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The Associations Between Accelerometer-Measured Physical Activity Levels and Mental Health in Children and Adolescents with Intellectual Disabilities During the COVID-19 Pandemic

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Abstract

To examine the associations between physical activity (PA) levels and mental health in children and adolescents with intellectual disabilities (IDs) during the COVID-19 pandemic, 117 participants aged between 6 and 17 years with IDs from 10 Hong Kong special schools were included. There were positive dose–response associations between PA (i.e., light PA, moderate PA, and vigorous PA) and mental health, and participants with higher levels of moderate-to-vigorous PA (MVPA) and self-concept (SC) had better social quality of life (QoL) than those with lower levels of MVPA and SC. Moreover, personal and environmental factors such as age, body mass index, school, sex, ID level, and parental education level influenced the PA levels and QoL in children and adolescents with IDs.

Keywords Youth · Quality of life · Self-concept · Special educational needs · Special schools

Introduction

Intellectual disabilities (IDs) are characterized by impairments in mental functioning and adaptive behaviors, such as conceptual, social, and practical skills (Regier et al., 2009), which usually develop before the age of 18 (Hessl et al., 2016). The prevalence of IDs varies between 1 and 3% globally with 85% being mild, 10% moderate, 3.5% severe, and 1.5% profound (Young et al., 2015). Obesity is more prevalent in children and adolescents with IDs than in those with typical development (TD) (Maïano et al., 2016). Moreover, children and adolescents with IDs face three to four times higher incidence of mental disorders than their peers with TD (Munir, 2016), and they are more likely to be exposed to socioeconomic disadvantage (Glasson et al., 2020).

The World Health Organization (WHO, 2020) suggested that children and adolescents living with disabilities should have an average of at least 60 min/day of moderate-to-vigorous intensity, most aerobic, physical activity (PA) weekly and at least three days/week of vigorous-intensity aerobic activity. PA intensities are classified as light (LPA), moderate (MPA), vigorous (VPA), and moderate-to-vigorous (MVPA), representing activities performed between 1.5 and 3, 3 and 6, 6 or more, and ≥ 3 metabolic equivalent of tasks, respectively (Bull et al., 2020). Previous studies used accelerometers to measure PA levels in children and adolescents with IDs. For example, Downs et al., (2016) found that children with IDs spent 49.4 min/day in MVPA with only 23.7% of them meeting the MVPA guidelines, and male participants engaged 12 more min/day in MVPA than female participants. Zhu et al. (2020) reported that youth with IDs spent 63.1 ± 30.72 min/day in LPA and 29.82 ± 20.65 min/day in MVPA, and youth with moderate ID were more active than those with severe ID. Environmental factors, such as school and family, were correlated with PA levels in children and adolescents with IDs (McGarty & Melville, 2018; Stanish et al., 2017).

The International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) framework (WHO, 2007) combines biological, individual, and social perspectives on health and functioning. Body functions and structures, activity limitation, and participation are essential outcomes of health status within the ICF-CY framework (Bendixen et al., 2012). According to the WHO (2007), body

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functions and structures include physiological and psychological functions and anatomical structures of body systems. Activity limitations refer to obstacles children and youth with disabilities may face when participating in activities (WHO, 2007). Participation refers to the restrictions that children and youth with disabilities may face in life situations (WHO, 2007). Personal and environmental factors are contextual factors in the ICF-CY framework that represent the backgrounds of life and living of children and adolescents with disabilities (WHO, 2007). The dynamic interaction between health conditions and contextual factors significantly affects the functioning and disability of an individual (WHO, 2007). Personal and environmental factors should be considered when assessing the mental health of children and adolescents with IDs (Simões & Santos, 2017).

As an essential indicator of mental health (Connell et al., 2014), quality of life (QoL) refers to life satisfaction, which can be affected by physical and psychological factors. Children and adolescents with IDs have lower QoL than those with TD (Biggs & Carter, 2016; Dahan-Oliel et al., 2012; Golubović & Skrbić, 2013), and individuals with mild ID have better QoL than those with moderate ID (Simões & Santos, 2017). According to self-concept (SC) theory, subjective feelings such as self-perception impact mental health (Keyes & Ryff, 2000). Children and adolescents with IDs have lower SC than their TD counterparts, such as behavioral, cognitive, and global SC (Maïano et al., 2019; Varsamis & Agaliotis, 2011). Meanwhile age and school have significant moderating effects on SC in children and adolescents with IDs (Maïano et al., 2019).

In response to the outbreak of COVID-19 in Hong Kong, precautionary measures have been used to curtail the spread of the pandemic. Examples include physical and social distancing; personal, home, and environmental hygiene measures such as mask-on requirements and disinfection of the premises; contact tracing; quarantining, and COVID-19 vaccination. Schools in Hong Kong have been closed or conducted whole-day online or half-day face-to-face classes where appropriate (Lau et al., 2022).

Children and adolescents with IDs are found to have lower levels of PA and mental health during the COVID-19 pandemic (Theis et al., 2021; Ueda et al., 2021). Previous studies examined the association between PA and mental health in ID populations before and during the COVID-19 pandemic. For example, PA was positively associated with physical QoL (Mensch et al., 2019) and emotional and psychological well-being (Puce et al., 2019) in children and adolescents with IDs before the pandemic, and health-related QoL in individuals with IDs during the pandemic (Nightingale et al., 2021). Meanwhile, MVPA and SC are fundamental components of adolescents' QoL. For example, it was found that MVPA was an antecedent of SC in adolescents (Garn et al., 2020); and the interaction between MVPA

and SC was negatively associated with psychological symptoms in adolescents (Baceviciene et al., 2019). Moreover, SC is a core indicator of QoL, and is positively associated with QoL in children and adolescents with IDs (Li et al., 2006; Saha et al., 2014).

