European Journal of Sport Science

WILEY

Official ECSS Journal
Open Access

ORIGINAL PAPER OPEN ACCESS

Effectiveness of a High-Intensity Interval Games Program in Extra-Curricular Context (MOVI-daFIT!) on Gross Motor Competence and Health-Related Quality of Life in Primary Schoolchildren: Cluster-Randomized Trial

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Received: 16 June 2024 | **Revised:** 4 April 2025 | **Accepted:** 13 April 2025

Funding: The Ministry of Economy and Competitiveness-Carlos III Health Institute (FIS PI16/01919) funded this study. Additional funding was obtained from the Research Network on Preventative Activities and Health Promotion (RD12/0005/0009). Open Access funding was provided by the Universidad de Castilla-La Mancha.

Keywords: health | motor skills | physical activity | school program

ABSTRACT

High-intensity interval training (HIIT) has emerged as a time-efficient approach to improve aerobic capacity, cardiovascular health, and cognitive functioning in children and adolescents. However, evidence regarding the impact of school-based HIIT programs on motor competence and health-related quality of life in children is limited. This study evaluated the effectiveness of a HIIT intervention, based on playground games on gross motor competence and health-related quality of life in schoolchildren aged 9–11 years. A cluster-randomized controlled trial was conducted with 562 participants. The intervention involved four weekly 60 min sessions of extracurricular physical activity using traditional games adapted to a HIIT protocol. Gross motor competence and health-related quality of life were assessed using the Movement Assessment Battery for Children-Second Edition (MABC-2) and the KIDSCREEN-27 questionnaire, respectively. Analyzes were conducted on an intention-to-treat basis using mixed linear regression models to compare changes from baseline to postintervention between the intervention and control groups. No significant improvements in gross motor competence or health-related quality of life were observed after adjusting for baseline variables, age, sex, and school. The results suggest that this HIIT-based program was not effective in enhancing gross motor competence or in improving health-related quality of life. Future programs could improve effectiveness by optimizing the balance between movement intensity and quality, aligning activities with gross motor competence assessment tools, emphasizing health-related quality of life components, training educators to enhance quality of life, extending intervention duration to impact self-esteem and psychological well-being, and improving adherence rates.

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; BMI, body mass index; CG, control group; GMC, gross motor competence; HIIT, high-intensity interval training; HRQoL, health-related quality of life; IG, intervention group; MC, motor competence; PA, physical activity; PE, physical education; SES, socioeconomic status.

Summary

- A one-school-year HIIT games program did not improve motor competence or health-related quality of life.
- Its effectiveness may be enhanced by linking exercise intensity with movement quality.
- Proper exercise execution and teacher feedback are essential.

1 | Introduction

Physical activity (PA) is essential for children's and adolescents' healthy growth and development (Janssen and LeBlanc 2010). It is also strongly linked to a wide range of health benefits (Warburton et al. 2006). However, studies show a deterioration in the prevalence of children and adolescents meeting PA recommendations (Guthold et al. 2020; Tremblay et al. 2022). In Spain, compliance with PA guidelines among 9-year-old was 60% for boys and 34.1% for girls (Aznar et al. 2011).

The school context has been recognized as an optimal environment for promoting PA. Thus, school-based PA interventions have been shown to significantly improve motor competence (MC) (Morgan et al. 2013), defined as a person's ability to execute different motor acts, including coordination of fine and gross motor skills essential for managing everyday tasks (Henderson et al. 2007). Similarly, previous studies have suggested that PA can enhance health-related quality of life (HRQoL) through interconnected biological, psychological, and social mechanisms (Janssen and LeBlanc 2010; Eime et al. 2013). In addition, previous systematic reviews have demonstrated that PA interventions can enhance HRQoL in children (Bermejo-Cantarero et al. 2024); however, the magnitude of these effects has often been limited or relatively small (Marker et al. 2018).

On the other hand, high-intensity interval training (HIIT) interventions have become a time-efficient way to improve aerobic capacity levels (García-Hermoso et al. 2016) and cardiovascular disease biomarkers (Eddolls et al. 2017) in youth in comparison to other types of exercise. They have also proven to be feasible and effective in school settings (Harris et al. 2021) and have shown positive effects on cognitive functioning in adolescents (Mezcua-Hidalgo et al. 2019). Importantly, HIIT has also emerged as a feasible strategy for children and adolescents with special educational needs, broadening its applicability (Poon et al. 2023). However, there is little evidence on the effect of school programs using HIIT in improving motor skills and HRQoL in children.

Participation in HIIT programs has been shown to enhance mental health in children and adolescents (Leahy et al. 2020). Specifically, HIIT interventions have been associated with improvements in well-being (Leahy et al. 2020) and psychological outcomes, such as self-concept and psychological well-being (Alves et al. 2021). Moreover, HIIT has shown potential benefits in reducing psychological distress among youth (Costigan et al. 2016). Considering that HRQoL is a multidimensional construct encompassing cognitive (Medalia and Erlich 2017), psychological (Gaspar et al. 2009), and physical health (Bond et al. 2017; Eather et al. 2022) domains, and that HIIT interventions have demonstrated positive effects on several indicators associated with HRQoL, it is reasonable to hypothesize that HIIT interventions could also positively influence HRQoL. However, existing studies on this topic yield mixed results, and few have specifically focused on the HRQoL construct (Leahy et al. 2020; Meßler et al. 2018). Similarly, there is limited evidence on the impact of HIIT interventions on MC. To our knowledge, only three studies of children and adolescents with attention-deficit/hyperactivity disorder (ADHD) have examined the effect of HIIT on MC. A 3-week multimodal HIIT program improved motor skills in boys with ADHD (Meßler et al. 2018), whereas a 6-week HIIT intervention demonstrated positive effects on perceptual-motor skills in both boys (Torabi et al. 2016) and girls (Torabi, Ebrahim, and Hemayattalab 2016). Therefore, further research is needed to analyze the impact of HIIT interventions on MC in children without developmental disorders.

As mentioned above, although HIIT programs in the school context have shown potential impact on various health-related outcomes, evidence regarding the effect of this type of intervention on MC and HRQoL remains limited. This study is valuable as it may help elucidate methodological aspects and intervention characteristics that could significantly enhance the effectiveness of HIIT interventions in MC and HRQoL in school-aged children. Thus, the objective of this study was to assess the effectiveness of a HIIT intervention based on playground games in an extracurricular context (MOVI-daFIT!) on gross motor competence (GMC) and HRQoL in primary school children.

2 | Materials and Methods

2.1 | Participants and Study Design

The MOVI-daFIT! study was a cluster-randomized controlled trial (NCT03236337), which included children from fourth and fifth grades of primary school (aged 9–11 years) and whose main objective was to increase physical fitness and reducing fat mass and cardiovascular risk (such as primary outcomes) and improve GMC and HRQoL (such as coprimary outcomes). Ten public schools in the province of Cuenca (Castilla-La Mancha, Spain) were invited to participate and all of them agreed to join the research. A total of 1284 schoolchildren were approached for taking part in the study, 562 (43,8%) agreed, with 276 (49,1%) assigned to the intervention group (IG) and 286 (50,9%) to the control group (CG) (Figure 1).

