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Original

LA SALUD CARDIORRESPIRATORIA DE LOS NIÑOS EN EDAD ESCOLAR ES DIRECTAMENTE PROPORCIONAL A LA PROPORCIÓN CINTURA-ESTATURA Y AL ESTADO SOCIOECONÓMICO DEL COLEGIO

CARDIORESPIRATORY FITNESS IS POSITIVELY ASSOCIATED WITH WAIST TO HEIGHT RATIO AND SCHOOL SOCIO ECONOMIC STATUS IN IRISH PRIMARY SCHOOL AGED CHILDREN

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RESUMEN

Contexto: La finalidad de este estudio es identificar cualquier relación entre la salud cardiorrespiratoria (*CRF*, *cardiorespiratory fitness* en inglés) y los indicadores de salud entre los niños irlandeses de 6 y 10 años de edad.

Métodos; Un total de 917 niños y niñas (de los cuales N=459 de 6 años y N=458 de 10) de 11 centros de educación primaria de Cork (Irlanda) participaron en el estudio. Se evaluaron varios factores: composición corporal, presión sanguínea (*BP*, *blood pressure*), *CRF* (con una carrera de 550-m) y el estado socioeconómico (*SES*, *socio-economic status*) del colegio. Niños y niñas fueron clasificados según alta o baja *CRF* en base a la desviación estándar (*SDS*, *standard deviation scores*) del tiempo de carrera. Durante una semana y mediante el uso de acelerómetros se recogieron datos sobre la actividad física (*PA*, *physical activity*) de una sub-muestra de 700 niños y niñas (76,3%).

Resultados; Múltiple regresión lineal reveló una proporcionalidad directa entre la *SDS* de carrera y la proporción cintura-estatura (*WHtR*, *waist-to-height ratio*) (β=8,24; p<0,0005) y el estado socioeconómico (*SES*) (β=0,36; p=0,008) para los niños de 6 años de edad. En el caso de los niños de 10 años, *WHtR* (β=5,95; p≤0,0005), *SES* (β=0,51; p<0,0005), *MVPA* (actividad física moderada a alta, *moderate to vigorous physical activity*) (β= -0,01; p=0,001) y el ritmo cardíaco en reposo (β=0,02; p<0,0005) eran pronosticadores directos de la *SDS* de carrera. Los niños de 10 años físicamente en forma tenían una menor *WHtR* y un mayor índice de masa corporal y tenían menor probabilidad de sobrepeso o obesidad que sus homólogos con menor aptitud física. Estos niños pasaban también menos tiempo en modo sedentario y más en actividad física ligera (*light PA*), alta y *MVPA* que los niños de 10 años con bajo *CRF* (p<0,005).

Conclusiones; Los niños físicamente en forma tienen una composición corporal más favorable. Esfuerzos para mejorar en un futuro la salud de los niños irlandeses deberían orientarse a la promoción de un mayor estado físico y deberían priorizar la distribución de recursos a los colegios con bajo estado socioeconómico.

Palabras clave: Salud, estado socioeconómico, la salud cardiorrespiratoria, la actividad física.

ABSTRACT

Background; The purpose of this paper is to examine any association between cardiorespiratory fitness (CRF) and markers of health among 6 and 10 year old Irish children.

Methods; A total of 917 children (6 year olds, N=459; 10 year olds, N=458) from 11 primary schools in Cork (Ireland) participated. Body composition, blood pressure (BP), CRF (550-metre distance run) and school socio-economic status (SES) were assessed. Children were classified as low or high fitness based on run-time standard deviation scores (SDS). Physical activity (PA) determined over 1 week by accelerometry was collected from a sub sample of 700 children (76.3%).

Results; Multiple linear regression revealed a positive association between run SDS and waist-to-height ratio (WHtR), (β=8.24, p<0.0005) and SES (β=0.36, p=0.008) among 6 year olds. For 10 year olds WHtR (β=5.96, p=<0.0005), SES (β=0.51, p<0.0005), MVPA (β= -0.01, p=0.001) and resting heart rate (β=0.02, p<0.0005) were positive predictors of run SDS. High fit 10 year olds had lower WHtR and body mass index and were less likely to be overweight or obese than their low fit counterparts. These children also spent less time sedentary and more time in light PA, vigorous PA and MVPA than low fit 10 year olds (p<0.005).