However, some research gaps remain to be addressed. First, although previous studies investigated the direct associations between PA and mental health in children and adolescents with IDs (Kapsal et al., 2019; Yang et al., 2021), no studies have explored the underlying mechanisms, such as the mediating effects of SC on the associations between PA and QoL and the interaction of MVPA and SC in relation to QoL. Second, the dose–response associations among PA levels, QoL, and SC are under-explored in children and adolescents with IDs, and potential moderators (i.e., personal and environmental factors) have rarely been studied. Third, due to the low intellectual function in children and adolescents with IDs, subjective PA measures have issues with recall bias, high rates of errors, and low rates of compliance (Leung et al., 2017); thus, accelerometer-measured PA levels are necessary to improve research quality. Based on these gaps, the objectives of our study were to (1) examine the associations among accelerometer-measured PA levels, QoL, and SC; (2) investigate the underlying mechanisms, such as mediation and interaction effects on the associations among PA levels, QoL, and SC; and (3) examine the moderating effects of personal and environmental factors on PA levels, QoL, and SC. The hypothesized model is illustrated in Fig. 1.

Methods

Participants

This study used a cross-sectional design, and data were collected during the COVID-19 pandemic from January to June 2021. A total of 201 students aged between 6 and 17 years with mild and moderate IDs from 10 Hong Kong special schools were recruited. The inclusion criteria were as follows: (1) being diagnosed with mild to moderate IDs by the Department of Health and Hospital Authority in Hong Kong according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (Regier et al., 2009); (2) having no other impairments such as physical, visual, or hearing disabilities; and (3) having no negative reaction to wearing the accelerometer. The teachers and parents were informed of the objectives of the study before data collection, and consent forms were sent to the participants and parents. Teachers and parents provided the participants' age, body mass index (BMI), sex, and parental education level. All measures and procedures were approved by the Joint Chinese University of Hong Kong – New Territories East
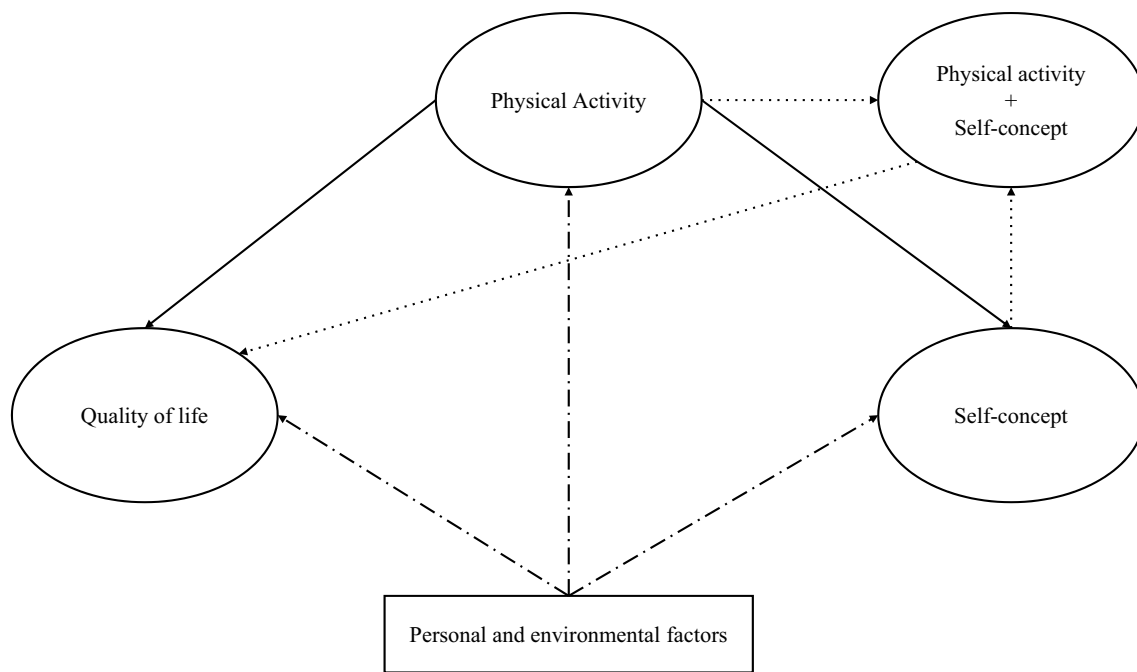
Fig. 1 The hypothesized model between accelerometer-measured physical activity levels and mental health in children and adolescents with intellectual disabilities. *Note.* Solid arrows denote significant association results; dotted arrows denote the mechanisms between physical activity, quality of life, and self-concept; dash-dotted arrows denote significant moderating effects of personal and environmental factors

Cluster Clinical Research Ethics Committee. The study findings are reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist (Appendix A).

Measures

We objectively gauged the 24-h PA levels using the GENE-Activ (Activ Insights Ltd, Kimbolton, Cambridgeshire, UK). The GENEActiv is a validated wrist-worn tri-axial accelerometer that achieves > 90% accuracy in classifying activity (Malaguti et al., 2021). The gravity-subtracted sum of vector magnitudes is calculated as follows:

$$SVM^g s = \left| \left(x^2 + y^2 + z^2 \right)^{1/2} - 1g \right|$$

The accelerometer has been used to assess PA levels in persons with IDs (Böhmer et al., 2021) and was configured to collect data at 85.7 Hz for seven days, including the time spent in LPA, MPA, VPA, and MVPA per day (Antczak et al., 2021). We used the GENEActiv cut-points for LPA (7–19 g s), MPA (20–60 g s), VPA (> 60 g s), and MVPA ($\geq$ 20 g s) in the left wrist and for LPA (6–21 g s), MPA (22–56 g s), VPA (> 56 g s), and MVPA ($\geq$ 22 g s) in the right wrist (Phillips et al., 2013). The total number of measurements in the sum was defined by multiplying the

recording frequency by the epoch length, and we employed a 15-s epoch, which is frequently used in children and adolescents with IDs (Wouters et al., 2019). We extracted the accelerometer data using the GENEActiv PC Software (version 3.3) and processed the data in the R studio (version 2021.09.0). The inclusion criteria for a valid participant were having less than 2 h of non-wear time and at least four valid days (three weekdays and one weekend) in a week (Antczak et al., 2021).