The sample size was calculated considering a mean change in cardiorespiratory fitness (VO_2max, mL/min/kg) of effect size 0.3 (Hedges'g) between the IG and the CG as reported in previous studies (Pozuelo-Carrascosa et al. 2018). Estimates were calculated with an alpha error of 0.05 and statistical power of 0.80. In addition, an average of 40 children per classroom was considered, with a dropout rate of 15%. Optimal design software was used to calculate sample sizes, taking into account the Donner and Klar models (Donner and Klar 2000).

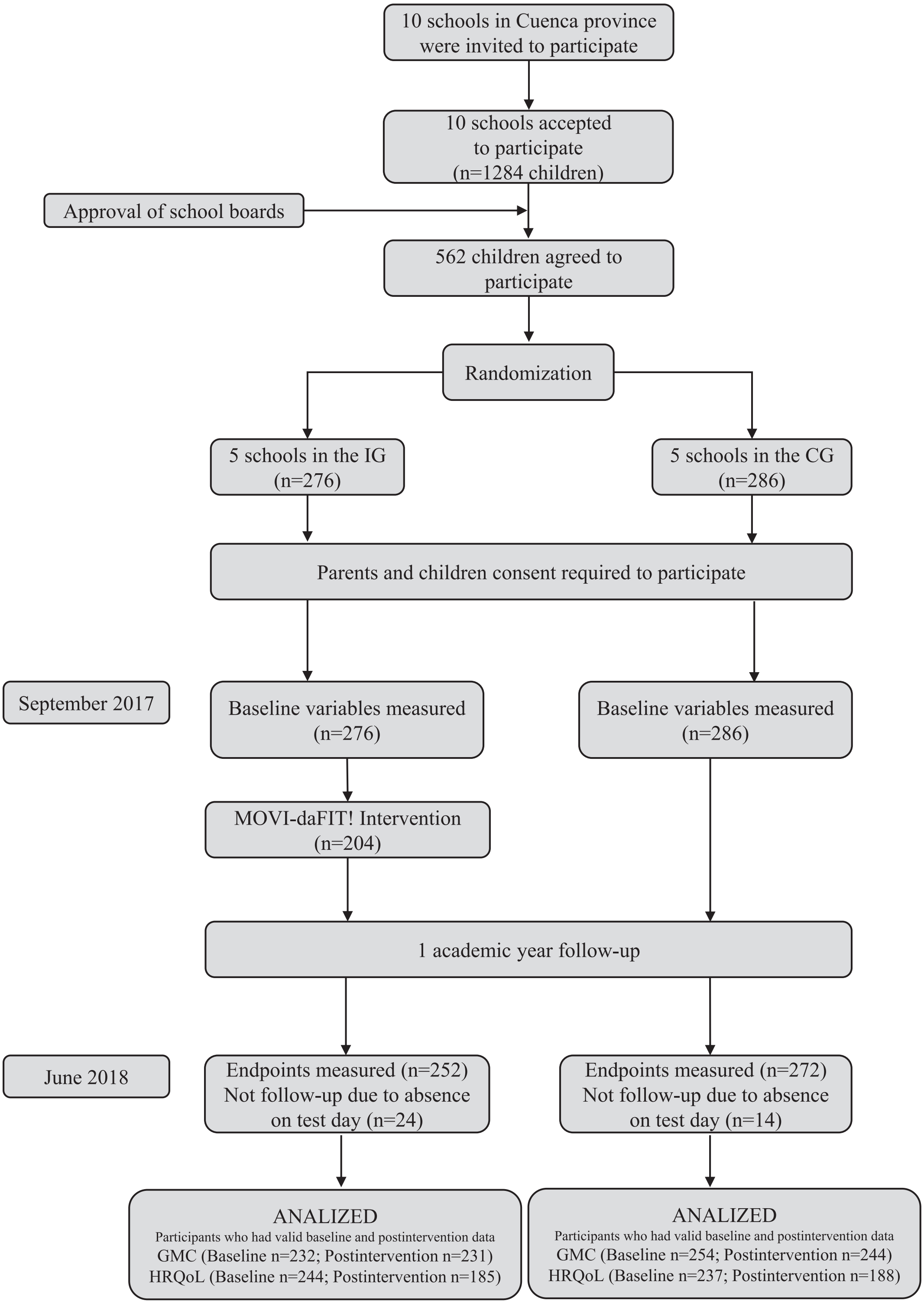

FIGURE 1 | Flow chart of trial participants. CG, control group; GMC, gross motor competence; HRQoL, health-related quality of life; and IG, intervention group.

The methods of MOVI-daFIT! study have been described in detail elsewhere (Martínez-Vizcaíno et al. 2019). This study followed the recommendations of The CONSORT 2010 statement (Campbell et al. 2004) and the Consensus on Exercise Reporting Template (CERT) for cluster-randomized trials (Slade et al. 2016).

The study protocol was approved by The Clinical Research Ethics Committee of the Virgen de la Luz Hospital in Cuenca (REG: 2016/PI021) and was supported by the Department of Education of the "Junta de Comunidades de Castilla-La Mancha" (Spain). The director's and the board of governors' approval was requested from each school. The children were informed about the objectives of the study and gave their verbal consent to participate, whereas parents or legal guardians of all of them provided written informed consent.

2.2 | Instrumentation and Study Variables

Baseline (September 2017) and postintervention (June 2018) measurements were carried out at the schools. The measurements were taken by several trained evaluators to minimize interobserver variability. The evaluators were blinded to the group to which the participants were assigned at baseline, however, end-of-follow-up measurements were not blinded as the participants could have informed the evaluators of their participation in the PA program.

Anthropometry and body composition. *Mass* was measured using a scale (Seca 861, Vogel and Halke, Hamburg, Germany) with the child in light clothing and barefoot. For *height*, a wall stadiometer (Seca 222, Vogel and Halke) was used with children barefoot and standing upright with their sagittal midline in contact with the backboard. Both weight and height were measured twice, and their average was considered for the analyzes. *Body mass index* (BMI) was calculated as weight (kg)/ height (m^2) (Warburton et al. 2006). The *percentage of body fat mass* was measured twice using an eight-electrode Tanita Segmental-418 bioimpedance analysis system (Tanita Corp., Tokyo, Japan) (Pietrobelli et al. 2004). The measurements were conducted before breakfast, after urination, and after a 15 min resting period.

Gross Motor Competence. The validated Spanish version of the Movement Assessment Battery for Children-Second Edition (MABC-2) was used (Henderson et al. 2007). This battery evaluates MC and is useful for detecting motor impairments in children aged 3–16 years. The MABC-2 contains versions appropriate for three age ranges (3–6, 7–10, and 11–16 years). Each version consists of eight motor tasks, classified into three categories: manual dexterity (3 items), aiming-catching (2 items), and static and dynamic balance (3 items). These three motor categories included in MABC-2 were recategorized into gross motor skills (including aiming-catching and balance) and fine motor skills (manual dexterity). Each test received a raw score, which was coded into a scaled score according to age-specific normative reference values proposed by the MABC-2 manual. A higher score indicates better MC. Due to the considerable number of tests included in the randomized controlled trial and the limited time available, fine motor skills were not evaluated.

