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An exploration of the perceived impact of COVID-19 on physical activity of Irish adolescents

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Abstract
Background Physical activity (PA) behaviours of adolescents were impacted by the stringent measures designed to prevent the spread of COVID-19, but little is known about the long-term impact of the pandemic on PA.
Purpose This study examines the perceived impact of COVID-19 on PA, the factors associated with these perceptions, and association with current PA behaviour.
Methods National representative sample from the island of Ireland completed the Children Sport Participation and Physical Activity (CSPPA) study in spring 2022. Questions included the 'perceived impact of COVID-19 restrictions' dimensions of PA and PA participation. Rasch analyses were used to determine item validity. Logistic regressions were used to determine risk and protective factors in the perceived positive impact and associations between the impact of COVID-19 and PA.
Results The scale was deemed reliable ($\alpha = 0.86$, $p < .001$) among the final sample of 12–20 year olds (weighted n = 2888). Perceived positive impact was lowest in school sport as PA levels increased and impact on fitness were highest among adolescents who were daily active (OR = 3.8, CI 2.7–5.3).
Discussion The pandemic had long lasting effects on adolescents' PA and health. Ways to overcome the lack of school sport during the pandemic is needed at post-primary school level. Making changes to school sport may be protective over low PA levels when considering the return from the pandemic.

Keywords Rasch analysis · Differential item functioning · School sport · Coronavirus · Children

1 Introduction

The COVID-19 pandemic affected the daily lives of people worldwide. Stringent measures, such as school closures and social distancing, were put in place to reduce the spread of the pandemic [1, 2], impacting ways to be physically active. At the height of the restrictions (Mar–Jun 2020), schools, leisure and fitness centres, and sport clubs were closed. In the Republic of Ireland, restrictions limited individuals to go outside their homes within a 5 km radius for exercise [3], coupled with a ban to have close in-person contact with other people. The restrictions in Northern Ireland were outlined by

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the United Kingdom (UK) government and differed from those in the Republic of Ireland with a "stay at home except for accessing medical care, daily exercise, shopping for essentials, and essential work travel" [4]. The entire island was locked down at this time.

Globally, in the first academic year (Sept 2020–June 2021) that followed, most schools reopened, although there were social distancing recommendations in place for adolescents. Recommendations included the creation of interaction 'bubbles' or 'pods' within which students were expected to remain during classroom activities. In addition, the usual movement of students, rather than teachers, between subject classes were not recommended (i.e. base classroom for student pods during the school day). Furthermore, large spaces, such as sports halls, were used as classrooms to maximise social distances between adolescents [5], reducing the available places to be physically active. Schools were given flexibility in implementing social distancing practices to best suit their individual needs and environmental contexts to avoid intermingling between classes during breaks. As vaccines were made available for school-aged children [6], the school term from Sept 2021 gradually returned back to normality.

As the pandemic spread, so did the vast array of evidence in relation to physical activity (PA) and COVID-19 [7]. For the majority of adolescents, the amount of PA reduced from pre-pandemic levels [8], although evidence is mixed. In a study of Irish adolescents, 20% reported doing more PA during the restrictions than before [9]. Notably, females who were not so physically active before the restrictions, reported new ways to be physically active, through home exercises and walking outdoors [10].

The majority of adolescents who took part in organised sports before the pandemic had these PA opportunities removed during lockdown and this was often a reason for doing less PA than usual [11]. A mitigating strategy to maintain PA levels came from the organised sport coaches, who set up remote sessions [12]. Other reported strategies was the rise of social influencers or celebrities, such as Joe Wicks in the UK, who created a channel for followers to do daily PA with him [13].

These experiences are likely to influence the way adolescents perceive the way the pandemic had an impact on their PA behaviours. Although these aforementioned initiatives may have stopped after the restrictions ended and schools reopened, there is still a need to be aware of the perceptions of the impact of COVID-19 on adolescents' PA. It has been well recognised and tested that perceptions of past behaviour are strong predictors of current behaviours, rooted in its influence towards individuals' motivation to be physical active [14]. Yet, less is known about risk and protective factors associated with these perceptions. As such, through an improved understanding of how adolescents perceived the impact of COVID-19 on PA, it may be possible to unveil novel ways to address the physical inactive pandemic. Therefore, the objectives of this study were to (i) examine the factor structure of items that measure the perceived impact of COVID-19 on PA, (ii) examine the risk and protective factors associated to the perceived impact of COVID-19 on PA, and (iii) examine the association between perceived positive COVID-19 impact items and PA behaviour.

2 Methods

2.1 Study design

The Children's Sport Participation and Physical Activity (CSPPA) study is a cross-sectional study based on a national representative sample of 10–20-year-olds. The initial sample was based on a single-stage cluster sampling method, where schools were stratified by school gender (boys only, girls only, mixed), socio-economic status (Republic of Ireland, disadvantaged or non-disadvantaged; Northern Ireland, percentage of free school meals), school location (urban or rural), and size (small, medium, large number of adolescents). A school was chosen at random and a year group from the school was put into the sampling frame, so that all adolescents in that year group were eligible to complete the online survey. A target sample of 3000 adolescents was sought to account for design effects. The study received ethical approval from the University of Limerick Education and Health Sciences' research ethics committee (2017_11_19_EHS) and was conducted in accordance with the Declaration of Helsinki. The adolescents voluntarily completed the online surveys during school class time under the supervision of the teacher through a robust survey provider, approved by the data protection officer at the University of Limerick. Teachers were given instructions on how to administer the survey. Informed consent was obtained from the parents or legal guardians of the students under the age of 16 years old and informed consent was obtained from the students over the age of 16 years old. Adolescents gave their assent prior to starting the survey and were free to withdraw from participation at any time without consequences.

Post-primary schools were allocated a random assignment to complete either survey A (with COVID-19 impact scale) or survey B (without COVID-19 impact scale). The primary school survey did not include items on COVID-19 impact,

hence were not included in the analyses. Only participants in schools allocated to survey A were kept in the data file for analyses. For the COVID-19 impact scale, 820 of the total participants (19%) were missing data. Those without responses to the scale were checked for randomness against levels of PA and were deemed missing at random (p = 0.765), hence were removed from the data file.