We measured the QoL of children and adolescents with IDs using the Chinese version of the Pediatric Quality of Life Inventory (PedsQL; Hu et al., 2013). The PedsQL has been used for children and adolescents with IDs (Golubović & Skrbić, 2013) and has satisfactory psychometric properties in the Chinese population (Hu et al., 2013). The PedsQL includes physical (eight items), emotional (five items), social (five items), and school (five items) QoL. In addition, the emotional, social, and school QoL items were averaged to produce a psychosocial QoL score, and the total QoL was generated by averaging all items. The PedsQL was completed by the parents as the parent proxy-report could provide supplementary information on children and adolescents' perceptions (Golubović & Skrbić, 2013). We gauged each item on a 5-point Likert scale ranging from 0 (never) to 4 (almost always) and reverse-transformed to a 0–100 scale (0 = 100, 1 = 75, 2 = 50, 3 = 25, 4 = 0); the higher the score, the greater the participants' QoL (Chan et al., 2021). In this

study, the internal consistency was acceptable to good, and Cronbach's alpha was 0.92 for the overall questionnaire with the subscales ranging from 0.73 to 0.90 (see Appendix B).

We used the Chinese version of the Physical Self-Description Questionnaire-Short Form (PSDQ-S) to assess the SC of children and adolescents with IDs (Marsh et al., 1994; Simons et al., 2012). There were 40 items in the PSDQ-S questionnaire, and each item had six options, ranging from 1 (false) to 6 (true) (Wang et al., 2015). PA (four items), appearance (three items), global (three items), and strength (three items) SC were included based on a previous study (Lau et al., 2008), and total SC was the mean score of the four subscales. The Cronbach's alpha of the total SC was 0.92, and that for the subscales ranged from 0.80 to 0.90, showing good internal consistency (see Appendix B).

Procedure

After obtaining consent from the participants and their parents, we visited each school twice. The first visit was to deliver the accelerometers. Participants were asked to wear the accelerometers for seven consecutive days, 24 h per day, including during school for half the day on weekdays and with their families in the afternoons, evenings, and weekends. The PA guidelines (WHO, 2020) and the instruction on the accelerometer, including wearing position, time, date, and precautions, were provided to the participants, their physical education teachers, and parents. One week later, we revisited the schools to collect the accelerometers and distribute questionnaires. All questionnaires were interview-administered in the classroom, with the assistance of physical education teachers, parents, and trained research assistants. Participants completed the PSDQ-S and their parents completed the parent proxy-report PedsQL. The questionnaires took approximately 15–20 min to complete.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26 (IBM Corporation, 2019) and M plus software version 8.3, and $p < 0.05$ was considered statistically significant. The participant characteristics and variables were illustrated as means and SDs for continuous variables or percentiles for categorical factors. The correlations among PA levels, QoL, and SC were tested using bivariate Pearson correlation (r). The internal consistency of the PedsQL and PSDQ-S was tested using Cronbach's alpha, and no less than 0.7 was regarded as acceptable (Upton et al., 2008). The moderating effects of categorical variables (i.e., sex, ID level, and parental education level) on PA levels, QoL, and SC were measured using multivariate analysis of variance.

Confirmatory factor analysis and structural equation modelling (SEM) were used to test the hypothesized model. We employed a combination of methods to explore the associations: (1) significant parameter estimates, (2) goodness of fit, (3) comparative fit index (CFI), (4) Tucker-Lewis index (TLI), (5) standardized root mean square residual (SRMR), and (6) root mean square error of approximation (RMSEA) (Hu & Bentler, 1999). A reasonable cutoff for the fit index of CFI and TLI is 0.90; an SRMR value of less than 0.08 is considered a good fit, and less than 0.10 is acceptable. The values of RMSEA are often interpreted as follows: 0, a perfect fit; < 0.05, a close fit; 0.05–0.08, a fair fit; 0.08–0.10, a mediocre fit; and > 0.10, a poor fit (Hu & Bentler, 1999). Bootstrapping was used to examine the mediating effects of SC on the associations between PA levels and QoL with 5000 bootstrap samples, and a bias-corrected and accelerated 95% confidence interval (CI) and a maximum likelihood estimation method for missing data were examined in the data analysis (Aruta et al., 2022). The moderating effects of continuous variables (age, BMI, and school) on PA levels, QoL, and SC were examined using SEM (Little et al., 2007).

Moreover, to assess the dose–response associations among PA levels, QoL, and SC in children and adolescents with IDs, a generalized linear model was used to calculate the mean differences (MDs) (with 95% CI). PA levels were determined by quartiles (Q1–Q4) with Q1 being the lowest quartile and the reference category, allowing for testing a linear trend across the quartiles (Jefferis et al., 2019; Van Roekel et al., 2015). A hierarchical approach was used in the study with Model 1 unadjusted, Model 2 adjusted for personal (i.e., age, BMI, sex, and ID level) and environmental factors (i.e., school and parental education level), and Model 3 further adjusted for health-related factors (i.e., PA levels). MVPA was included as a covariate for the analysis of LPA, and LPA was a covariate for the analyses of MPA, VPA, and MVPA (Van Roekel et al., 2015). The covariates in Models 2 and 3 were selected from the ICF-CY framework (WHO, 2007), as shown in Fig. 2. To assess the interaction between MVPA and SC in relation to QoL, participants were categorized into four groups based on dichotomized MVPA and SC variables using median values as the cut-off: group 1, lower levels of MVPA and SC; group 2, lower MVPA and higher SC; group 3, higher MVPA and lower SC; and group 4, higher levels of MVPA and SC (Baceviciene et al., 2019; Van Roekel et al., 2015). The confounder-adjusted generalized linear model was repeated using group 1 (lower levels of MVPA and SC) as the reference category.