Health-related quality of life. The validated and reliable Spanish self-report version of the KIDSCREEN-27 was used (The KIDSCREEN Group Europe 2006). The KIDSCREEN-27 is a multidimensional measure of generic HRQoL. This self-reported questionnaire aims to assess five dimensions of HRQoL: physical well-being (5 items), psychological well-being (7 items), autonomy and parents (7 items), peers and social support (4 items), and school environment (4 items). All five dimensions yielded Rasch scores, which were transformed into T-values according to the manual. In addition, the HRQoL index (KIDSCREEN-10 index) was also calculated according to the manual. For all dimensions, higher values indicate better HRQoL.

Socioeconomic status (SES). Family SES was assessed using self-reported occupation and education questions completed by parents. An index of SES was calculated based on parents' education and occupation levels according to procedures from the Spanish Society of Epidemiology scale (Domingo-Salvany et al. 2000), which classifies family SES in five categories: very low, low, medium-low, medium-high, and high SES. Due to the small sample size in the categories at both ends of the scale, they were clustered into three categories: low/upper low, middle, and upper/middle-upper SES.

2.3 | Procedure

The MOVI-daFIT! intervention. The intervention consists of an age-appropriate adapted HIIT program based on playground games for the IG which run from October 2017 to May 2018. It is a recreational, noncompetitive, and play-based program designed to improve health and ensure the inclusion of all children, regardless of gender, motor skills, or physical fitness. It also allows children to foster social connectivity and teamwork, and to learn playground games and motor skills that will encourage them to be active in their leisure time after the program. Two physical education (PE) and sport sciences graduates designed the MOVI-daFIT! program, whereas qualified PE teachers as well as PA and sports trainers implemented the program. Facilitators, in addition to being trained PE teachers, participated in a one-day training session on program implementation. Furthermore, program coordinators maintained regular contact with facilitators (via phone and email) and conducted periodic site visits to provide feedback and ensure the quality of program delivery.

Each IG comprised 20 to 25 students. The PA sessions were voluntary and took place outside of school hours. The design and key features of the HIIT intervention, together with a detailed description of the games used in this study, are described in an e-book (Ruiz-Hermosa et al. 2020). Overall, the children participated 4 times/week in a total of 102 sessions, each lasting 60 min. Each session was structured into 3 parts: (i) 15 min of set-up and warm-up games; (ii) 28 min of games using the HIIT protocol, which included a 4-min game of high-intensity activity (at 85%–90% of the maximum heart rate-HRmax, approximately 178–190 bpm) and a recovery game activity lasting 3 min (at 65%–75% of the HRmax, approximately 136–147 bpm), and this sequence was repeated 4 times; and (iii) children played a 10-min low-intensity game for cool-down. To increase the workload, after the 12th week of the program, the duration of the HIIT segment was increased from 28 to 32 min, structured into 4 blocks of alternating 5-min high-intensity activity with 3-min recovery activity. During this phase, the warm-up and the cool-down each lasted approximately 10 min.

To ensure program fidelity, session plans were provided in advance, enabling facilitators to adhere to the established schedule and address any potential questions before implementation. Heart rate monitors (Polar; F1TM, Finland) were used to verify that children achieved the planned intensity of PA. When the target heart rate was not met, trainers applied the following adaptations to reach the daily session goals: (1) ensuring no student remained idle by incorporating exercises performed in place (e.g., squats, jumping jacks, mountain climbers, planks, and high knees) while waiting their turn in relay games or after being "saved" in tag games; (2) reducing the playing area in specific activities; (3) increasing the number of chasers in tag-style games; (4) replacing student elimination with penalty points assigned per player; and (5) adding new rules to make games more dynamic, such as prohibiting passing the ball back to the same player who just made the pass in team games. Conversely, when children exceeded the planned heart rate, recovery games were omitted, and they rested while standing and listening to instructions for the next game (Ruiz-Hermosa et al. 2020).

On the other hand, children in both the IG and the CG continued to attend two regular 50-min physical education sessions per week as mandated by Spanish educational law.

Process evaluation. Program monitors were in charge of recording attendance at each session. In order to increase adherence to the program, children who attended more than 70% of the sessions were given small gifts featuring the program mascot as a reward (spinners, fidgets, t-shirts, etc.). Parents were provided with a phone number and email address to receive updates on the program's progress. Monitors were regularly contacted by phone and email to monitor children's attendance at the program and researchers visited some of the sessions to support monitors during session implementation. In addition, researchers visited the schools to evaluate program success and administer satisfaction surveys to children and parents. Finally, the monitors were also in charge of documenting adverse effects related to the program and tracking reasons for dropouts.

2.4 | Data Analysis

Researchers entering the participant outcomes into the database and doing the analyzes were unaware of the participants' allocation. The data were entered twice into the statistical analysis software and cross-checked to ensure accuracy and prevent potential bias.

The number of participants analyzed for HRQoL was lower than those assessed for MC. This discrepancy is due to some children not completing the HRQoL questionnaire correctly, such as leaving items unanswered or providing multiple responses to a single item, which led to their exclusion from the final analysis.

To evaluate the effectiveness of the randomization process, an initial exploration of outlier values was performed, and the normal distribution of the variables was assessed using the Kolmogorov–Smirnov test. All variables fitted to a normal distribution.

Analyzes were conducted on the intention-to-treat basis. To test differences between the IG and CG, mixed linear regression models (Verbeke and Molenberghs 2009) were employed to evaluate the variation between baseline and postintervention measurements for the total sample as well as by sex. Each outcome was considered as the dependent variable, and the intervention was considered as the fixed effect. Baseline data of the outcome variable, age, sex, and cluster factor school were included as covariates. The estimated effect for quantitative outcomes reflects the adjusted difference between groups over time. Additionally, results are presented as the crude variation, calculated as the difference in mean changes between intervention and control groups: (Mean_IG_post − Mean_IG_pre) − (Mean_CG_post − Mean_CG_pre).

Additionally, subgroup analyzes were performed, including two weight status subgroups (normal weight and overweight/obesity) and two SES subgroups (low and medium/high), according to the International Obesity Task Force (Cole and Lobstein 2012) and the Spanish Society of Epidemiology (Domingo-Salvany et al. 2000), respectively.

The analyzes were carried out using the Stata 16.0 software and were deemed statistically significant at $p < 0.05$.