Sample weights were applied to the data collected from the database from Republic of Ireland's and Northern Ireland's Department of Education. The weights were based on the proportion of male and females within each year group. Population data for adolescents who identify as other or non-binary was not available, hence respondents who identified themselves as other, non-binary, or did not want to say were weighted as 1.

2.2 Variables

2.2.1 COVID-19 impact scale

Questions were adapted from those used in the Health Behaviour in School-age Children (HBSC) 2022 study [15]. The CSPPA study focused on dimensions of sport and PA [16], hence the adaptation of the HBSC items were based on the behaviours and context of PA deemed suitable by the research team. Adolescents were asked to rate the impact from COVID-19 on the following dimensions, (a) overall PA, (b) school sport and PA, (c) extra-curriculum sport, (d) community sport or PA, (e) fitness, and (f) overall health. The question layout was in a matrix with a five-point scale with higher scores on the scale indicating a more positive perception of the impact of COVID-19 on each dimension. The response options included 'very negative' (1), 'negative' (2), 'neither negative or positive' (3), 'positive' (4), and 'very positive' (5). In order to meet the aims of the study to investigate positive compared to other impacts (negative and neither), the items were dichotomised to reflect perceived positive impact (1) and any other perceived impact (0). This method was chosen as it has been used in studies conducted by the HBSC study [17].

2.2.2 Physical activity participation

At the beginning of the questions on PA behaviour, adolescents were given a definition of moderate to vigorous PA (MVPA) intensity, including examples. The single item question has been used extensively in international monitoring studies among school-age children [18, 19] originating from studies by Prochaska et al. [20]. In CSPPA, the two original questions regarding PA were used; one item asked how many days they were physically active for a total of at least 60 min in the past 7 days and another asked the same question but during a typical week. The response scale was 0 to 7 days. The answers to these items were averaged and a derived variable was created with the following recoding 1 = Low active (0–2 days), 2 = Somewhat active (3–4 days), 3 = Active (5–6 days), and 4 = Daily active (7 days). These items have shown acceptable validity through agreement against accelerometers [21] and were considered reliable [22] among same age adolescents.

In addition, adolescents were asked "During the past 7 days, on how many days did you do exercises that may strengthen your muscles, for example, as push-ups, sit-ups, weightlifting or heavy yard work?" There were eight responses from 0 to 7 days. The response categories were recoded into dichotomous outcomes, depending on if they met the WHO muscle strengthening guidelines of at least 3 days a week [23].

2.3 Risk and protective factors

The adolescents were asked to identify their gender as female (1), male (2), and were given the option to identify as non-binary, other, or rather not say. There were too few cases for those who identified as non-binary (n = 53) or other (n = 16) to group, and as gender was treated as a risk or protective factor, those who reported "I'd rather not say" (n = 58) were also removed from the analyses. The adolescents entered their age, and due to data protection regulations, this variable was derived so that there were groups of 10-11y (1), 12-13y (2), 14-15y (3), and 16-20y (4). Although the last group appears to be of 4 years, they consist of students on the island of Ireland in either the senior cycle (ROI) or 'A-levels' (NI) stage of learning. As students who are over 18 years old may remain in school, it was deemed more suitable to broaden the age group and include their responses, as opposed to exclude them. Due to the COVID-19 items being only available to adolescents in post-primary schools, ages 10-11y were removed (n = 24) as they were considered as outliers.

Self-reporting on the presence of disabilities was measured using the self-report version of the UNICEF/Washington Group questions on functional difficulties [24]. There were 11 functions measured: seeing, hearing, walking, self-care,

speaking, learning, remembering, concentration, behaviour control, accepting changes to routines, and making friends. The response scale contained four options, no difficulty (1), some difficulty (2), a lot of difficulty (3), and cannot do (4). As per international recommendations [25], individuals who ranked a lot of difficulty or cannot do for a particular function were coded to have functional difficulties. Having at least one function with functional difficulties resulted in the individual being coded as a person with disabilities, as recommended by the Washington Group/UNICEF for making internationally comparable estimates of disabilities [26].

The Family Affluence Scale (FAS) was used to assess socioeconomic status (SES) and was measured using six items on material wealth in the student's family. Items included a) car ownership, b) own bedroom, c) number of computers in their house, d) number of bathrooms in their house, e) if they have a dishwasher, and f) number of times they travelled outside of Ireland for a holiday in the last year. The items were sum scored and then ranked for a relative FAS scale with lower 20% as low FAS, highest 20% as high FAS, and the 60% in the middle as medium FAS. These items have been used extensively for adolescent self-report studies as a proxy for social economic status [27].

Students were asked to describe their residence by the size of the jurisdiction where they live. The options included 'village < 3,000 people', 'town < 20,000 people', 'suburban < 70,000 people', and 'city > 70,000 people'. The address of the school was coded by the researchers to determine if the school was in an urban or rural environment.

2.3.1 Statistical methods

The analyses for the first aim (factor structure of the COVID-19 impact scale), was to use differential item functioning (DIF) through a Rasch model run on Jamovi 2.4.11 using the snowIRT—Item Response Theory module [28]. All COVID-19 items were tested through DIF to predict if the response scale was performing accurately. It was expected that items would hold well through DIF. To determine the factor structure, principal component analyses, with a Promax rotation, were carried out to reveal one factor was present from the 6 items. All factor loadings were between 0.78 and 0.84, with eigenvalue of 3.93. The Cronbach alpha was a = 0.894 for the single factor.

The second aim of the study (risk and protective factors associated with the COVID-19 impact scale) was analysed by multiple binary regression analyses for each item on the COVID-19 scale. The items in COVID-19 scale were dichotomised so that negative and no impact were grouped together, as the reference category, and responses of positive impact as the outcome. Risk and protective factors were gender, age, disability status and FAS, residential place of dwelling, school location, and jurisdiction of Ireland. Reference categories were male, 12-13y olds, no disability, low FAS, living in a village, rural schools, and data collected from the Republic of Ireland.

To answer the third research question (association between COVID-19 impact items and PA behaviour), the association between PA behaviour and the impact score were analysed through a multinomial linear regression analysis for MVPA and binary logistic for muscle strengthening as dependent variables, with other variables used as covariates.