Discussion/Conclusions; Children with higher fitness had more favourable body composition. Efforts to improve the future health of Irish children should consider targeting the promotion of increased fitness and prioritise the distribution of resources to low SES schools.

Keywords: Child health, socio-economic status, cardiorespiratory fitness, physical activity.

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INTRODUCCIÓN

Cardiorespiratory fitness (CRF) is a powerful marker of health among children (Boddy et al., 2012; Ortega et al., 2008) with studies demonstrating low CRF is associated with obesity, high blood pressure (BP) and the metabolic syndrome in young people (Janssen & Leblanc, 2010). There is evidence that school-based initiatives that target increased fitness can improve child health (Carrel et al., 2005; Kovacs et al., 2009). Furthermore, CRF during childhood can predict a healthier cardiovascular profile in adulthood (Dwyer et al., 2009; Hruby et al., 2012; Twisk et al., 2002) but recent evidence has shown levels of CRF to be declining globally among this population (Boddy et al., 2012; Sandercock et al., 2010; Tomkinson & Olds, 2007). Factors implicated in this decline are increased body mass (Sandercock et al., 2010), decreased physical activity (PA) and increased time spent in sedentary behaviour (Aggio et al., 2012) but limited evidence is available outlining the potential interactions of such factors among children. Understanding if there are any relationships between CRF and health markers such as body composition measures and PA may provide a valuable addition for school-based initiatives intended to foster fitness improvements as a means of improving the future health of children.

Although there is lack of Irish data, one study has reported that one in four Irish primary school children have a low level of fitness, are overweight or obese and have elevated BP (Woods et al., 2010). Furthermore, only 19% of Irish children are meeting the recommended guideline of 60 minutes moderate to vigorous PA (MVPA) per day (Woods et al., 2010). Associations between parameters of health are important to explore because emphasis is often placed on monitoring these during interventions aimed at improving child health. In addition regular assessment of fitness might be warranted as a measure of future health benefit or risk of future disease.

Research on the relationships between CRF and markers of health among Irish children has focused on relatively small samples (Hussey et al., 2007), self-report methodology (Coppinger et al., 2014) and older age primary school children (Kilbride et al., 2013). The purpose of this study therefore, is to examine any association between CRF and markers of health including objectively measured PA among a large sample of Irish 6 and 10 year old primary school children. Whether or not these health markers and intensities of PA vary between fit and unfit children will also be explored. Such findings will clarify if a relationship exists between CRF and parameters of health which could have important implications for public health policy making and developing optimal programmes to improve and monitor the health of Irish children

MATERIAL Y MÉTODOS

Overview

The Project Spraoi Randomised Control Trial (ISRCTN92611015, www.cit.ie/projectspraoi), was initiated in primary schools in Cork, Ireland, in September 2013. The main aim of the programme is to promote increased PA and improved nutritional knowledge and attitudes among Irish primary school children. It is based on a New Zealand (NZ) school based health promotion intervention titled, 'Project Energize,' (www.projectenergize.org.nz), which has shown measureable improvements in the health of NZ children (Sport Waikato, 2011). The Project Spraoi methodological approach; including design, protocol and sampling framework has been published elsewhere (Coppinger et al., 2016). Eleven schools that expressed a willingness to participate that were not currently participating in another PA and/or healthy eating/nutrition intervention were recruited. Although the study is limited in that schools were selected via a convenience sampling approach, all mainstream school types in Cork and Ireland (Urban, rural, single-sex girls, single-sex boys, mixed, low socio-economic status (SES) and middle/high SES) were represented. Baseline evaluation was carried out at the beginning of each schools' involvement in the project (September/October: Year 1). Ethical approval was attained from Cork Institute of Technology's Research Ethics Committee in September 2013.

Participants

A total of 917 children (6 year olds, N=459; 10 year olds, N=458) from 11 Cork schools consented to participate (52.7% boys; 47.3% girls). These age groups were chosen on the basis that they mark sensitive periods of growth for the child (mid-childhood & early adolescence) (Cameron & Demerath, 2002) and to allow for follow up after 2

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school years. Of the 917 children, 29.1% (n=5) attended schools classified as low SES which is based on a combination of parent employment status, local authority accommodation (social housing for people who cannot afford to buy their own homes), lone parenthood, travellers (community within Ireland who are traditionally nomadic), free book grants (funding provided to schools for assistance with books) and large families (Archer & Sofrioniou, 2008).

