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Individual responsiveness to a school-based karate intervention: An ancillary analysis of a randomized controlled trial

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Introduction: School-based sport interventions have shown beneficial effects on psychosocial functioning and academic performance in children. However, the inter-individual variability in response to these types of interventions remains unclear. We aimed to determine which children benefit most from a school-based sport intervention.

Methods: This is an ancillary analysis of a randomized controlled trial assessing the effects of a 1-year school-based karate intervention (versus "traditional" physical education lessons) in children (7–8 years) from twenty schools across five European countries. Outcomes included psychosocial functioning (Strengths and Difficulties Questionnaire [SDQ] for parents) and academic performance (grade point average). Only participants of the intervention group were included in the present ancillary analysis, and were categorized as responders or non-responders for the analyzed outcomes attending to whether improvements surpassed a minimal clinically important difference.

Results: About 388 children (187 girls) from the intervention group completed the study, of which 17% and 46% were considered responders for SDQ and academic performance, respectively. Responders for the SDQ presented higher SDQ scores (i.e., higher psychosocial difficulties) at baseline than non-responders ($p < 0.001$). Responders for academic performance were mostly males ($p = 0.017$), with an older age ($p = 0.030$), and with worse academic performance ($p < 0.001$) at baseline compared with non-responders, and tended to present higher SDQ scores ($p = 0.055$). Responders for one outcome obtained greater benefits from the intervention on the other outcome (e.g., responders for SDQ improved academic performance [$p < 0.001$] compared with non-responders).

Conclusions: A school-based sport intervention (karate) seems particularly effective for children with psychosocial difficulties and low academic performance.

Tania Pinto-Escalona and Pedro L. Valenzuela Contributed equally as first co-authors.

KEYWORDS
academic achievement, martial arts, physical education, psychosocial difficulties, responders, sport

1 | INTRODUCTION

Strong experimental and observational evidence supports that school-based sport interventions benefit psychosocial functioning and academic performance in children.[1,2] For instance, Harrison and Narayan found an inverse association between participation in team sports at school and the presence psychosocial difficulties,[3] whereas Wretman reported that sport participation at school was positively associated with academic performance.[4]

It remains unclear, however, whether all types of sport benefit psychosocial functioning and academic performance. In this regard, growing evidence suggests that participating in martial arts could be particularly beneficial.[5-9] For instance, Lakes and Hoyt reported positive effects of a 3-month school-based martial arts intervention on cognitive and affective self-regulation, prosocial behavior, classroom's conduct, and maths performance in children.[7] However, although preliminary evidence supports the beneficial effects of karate on psychosocial functioning and academic performance,[8,10,11] there is a lack of large randomized controlled trials (RCT).

In order to fill the abovementioned research gap, a recent cluster RCT by our research group showed that a one-year school-based karate intervention was overall effective for the improvement of academic performance, conduct problems, and physical fitness in 721 European primary school children.[12]

Scarce evidence exists, however, on the inter-individual variability in response to school-based sport interventions. Most exercise studies report mean data under the assumption that the group average represents the response of most individuals, but there is usually inter-individual variability in response to a given exercise intervention.[13] Sports science research is becoming increasingly attuned to the fact that after an exercise intervention which is overall statistically beneficial, some participants—known in the literature as "non-responders"—can show no benefits or even negative adaptations.[14] In this regard, although research supports the benefits of sport interventions—and particularly karate—on psychosocial functioning and academic performance, to the best of or knowledge no previous studies have determined whether inter-individual variability exists in response to these interventions. Moreover, in case that inter-individual variability exists, the analysis of those variables associated with a greater responsiveness could be of major relevance in order to individualize sport interventions so as to maximize responsiveness.

The aim of the present ancillary analysis was to analyze the inter-individual variability in response to a one-year school-based karate intervention through the analysis of responders and non-responders for psychosocial functioning and academic performance, as well as to determine those characteristics associated with a greater responsiveness.

2 | MATERIAL AND METHODS

2.1 | Study design

This is an ancillary analysis of our recent multi-country cluster RCT (*Sport at School* project), whose details can be found elsewhere.[12] Due to the apparent variability observed in our RCT, we performed this ancillary analysis (not originally planned) to examine inter-individual responses.

During the 2017–2018 academic year, a school-based karate intervention was implemented with second-grade students from 20 European schools (4 schools per country: Spain, Portugal, France, Germany, and Poland). Participants were randomized on a school basis to either a control (traditional Physical Education lessons) or an intervention group (*Karate Mind and Movement* program). Children who did not usually participate in Physical Education lessons due to health problems or disabilities were excluded. Moreover, for the present ancillary analysis, only children in the intervention group were included, and were categorized as either responders (positive change) or non-responders (no or detrimental change) attending to whether improvements for the analyzed outcomes surpassed the minimal clinically important difference.