Analyses for aims two and three were carried out on IBM SPSS 29.0. The study has been registered on the OSF as a secondary data preregistration (https://osf.io/gufc9). During the production of the study, we chose to carry out one analytical deviation from the protocol. This was in relation to the third research question, where multinomial regression was used, as MVPA was the dependent variable, and the different items of perceived impact of COVID-19 were treated as independent variables. The main reason for this was to reduce the number of statistical tests as well as have more detailed results based on the category variables of independent and dependent variables. We did carry out the multiple linear regression tests as outlined in the protocol, and the direction of results hardly changed, but we felt the categorical approach provided more informative results than using the normally distributed variables.

3 Results

3.1 Participants

The final weighted data set consisted of 2888 participants (male = 50.4%, female = 49.6%) who completed the items on COVID-19. There were subtle differences in the sample between adolescents in Northern Ireland and the Republic of Ireland (Table 1). Most notably, the sample in the Republic of Ireland compared to those in Northern Ireland were generally older, more affluent, from rural locations, and more physically active.

Table 1 Distribution of sample of adolescents in the study, with comparison by χ^2 Test of Independence

	Northern Ireland	Republic of Ireland	Total	P-value
Total (n)	757	2131	2888	
Gender				0.729
Female	49.0%	49.7%	49.6%	
Male	51.0%	50.3%	50.4%	
Age Group				< 0.001
12-13y	33.3%	19.3%	23.0%	
14-15y	39.6%	38.2%	38.6%	
16-20y	27.1%	42.5%	38.5%	
Person with functional difficulties				0.093
Without Disabilities	69.0%	72.2%	71.3%	
With Disabilities	31.0%	27.8%	28.7%	
Family affluence categories				< 0.001
Low family affluence	30.5%	20.1%	22.8%	
Medium family affluence	50.4%	57.5%	55.6%	
High family affluence	19.0%	22.4%	21.5%	
School location				< 0.001
Rural	24.2%	77.5%	63.6%	
Urban	75.8%	22.5%	36.5%	
Moderate-to-vigorous physical activity				0.028
Low active (0–2 days)	19.0%	14.9%	16.0%	
Somewhat active (3–4 days)	36.7%	37.4%	37.2%	
Active (5–6 days)	32.0%	36.1%	35.0%	
Daily active (7 days)	12.3%	11.5%	11.7%	
Muscle strengthening activity				0.323
Not meeting muscle guidelines (< 3 days a week)	60.9%	58.9%	59.4%	
Meeting muscle guidelines (at least 3 days a week)	39.1%	41.1%	40.6%	

3.2 Outcomes data

Approximately half the respondents reported a positive impact of COVID-19 on overall PA, their fitness levels and overall health. A third reported positive impact on school sport and extracurricular activities. More males than females reported a positive impact on school sport ($p < 0.001$), extra-curriculum ($p < 0.001$) and community sport ($p = 0.009$) (Table 2).

3.3 Rigorousness of perceived COVID-19 impact scale

Based on the Item Response Theory's Polytomous Rasch analyses, the person reliability score was 0.863 ($p < 0.001$), implying that the results of the perceived COVID-19 impact can be estimated with a precision of 86%. The Cronbach α was equally high ($\alpha = 0.894$) across all items for a single factor with correlations between items ranging from 0.45 (Overall health x Extra curriculum sport) to 0.73 (Overall health x Fitness level). For each of the items, there were slightly higher infit scores than outfit scores, suggesting that information were closer fit than the outliers against the expected scores. The lowest outfit score was 0.87 for the item of impact on Fitness level, and the highest of infit score was 1.08 for the item on impact on Overall PA (Appendix Table 1). Overall, the distribution was acceptable to be used as a five-point scale for all the items (Appendix Fig. 1).

3.4 Factors associated with PA COVID-19 impact scale

Perceptions of a positive impact of COVID-19 on the PA items were remarkably lower among adolescents with disabilities, particularly in the impact on Fitness levels (OR = 0.67, CI 0.57–0.80) compared to adolescents without disabilities (Table 3). Similarly, the odds ratio for adolescents living in cities was the lowest in the perceived impact on School sport (OR = 0.61, CI 0.44–0.84) and Overall health (OR = 0.61, CI 0.45–0.81). There were more females than males who reported positive impact of COVID-19 on School sport (OR = 1.36, CI 1.16–1.60), Extra curriculum sport (OR = 1.82, CI 1.55–2.15) and Community sport (OR = 1.18, CI 1.01–1.38). The opposite was true for older adolescents, since the odds ratios reduced as age groups increased from the reference group of 12–13-year-olds. In addition, the odds ratios for adolescents in high family affluence groups to report perceived positive impact on all areas of PA were generally higher, compared to low family affluence groups. There was only one difference in relation to which jurisdiction the adolescent students were located, where more perceived positive impact on Extra-curriculum sport was reported by those in the Republic of Ireland than those in Northern Ireland (OR = 1.26, CI 1.01–1.57).

3.5 Associations between PA COVID-19 impact scale and PA

Perceived positive COVID-19 impact scale scores were associated with increased days of MVPA and muscle strengthening (Fig. 1). When compared to those who reported 0–2 days (low active), there were positive associations between PA COVID-19 impact and those who reported 3–4 days (somewhat active; OR = 1.72, CI 1.51–1.95), 5–6 days (active; OR = 2.23, CI 1.96–2.55), and daily MVPA (daily active; OR = 2.50, CI 2.11–2.94). There was also a positive association with reporting 3–7 days of muscle strengthening in a week (meeting WHO guidelines; OR = 1.37, CI 1.26–1.49) when compared to those who reported 0–2 days (not meeting WHO guidelines). There was a positive association between males and high family affluence adolescents with muscle strengthening at least 3 times a week (meeting WHO guidelines), compared to the respective reference categories. The odds ratios can be seen in Fig. 1.