3 | Results

3.1 | Effectiveness on Motor Competence and Health-Related Quality of Life

Figure 1 shows the flow diagram of schools and study participants for MC and HRQoL, respectively. All 10 schools agreed to participate in the study, resulting in a total sample of 562 children. Of these, 475 (85.4%) and 373 (66.4%) had valid data for both measurements (baseline and after the intervention in HRQoL and GMC, respectively). These data were used for the analysis. No differences in age, sex, or BMI were found between children with valid data and those without. Descriptive baseline characteristics of the study sample of the IG ($n = 231$ in GMC and $n = 185$ in HRQoL) versus the CG ($n = 244$ in GMC and $n = 188$ in HRQoL) with total sample are presented in Table 1. No significant differences in baseline characteristics and outcome variables were found between the IG and the CG for the total sample, except for static balance in favor of the IG.

Table 2 presents data on GMC and HRQoL outcomes at baseline and after the intervention as well as the adjusted differences between the IG and the CG after the MOVI-daFIT! intervention, controlling for age, sex, and cluster factor school. No statistically significant changes in HRQoL or GMC variables were found in the total sample or when analized by sex (Tables S1–S3).

Subgroup analyzes based on weight status and SES revealed no significant differences in any of the analyzes conducted (Tables S4 and S5).

3.2 | Evaluation of the Intervention

Compliance with attendance in the program. A total of 204 (73.9%) of the 276 students who took part in the baseline measurements in the IG were enrolled in the MOVI-daFIT! intervention. Of these, 50 (24.5%) children attended more than 70% of the 102 total sessions and 102 (50%) attended more than 50% of the sessions.

TABLE 1 | Baseline characteristics among the intervention group versus the control group.

	Intervention group Total sample (n = 231)	Control group Total sample (n = 244)
Characteristics		
Age (years)	9.84 (0.58)	9.99 (0.58)
Socioeconomic status (%)		
Lower–upper lower	25.13%	21.27%
Lower middle	51.28%	53.85%
Upper middle–upper	23.59%	24.88%
Anthropometry and body composition		
Weight (kg)	35.97 (9.44)	35.78 (9.25)
Height (cm)	140.32 (6.69)	140.39 (7.25)
Body mass index (kg/m^2)	18.12 (3.83)	17.98 (3.63)
Body fat mass (%)	23.55 (6.94)	23.87 (6.33)
GMC		
Aiming-catching	18.73 (5.70)	18.22 (5.35)
Balance	30.67 (5.15)	30.09 (4.99)
Static balance	9.94 (3.09)	9.10 (3.24)
Dynamic balance	20.74 (3.42)	20.99 (3.13)
GMC	49.40 (8.45)	48.31 (7.78)
HRQoL	***n* = 185**	***n* = 188**
Physical	52.48 (7.83)	52.47 (9.20)
Psychological	55.74 (8.84)	56.27 (9.67)
Parents	54.50 (9.51)	54.26 (9.88)
Peers	57.41 (7.79)	56.88 (8.57)
School	60.98 (7.65)	59.85 (9.24)
Global HRQoL index	57.42 (8.96)	57.25 (10.52)

Note: Results are shown as means and standard deviations, except for socioeconomic status, which are shown as percentages (%). GMC outcomes are shown using scaled scores.
Abbreviations: GMC, gross motor competence and HRQoL, health-related quality of life.

Compliance with the high-intensity requirements of program activities. The average heart rate for each session was 163 bpm (77.6% HRmax). In games involving intense PA, the mean heart rate was 189 bpm (94% HRmax), whereas in games involving recovery, it was 120 bpm (60% HRmax). Eighty percent of the program monitors communicated that the suggested games almost always reached the expected HR, and all of them indicated that the children were constantly engaged in the activities. Program monitors most frequently increased intensity by (i) enforcing rules to keep children active through stationary exercises (e.g., skipping, planks, and squats) while waiting their turn; (ii) reducing the play area; and (iii) extending play time by adding more taggers or avoiding player elimination. Instructors expressed that adjustments were made to increase the intensity, and almost never because students exceeded the planned intensity.

Satisfaction with the program. Children and their parents responded to a questionnaire to gauge satisfaction with the program's activities (Martínez-Vizcaíno et al. 2019). Overall, 93.3% of the children reported enjoying MOVI-daFIT!, and 80% said their parents did not need to remind them to attend the sessions. In addition, 93.2% of the parents indicated that the activities performed were fun for their children, and 46.9% said that MOVI-daFIT! had increased their children's PA levels. Furthermore, 90.6% of parents reported that they were satisfied or very satisfied with the program.

3.3 | Adverse Outcomes

No adverse outcomes were reported by children during the measurement process or PA sessions.

4 | Discussion

To our knowledge, this is the first study to assess the effectiveness of a school-based intervention incorporating a HIIT protocol into playground games to assess its effect on GMC and HRQoL in typically developing children. The results of this study showed that the MOVI-daFIT! intervention was not effective in improving GMC or HRQoL.

In relation to MC, our results differ from those reported by Meßler et al. 2018, who found that a 3-week HIIT program (three sessions/week of 4-min sets of exercise at 95% HRmax, with 3-min intervals at < 60% of HRmax) was more effective than low-to-moderate intensity exercise therapy (namely, three weekly 60-min sessions of ball and team games and climbing at low-to-moderate intensity, < 70% HRmax) for improving MC (including manual dexterity, ball skills, and overall MC score) and HRQoL (self-esteem and friends) in boys with ADHD. Our results also differ from those of studies by Torabi et al. 2016, and Torabi, Ebrahim, and Hemayattalab 2016, which revealed a positive impact on perceptual-motor skills in adolescents with ADHD after a HIIT program in which the exercise protocol consisted of 20 m shuttle runs with different repetitions in weeks one to six, with rest intervals of 20–30 s between runs, compared to adolescents with the same disorder who did not participate in physical exercise. Several factors may explain these discrepancies. First, the HIIT protocol used in Torabi's studies (Torabi et al. 2016; Torabi et al. 2016b) differed from ours, with both high-intensity and rest periods being significantly shorter. Second, Torabi's studies (Torabi et al. 2016; Torabi et al. 2016b) employed the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks and Bruininks 2012), a different MC assessment tool, which may limit comparability of results. Third, the intervention duration in the cited studies was considerably shorter —three (Meßler et al. 2018) and six (Torabi et al. 2016; Torabi et al. 2016b) weeks— compared to the 8-month intervention in our study. This extended duration may have attenuated the immediate positive effects on MC due to potential declines in engagement or adaptation over time. Fourth, unlike our intervention, which incorporated modified games to maintain intensity, the programs in the cited studies (Meßler et al. 2018; Torabi et al. 2016; Torabi et al. 2016b) were

TABLE 2 | Changes on gross motor competence (GMC) and health-related quality of life (HRQoL).