Online written informed consent was obtained from parents or legal guardians of all the participants. All procedures were conducted in accordance with the ethical standards from the 1964 Declaration of Helsinki and its later amendments, and were approved by the Relevant Ethics Committee (Complutense University of Madrid, Spain).

2.2 | Intervention

Participants in the intervention group replaced their habitual physical education lessons (2 hours/week) with a karate intervention based on the *Karate Mind and Movement* program. The intervention provided children with sensory-motor stimuli for the development of basic motor skills and cognitive performance while facilitating collaboration. All sessions were practiced barefoot and started with initial karate bows and movements aimed at developing body awareness, balance, and coordination. The main part consisted of non-specific motor tasks aimed at improving cardiorespiratory fitness, strength, coordination, balance, and flexibility (e.g., somersaults, jumps, dynamic flexibility, advance in lunge position, going around vertical plastic sticks, and kicking to sponge balls). The final part of the sessions included stretching exercises, discussion about the class (e.g., feelings, difficulties), and final bows (see Pinto-Escalona et al. for more details).[12]

2.3 | Outcomes

All outcomes were analyzed at baseline and after the one academic year intervention. The primary outcomes of the original RCT and of this ancillary analysis were psychosocial functioning and academic performance.

Children's psychosocial functioning was assessed through the online version of the *Strengths and Difficulties Questionnaire* (SDQ) for parents, with a higher score reflecting more psychosocial difficulties.[15] The SDQ is a 25-item screening questionnaire with five scales, each consisting of five items, generating scores for emotional symptoms, conduct problems, hyperactivity/inattention, peer problems, and prosocial behavior. The first four scales were summed to generate a "total difficulties" score ranging from 0 to 40.

Academic performance was assessed as the grade point average (GPA) of all school subjects. Grades were reported by school teachers using a scale ranging from 0 (lowest score) to 10 (highest score).

Other analyzed variables used to compare responders and non-responders included cardiorespiratory fitness (assessed by means of the multistage 20-meter shuttle run test)[16,17] anthropometric characteristics (i.e., height, weight, body mass index, and weight status [normal weight or overweight/obesity] attending to age- and sex-specific percentiles body mass index),[18] physical activity levels (assessed through the Physical Activity Questionnaire for Children [PAQ-C]),[19] and socioeconomic status (assessed through the Q1009 question from the Short Questionnaire Rotation A).[20]

2.4 | Individual responsiveness

Participants were classified as responders for either SDQ or academic performance if they improved beyond a certain threshold. In the case of SDQ, participants were classified as responders attending to the Reliable Change Index, which has been proposed as a valid method for identifying meaningful changes in this scale.[21] Thus, participants in the intervention group were categorized as responders for SDQ if they reduced their "total difficulties" SDQ score by more than 1.96 points.

In the case of academic performance, as no information was found in the scientific literature regarding the threshold for clinically meaningful changes for this outcome, one-fifth of the between-subject standard deviation (SD) at baseline was taken as the threshold for clinically relevant improvements.[22,23] Thus, participants in the intervention group were categorized as responders for academic performance if they increased their GPA by more than 0.304 points.

In order to confirm whether true inter-individual differences in response to the intervention were present and that differences were not simply due to random within-subject variation, we computed the difference in SDs of the changes (post-intervention minus baseline) of the intervention and control groups as proposed elsewhere,[24] with data from the control group serving as an indicator of random within-subject variation and measurement error. We then checked that the computed difference (SD_R, which represents the typical true inter-individual variation in response to the intervention) was clinically meaningful. For both the SDQ and GPA, a greater variability was observed in the intervention than in the control group, with the SD_R (1.90 points for SDQ and 0.509 points for GPA) being greater or at least equal to the thresholds used to determine clinically meaningful responses in these outcomes. Thus, the individual variability observed can be considered clinically meaningful and not due to random error or statistical artifacts.

2.5 | Statistical analysis

Descriptive statistics are reported as mean ± standard deviation (SD) or percentages (%) for continuous and dichotomous variables, respectively.

One-way analyses of covariance (ANCOVA) and chi-squared tests (χ^2) were performed to assess baseline differences between responders and non-responders for continuous and dichotomous variables, respectively, using age, sex, country, school, and socioeconomic status as covariates.

Differences in the effect of the intervention between responders and non-responders were assessed using a mixed design repeated measures ANCOVA, with time (pre–post) as the within-subject factor and responsiveness status (responders versus non-responders) as the between-subject factor. All statistical analyses were conducted using a statistical Package (SPSS, version 25), and the statistical significance level was set at $p < 0.05$.