4 Discussion

Findings from the current study suggest the scale on the perceived impact of COVID on adolescents' PA and health is a robust measure in its original format. In line with the study objectives, gender was a risk and protective factor on the perceived impact of COVID-19 on PA, and finally, there were positive associations between the impact of COVID-19 on extra-curriculum, community sport, and fitness levels with daily MVPA. With these main findings, we found the scale to be a suitable composite of different PA contexts, as well as with overall health. Such a finding helps to verify the psychometric properties of the measure, particularly when exploring associations with other factors. COVID-19 affected the lives of all people, with reports of increased negative PA behaviours and being unable to rebound back to normal PA levels [15, 29]. Survey measures are helpful to assess perceptions of individuals through quantitative research methods, and can be used to supplement interview data, particularly in relation to the wellbeing of individuals during the COVID-19 pandemic [30].

Our findings about the differences between males and females' perceptions provide insight to expand the current understanding of known gender differences in sport participation and PA and how the COVID-19 pandemic restrictions

Table 2 The impact of COVID-19 (%) on various items on PA by gender

	Females (n = 1431)			Males (n = 1457)			Total (n = 2888)			p-value
	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	
Overall PA	25.1	24.4	50.6	27.3	23.8	48.9	26.2	24.1	49.7	0.393
School sport	38.0	31.3	30.7	32.1	30.1	37.8	35.0	30.7	34.3	< 0.001
Extra-curriculum sport	37.2	37.3	25.5	27.4	34.1	38.5	32.2	35.7	32.1	< 0.001
Community sport	32.9	27.6	39.4	27.9	28.2	43.9	30.4	27.9	41.7	0.009
Fitness level	22.9	27.4	49.7	22.2	25.8	52.0	22.5	26.6	50.9	0.458
Overall health	18.1	29.7	52.2	16.3	30.3	53.3	17.2	30.0	52.7	0.454

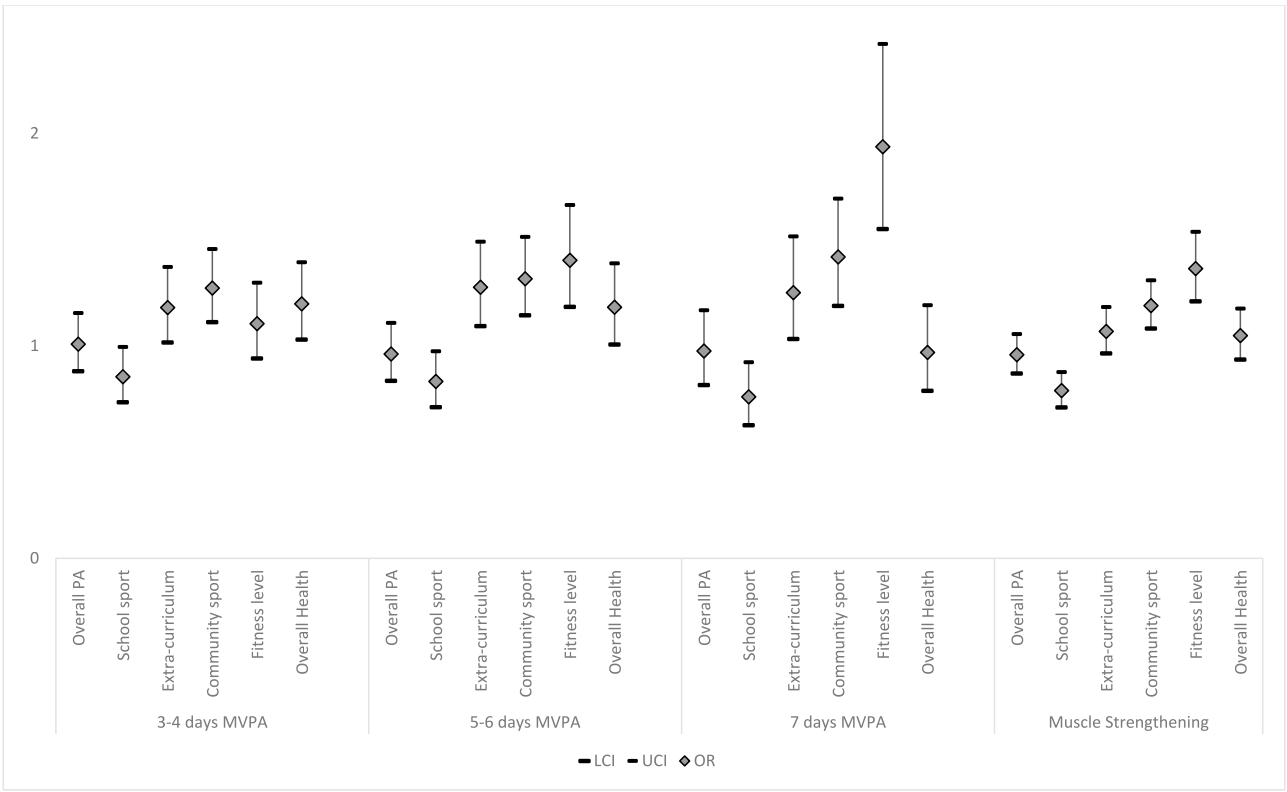

Fig. 1 Odds ratios from multinomial (MVPA) and binary (muscle dtrengthening) logistic regressions and the association with PA impact of COVID-19 with 0–2 days as reference categories

may have impacted on existing gender differences in PA. Evidence from around the globe consistently shows that males participate in more PA than females [18]. Data from Ireland supports this global trend, with more males than females reporting to engage in regular PA and sport [31]. In Ireland, targeted programmes have been shown to be effective to promote PA among female adolescents [32]. Despite these small wins, these female focused programmes often face challenges such as dealing with competitive sport drop out [33], increased homework, other maladaptive patterns of behaviour that take time away from being physically active [34], as well as lower social support to participate in PA and sport when compared to their male counterparts [31].

Irish adolescents had reported that time spent at home during the COVID-19 pandemic had mixed effects on PA behaviour, with females reported to do more PA and males reported difficulties to stay active [11]. Perceptions of the impact were likely to be influenced by prior experiences in PA [14], which was also shown in a study by Arundel et al. [35], where prior PA levels were deemed as a predictor for the way COVID-19 impacted PA levels. Further evidence of pre-pandemic behaviours were discussed from earlier reports of Irish adolescents' behaviours, where, on average, 13–16% more males than females participated in school sports [16]. In Ireland, extra-curriculum time takes place during school breaks and afterschool. It was one lost opportunity to be physically active during lockdown and during the immediate return to school [11]. Ridgers et al. [36] reported females participated in less PA during recess time than their male counterparts, thus it is logical that fewer males than females had reported a positive impact on PA during school sports.