Results

Of the 201 children and adolescents with IDs from 10 special schools in Hong Kong, 47 (23%) did not agree to participate, 17 (9%) did not follow accelerometer instruction, and 20 participants (10%) with missing data in questionnaires
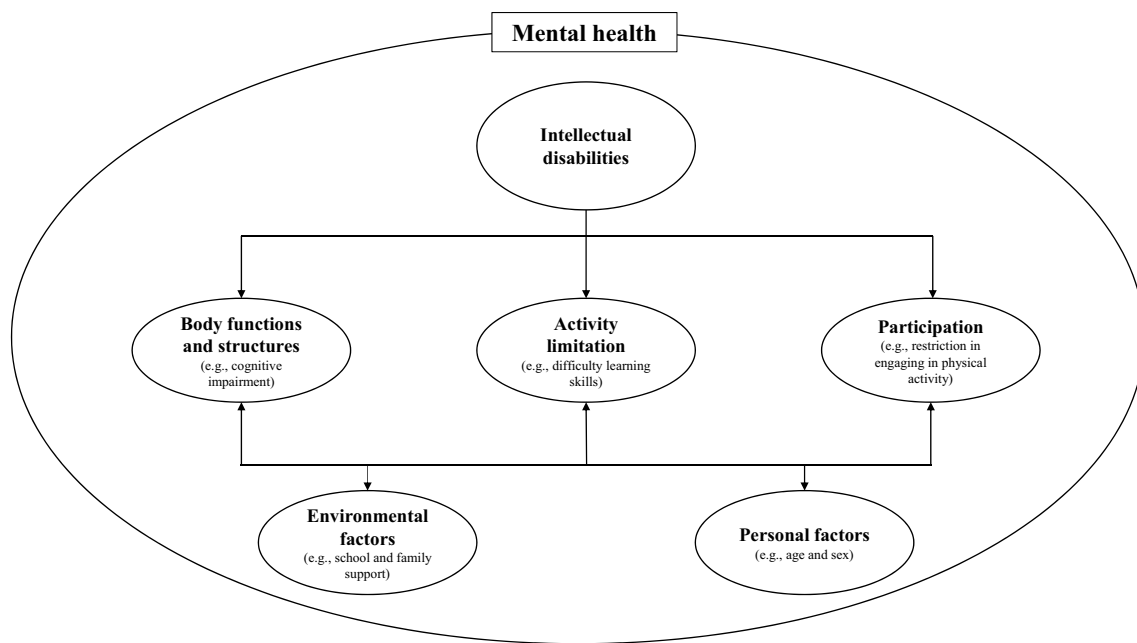
Fig. 2 ICF-CY framework showing relevant factors for studying the associations between physical activity and mental health in children and adolescents with intellectual disabilities

were excluded. Finally, 117 participants (58%) with valid data from the accelerometers and questionnaires were included in the study. The characteristics of the participants and the variables are presented in Table 1. The average age of participants was 13.17 ± 3.82 years, and the mean BMI was 20.90 ± 5.10 kg/m^2; 73.5% were male, and 52.1% had mild ID. The majority of parents (64.1%) had less than college/university education, and 42 parents (35.9%) had college/university education or higher. Participants spent 254.09 ± 78.42 min/day in LPA and 34.92 ± 26.00 min/day in MVPA, and only 16 participants (13.7%) met the 60-min/day MVPA guidelines. Further, the total QoL score was 64.43 ± 15.28 with the highest score in physical QoL (74.52 ± 17.83) and the lowest in social QoL (47.70 ± 23.90). The total SC score was 4.30 ± 1.05 with the highest score in appearance SC (4.47 ± 1.27) and the lowest in PA SC (3.90 ± 1.37). The correlations among PA levels, QoL, and SC are shown in Appendix C.

The measurement model was tested using 26 indicators (three indicators for PA, 12 for QoL, and 11 for SC). The model fit indices for assessing the mediating role of SC in the associations between PA levels and QoL were acceptable: $\chi^2_{(284)} = 424.869$, $p < 0.01$, CFI = 0.912, TLI = 0.900, RMSEA = 0.066, 90% CI = [0.053, 0.079], SRMR = 0.095. The factor loadings (λ) were all statistically significant and acceptable, ranging from 0.614 to 0.951; all of the latent variables' values of composite reliability were larger than 0.80 (i.e., PA = 0.872, QoL = 0.958, and SC = 0.960), and values of average variance extracted were no less than 0.50

(i.e., PA = 0.648, QoL = 0.658, and SC = 0.687). The results showed that VPA negatively predicted SC ($\beta = -0.318$, $p < 0.01$, 95% CI = [−0.522, −0.119]), age had negative moderating effects on MPA ($\beta = -0.211$, $p < 0.05$), BMI had negative moderating effects on MPA ($\beta = -0.318$, $p < 0.01$) and VPA ($\beta = -0.187$, $p < 0.05$), and school had significant moderating effects on QoL ($\beta = -0.286$, $p < 0.01$). Moreover, SC was positively associated with QoL [$\beta = 0.268$, $p < 0.05$, 95% CI = (0.020, 0.498)] but had no mediating effect on the association between PA levels and QoL ($p > 0.05$).

To investigate the dose–response associations among PA levels, QoL, and SC in children and adolescents with IDs, participants were grouped according to PA quartiles. For example, LPA (Q1: < 188.72 min, Q2: 188.72–254.23 min, Q3: 254.24–311.55 min, Q4: > 311.55 min), MPA (Q1: < 15.39 min, Q2: 15.39–26.56 min, Q3: 26.57–45.91 min, Q4: > 45.91 min), VPA (Q1: < 0.10 min, Q2: 0.10–0.53 min, Q3: 0.54–1.53 min, Q4: > 1.53 min), and MVPA (Q1: < 16.07 min, Q2: 16.07–27.18 min, Q3: 27.19–46.26 min, Q4: > 46.26 min). The associations among PA levels, QoL, and SC are shown in Appendix D, and the fully adjusted associations (Model 3) are shown in Figs. 3 and 4. Fully adjusted results showed that there were positive dose–response associations between LPA and school QoL (MD Q2 vs. Q1 = 10.68, $p < 0.05$, 95% CI = [0.17, 21.18]), between VPA and total QoL (MD Q3 vs. Q1 = 10.48, $p < 0.05$, 95% CI = [1.91, 19.04]), and between MPA and appearance SC (MD Q4 vs. Q1 = 1.38,

Table 1 Characteristics of participants and variables (N = 117)