Testing Measures and Protocol

Cardiorespiratory fitness (time taken to complete a 550-metre (m) distance run), anthropometric (height, body mass and waist circumference) and BP measures were collected following the evaluation methods of 'Project Energize' (Graham et al., 2008). The 550-m distance run has been found to be a valid test of CRF among children (Hamlin et al., 2014) and was measured as the time taken to complete 5 laps of an outdoor 26.5m by 42.5m surface (grass, artificial turf, weather synthetic track) arranged in an oval shape, after completion of the anthropometric and BP test battery. All measures were conducted by a team of 5 researchers that were trained over 3 separate workshops by experienced researchers.

Age and sex specific run-time standard deviation scores (SDS) were calculated using the run centile curves developed by 'Project Energize' evaluation data (Rush & Obolonkin, 2014). Among 2 children categorised in the same age and gender group a higher run-time SDS was the result of a slower run-time and a lower run-time SDS was the result of a faster run-time. Run-time SDS were used to group participants into a binary CRF variable: low CRF (>0 run-time SDS/slower run-time) or high CRF (≤0 run-time SDS/faster run-time). Body mass index (BMI) was calculated by dividing body mass (kg) by height in metres squared (m^2). International Obesity Task Force age and sex specific body mass index (BMI) criteria were used to categorise children as thin, normal weight, overweight or obese (Cole & Lobstein, 2012). Waist to height ratio (WHtR) was calculated by dividing waist circumference in centimetres (cm) by height in cm.

Physical activity and sedentary behaviour were objectively measured over 7 days using triaxial accelerometers (Actigraph; model 7164, GT3X and wGT3X+, Fort Walton Beach, FL, USA) at 30Hz/5 second epochs, on a subsample of 700 children. To be included in analysis, participants were required to wear the accelerometer for a minimum of 600 minutes on 3 week days and 1 weekend day (Rowlands et al., 2008; Troiano et al., 2008). One hundred and fifty one (43.5%) 6 year olds and 195 (55.2%) 10 year olds achieved the minimum accelerometer wear time criteria, respectively (Coppinger et al., 2016). Minutes of PA in different intensities were calculated using cut points developed by Evenson et al. (2008) among children of similar ages (Evenson et al., 2008). Outcome variables calculated were percentage of time in sedentary, light (LPA), moderate (MPA), vigorous (VPA) and MVPA intensity activity relative to total wear time with the aim of providing a standardised value. Mean daily minutes in MVPA was used to assess levels of adherence to the recommended 60 minutes of MVPA per day (Department of Health and Children & Health Services Executive, 2009).

Data Processing and Analysis

Data was stored and analysed using IBM SPSS (Statistical Package for Social Studies), Version 22. Separate analyses were conducted for 6 and 10 year olds. Data was assessed for normality using the Kolmogorov-Smirnov (n≥100) or Shapiro-Wilk (n<100) goodness-of-fit tests. Mean and standard deviation scores were calculated for continuous variables (Run-time SDS, BMI, WHtR, systolic BP, diastolic BP, resting heart rate (HR), percentage sedentary time and MVPA. Frequencies were used to summarise categorical variables (BMI, level of attainment of 60 minutes of MVPA and CRF).

Spearman's rank-correlation was used to explore the relationship between variables. Multiple linear regression analysis using the stepwise method was performed to investigate the association between run-time SDS and anthropometric (BMI and WHtR) and physiological (Systolic BP, diastolic BP and resting HR) measures, percentage sedentary time and MVPA. Run-time SDS was entered as the dependent variable; markers of health were entered as potential predictor variables. Gender and school SES were entered as indicator variables. Unusual cases were removed using casewise diagnosis. Residuals were checked for normality (p>0.05) and homoscedasticity using the Durbin-Watson statistic >1.

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Mann-Whitney U Tests and independent sample *t*-tests were used to examine differences between children categorised as low or high CRF across anthropometric and physiological measures and percentage of time in sedentary, LPA, MPA, VPA and MVPA. As all data was not normally distributed both parametric and non-parametric tests were conducted. No differences were found and parametric tests are presented in the current paper. Differences between CRF categories across categorical variable were examined using a Chi-squared test. All statistical testing was carried out using a 5% level of significance.