The oldest age group (16-20y) were also more likely to report a positive impact of COVID-19 on overall PA, despite having the lowest levels of PA, and fewer were likely to report a negative impact on PA in the school. The low frequency of a perceived negative impact could be due to the overall positive responses to the scale seen from the Rasch analyses, coupled with low amounts of students of this age who participate in school sport [16]. Time and costs are consistently cited barriers to sport participation in children and adolescents [31], particularly for older adolescents where time would be spent on preparing for end of school exams, such as leaving certs and A-levels. With schools closed, and many other socialising options restricted, older adolescents might have had more time available than usual to engage in PA [11].

In the Republic of Ireland, examinable Leaving Certificate Physical Education (LCPE) was piloted in 2018, and has been rolled out nationally since September 2020, with approximately half of all post-primary schools in Ireland now

Table 3 Factors associated with a perceived positive impact from COVID-19

	Overall PA			School sport			Extra-curriculum			Community sport			Fitness			Health		
	B	LCI	UCI	B	LCI	UCI	B	LCI	UCI	B	LCI	UCI	B	LCI	UCI	B	LCI	UCI
Gender																		
Female	REF			REF			REF			REF			REF			REF		
Male	0.88	0.76	1.03	**1.36**	**1.16**	**1.60**	**1.82**	**1.55**	**2.15**	**1.18**	**1.01**	**1.37**	1.04	0.89	1.21	1.01	0.87	1.17
Age Group																		
12-13y	REF			REF			REF			REF			REF			REF		
14-15y	0.95	0.78	1.16	**0.76**	**0.62**	**0.93**	**0.72**	**0.58**	**0.88**	0.82	0.67	1.00	1.00	0.82	1.22	0.93	0.76	1.14
16-20y	1.14	0.93	1.39	**0.60**	**0.49**	**0.75**	**0.54**	**0.44**	**0.68**	**0.75**	**0.61**	**0.92**	0.91	0.75	1.11	**0.75**	**0.61**	**0.92**
Disabiities																		
No Disabilities	REF			REF			REF			REF			REF			REF		
Disabilities	**0.73**	**0.62**	**0.87**	**0.77**	**0.64**	**0.92**	**0.75**	**0.63**	**0.90**	**0.77**	**0.65**	**0.92**	**0.67**	**0.57**	**0.80**	**0.72**	**0.61**	**0.85**
Family affluence																		
Low	REF			REF			REF			REF			REF			REF		
Medium	1.11	0.92	1.34	0.95	0.78	1.16	0.95	0.78	1.17	1.14	0.94	1.39	1.24	1.03	1.49	1.19	0.99	1.44
High	**1.79**	**1.43**	**2.25**	**1.58**	**1.25**	**2.00**	**1.56**	**1.23**	**1.98**	**1.88**	**1.49**	**2.36**	**1.89**	**1.51**	**2.37**	**1.74**	**1.39**	**2.19**
Home location																		
Village	REF			REF			REF			REF			REF			REF		
Towns	**0.73**	**0.61**	**0.87**	0.86	0.71	1.04	**0.78**	**0.64**	**0.95**	**0.83**	**0.69**	**0.99**	**0.71**	**0.60**	**0.85**	**0.83**	**0.69**	**0.99**
Suburban	0.83	0.66	1.05	0.85	0.66	1.09	0.83	0.65	1.07	0.94	0.74	1.19	0.84	0.66	1.06	**0.76**	**0.60**	**0.96**
City	**0.71**	**0.53**	**0.95**	**0.61**	**0.44**	**0.84**	**0.58**	**0.42**	**0.81**	**0.62**	**0.45**	**0.84**	**0.69**	**0.52**	**0.93**	**0.61**	**0.45**	**0.81**
School Location																		
Rural	REF			REF			REF			REF			REF			REF		
Urban	**0.78**	**0.64**	**0.95**	0.89	0.72	1.10	0.95	0.77	1.18	0.85	0.70	1.05	0.86	0.70	1.05	0.82	0.67	1.00
Jurisdiction																		
Northern Ireland	REF			REF			REF			REF			REF			REF		
Republic of Ireland	0.94	0.77	1.15	1.12	0.90	1.39	**1.26**	**1.01**	**1.57**	1.09	0.88	1.33	1.07	0.87	1.31	0.93	0.76	1.14

Bold text; $p < 0.05$

offering LCPE (~ 330 schools) to their 5th and 6th year students (aged approximately 16–20 years). Such a curricular change may have equipped some older students in the ROI with skills and knowledge to overcome barriers that occurred from the pandemic restrictions. Students and teachers' competencies in digital technology increased during this period [37], and this increase may have led to improved understanding of ways to be physically active amongst these adolescents, especially given the compulsory student component of physical activity related assessment in LCPE. It should be noted however that only a small proportion of Leaving Certificate students in those schools offering LCPE elect to take this subject. The rise of social media use during lockdown and online role models may have also been another viable source of inspiration [13]. Other students often experienced the struggles of physical educators to produce high quality physical education over digital platforms during the pandemic [38, 39].

A consistent result, of more positive impact from COVID-19 across all items, appeared among adolescents without disabilities or from high family affluence, when compared to those with disabilities or from low affluence families, respectively. Adolescents with disabilities were affected negatively by the pandemic, with family supporting attitudes towards PA had played a role in activity behaviours [40]. During the restrictions, increases of PA were reported by those who had access to ways to be physically active, such as equipment at home and more computers and phones to connect to the internet [41], of which these items are considered to be more readily available among higher affluent families compared to lower affluent families. These disparities still exist, and the pandemic may have highlighted inequities that need to be addressed in future health promotion work.

Not surprisingly, more active adolescents (MVPA levels increased compared to low active adolescents) were increasingly likely to report a perceived positive impact of COVID-19 on each item related to PA, particularly on the impact on community sports. These patterns could be related to the concept of physical literacy [42, 43]. Researchers have found adolescents with higher levels of physical literacy domains, such as confidence, motivation and enjoyment of

PA, are more likely to engage in PA and may have been more likely to seek opportunities for PA during the restrictions than those who are less physically active and have lower physical literacy [44, 45]. More insights are needed to confirm these reasons.