Variable	Dimension	Mean ± SD/N (%)
Age (years)	Overall	13.17 ± 3.82
Body mass index (kg/m^2)	Overall	20.90 ± 5.10
School	Overall	10 (26.3%)
Sex	Male	86 (73.5%)
	Female	31 (26.5%)
ID level	Mild ID	61 (52.1%)
	Moderate ID	56 (47.9%)
Parental education level	< College/university	75 (64.1%)
	≥ College/university	42 (35.9%)
Physical activity (min per day)	Light physical activity	254.09 ± 78.42
	Moderate physical activity	33.24 ± 25.24
	Vigorous physical activity	1.21 ± 1.61
	Moderate-to-vigorous physical activity	34.92 ± 26.00
	Participants meeting MVPA guidelines	16 (13.7%)
Mental health		
Quality of life (QoL), range 0–100	Physical QoL	74.52 ± 17.83
	Emotional QoL	69.43 ± 15.26
	Social QoL	47.70 ± 23.90
	School QoL	58.15 ± 18.83
	Psychosocial QoL	58.50 ± 16.74
	Total QoL	64.43 ± 15.28
Self-concept (SC), range 1–6	Physical activity SC	3.90 ± 1.37
	Appearance SC	4.47 ± 1.27
	Global SC	4.34 ± 1.29
	Strength SC	4.45 ± 1.15
	Total SC	4.30 ± 1.05
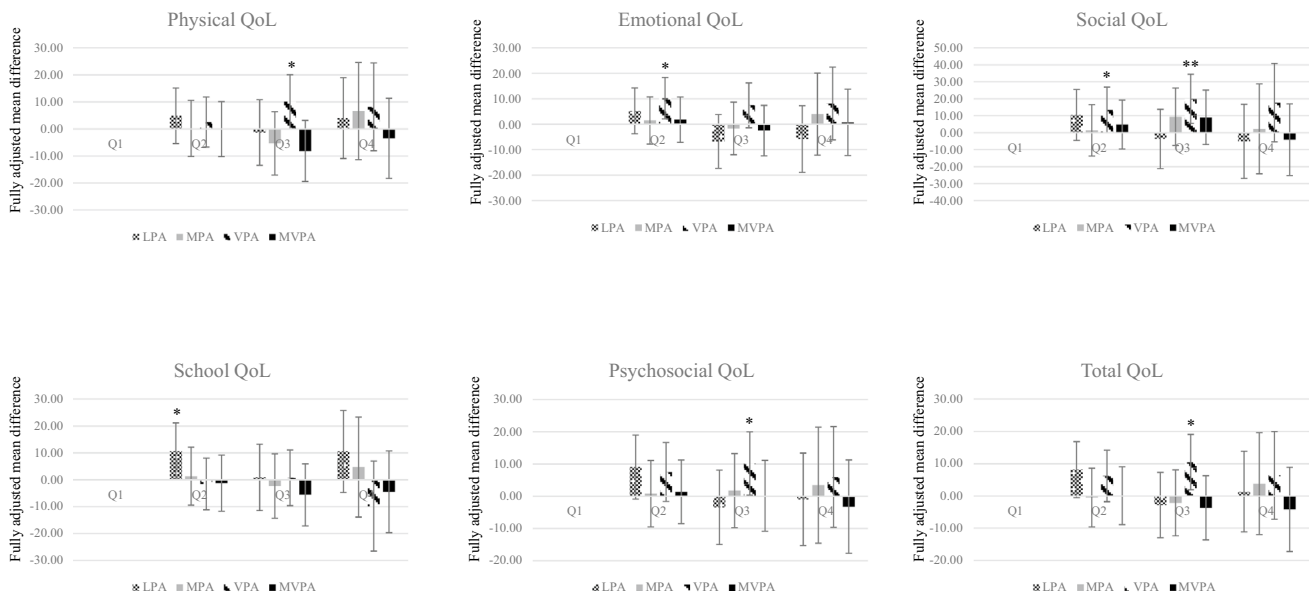
Fig. 3 The dose–response associations between physical activity and quality of life in children and adolescents with intellectual disabilities. *Note.* Generalized linear model results were fully adjusted for personal, environmental, and health-related factors; $^*p < 0.05$; $^{**}p < 0.01$
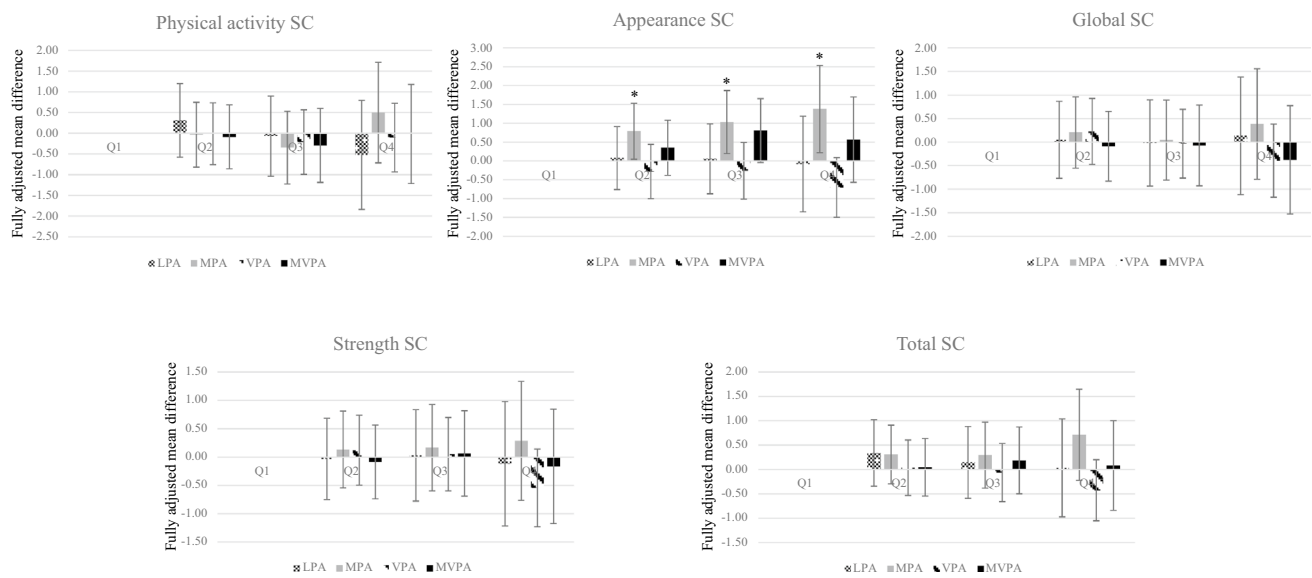
Fig. 4 The dose–response associations between physical activity and self-concept in children and adolescents with intellectual disabilities. *Note.* Generalized linear model results were fully adjusted for personal, environmental, and health-related factors; *$p < 0.05$

$p < 0.05$, 95% CI = [0.22, 2.54]), indicating that participants who spent 188.72–254.23 min/day in LPA had better school QoL than those who spent less than 188.72 min/day in LPA; better total QoL was found in participants who spent 0.54–1.53 min/day in VPA compared with less than 0.10 min/day in VPA; participants who spent more than 45.91 min/day in MPA had better appearance SC than those who spent less than 15.39 min/day in MPA.