Outcome	Baseline		After intervention		Difference between after intervention and baseline		Crude variation	Effect estimate	
	Intervention Group	Control Group	Intervention group	Control group	Intervention group	Control group	ΔIG–ΔCG[a]	Estimate[b] (95% CI)	*p*-value
GMC	$n = 231$	$n = 244$	$n = 231$	$n = 244$					
Aiming-catching	18.73 (5.70)	18.22 (5.35)	19.30 (5.30)	19.68 (5.01)	0.58	1.46	−0.88	−0.59 (−1.38 to 0.20)	0.143
Balance	30.67 (5.15)	30.09 (4.99)	32.92 (4.61)	32.83 (3.57)	2.25	2.74	−0.49	−0.19 (−1.1 to 0.70)	0.667
Static balance	9.94 (3.09)	9.10 (3.24)	10.68 (2.93)	10.27 (3.01)	0.74	1.17	−0.43	0.08 (−0.71–0.87)	0.841
Dynamic balance	20.74 (3.42)	20.99 (3.13)	22.24 (2.66)	22.56 (1.62)	1.51	1.57	−0.06	−0.37 (−0.81 to 0.80)	0.107
GMC	49.40 (8.45)	48.31 (7.78)	52.22 (7.69)	52.50 (6.34)	2.82	4.19	−1.37	−0.82 (−1.97 to 0.34)	0.165
HRQoL	$n = 185$	$n = 188$	$n = 185$	$n = 188$					
Physical	52.48 (7.83)	52.47 (9.20)	55.76 (9.40)	55.08 (9.31)	3.28	2.61	0.67	0.36 (−1.64–2.36)	0.722
Psychological	55.74 (8.84)	56.27 (9.67)	57.47 (9.67)	56.99 (9.44)	1.73	0.72	1.00	0.65 (−1.58–2.88)	0.568
Parents	54.50 (9.51)	54.26 (9.88)	55.80 (9.99)	54.97 (9.89)	1.30	0.71	0.59	0.45 (−1.77–2.67)	0.689
Peers	57.41 (7.79)	56.88 (8.57)	57.10 (8.53)	55.96 (8.41)	−0.31	−0.92	0.61	1.28 (−0.75–3.31)	0.216
School	60.98 (7.65)	59.85 (9.24)	59.45 (9.25)	58.81 (9.23)	−1.53	−1.04	−0.49	−0.30 (−2.49 to 1.90)	0.792
Global HRQoL index	57.42 (8.96)	57.25 (10.52)	59.09 (10.71)	58.61 (10.47)	1.66	1.36	0.30	0.11 (−2.44–2.67)	0.929

Note: Results are shown as means and standard deviations. GMC outcomes are shown using scaled scores.
Abbreviations: CG, control group; CI, confidence interval; and IG, intervention group.
[a]Crude variations describe differences between mean change in the intervention group and mean change in the control group.
[b]Intervention effects were estimated with mixed linear regression models adjusted for each baseline outcome variable, age, sex, and cluster-factor school.

explicitly designed to improve MC, potentially influencing outcomes. In line with this, previous research on non-HIIT PA interventions has reported positive effects on MC (Morgan et al. 2013; Roth et al. 2015; Bellows et al. 2013; Jiménez-Díaz et al. 2019; Kelly et al. 2021; Tsapakidou et al. 2014; Alhassan et al. 2012), particularly in programs focused on developing fundamental motor skills (Morgan et al. 2013). Finally, the cited studies (Meßler et al. 2018; Torabi et al. 2016; Torabi et al. 2016b) examined children and adolescents with ADHD, limiting the generalizability and comparability of their findings to typically developing children.

The findings of this study regarding the effects of PA interventions on HRQoL align with those reported in systematic reviews (Andermo et al. 2020; Hale et al. 2023; Rafferty et al. 2016), which indicate that school-based interventions often yield no significant effects on HRQoL or produce inconclusive results. Conversely, other reviews and meta-analyses (Marker et al. 2018; Andermo et al. 2020) have highlighted improvements in well-being and HRQoL associated with school-based PA interventions. In this study, the IG exhibited a trend toward improvement across all HRQoL domains, except for the school environment. However, these improvements did not reach statistical significance. Several factors may explain this lack of significant outcomes, such as the type of activity, the physical and social environment of PA, or the way in which it is delivered (Vella et al. 2023). Specifically, (i) the intervention design did not consider factors known to support adherence (type); (ii) instructors did not deliver PA sessions using an instructional style that satisfies individuals' basic needs for autonomy, competence, and social connection (delivery); (iii) lack of participation in PA activities with others who provide support, facilitate positive interactions, or make people feel valued (social environment); (iv) PA was not undertaken outside in pleasant natural environments (physical environment); and (v) teachers did not receive specific training focused on enhancing HRQoL or mental health, and no data were recorded by researchers to confirm that sessions were delivered as intended (delivery). Evidence suggests that the impact of PA on youth mental health and well-being, including HRQoL, can be influenced by the quality of session delivery (Vella et al. 2023). Therefore, the absence of these elements may have limited the effectiveness of the intervention in improving HRQoL.

The ineffectiveness of the MOVI-daFIT! intervention in GMC and HRQoL could be explained by (i) although the philosophy of the MOVI-daFit program was to offer playground games (favoring cooperation and teamwork) and was based on the development of basic motor skills, it should be noted that the main focus was on keeping the intensity of PA high during the games. Thus, program monitors and children focused on increasing the intensity of the exercise (quantitative aspect of the movement) and not on its quality, which would be more associated with the measurements of MC. In addition, a higher exercise intensity could, in turn, lead to greater fatigue, which could be detrimental to motor performance (Branscheidt et al. 2019). (ii) It is likely that the battery used to assess GMC (MABC-2) did not actually measure the skills developed in the program. For example, all static balance positions were omitted, which is a key component (balance) assessed by the MABC-2 battery. (iii) As mentioned, teachers did not receive specific training focused on enhancing quality of life or mental health (Vella et al. 2023). (iv) Although our intervention lasted for one school year, this duration may be adequate to achieve changes in physical health variables, such as cardiorespiratory fitness, but may be insufficient to produce changes in self-esteem or psychological well-being (Resaland et al. 2019). (v) Finally, the low rate of adherence to the program could have influenced its effectiveness, since many of the participants did not receive the treatment as designed. The Spanish context, where schoolchildren have access to a wide range of extracurricular activities, combined with the voluntary nature of our program, may have influenced the low adherence rate. Greater involvement from schools, by integrating the program into the academic curriculum as a graded activity, could have improved adherence rates and, consequently, the intervention's effectiveness. This consideration should be taken into account when designing and implementing future school-based interventions.

4.1 | Implications for School Health Policy, Practice, and Equity

Our intervention is characterized by its noncompetitive nature and inclusivity, making it suitable for all children except those with severe disabilities. Furthermore, our data indicate that HIIT interventions are suitable for integration into playground games. Given that children's natural PA patterns involve brief bursts of intense activity interspersed with periods of low-moderate intensity, HIIT programs appear to be acceptable given the characteristics of children's PA patterns. Because the intervention was conducted in a school setting, no children were excluded on the basis of sex, ethnicity, fitness level, or motor skills. This intervention is highly replicable, as the MOVI-daFIT! games are described in detail in an e-book (Ruiz-Hermosa et al. 2020). The program was well received, likely due to its game-based approach. Moreover, no adverse effects were reported. Regarding program satisfaction, results showed that 93.3% of children enjoyed participating in MOVI-daFit! and 80% needed no reminders to attend. Additionally, 93.2% of parents found the activities enjoyable for their children, 46.9% observed increased PA levels, and 90.6% were satisfied or very satisfied with the program.

