 – 70.90	**<0.001**
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	**0.015**

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 (β) 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		
	β	**95% CI**	***p*-value**
Intercept	21.46	6.7 – 36.22	**0.005**
Baseline HRQoL	0.52	0.42 – 0.63	**<0.001**
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	**0.045**

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 (β) 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.

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

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

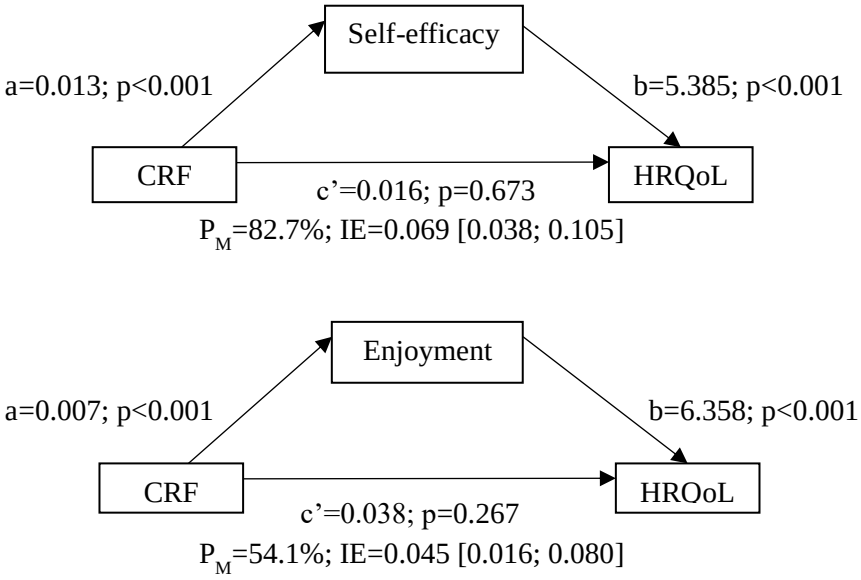

Figure 1. Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) mediation models of the cross-sectional relationship between CRF and HRQoL, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical 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_M: percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

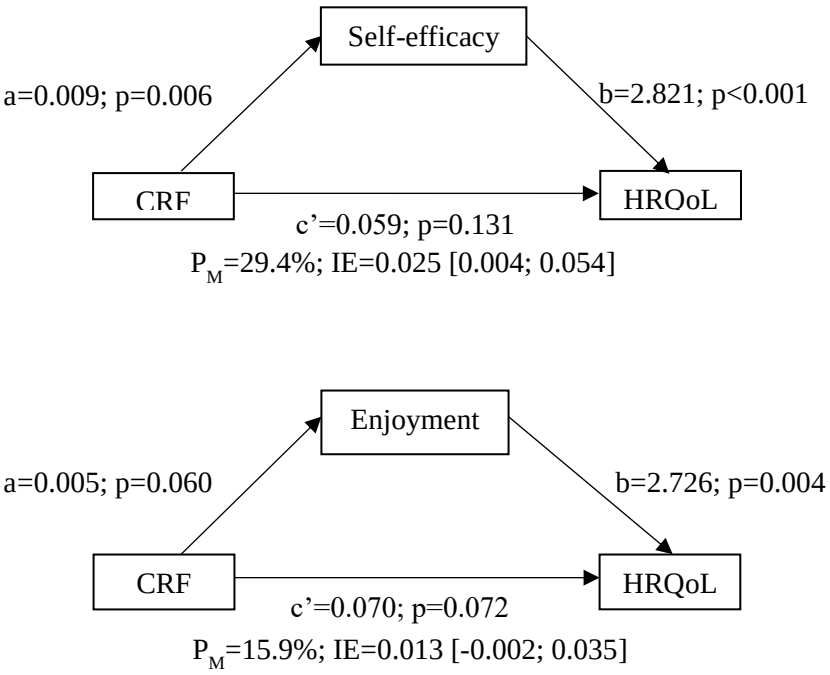

Figure 2. Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) of the longitudinal relationship between CRF at baseline and HRQoL at 12-week follow-up, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous 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_M: percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