The interaction between MVPA and SC in relation to QoL in children and adolescents with IDs is shown in Table 2. Participants were grouped according to the interaction between MVPA and SC. For example, group 1 had lower levels of MVPA (< 27.19 min/day) and SC (< 4.17), group 2 had lower MVPA (< 27.19 min/day) and higher SC (≥ 4.17), group 3 had higher MVPA (≥ 27.19 min/day) and lower SC (< 4.17), and group 4 had higher levels of MVPA (≥ 27.19 min/day) and SC (≥ 4.17). The fully adjusted results (Model 3) suggested that participants with higher levels of MVPA (≥ 27.19 min/day) and SC (≥ 4.17) had better social QoL than those with lower levels of MVPA (< 27.19 min/day) and SC (< 4.17) (MD = 17.92, $p < 0.05$, 95% CI = [1.85, 34.00]).

Table 3 presents the moderating effects of sex, ID level, and parental education level on PA levels and mental health. The interaction of sex, ID level, and parental education level had significant moderating effects on PA levels (F = 1.76, $p < 0.05$) and QoL (F = 1.69, $p < 0.05$). Moreover, sex had significant moderating effects on LPA (F = 9.99, $p < 0.01$), which meant that male participants had higher LPA levels (267.34 ± 75.82 min/day) than their female counterparts (217.32 ± 74.75 min/day). ID level had moderating effects

on QoL (total QoL: F = 15.99, $p < 0.01$), which meant that participants with mild ID had higher total QoL scores (70.19 ± 14.40) than those with moderate ID (58.89 ± 14.12). Parental education level had moderating effects on MPA (F = 5.80, $p < 0.05$) and MVPA (F = 5.16, $p < 0.05$), indicating that participants with higher parental education levels spent more time in MPA (41.34 ± 31.10 min/day) and MVPA (42.09 ± 32.09 min/day) than those with lower parental education levels (MPA: 29.86 ± 20.36 min/day, MVPA: 30.90 ± 21.07 min/day).

Discussion

Our cross-sectional study, conducted during the COVID-19 pandemic, examined the associations between accelerometer-measured PA levels and mental health in children and adolescents with IDs. PA levels (i.e., LPA, MPA, and VPA) had positive dose–response associations with mental health, and the interaction between MVPA and SC was positively associated with social QoL. VPA had negative predictive effects on SC in children and adolescents with IDs. Moreover, age, BMI, and school significantly moderated PA levels and QoL. Male participants with mild ID and higher parental education levels had higher levels of PA and QoL than their counterparts.

Consistent with previous studies, children and adolescents with IDs spent 34.92 ± 26.00 min/day in MVPA, and only 16 participants (13.7%) met the 60-min/day MVPA guidelines during the COVID-19 pandemic. For example, Yuan et al. (2021) used an online questionnaire to measure PA levels

Table 2 The interaction of moderate-to-vigorous physical activity and self-concept in relation to quality of life

	Group 1	Group 2 (n = 30)				Group 3 (n = 29)				Group 4 (n = 29)			
	(n = 29)	MD	p	lower	upper	MD	p	lower	upper	MD	p	lower	upper
Physical quality of life (QoL)													
Model 1	Ref	9.78	0.06	− 0.23	19.79	− 0.55	0.92	− 10.79	9.69	7.04	0.18	− 3.20	17.28
Model 2	Ref	6.90	0.16	− 2.81	16.60	− 6.29	0.23	− 16.50	3.93	2.89	0.61	− 8.20	13.98
Model 3	Ref	5.27	0.28	− 4.32	14.87	− 9.25	0.12	− 20.89	2.39	− 2.02	0.75	− 14.28	10.23
Emotional QoL													
Model 1	Ref	7.97	0.06	− 0.26	16.20	0.71	0.87	− 7.72	9.14	3.33	0.44	− 5.10	11.76
Model 2	Ref	7.71	0.06	− 0.28	15.69	− 1.02	0.81	− 9.48	7.44	2.53	0.59	− 6.65	11.71
Model 3	Ref	7.13	0.08	− 0.87	15.13	0.29	0.95	− 9.51	10.10	4.82	0.35	− 5.35	14.99
Social QoL													
Model 1	Ref	6.53	0.34	− 6.97	20.04	− 0.82	0.91	− 14.64	13.01	6.71	0.35	− 7.30	20.72
Model 2	Ref	8.79	0.18	− 3.93	21.52	0.24	0.97	− 13.24	13.73	16.32*	**0.03**	1.52	31.11
Model 3	Ref	6.48	0.31	− 6.08	19.04	2.33	0.77	− 13.06	17.72	17.92*	**0.03**	1.85	34.00
School QoL													
Model 1	Ref	3.26	0.54	− 7.23	13.75	− 3.21	0.56	− 13.95	7.53	− 1.72	0.75	− 12.46	9.02
Model 2	Ref	4.74	0.35	− 5.23	14.72	− 5.31	0.32	− 15.80	5.18	1.01	0.86	− 10.38	12.39
Model 3	Ref	2.26	0.64	− 7.20	11.72	− 4.39	0.45	− 15.84	7.06	− 0.31	0.96	− 12.17	11.55
Psychosocial QoL													
Model 1	Ref	5.81	0.22	− 3.53	15.14	− 1.26	0.80	− 10.81	8.30	2.67	0.59	− 7.01	12.35
Model 2	Ref	7.03	0.12	− 1.75	15.81	− 1.99	0.67	− 11.23	7.24	6.97	0.18	− 3.17	17.10
Model 3	Ref	5.09	0.25	− 3.64	13.82	− 0.59	0.91	− 11.15	9.97	8.04	0.15	− 2.98	19.07
Total QoL													
Model 1	Ref	0.48	0.93	− 10.73	11.69	− 0.78	0.89	− 12.22	10.65	2.98	0.62	− 8.71	14.68
Model 2	Ref	5.56	0.18	− 2.56	13.67	− 4.75	0.27	− 13.23	3.72	4.21	0.38	− 5.10	13.53
Model 3	Ref	3.71	0.37	− 4.45	11.87	− 5.02	0.31	− 14.77	4.74	2.93	0.58	− 7.43	13.28