4.2 | Limitations

Several limitations have been identified. (i) Our intervention may have introduced selection bias, as it was implemented mainly in rural areas, and this could limit its generalization to urban school contexts. (ii) Although the evaluators were unaware of the allocation to each group, it should be noted that at the end of the follow-up, participants may have informed the evaluators that they were taking part in a PA program, thus making it impossible to ensure blinding at the follow-up measurement. (iii) Due to the voluntary nature of the program, conclusions about a compulsory setting cannot be drawn. (iv) The low adherence rate of schoolchildren to the program may have influenced the effectiveness of the intervention. (v) The program did not control PA patterns in the participants, so it is feasible that more active children during the intervention would manifest compensatory behaviors during the rest of the day or on weekends, which would compromise the effects of the intervention. (vi) An integral approach was not used in the design and implementation of the intervention, and overwhelming evidence support that isolated school-based interventions do not usually reach their full potential for impact (Mavilidi et al. 2018; Haggis et al. 2013), since several key factors will determine the effectiveness of interventions in school. (vii) Although the level of satisfaction and enjoyment with the program was very high, it is likely that other characteristics of the games not measured in our study, such as aspects of social climate and group cohesion, may have influenced adherence and consequently the effectiveness of the program. Therefore, future studies on educational programs should consider these aspects to gain a more complete understanding of the intervention's impact. (viii) Teachers did not receive specific training aimed at enhancing HRQoL or mental health, and researchers did not conduct observations to verify the quality of session delivery (Vella et al. 2023). Future studies should take this into account to improve the impact of PA interventions on HRQoL and mental health outcomes.

4.3 | Conclusion

This study shows that the one-school-year high-intensity interval games program, MOVI-daFIT!, was not effective in improving GMC or HRQoL in typically developing children.

Despite the potential of implementing HIIT programs in schools to improve health indicators such as physical fitness and body composition, this study did not demonstrate a significanteffect of the intervention on GMC and HRQoL. The program's effectiveness could be enhanced by designing activities that balance exercise intensity with movement quality—ensuring correct execution and incorporating feedback from teachers—while aligning motor skill development with the domains assessed by the chosen MC evaluation tools. Additionally, a more targeted approach to the development of HRQoL-related dimensions—such as activities that foster peer relationships, satisfy basic psychological needs, and strengthen self-concept—could further improve intervention outcomes.

Author Contributions

Vicente Martínez-Vizcaíno was the principal investigator and obtained the funding. Antonio Fernández-Sánchez wrote the first draft of the manuscript with the support of Mairena Sánchez-López and Abel Ruiz-Hermosa. Andrés Redondo-Tébar and Vicente Martínez-Vizcaíno gave statistical and epidemiological support. Diana P. Pozuelo-Carrascosa and Estela Jiménez-López conducted the study. All author listed on the manuscript have revised and approved this version of the manuscript and take full responsibility for the manuscript.

Acknowledgments

The authors thank the schools, families, and children for their enthusiastic participation in the study. The authors thank all members of the Cuenca Study Group who helped make this study possible. Members of the Cuenca Study Group: Carlos Berlanga-Macías, Blanca Notario-Pacheco, Ana Díez-Fernández, María Jesús Pardo-Guijarro, María Eugenia Visier-Alfonso, Celia Álvarez-Bueno, Marta Nieto-López, Alberto González-García, Jorge Cañete García-Prieto, Ana Torres-Costoso, Antonio García-Hermoso, Caterina Pesce, and Ricardo Cuevas-Campos. The authors also thank the University of Castilla-La Mancha for providing Open Access funding.

Ethics Statement

All procedures performed in this study were conducted in accordance with the Declaration of Helsinki and its ethical principles for research involving humans subjects. The study was approved by the management team of each school and by the Clinical Research Ethics Committee of Virgen de la Luz Hospital in Cuenca, Spain. (REG: 2016/PI021).

Consent

All parents signed an informed consent form prior to their children's participation in the study. Before data collection, all children were asked whether they wished to participate and were informed they could drop out at any time during the study. All data were handled confidentially. All authors report that (1) the manuscript has not been submitted to or is not under consideration by another journal, (2) none of the content of this manuscript has been published before, and (3) have read and approved the manuscript and are willing to cede copyright of the manuscript should it be accepted for publication.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author (Abel Ruiz-Hermosa) upon reasonable request. The data are not publicly available due to containing information that could compromise the privacy of research participants.

References

Alhassan, S., O. Nwaokelemeh, M. Ghazarian, J. Roberts, A. Mendoza, and S. Shitole. 2012. "Effects of Locomotor Skill Program on Minority Preschoolers' Physical Activity Levels." *Pediatric Exercise Science* 24, no. 3: 435–449. https://doi.org/10.1123/pes.24.3.435.

Alves, A. R., R. Dias, H. P. Neiva, et al. 2021. "High-Intensity Interval Training Upon Cognitive and Psychological Outcomes in Youth: A Systematic Review." *International Journal of Environmental Research and Public Health* 18, no. 10: 5344. https://doi.org/10.3390/ijerph18105344.

Andermo, S., M. Hallgren, T.-T.-D. Nguyen, et al. 2020. "School-Related Physical Activity Interventions and Mental Health Among Children: A Systematic Review and Meta-Analysis." *Sports Med - Open* 6, no. 1: 25. https://doi.org/10.1186/s40798-020-00254-x.

Aznar, S., P. J. Naylor, P. Silva, et al. 2011. "Patterns of Physical Activity in Spanish Children: A Descriptive Pilot Study." *Child: Care, Health and Development* 37, no. 3: 322–328. https://doi.org/10.1111/j.1365-2214.2010.01175.x.

Bellows, L. L., P. L. Davies, J. Anderson, and C. Kennedy. 2013. "Effectiveness of a Physical Activity Intervention for Head Start Preschoolers: A Randomized Intervention Study." *American Journal of Occupation Therapy Official Public American Occupation Therapy Association* 67, no. 1: 28–36. https://doi.org/10.5014/ajot.2013.005777.

Bermejo-Cantarero, A., M. Sánchez-López, C. Álvarez-Bueno, A. Redondo-Tébar, A. García-Hermoso, and V. Martínez-Vizcaino. 2024. "Are Physical Activity Interventions Effective in Improving Health-Related Quality of Life in Children and Adolescents? A Systematic Review and Meta-Analysis." *Sports Health* 16, no. 6: 877–885. https://doi.org/10.1177/19417381231190885.

Bond, B., K. Weston, C. Williams, and A. Barker. 2017. "Perspectives on High-Intensity Interval Exercise for Health Promotion in Children and Adolescents." *Open Access Journal of Sports Medicine* 8: 243–265. https://doi.org/10.2147/OAJSM.S127395.