The pattern associated with muscle strengthening exercises for at least three days a week was not so clear. In most cases, there were positive associations. Yet, there were no associations with school related PA, and this could be due to the low levels of muscle strengthening activities in the schools [46], or that muscle strengthening has, in the past, been reported by the amount of out-of-school exercise [47]. Adolescents made use of social media channels during the pandemic, with celebrities such as Joe Wicks providing physical fitness exercises and activities to do [13]. These results have demonstrated potential lasting effects of around two years after from living through the pandemic [29]. Researchers who have conducted one-year follow up studies have reported a decline on fitness levels of children and these could have detrimental effects if not intervened [48, 49]. The perceived impact of COVID-19 on PA provided by these adolescents may shed light into programmes that bring back PA and fitness levels among adolescents.

4.1 Strengths and limitations

This study was conducted from self-report measures on items related to COVID-19, approximately two years after the initial school closures. Some recall bias of the actual impact on the different areas and settings for PA may be present in the instrument. The data were cross-sectional, therefore causality between variables cannot be truly established. All individuals were treated the same in the Rasch analyses, and there is likely to be variation in responses. Investigating different profiles of how the impact of COVID-19 was for different people on the current PA levels is beyond the scope of this study and it could be the direction for future studies on this area. The analysis was only on the positive compared to other responses (neutral and negative) and could have used other regrouping, such as negative compared to other responses to answer other research questions. There could have been more potential and residual confounders, other than the sociodemographic variables used in this study, although, as this is the first time we have data on the impact of COVID-19 on PA, we decided to not include further confounders.

This study was based on a national representative sample of adolescents in post-primary schools on the island of Ireland. The scale was used for the first time, without the normal procedures to test and validate the measures given the changing landscape of the pandemic we were living through during data design and collection. The resulting items demonstrated suitable use and may be useful in other contexts to assess the perceptions of adolescents' experience and impact from COVID-19. With more confidence that the measures used have acceptable psychometric testing, the examination of the risk and protective factors on these associations shed light into the differences in the way adolescents considered how COVID-19 had an impact on their PA behaviour. Furthermore, the positive associations with PA and perceived positive impact are informative to developing theory-based programmes to promote PA for health among adolescents as life returns from COVID-19 era.

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Data availability Dataset is shared onto the Irish Social Science Data Archive and can be accessed through https://www.ucd.ie/issda/data/csppa/csppa2022/. The study was registered on the OSF. https://osf.io/gufc9.

Declarations

Competing interests The authors declare no competing interests.

Appendix 1

Item functioning

Item statistics of the rating scale model

	Measure	S.E	Infit	Outfit
Overall physical activity	– 2.58	0.0233	1.074	1.045
School sport	– 2.01	0.0230	0.945	0.948
Extra curriculum	– 2.02	0.0230	1.056	1.052
Community Sport	– 2.35	0.0231	1.088	1.034
Fitness Level	– 2.71	0.0235	0.900	0.884
Overall health	– 2.90	0.0237	1.005	1.003

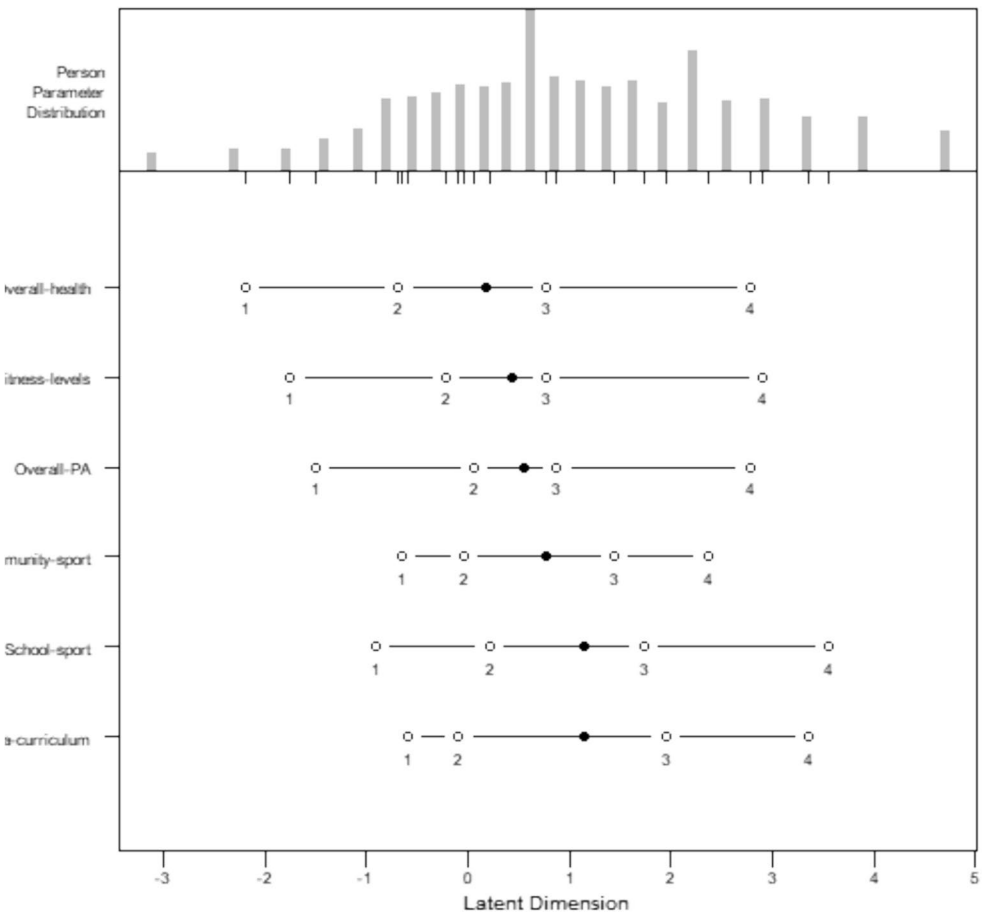

Fig. 2 Person-Item Map for each

Infit = Information-weighted mean square statistic; Outfit = Outlier-sensitive means square statistic
See Fig. 2 here.