RESULTADOS

Anthropometry, BP, run-time SDS and PA measures of 6 year old and 10 year old children along with categories of selected health measures are summarised in Table 1. Overall, markers of health were similar in the full sample compared to the sub sample who achieved the accelerometer wear time criteria. Using run centile curves developed by Rush & Obolonkin (2014), 82.1% (340) of 6 year olds and 62.3% (264) of 10 year olds were classified as having low CRF (>0 run-time SDS). A total of 17.4% of 6 year old participants and 19.0% of 10 year old participants were either overweight or obese. Overall, 53.3% of 6 year olds and 39.0% of 10 year olds reached the Department of Health and Children's PA guidelines of at least 60 minutes of daily MVPA (Department of Health and Children & Health Services Executive, 2009).

Table 1. Anthropometry, blood pressure (BP), physical activity (PA) and run-time measures for 6 year old and 10 year old children

	6 year olds		10 year olds	
	N	Mean ± SD	N	Mean ± SD
Age (years)	459	6.1 ± 0.4	457	10.0 ± 0.4
Run-Time SDS	414	0.83 ± 0.72	424	0.62 ± 0.88
BMI (kg/m^2)	454	16.33 ± 1.91	452	17.71 ± 2.88
WHtR (cm/cm)	452	0.46 ± 0.04	452	0.44 ± 0.05
Systolic BP (mmHg)	425	101.4 ± 10.2	431	108.9 ± 11.9
Diastolic BP (mmHg)	425	60.0 ± 9.7	431	64.4 ± 9.7
Resting HR (bpm)	425	88.2 ± 11.6	431	81.3 ± 12.0
MVPA (mins) per day	151	63.7 ± 19.4	195	57.8 ± 20.2
Sedentary (% relative to total wear time)	151	62.7 ± 6.3	195	63.7 ± 19.4
	N	%	N	%
IOTF Overweight or Obese	79	17.4	86	19.0
Achieving 60 mins MVPA per day	80	53.3	76	39.0
>0 run-time SDS (Slower run time)	340	82.1	264	62.3
≤0 run-time SDS (Faster run time)	74	17.9	160	37.7

SDS, standard deviation; WHtR, waist-to-hieght ratio; BP, blood pressure; HR, heart rate; MVPA, moderate to vigorous physical activity; IOTF, International Obesity Task Force.

Multiple linear regression analysis models are presented in Table 2. From these models, the percentage of explained variance (adjusted R^2) for run-time SDS was 24% for 6 year olds and 42% for 10 year olds. Among 6 year old participants, it was found that as WHtR increases by 1 unit, run-time SDS increases by 8.24 units (p<0.0005), as school status changes from middle/high to low SES, run-time SDS increases by 0.36 units (p=0.008) and as diastolic BP increases by 1 unit, run-time SDS decreases by 0.01 units. For 10 year old participants as WHtR increases by 1 unit, run-time SDS increases by 5.96 units (p<0.0005), as school SES changes from middle/high to low SES, run-time SDS increases by 0.51 units (p<0.0005), as MVPA increases by 1 unit, run-time SDS decreases by 0.01 units (p=0.001), as resting HR increases by 1 unit, run-time SDS increases by 0.02 units (p<0.0005) and as systolic BP increases, run-time SDS decreases by 0.02 units (p<0.0005). All other variables did not explain a significant variation in run-time SDS.

Table 2. Predictors of run-time standard deviation score among 6 and 10 year old children.

Model	N	Independent variables	R^2	Beta	SE Beta	p-value
6 year olds	128	WHtR (cm/cm)	0.24	8.24	0.38	<0.005
		School SES (middle/high - low)		0.36	0.22	0.008
		Diastolic BP (mmHg)		-0.01	-0.18	0.023
10 year olds	172	WHtR (cm/cm)	0.42	5.96	0.32	<0.0005
		School SES (middle/high - low)		0.51	0.26	<0.0005
		MVPA (mins)		-0.01	-0.22	0.001
		Resting HR (bpm)		0.02	0.27	<0.005
		Systolic BP (mmHg)		-0.02	-0.23	<0.005

WHtR, waist-to-height ratio; SES, socio-economic status; BP, blood pressure; MVPA, moderate to vigorous physical activity; HR, heart rate.

Independent sample *t*-tests were used to assess differences between children classified as having low or high CRF. Across both age cohorts, participants in the high fitness group had significantly lower WHtR than their low fitness counterparts (0.45 for high fit v's 0.46 for low fit 6 year olds; p=0.001 and 0.42 for high fit v's 0.45 for low fit 10 year olds; p<0.0005), (Table 3). In addition, 10 year olds in the high fitness group had significantly lower BMI (16.91 for high fit v's 18.0 for low fit; p=0.003) and lower resting HR (77.7 for high fit v's 83.3 for low fit; p<0.0005) than participants in the low fitness group.