Branscheidt M., P. Kassavetis, M. Anaya, et al. 2019. "Fatigue Induces Long-Lasting Detrimental Changes in Motor-Skill Learning." *Elife* 8: e40578. https://doi.org/10.7554/eLife.40578.

Bruininks, R. H., and B. D. Bruininks. 2012. Bruininks-Oseretsky Test of Motor Proficiency. 2nd ed. https://doi.org/10.1037/t14991-000.

Campbell, M. K., D. R. Elbourne, and D. G. Altman. 2004. "CONSORT Statement: Extension to Cluster Randomised Trials." *BMJ* 328, no. 7441: 702–708. https://doi.org/10.1136/bmj.328.7441.702.

Cole, T. J., and T. Lobstein. 2012. "Extended International (IOTF) Body Mass Index Cut-Offs for Thinness, Overweight and Obesity." *Pediatr Obes* 7, no. 4: 284–294. https://doi.org/10.1111/j.2047-6310.2012.00064.x.

Costigan, S. A., N. Eather, R. C. Plotnikoff, C. H. Hillman, and D. R. Lubans. 2016. "High-Intensity Interval Training for Cognitive and Mental Health in Adolescents." *Medicine & Science in Sports & Exercise* 48, no. 10: 1985–1993. https://doi.org/10.1249/MSS.0000000000000993.

Domingo-Salvany, A., E. Regidor, J. Alonso, and C. Alvarez-Dardet. 2000. "Proposal for a Social Class Measure. Working Group of the Spanish Society of Epidemiology and the Spanish Society of Family and Community Medicine." *Atención Primaria* 25, no. 5: 350–363.

Donner, A., and N. Klar. 2000. *Design and Analysis of Cluster Randomization Trials in Health Research*. Oxf Univ Press.

Eather, N., M. Babic, N. Riley, S. A. Costigan, and D. R. Lubans. 2022. "Impact of Embedding High-Intensity Interval Training in Schools and Sports Training on Children and Adolescent's Cardiometabolic Health and Health-Related Fitness: Systematic Review and Meta-Analysis." *Journal of Teaching in Physical Education* 42, no. 2: 1–13. https://doi.org/10.1123/jtpe.2021-0165.

Eddolls, W. T. B., M. A. McNarry, G. Stratton, C. O. N. Winn, and K. A. Mackintosh. 2017. "High-Intensity Interval Training Interventions in Children and Adolescents: A Systematic Review." *Sports Med Auckl NZ* 47, no. 11: 2363–2374. https://doi.org/10.1007/s40279-017-0753-8.

Eime, R. M., J. A. Young, J. T. Harvey, M. J. Charity, and W. R. Payne. 2013. "A Systematic Review of the Psychological and Social Benefits of Participation in Sport for Children and Adolescents: Informing Development of a Conceptual Model of Health through Sport." *International Journal of Behavioral Nutrition and Physical Activity* 10, no. 1: 98. https://doi.org/10.1186/1479-5868-10-98.

García-Hermoso, A., A. J. Cerrillo-Urbina, T. Herrera-Valenzuela, C. Cristi-Montero, J. M. Saavedra, and V. Martínez-Vizcaíno. 2016. "Is High-Intensity Interval Training More Effective on Improving Cardiometabolic Risk and Aerobic Capacity Than Other Forms of Exercise in Overweight and Obese Youth? A Meta-Analysis." *Obesity Review Official Journal of International Association Study Obesity* 17, no. 6: 531–540. https://doi.org/10.1111/obr.12395.

Gaspar, T., M. Matos, J. Pais-Ribeiro, L. José, I. Leal, and A. Ferreira. 2009. "Health-related Quality of Life in Children and Adolescents and Associated Factors." *Journal of Cognitive and Behavioral Psychotherapies* 9: 33–48.

Guthold, R., G. A. Stevens, L. M. Riley, and F. C. Bull. 2020. "Global Trends in Insufficient Physical Activity Among Adolescents: A Pooled Analysis of 298 Population-Based Surveys With 1·6 Million Participants." *Lancet Child Adolesc Health* 4, no. 1: 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2.

Haggis, C., J. Sims-Gould, M. Winters, K. Gutteridge, and H. A. McKay. 2013. "Sustained Impact of Community-Based Physical Activity Interventions: Key Elements for Success." *BMC Public Health* 13, no. 1: 892. https://doi.org/10.1186/1471-2458-13-892.

Hale, G. E., L. Colquhoun, D. Lancastle, N. Lewis, and P. J. Tyson. 2023. "Physical Activity Interventions for the Mental Health of Children: A Systematic Review." *Child: Care, Health and Development* 49, no. 2: 211–229. https://doi.org/10.1111/cch.13048.

Harris, N., I. Warbrick, D. Atkins, A. Vandal, L. Plank, and D. R. Lubans. 2021. "Feasibility and Provisional Efficacy of Embedding High-Intensity Interval Training into Physical Education Lessons: A Pilot Cluster-Randomized Controlled Trial." *Pediatric Exercise Science* 33, no. 4: 186–195. https://doi.org/10.1123/pes.2020-0255.

Henderson, S. E., D. Sugden, and A. L. Barnett. 2007. "Movement Assessment Battery for Children-2." *PsycTESTS Dataset*. https://doi.org/10.1037/t55281-000.

Janssen, I., and A. G. LeBlanc. 2010. "Systematic Review of the Health Benefits of Physical Activity and Fitness in School-Aged Children and Youth." *International Journal of Behavioral Nutrition and Physical Activity* 7, no. 1: 40. https://doi.org/10.1186/1479-5868-7-40.

Jiménez-Díaz, J., K. Chaves-Castro, and W. Salazar. 2019. "Effects of Different Movement Programs on Motor Competence: A Systematic Review With Meta-Analysis." *Journal of Physical Activity and Health* 16, no. 8: 657–666. https://doi.org/10.1123/jpah.2018-0179.

Kelly, L., S. O'Connor, A. J. Harrison, and N. J. Ní Chéilleachair. 2021. "Effects of an 8-week School-Based Intervention Programme on Irish School Children's Fundamental Movement Skills." *Physical Education and Sport Pedagogy* 26, no. 6: 593–612. https://doi.org/10.1080/17408989.2020.1834526.

Leahy, A. A., M. F. Mavilidi, J. J. Smith, et al. 2020. "Review of High-Intensity Interval Training for Cognitive and Mental Health in Youth." *Medicine & Science in Sports & Exercise* 52, no. 10: 2224–2234. https://doi.org/10.1249/MSS.0000000000002359.

Marker, A. M., R. G. Steele, and A. E. Noser. 2018. "Physical Activity and Health-Related Quality of Life in Children and Adolescents: A Systematic Review and Meta-Analysis." *Health Psychology* 37, no. 10: 893–903. https://doi.org/10.1037/hea0000653.