4. Discussion

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

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

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

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

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

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

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

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

Strengths of this study include the homogeneous age-matched and relatively large sample of children. The multilevel analyses accounted for school-level variance and adjusted for important fixed effects confounders. Furthermore, the mediation models added significant novelty to provide improved insights into the CRF-HRQoL relationships. There are also limitations which warrant consideration. The findings obtained from the cross-sectional elements of the study preclude claims of causal inferences and directionality between CRF and HRQoL, whereas there is more confidence about causality in those from the longitudinal aspects which controlled for baseline HRQoL and confounders. The 12-weeks duration of the follow-up is short which limits the significance of the longitudinal results. Moreover, the sample was drawn from one geographical region of northwest England, therefore the results may not be generalizable to populations elsewhere. MVPA was assessed using a self-report instrument which is open to recall and social desirability biases; however, the YAP is a validated method that was administered in the same way at both time points, thus limiting variation in responses between baseline and follow-up. Lastly, we acknowledge that more accurate estimates of CRF could have been obtained using a laboratory-based physiological direct measure. However, such measures were not feasible within our study, and the 20mSRT is the most widely used field-based test of CRF in children, which demonstrates criterion validity against gas-analyzed peakVO_2, and has strong ecological validity and feasibility in school settings.

5. Conclusion

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

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Supplementary material

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

	Model 1		
	β	**95% CI**	***p***
Intercept	57.30	44.94 – 49.66	**<0.001**
Cardiorespiratory fitness	0.09	0.04 – 0.16	**0.002**

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

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

	Model 1		
	β	**95% CI**	***p***
Intercept	47.75	44.06 – 49.43	**<0.001**
Cardiorespiratory fitness	0.11	0.03 – 0.18	**0.004**

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

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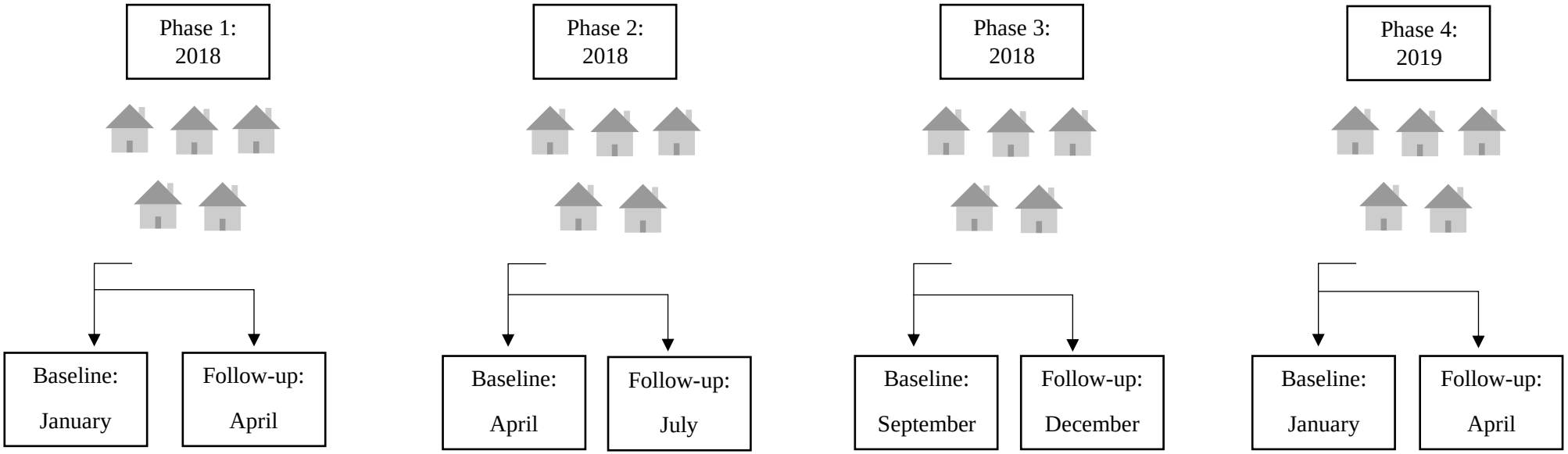

Supplementary figure 1. Active West Lancs Programme phases of data collection.