Table 3. Mean, standard deviation (SD) and p-value of health measures across cardiorespiratory fitness (CRF) category by age cohort.

	6 year olds					**10 year olds**				
CRF Category	**Low**		**High**			**Low**		**High**		
	N	Mean ± SD	N	Mean ± SD	p-value	N	Mean ± SD	N	Mean ± SD	p-value
BMI (kg/m²)	337	16.29 ± 1.80	74	16.04 ± 1.57	0.218	261	18.00 ± 3.04	158	16.91 ± 1.81	0.003
WHtR (cm/cm)	336	0.46 ± 0.03	74	0.45 ± 0.03	0.001	261	0.45 ± 0.05	158	0.42 ± 0.03	<0.0005
Systolic BP (mmHg)	320	101.1 ± 10.6	71	102.7 ± 8.4	0.149	246	109.0 ± 12.1	155	108.5 ± 11.3	0.939
Diastolic BP (mmHg)	320	59.9 ± 10.1	71	60.2 ± 8.9	0.562	246	64.8 ± 9.9	155	63.5 ± 9.2	0.329
Resting HR (bpm)	320	88.0 ± 12.1	71	87.3 ± 9.5	0.607	246	83.3 ± 11.5	155	77.7 ± 11.9	<0.0005

WHtR, waist-to-height ratio; BP, blood pressure; HR, heart rate. P-value for difference between low and high CRF categories from independent sample *t*-tests.

No significant differences were found among 6 year olds between CRF groups across percentage of time spent in sedentary, LPA, MPA, VPA and MVPA (Table 4). However, 10 year old participants in the high fitness group had significantly lower prevalence of sedentary time (68.2% v's 70.2%; p=0.015) and significantly higher prevalence of LPA (24.1% v's 22.9%; p=0.024), VPA (3.5% v's 3.0% p=0.015) and MVPA (7.7% v's 7.0%; p=0.039) than their low fitness counterparts, respectively.

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Table 4. Percentage of time being sedentary and time spent in each physical activity intensity across cardiorespiratory fitness (CRF) category by age cohort. Data presented as mean, standard deviation (SD) and p-value.

	6 year olds					10 year olds				
CRF Category	**Low**		**High**			**Low**		**High**		
	N	Mean ± SD	N	Mean ± SD	p-value	N	Mean ± SD	N	Mean ± SD	p-value
Sedentary time (%)	109	62.7 ± 5.5	25	61.9 ± 8.0	0.416	108	70.2 ± 5.2	77	68.2 ± 5.1	0.015
LPA (%)	109	28.6 ± 4.3	25	29.3 ± 5.8	0.617	108	22.9 ± 3.7	77	24.1 ± 3.6	0.024
MPA (%)	109	5.0 ± 1.2	25	5.2 ± 1.6	0.538	108	4.0 ± 1.3	77	4.2 ± 1.3	0.216
VPA (%)	109	3.7 ± 1.3	25	3.7 ± 1.7	0.924	108	3.0 ± 1.3	77	3.5 ± 1.7	0.015
MVPA (%)	109	8.6 ± 2.3	25	8.9 ± 3.1	0.707	108	7.0 ± 2.3	77	7.7 ± 2.7	0.039

LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate to vigorous physical activity. P-value for difference between low and high CRF categories from independent sample *t*-tests.

The Chi-squared test revealed a statistically significant association between fitness groups and BMI categories among 10 year old participants (Table 5). The prevalence of overweight or obesity was 14.9% among 10 year old participants in the high fitness groups versus 85.1% in the low fitness group (p<0.0005). For 6 year olds, the prevalence of overweight or obesity was 10.6% among participants in the high fitness group, versus 89.4% among participants in the low fitness group (p=0.114). There was no difference between CRF groups and the percentage of participants achieving the MVPA guidelines for both age cohorts (Table 5).

Table 5. Relationships between low and high cardiorespiratory fitness (CRF) and overweight or obesity and time spent in moderate to vigorous physical categories by age cohort.