Martínez-Vizcaíno, V., C. Álvarez-Bueno, I. Cavero-Redondo, et al. 2019. "MOVI-daFIT! Intervention: Rationale and Design of a Cluster Randomized Controlled Trial Testing the Effects on Improving Adiposity, Cognition, and Subclinical Atherosclerosis by Increasing Cardiorespiratory Fitness in Children." *Medicine (Baltimore)* 98, no. 9: e14737. https://doi.org/10.1097/MD.0000000000014737.

Mavilidi, M. F., M. Ruiter, M. Schmidt, et al. 2018. "A Narrative Review of School-Based Physical Activity for Enhancing Cognition and Learning: The Importance of Relevancy and Integration." *Frontiers in Psychology* 9. https://doi.org/10.3389/fpsyg.2018.02079.

Medalia, A., and M. Erlich. 2017. "Why Cognitive Health Matters." *American Journal of Public Health* 107, no. 1: 45–47. https://doi.org/10.2105/AJPH.2016.303544.

Mezcua-Hidalgo, A., A. Ruiz-Ariza, S. Suárez-Manzano, and E. J. Martínez-López. 2019. "48-Hour Effects of Monitored Cooperative High-Intensity Interval Training on Adolescent Cognitive Functioning." *Percept Mot Skills* 126, no. 2: 202–222. https://doi.org/10.1177/0031512518825197.

Meßler, C. F., H.-C. Holmberg, and B. Sperlich. 2018. "Multimodal Therapy Involving High-Intensity Interval Training Improves the Physical Fitness, Motor Skills, Social Behavior, and Quality of Life of Boys With ADHD: A Randomized Controlled Study." *Journal of Attention Disorders* 22, no. 8: 806–812. https://doi.org/10.1177/1087054716636936.

Morgan, P. J., L. M. Barnett, D. P. Cliff, et al. 2013. "Fundamental Movement Skill Interventions in Youth: A Systematic Review and Meta-Analysis." *Pediatrics* 132, no. 5: e1361–e1383. https://doi.org/10.1542/peds.2013-1167.

Pietrobelli, A., F. Rubiano, M. P. St-Onge, and S. B. Heymsfield. 2004. "New Bioimpedance Analysis System: Improved Phenotyping With

Whole-Body Analysis." *European Journal of Clinical Nutrition* 58, no. 11: 1479–1484. https://doi.org/10.1038/sj.ejcn.1601993.

Poon, E. T.-C., W. Wongpipit, F. Sun, A. C.-Y. Tse, and C. H.-P. Sit. 2023. "High-intensity Interval Training in Children and Adolescents With Special Educational Needs: A Systematic Review and Narrative Synthesis." *International Journal of Behavioral Nutrition and Physical Activity* 20, no. 1: 13. https://doi.org/10.1186/s12966-023-01421-5.

Pozuelo-Carrascosa, D. P., A. García-Hermoso, C. Álvarez-Bueno, M. Sánchez-López, and V. Martinez-Vizcaino. 2018. "Effectiveness of School-Based Physical Activity Programmes on Cardiorespiratory Fitness in Children: A Meta-Analysis of Randomised Controlled Trials." *British Journal of Sports Medicine* 52, no. 19: 1234–1240. https://doi.org/10.1136/bjsports-2017-097600.

Rafferty, R., G. Breslin, D. Brennan, and D. Hassan. 2016. "A Systematic Review of School-Based Physical Activity Interventions on Children's Wellbeing." *International Review of Sport and Exercise Psychology* 9, no. 1: 215–230. https://doi.org/10.1080/1750984X.2016.1164228.

Resaland, G. K., E. Aadland, V. F. Moe, R. L. Kolotkin, S. A. Anderssen, and J. R. Andersen. 2019. "Effects of a Physical Activity Intervention on Schoolchildren's Health-Related Quality of Life: The Active Smarter Kids (ASK) Cluster-Randomized Controlled Trial." *Preventive Medicine Report* 13: 1–4. https://doi.org/10.1016/j.pmedr.2018.11.002.

Roth, K., S. Kriemler, W. Lehmacher, K. C. Ruf, C. Graf, and H. Hebestreit. 2015. "Effects of a Physical Activity Intervention in Preschool Children." *Medicine & Science in Sports & Exercise* 47, no. 12: 2542–2551. https://doi.org/10.1249/MSS.0000000000000703.

Ruiz-Hermosa, A., M. Sánchez-López, V. Martínez-Vizcaino, and A. Redondo-Tébar. 2020. *MOVI-da FIT! an After-School Program of Physical Activity Based on the HIIT Methodology to Prevent Obesity and Improve Physical Fitness and Academic Performance*. Ediciones de la Universidad de Castilla-La Mancha.

Slade, S. C., C. E. Dionne, M. Underwood, and R. Buchbinder. 2016. "Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement." *British Journal of Sports Medicine* 50, no. 23: 1428–1437. https://doi.org/10.1136/bjsports-2016-096651.

The KIDSCREEN Group Europe 2006. *The KIDSCREEN Questionnaires-Quality of Life Questionnaires for Children and Adolescents*. Pabst Science Publishers.

Torabi, F., R. Ebrahim, and R. Hemayattalab. 2016. "The Effect of High Intensity Interval Training on Serum Serotonin and Perceptual-Motor Skills in Boys' Student With Attention Deficit Hyperactivity Disorder." *Pajoohandeh J* 21, no. 3: 167–173.

Torabi, F., R. Ebrahim, R. Hemayattalab, and A. Ramezankhani. 2016. "Effect of 6 Weeks High Intensity Interval Training on Dopamine Levels and Improvement of Perceptual Motor Skills in Adolescent Girls With Attention Deficit Hyperactivity Disorder." *Razi Journal of Medical Sciences* 23, no. 148: 106–114.

Tremblay, M. S., J. D. Barnes, I. Demchenko, et al. 2022. "Active Healthy Kids Global Alliance Global Matrix 4.0-A Resource for Physical Activity Researchers." *Journal of Physical Activity and Health* 19, no. 11: 693–699. https://doi.org/10.1123/jpah.2022-0257.

Tsapakidou, A., S. Stefanidou, and E. Tsompanaki. 2014. "Locomotor Development of Children Aged 3.5 to 5 Years in Nursery Schools in Greece." *Review of European Studies* 6, no. 2: p1. https://doi.org/10.5539/res.v6n2p1.

Vella, S. A., E. Aidman, M. Teychenne, et al. 2023. "Optimising the Effects of Physical Activity on Mental Health and Wellbeing: A Joint Consensus Statement From Sports Medicine Australia and the Australian Psychological Society." *Journal of Science and Medicine in Sport* 26, no. 2: 132–139. https://doi.org/10.1016/j.jsams.2023.01.001.

Verbeke, G., and G. Molenberghs. 2009. *Linear Mixed Models for Longitudinal Data*. Springer Science and Business Media.

Warburton, D. E. R., C. W. Nicol, and S. S. D. Bredin. 2006. "Health Benefits of Physical Activity: The Evidence." *Canadian Medical Association Journal* 174, no. 6: 801–809. https://doi.org/10.1503/cmaj.051351.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.