References

1. UNESCO. Survey on national education responses to COVID-19 school closures 2020.
2. Viner RM, Russell SJ, Croker H, Packer J, Ward J, Stansfield C, et al. School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. Lancet Child Adolescent Health. 2020;4:397–404. https://doi.org/10.1016/S2352-4642(20)30095-X.
3. Ellis WE, Talebi S, Dumas TM, Forbes L. Adolescents' physical activity and psychological adjustment across the first year of the COVID-19 pandemic. J Phys Act Health. 2022;19:481–9. https://doi.org/10.1123/jpah.2022-0018.
4. Davies NG, Barnard RC, Jarvis CI, Russell TW, Semple MG, Jit M, et al. Association of tiered restrictions and a second lockdown with COVID-19 deaths and hospital admissions in England: a modelling study. Lancet Infect Dis. 2021;21:482–92. https://doi.org/10.1016/S1473-3099(20)30984-1.
5. UNICEF, Bank W. Framework for reopening schools 2020.
6. Eberhardt CS, Siegrist C-A. Is there a role for childhood vaccination against COVID-19? Pediatr Allergy Immunol. 2021;32:9–16.
7. Kharel M, Sakamoto JL, Carandang RR, Ulambayar S, Shibanuma A, Yarotskaya E, et al. Impact of COVID-19 pandemic lockdown on movement behaviours of children and adolescents: a systematic review. BMJ Glob Health. 2022;7: e007190. https://doi.org/10.1136/bmjgh-2021-007190.
8. Stockwell S, Trott M, Tully M, Shin J, Barnett Y, Butler L, et al. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. BMJ Open Sport Exercise Med. 2021;7:e000960.
9. Ng KW, Koski P, Lyyra N, Palomaki S, Mononen K, Blomqvist M, et al. Finnish late adolescents' physical activity during COVID-19 spring 2020 lockdown. BMC Public Health. 2021;21:2197. https://doi.org/10.1186/s12889-021-12263-w.
10. O'Kane SM, Lahart IM, Gallagher AM, Carlin A, Faulkner M, Jago R, et al. Changes in Physical activity, sleep, mental health, and social media use during COVID-19 lockdown among adolescent girls: a mixed-methods study. J Phys Act Health. 2021;18:677–85. https://doi.org/10.1123/jpah.2020-0649.
11. Ng KW, Cooper J, McHale F, Clifford J, Woods C. Barriers and facilitators to changes in adolescent physical activity during COVID-19. BMJ Open Sport Exerc Med. 2020;6: e000919. https://doi.org/10.1136/bmjsem-2020-000919.
12. Zago M, Lovecchio N, Galli M. Players at home: physical activity and quality of life in 12–17 years-old football (soccer) players during the COVID-19 lockdown. Int J Sports Sci Coach. 2022;17:626–36. https://doi.org/10.1177/17479541211041703.
13. Ahmed W, Aiyenitaju O, Chadwick S, Hardey M, Fenton A. The influence of Joe Wicks on physical activity during the COVID-19 pandemic: Thematic, location, and social network analysis of x data. J Med Internet Res. 2024;26: e49921. https://doi.org/10.2196/49921.
14. Hagger MS, Chatzisarantis NLD, Biddle SJH. The influence of self-efficacy and past behaviour on the physical activity intentions of young people. J Sports Sci. 2001;19:711–25.
15. Ng KW, Moreno-Maldonado C, Stavrou M, Lenzi M. Left behind: inequalities in the negative impacts of the COVID-19 pandemic among adolescents in the WHO European Region: Impact of the COVID-19 pandemic on young people's health and well-being from the findings of the HBSC survey round 2021/2022. Copenhagen, Denmark: WHO Regional Office for Europe; 2023.
16. Woods CB, Powell C, Saunders JA, O'Brien W, Murphy MH, Duff C, et al. The children's sport participation and physical activity study 2018 (CSPPA 2018) 2018.
17. Residori C, Költő A, Dóra Eszter V, Gabhainn SN. Age, gender and class: how the COVID-19 pandemic affected school-aged children in the WHO European Region: impact of the COVID-19 pandemic on young people's health and well-being from the findings of the HBSC survey round 2021/2022 2023.
18. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1.6 million participants. Lancet Child Adolescent Health. 2020;4:23–35.
19. Kalman M, Inchley JC, Sigmundová D, Iannotti RJ, Tynjälä JA, Hamrik Z, et al. Secular trends in moderate-to-vigorous physical activity in 32 countries from 2002 to 2010: a cross-national perspective. Eur J Pub Health. 2015;25:37–40.
20. Prochaska JJ, Sallis JF, Long B. A physical activity screening measure for use with adolescents in primary care. Arch Pediatr Adolesc Med. 2001;155:554.
21. Hardie-Murphy M, Rowe DA, Belton S, Woods CB. Validity of a two-item physical activity questionnaire for assessing attainment of physical activity guidelines in youth. BMC Public Health. 2015. https://doi.org/10.1186/s12889-015-2418-6.
22. Ng KW, Hämylä R, Tynjälä J, Villberg J, Tammelin T, Kannas L, et al. Test-retest reliability of adolescents' self-reported physical activity item in two consecutive surveys. Arch Public Health. 2019;77:9. https://doi.org/10.1186/s13690-019-0335-3.
23. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54:1451–62. https://doi.org/10.1136/bjsports-2020-102955.
24. Ng KW, Asunta P, Kärnä E, Rintala P. Adapting school physical activity and health surveys for children with disabilities. Alter Eur J Dis Res. 2022;16:73–93.
25. Loeb M, Mont D, Cappa C, Palma ED, Madans J, Crialesi R. The development and testing of a module on child functioning for identifying children with disabilities on surveys. I: background. Dis Health J. 2018;11:495–501.
26. Cappa C, Mont D, Loeb M, et al. The development and testing of a module on child functioning for identifying children with disabilities on surveys. III: Field testing. Disabil Health J. 2018;11(4):510–8. https://doi.org/10.1016/j.dhjo.2018.06.004.
27. Currie C, Alemán Díaz AY, Bosáková L, De Looze M. The international Family Affluence Scale (FAS): Charting 25 years of indicator development, evidence produced, and policy impact on adolescent health inequalities. SSM Population Health. 2023. https://doi.org/10.1016/j.ssmph.2023.101599.