	6 year olds			10 year olds		
	Low CRF	**High CRF**	**p-value**	**Low CRF**	**High CRF**	**p-value**
IOTF Overweight or obese (BMI)	N=59 (89.4%)	N=7 (10.6%)	0.114	N=63 (85.1%)	N=11 (14.9%)	<0.0005
IOTF Not overweight or obese (BMI)	N= 278 (80.6%)	N=67 (19.4%)		N= 198 (57.4%)	N= 147 (42.6%)	
Not achieving 60 mins MVPA	N=49 (81.7%)	N=11 (18.3%)	1.000	N=73 (63.5%)	N=42 (36.5%)	0.091
Achieving 60 mins MVPA	N=60 (81.1%)	N=14 (18.9%)		N=35 (50.0%)	N=35 (50.0%)	

IOTF, International Obesity Task Force; MVPA, moderate to vigorous physical activity. P-value for association between low and high CRF categories and selected categorical variables from the Chi-squared test with Fishers Exact Test.

DISCUSIÓN

A positive relationship between CRF, WHtR and school SES among Irish children has been shown. For 10 year old children MVPA was also a predictor of CRF. In addition, 10 year old children categorised as high fit were found to have a healthier profile across BMI, WHtR, resting HR, percentage of time spent sedentary and percentages of time in LPA, VPA and MVPA compared to their low fit counterparts. This trend was not as pronounced among 6 year old children. These findings are in agreement with a systematic review which reported that aerobic activity is associated with cardio-metabolic health and obesity among children and youth (Janssen & Leblanc, 2010). Cardiorespiratory fitness among children has been reported to be declining in recent decades, (Tomkinson & Olds, 2007) and one study of children from the UK has reported that fitness is falling at twice the global average rate (Sandercock et al., 2010). Given the potential persistence of obesity and associated insulin resistance into adulthood (Dwyer et al., 2009), these findings provide support for initiatives aimed at increasing CRF among children.

Among 6 year olds up to 24% of the variation in CRF could be explained by WHtR, school SES and diastolic BP. Previous research examining associations between CRF and health markers among younger children is limited, however one study among older children did previously report a weak correlation between CRF and WHtR (Ullrich-French et al., 2010). Ostojic et al. (2011) reported a moderate association between waist circumference and aerobic fitness among 6-14-year old Serbian youth however a measure of SES was not reported in this study and may therefore exist (Ostojic et al., 2011). Among 10 year olds 42% of the variation in CRF was explained by WHtR, school SES, MVPA, resting HR and systolic BP. The findings provide support for those reported by Klasson-Heggebo et al. (2006) who found a strong graded relationship between CRF, waist circumference and the sum of four skinfolds among 9 and 15 year old Europeans (Klasson-Heggebo et al., 2006) and also Aires et al. (2010) who reported a small association between CRF and BMI and a moderate association between CRF and MVPA, however it should be noted that this finding was with an older cohort (11-18 year olds from Portugal) (Aires et al., 2010). The current study revealed that as CRF improved, diastolic BP increased among 6 year olds and systolic BP increased among 10 year olds. This is contrary to previous work (Klasson-Heggebo et al., 2006; Ullrich-French et al., 2010) yet within these studies Klasson-Heggebo et al. (2006) reported a weak association between fitness and diastolic BP while Ullrich-French et al. (2010) found no association between fitness and systolic BP. It has been suggested that obtaining measurements over several visits is important in characterising children's BP and could be a means of strengthening future work relating to children's BP (Gillman & Cook, 1995). The lower prevalence of explained variation in CRF among 6 year olds could be due factors such as motivation, inability of this age group to keep a steady pace for the duration of the test and lack of experience in distance running (Hamlin et al., 2014). The positive association for WHtR among both age groups and PA among 10 year olds suggest that increasing children's CRF may potentially improve body composition and PA levels; all of which are important factors in long term health.

Within both models WHtR was the strongest predictor of CRF. An association between WHtR and cardio-metabolic risk factors among children has also been found in previous research (Mokha et al., 2010). WHtR provides an indicator of body composition that is non age dependent and increasingly recommended for use with children in combination with BMI as it considers both height and central obesity (Weili et al., 2007; Zhou et al., 2014). Central adiposity has been reported to be a better predictor of premature mortality than BMI, therefore this finding suggests that WHtR should be considered in addition to BMI as a measure of adiposity (Saydah et al., 2013) and along with CRF could be used as a useful and practical tool to monitor children's health within the school environment.