The interaction of moderate-to-vigorous physical activity and self-concept was divided into four groups, and group 1 as the reference category; model 1: unadjusted; model 2: adjusted for personal and environmental factors; model 3: adjusted for model 2 + health-related factors; $^*p < 0.05$

Bold values indicates statistical significance

in children and adolescents with IDs during the COVID-19 pandemic and observed that participants spent 10 min/day in MVPA, and only 17.4% met the 60-min/day MVPA guidelines. A previous accelerometer-based study reported that children with IDs spent 49.4 min/day in MVPA with only 23.7% meeting the MVPA guidelines (Downs et al., 2016); Zhu et al. (2020) reported that youth with moderate to severe IDs spent 29.82 ± 20.65 min/day in MVPA. Wouters et al. (2019) compared the different cut-points in participants with IDs, suggesting the underestimation of MVPA levels in children and adolescents with IDs. These different measures may lead to differences in PA levels, and standardized accelerometer protocols for children and adolescents with IDs are needed to better understand the actual PA levels for this population (Leung et al., 2017).

This study found similar PA levels and mental health outcomes as those conducted before the COVID-19 pandemic (Golubović & Skrbić, 2013; Sit et al., 2019; Zhu et al., 2020). During the data-collection process (January to June 2021), the number of confirmed COVID-19 cases in Hong Kong ranged from 0 to 107 per day. Children and adolescents with IDs attended physical education classes in special schools and performed exercises with mask-on in indoor/outdoor sports facilities. PA participation may decrease the harmful effects of COVID-19 on the mental health of children and adolescents with IDs, however, this conjecture needs further research attention.

Moreover, positive dose–response associations were found among LPA, VPA, and QoL in children and adolescents with IDs during the COVID-19 pandemic, which is consistent with previous studies. For example, Nightingale et al. (2021) found a positive association between leisure-time PA and health-related QoL in individuals with IDs during the COVID-19 pandemic. Daytime activity was also found to be positively associated with QoL in people with IDs (Simões & Santos, 2017). Previous studies also reported significant associations between PA and physical well-being in children with IDs (Mensch et al., 2019); and Puce et al. (2019) indicated that competitive sports were positively associated with emotional

Table 3 Moderating effects of sex, ID level, and parental education level on physical activity, quality of life and self-concept

	Sex		ID level		Parental education level	
	Male (n = 86)	Female (n = 31)	Mild ID (n = 61)	Moderate ID (n = 56)	< College/University (n = 75)	≥ College/university (n = 42)
Physical activity (min per day) [a,g]						
LPA[a,d,e,g]	267.34 ± 75.82	217.32 ± 74.75	242.38 ± 73.26	266.84 ± 82.44	247.34 ± 72.91	266.14 ± 87.01
MPA[c,e,g]	36.44 ± 24.76	27.18 ± 25.71	33.20 ± 22.09	34.83 ± 28.45	29.86 ± 20.36	41.34 ± 31.10
VPA	1.34 ± 1.72	0.83 ± 1.23	1.23 ± 1.73	1.18 ± 1.49	1.04 ± 1.36	1.51 ± 1.97
MVPA[c,e,g]	37.41 ± 25.60	28.01 ± 26.26	34.43 ± 23.03	35.44 ± 29.10	30.90 ± 21.07	42.09 ± 32.09
Quality of life (QoL)[b,d,g]						
Physical QoL[b,d,f,g]	75.67 ± 19.09	71.03 ± 13.01	80.88 ± 16.35	68.52 ± 17.20	72.84 ± 18.29	77.62 ± 16.76
Emotional QoL[b,d]	69.87 ± 16.47	68.15 ± 11.19	73.08 ± 15.75	65.93 ± 14.04	68.48 ± 15.80	71.22 ± 14.26
Social QoL[b,d,f]	47.83 ± 23.95	47.31 ± 24.22	53.84 ± 22.41	41.79 ± 24.00	49.57 ± 23.78	44.17 ± 24.07
School QoL[b,d,f,g]	57.77 ± 20.52	59.26 ± 13.01	63.82 ± 17.86	52.59 ± 18.24	56.71 ± 17.25	60.81 ± 21.43
Psychosocial QoL[b,d,f,g]	58.61 ± 17.52	58.17 ± 14.49	63.56 ± 15.88	53.54 ± 16.20	58.48 ± 16.16	58.53 ± 18.00
Total QoL[b,d,f,g]	64.88 ± 16.45	63.05 ± 11.10	70.19 ± 14.40	58.89 ± 14.12	63.88 ± 14.98	65.44 ± 15.97
Self-concept (SC)						
Physical activity SC	4.00 ± 1.36	3.61 ± 1.38	4.01 ± 1.30	3.79 ± 1.44	3.95 ± 1.50	3.78 ± 1.14
Appearance SC	4.48 ± 1.30	4.46 ± 1.22	4.45 ± 1.31	4.50 ± 1.25	4.59 ± 1.30	4.28 ± 1.22
Global SC	4.38 ± 1.29	4.22 ± 1.31	4.43 ± 1.17	4.25 ± 1.41	4.39 ± 1.31	4.36 ± 1.18
Strength SC	4.55 ± 1.18	4.20 ± 1.03	4.49 ± 1.10	4.42 ± 1.21	4.52 ± 1.16	4.38 ± 1.14
Total SC	4.35 ± 1.07	4.16 ± 1.02	4.34 ± 0.95	4.26 ± 1.15	4.36 ± 1.08	4.20 ± 1.01

MANOVA results were means and SDs

[a]significant differences at $p < 0.05$ or $p < 0.01$ for the main effects of sex