28. Aryadoust V, Ng LY, Sayama H. A comprehensive review of Rasch measurement in language assessment: recommendations and guidelines for research. Lang Test. 2021;38:6–40. https://doi.org/10.1177/0265532220927487.
29. Haug E, Mæland S, Lehmann S, Bjørknes R, Fadnes LT, Sandal GM, et al. Increased gaming during COVID-19 predicts physical inactivity among youth in Norway—a two-wave longitudinal cohort study. Front Public Health. 2022;10: 812932. https://doi.org/10.3389/fpubh.2022.812932.
30. Ranieri V, Sem Stoltenberg A, Pizzo E, Montaldo C, Bizzi E, Edwards S, et al. COVID-19 welbeing study: a protocol examining perceived coercion and psychological well-being during the COVID-19 pandemic by means of an online survey, asynchronous virtual focus groups and individual interviews. BMJ Open. 2021;11: e043418. https://doi.org/10.1136/bmjopen-2020-043418.
31. Woods CB, Crowley E, Powell C, O'Brien W, Murphy MH, Belton S, et al. Socio-ecological correlates of physical activity in a nationally representative sample of adolescents across Ireland and Northern Ireland. Preventive Med Rep. 2021;23: 101472. https://doi.org/10.1016/j.pmedr.2021.101472.
32. O'Brien W, Hogan I, Coppinger T. Coaches' Experience of the "Gaelic4Teens" program in Ireland. Int Sport Coaching J. 2023;10:70–7. https://doi.org/10.1123/iscj.2021-0094.
33. Crane J, Temple V. A systematic review of dropout from organized sport among children and youth. Eur Phys Educ Rev. 2015;21:114–31. https://doi.org/10.1177/1356336X14555294.
34. Yu J, McLellan R, Winter L. Which boys and which girls are falling behind? Linking adolescents' gender role profiles to motivation, engagement, and achievement. J Youth Adolescence. 2021;50:336–52. https://doi.org/10.1007/s10964-020-01293-z.
35. Arundell L, Salmon J, Timperio A, Sahlqvist S, Uddin R, Veitch J, et al. Physical activity and active recreation before and during COVID-19: the our life at home study. J Sci Med Sport. 2022;25:235–41. https://doi.org/10.1016/j.jsams.2021.10.004.
36. Ridgers ND, Timperio A, Crawford D, Salmon J. What factors are associated with adolescents' school break time physical activity and sedentary time? PLoS ONE. 2013;8: e56838. https://doi.org/10.1371/journal.pone.0056838.
37. O'Brien N, O'Brien W, Costa J, Adamakis M. Physical education student teachers' wellbeing during COVID-19: Resilience resources and challenges from school placement. Eur Phys Educ Rev. 2022;28:873–89. https://doi.org/10.1177/1356336X221088399.
38. Centeio E, Mercier K, Garn A, Erwin H, Marttinen R, Foley J. The success and struggles of physical education teachers while teaching online during the COVID-19 pandemic. J Teach Phys Educ. 2021;40:667–73. https://doi.org/10.1123/jtpe.2020-0295.
39. Kovacs VA, Csanyi T, Blagus R, Brandes M, Starc G, Rocha P, et al. Ringing the bell for quality P.E.: What are the realities of remote physical education? Eur J Public Health. 2022;32:38–43. https://doi.org/10.1093/eurpub/ckac082.
40. Arbour-Nicitopoulos KP, Mitra R, Sharma R, Moore SA. Outdoor physical activity and play among Canadian children and youth with disabilities during the COVID-19 pandemic: findings from the national physical activity measurement study. Adapt Phys Activ Q. 2023;40:571–86. https://doi.org/10.1123/apaq.2022-0080.
41. Wilson K, Schmidt A, Hess A, Vanos J, Ross A. Shifts in self-reported physical activity, sedentary behavior, and play among lower-socioeconomic children during the COVID-19 pandemic: a repeated cross-sectional study. Am J Health Promot. 2022;36:1335–8. https://doi.org/10.1177/08901171221091234.
42. Whitehead M. The concept of physical literacy. Phys Educ Sport Pedagog. 2001;6:127–38.
43. Whitehead M. Physical literacy : Throughout the lifecourse 2010.
44. Belanger K, Barnes JD, Longmuir PE, Anderson KD, Bruner B, Copeland JL, et al. The relationship between physical literacy scores and adherence to Canadian physical activity and sedentary behaviour guidelines. BMC Public Health. 2018;18:1042. https://doi.org/10.1186/s12889-018-5897-4.
45. Brown DMY, Dudley DA, Cairney J. Physical literacy profiles are associated with differences in children's physical activity participation: a latent profile analysis approach. J Sci Med Sport. 2020;23:1062–7. https://doi.org/10.1016/j.jsams.2020.05.007.
46. Varea V, González-Calvo G. Touchless classes and absent bodies: teaching physical education in times of COVID-19. Sport Educ Soc. 2020;26:831–45.
47. Sigmundová D, Sigmund E, Tesler R, Ng KW, Hamrik Z, Mathisen FKS, et al. Vigorous physical activity in relation to family affluence: time trends in Europe and North America. Int J Public Health. 2019;64:1049–58. https://doi.org/10.1007/s00038-019-01271-8.
48. Basterfield L, Burn NL, Galna B, Batten H, Goffe L, Karoblyte G, et al. Changes in children's physical fitness, BMI and health-related quality of life after the first 2020 COVID-19 lockdown in England: a longitudinal study. J Sports Sci. 2022;40:1088–96. https://doi.org/10.1080/02640414.2022.2047504.
49. Jurak G, Morrison SA, Kovač M, Leskošek B, Sember V, Strel J, et al. A COVID-19 crisis in child physical fitness: creating a barometric tool of public health engagement for the Republic of Slovenia. Front Public Health. 2021;9: 644235. https://doi.org/10.3389/fpubh.2021.644235.