School SES was identified as a significant predictor factor of CRF among both age groups. Little is known about the interrelations of fitness, health markers and SES among Irish children however there is some evidence of social inequalities for physical inactivity, type of PA and BMI (Williams et al., 2009). Self-reported data from the Growing Up In Ireland National Longitudinal Study suggest children from lower SES groups are more likely to spend more time engaged in sedentary behaviours compared to children from higher SES groups and participation in structured sports clubs has been found to increase with family income (Williams et al., 2009). Body size has also been related to social class, with 33% of 9 year old children from semi-skilled/unskilled backgrounds classified as overweight or obese, compared to 22% of children whose parents work in professional/managerial roles (Williams et al., 2009). Elsewhere, Ullrich-French et al. (2010) found no significant association of SES with sedentary behaviour, WHtR, BMI and BP, while controlling for CRF but suggested that limited representation across SES was a possible reason for this (Ullrich-French et al., 2010). Jin et al. (2015) found that 2-9 year olds with lower family income were less physically fit than those with higher family income (Jin & Jones-Smith, 2015) while Jimenez-Pavon et al. (2010) reported modest association between SES, fitness and body composition among

Spanish youth (Jimenez-Pavon et al., 2010). The discrepancies among studies could be due to different methodologies used to assess SES factors. As high SES is known to be a strong predicator of low morbidity (Kujala, 2010), this finding is important as it adds to our understanding of the potential association of SES and CRF among children. It underlines the responsibilities of policy makers to prioritise programmes to improve the health of Irish children to low SES schools.

Examination of health makers across CRF groups revealed that children categorised as having high fitness across both age groups had lower WHtR than those with low fitness. Among 10 year old children BMI was also found to be significantly lower among those with high CRF. This is in agreement with previous research (Hussey et al., 2007; Martins et al., 2010). Hussey et al. (2007) found a negative correlation between CRF and BMI among Irish 7 and 10 year olds (Hussey et al., 2007), while Martins et al. (2010) reported significantly lower BMI and significantly higher fitness among Portuguese 10-16 year olds (Martins et al., 2010). Ten year olds in the current study who were fitter were also less likely to be overweight or obese which is supported by previous work (Aires et al., 2010; Klasson-Heggebo et al., 2006) and makes the associations between WHtR, PA and CRF particularly important for attenuating health risk among children.

Among 10 year old children in the high CRF group the percentage of time spent sedentary was significantly lower while LPA and VPA were significantly higher. Similar findings relating to CRF and VPA were reported among 7-10 year old Irish children (Hussey et al., 2007) and 9-10 year old European children (Ruiz et al., 2006). In addition, Hussey et al. (2007) reported an association between CRF and sedentary time among boys only (Hussey et al., 2007). Ruiz et al. (2006) did not present sedentary data but concluded that both the intensity and total amount of PA was associated with fitness among children suggesting that the higher prevalence of LPA among 10 year olds considered fit may have contributed to higher levels of CRF (Ruiz et al., 2006). These findings among 10 year olds are important given early childhood and adolescence is a time in which lasting habits are established (Gluckman et al., 2009) and also a time when the steepest increase in sedentary behaviour has been found to occur (World Health Organisation, 2017). Thus interventions implemented during these periods have the potential to have a significant influence on lifelong health and based on the current findings should target decreasing sedentary time and increasing PA of all intensities.

A particular strength of this study lies in the fact that it is the first Irish study addressing the association of CRF with a range of health markers including objectively measured PA among younger and older age primary school children. In particular, the inclusion of 6 years olds adds new information on a less studied age group. Overall, this study adds to the growing body of evidence regarding the contributions of CRF to children’s health. Some limitations of the present study should be highlighted. Confounding factors such as diet, screen time or sports participation which were not assessed, may have affected the association. Also despite the value of objectively measured PA a large proportion of children (50.6%) did not meet the wear time criteria and thus were excluded from analysis. CRF was estimated using a field test (550-m distance run) which although validated, a more direct measure of $VO_{2\ Peak}$ in a laboratory setting would provide a more accurate fitness measurement. The study was also limited by its cross sectional design and potential effect of clustering at school level.

CONCLUSIONES

The present study shows that WHtR and school SES are all positively associated with CRF in primary school-aged children. MVPA was also found to be positively associated with CRF among 10 year olds. Furthermore, WHtR was found as the best predictor of CRF and should therefore be considered as a regular screening measure for health amongst this population. Those with higher CRF were found to have a better health profile than those with lower CRF, this was more pronounced among 10 year olds. Strategies to improve the health of primary school children should target increased CRF and prioritise low SES schools.

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