[b]significant differences at $p < 0.05$ or $p < 0.01$ for the main effects of ID level

[c]significant differences at $p < 0.05$ or $p < 0.01$ for the main effects of parental education level

[d]significant differences at $p < 0.05$ or $p < 0.01$ for the effects of interaction (sex by ID level)

[e]significant differences at $p < 0.05$ or $p < 0.01$ for the effects of interaction (sex by parental education level)

[f]significant differences at $p < 0.05$ or $p < 0.01$ for the effects of interaction (ID level by parental education level)

[g]significant differences at $p < 0.05$ or $p < 0.01$ for the effects of interaction (sex by ID level by parental education level)

and psychological well-being in children with IDs. Moreover, a dose–response relationship has been found between physical inactivity and mental disorders in children and adolescents (Liu et al., 2016). Although dose–response associations have rarely been investigated in the ID population, there may be optimal PA levels for mental health in children and adolescents with IDs because of the ceiling effect of PA levels for improving mental health.

In our study, MPA had positive dose–response associations with appearance SC, and the interaction between MVPA and SC was positively associated with social QoL in children and adolescents with IDs during the COVID-19 pandemic, which is in line with previous studies. For example, PA was positively associated with the appearance SC in youth according to psychosocial mechanisms (Lubans et al., 2016), and MPA was positively associated with SC in children and adolescents with disabilities (Te Velde et al., 2018). Further, MVPA and SC are fundamental components of adolescents' QoL (Garn et al., 2020), and the interaction between MVPA and SC is negatively associated with

psychological symptoms in adolescents (Baceviciene et al., 2019). We also found that VPA negatively predicted SC in children and adolescents with IDs during the COVID-19 pandemic. The predictive effects could be explained by social comparison leading to social stigma and negative SC in adolescents with IDs (Chien et al., 2020).

In the present study, age, BMI, and school had moderating effects on PA levels and QoL, and male participants with mild ID and higher parental education levels reported higher levels of PA and QoL than their counterparts, which is consistent with previous findings. For example, age was negatively associated with PA levels in children with disabilities (Cook et al., 2015), and school was significantly associated with PA levels and mental health in persons with IDs (Maïano et al., 2019; Simões & Santos, 2017; Stanish et al., 2017). Moreover, female participants had lower PA levels than their male counterparts before and during the COVID-19 pandemic (Downs et al., 2016; El-Osta et al., 2021; Martin Ginis et al., 2021; Rogers et al., 2020). People with moderate ID had lower QoL than those with mild ID

(Simões & Santos, 2017), and ID level negatively moderated PA levels of individuals with IDs (Dairo et al., 2016; Zhu et al., 2020). Furthermore, socioeconomic factors such as household income and parental education level were positively associated with PA levels during the COVID-19 pandemic (Rogers et al., 2020). However, the associations between BMI and PA levels were understudied in children and adolescents with IDs (Maïano et al., 2016), and more studies are needed to determine the moderating effects of BMI on PA levels and mental health in this vulnerable group.

This study has implications for improving PA levels and mental health in children and adolescents with IDs during the COVID-19 pandemic. First, children and adolescents with IDs attended special schools for half a day and spent most of their time with their families during the COVID-19 pandemic. Teachers and parents could promote PA levels in children and adolescents with IDs, such as increasing active time in schools and home environments, promoting active breaks between classes at school, utilizing active transportation to schools, and increasing MVPA levels in physical education classes (Healy et al., 2018). Professional skills and social support could be provided to parents as parental QoL and stress are significantly associated with QoL of children with IDs during the COVID-19 pandemic (Ueda et al., 2021). Second, the interaction between MVPA and SC was positively associated with QoL according to the SC theory (Keyes & Ryff, 2000), and personal and environmental factors based on the ICF-CY framework (WHO, 2007) had moderating effects on PA and QoL in children and adolescents with IDs, suggesting that individualized PA programmes considering personal and environmental factors could be provided to improve their self-confidence in PA and mental health (Temple & Stanish, 2011). Third, our study found that the COVID-19 pandemic did not impact the PA levels of individuals with IDs more than what has been reported in the literature (Theis et al., 2021; Ueda et al., 2021). The reason may be that our study was conducted in different cultures and COVID phases (Sallis et al., 2020), and more studies are needed to examine the impact of the COVID-19 pandemic on PA levels and mental health across cultures and phases.

To the best of our knowledge, this cross-sectional study, grounded in the ICF-CY framework, was the first to investigate the associations between accelerometer-measured PA levels and mental health in children and adolescents with IDs during the COVID-19 pandemic in Hong Kong. This study has several strengths, including children and adolescents with IDs from a well-representative sample (i.e., participants were recruited from 10 special schools, which represented 26.3% of the 38 special schools for children and adolescents with mild and moderate IDs in Hong Kong), the use of an objective measure of PA, and data collection

during the COVID-19 pandemic. Second, we examined the interaction (i.e., MVPA, QoL, and SC) and moderation effects (i.e., personal and environmental factors) by taking the SC theory (Keyes & Ryff, 2000) and ICF-CY (WHO, 2007) as theoretical frameworks into consideration. Several limitations should be noted. First, this study did not examine the PA levels and mental health of children and adolescents with IDs before the COVID-19 pandemic, and thus we are not able to compare the outcome differences before and during the COVID-19 pandemic. Second, our study only included children and adolescents with mild and moderate IDs, which may limit the generalizability of our results. Future studies should include children and adolescents with severe or profound ID. Finally, research on GENEActiv cut-points is rare, and more studies are needed on evaluating PA levels and cut-points in children and adolescents with IDs.

Conclusions

In the context of the COVID-19 pandemic, there were positive dose–response associations between PA levels and mental health, and the interaction between MVPA and SC was positively associated with social QoL in children and adolescents with IDs. Using the ICF-CY framework, personal (i.e., age, BMI, ID level, and sex) and environmental factors (i.e., school and parental education level) were found to influence PA levels and QoL in children and adolescents with IDs. PA participation may decrease the negative effects of the COVID-19 pandemic on mental health of children and adolescents with IDs. Future research should consider PA interventions in mental health services for children and adolescents with IDs and provide professional support to parents and teachers.

Declarations

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