3 | RESULTS

Three hundred eighty-eight children (187 girls and 201 boys; 7.4 ± 0.5 years) participated in the intervention group and were included in this ancillary analysis. 17.3% of the participants were categorized as responders for SDQ (descriptive characteristics are shown in Table 1). Responders and non-responders for SDQ were similar (all $p > 0.05$) for most baseline variables, but the former presented greater psychosocial difficulties at baseline ($p < 0.001$), including higher scores for emotional symptoms ($p < 0.001$), hyperactivity/inattention ($p < 0.001$), and prosocial behavior ($p = 0.043$). On the contrary, 46.4% of the participants were categorized as responders for academic performance (descriptive characteristics are shown in Table 2). No between-group differences were found between responders and non-responders except for an older age ($p = 0.030$), a greater proportion of boys ($p = 0.017$), a worse GPA ($p < 0.001$), and a non-significant trend ($p = 0.055$) toward higher psychosocial difficulties in responders for academic performance compared with non-responders.

Responders for the SDQ improved their academic performance to a greater extent compared with non-responders ($p = 0.045$), with no significant differences were found for the remaining outcomes (all $p > 0.05$, Table 3). In the same line, compared with non-responders for academic performance, responders tended to show greater reductions of their psychosocial difficulties ($p < 0.1$ for overall SDQ scores, as well as for hyperactivity/inattention and prosocial behavior ($p = 0.074$) (Table 4).

4 | DISCUSSION

Although growing evidence supports the beneficial effects of school-based sport interventions—particularly those focused on martial arts—on psychosocial functioning and academic achievement, to date scarce evidence exists on whether inter-individual variability exists on response to these interventions or on those participants' characteristics associated with a greater responsiveness. The results of the present ancillary analysis show that inter-individual variability exists in response to a one academic

TABLE 1 Baseline characteristics of responders and non-responders for the Strength and Difficulties Questionnaire (SDQ)

Outcomes	SDQ responders baseline (n = 36)	SDQ non-responders baseline (n = 166)	*p*-value
Age (years, mean ± SD [95% CI])	7.38 ± 0.40 (7.25 to 7.51)	7.37 ± 0.37 (7.32 to 7.44)	0.630
Sex (girls, %)	25, 69.4%	90, 52.3%	0.060
Socioeconomic status (score, mean ± SD)	4.51 ±1.23	5.09 ±1.24	0.136
Academic performance (GPA, mean ± SD [95% CI])	7.49 ±1.30 (7.05 to 7.93)	8.12 ±1.52 (7.89 to 8.35)	0.109
Psychosocial difficulties (score, mean ± SD [95% CI])	22.72 ±3.93 (21.44 to 24.00)	17.54 ±4.48 (16.86 to 18.22)	**<0.001**
Emotional symptoms (score, mean ± SD [95% CI])	3.47 ±2.04 (2.80 to 4.14)	1.94 ±1.56 (1.70 to 2.18)	**<0.001**
Conduct problems (score, mean ± SD [95% CI])	2.31 ±1.67 (1.76 to 2.86)	1.86 ±1.43 (1.64 to 2.08)	0.185
Hyperactivity/inattention (score, mean ± SD [95% CI])	5.72 ±2.05 (5.05 to 6.39)	3.92 ±2.36 (3.56 to 4.28)	**<0.001**
Peers problems (score, mean ± SD [95% CI])	2.22 ±1.87 (1.61 to 2.83)	1.49 ±1.57 (1.25 to 1.73)	0.063
Prosocial behavior (score, mean ± SD [95% CI])	9.00 ±1.20 (8.61 to 9.39)	8.33 ±1.77 (8.06 to 8.60)	**0.043**
Overweight/Obese (%)	8, 24.2%	42, 29%	0.586
Body Mass Index (kg/m^2, mean ± SD [95% CI])	16.42 ±2.65 (15.52 to 17.32)	16.60 ±2.00 (16.26 to 16.93)	0.669
Physical activity level (low active, %)	17, 53.1%	95, 56.9%	0.694
Physical activity score (score, mean ± SD [95% CI])	2.72 ±0.51 (2.54 to 2.90)	2.71 ±0.64 (2.61 to 2.81)	0.217
Cardio-respiratory fitness (ml/kg/min, mean ± SD [95% CI])	22.6 ±8.14 (18.99 to 26.21)	26.0 ±12.68 (23.60 to 28.40)	0.758

Note: Data are shown as mean ± SD and 95% CI or mean %. Analyses derived from chi-squared tests and one-way ANCOVA for dichotomous and continuous variables, respectively. One-way ANCOVA analyses were adjusted for countries, schools, age, sex, and socioeconomic status. Significant p-values are in bold; SD, standard deviation.

Abbreviations: CI, confidence interval.

TABLE 2 Baseline characteristics of responders and non-responders for academic performance

Outcomes	Academic performance responders baseline (n = 149)	Academic performance non-responders baseline (n = 154)	*p*-value
Age (years, mean ±SD [95% CI])	7.51 ± 0.52 (7.43 to 7.59)	7.37 ± 0.40 (7.31 to 7.43)	**0.030**
Sex (girls, %)	75, 41.7%	112, 53.8%	**0.017**
Socioeconomic status (score, mean ± SD)	5.32 ± 1.21	4.87 ± 1.29	0.906
Academic performance (GPA, mean ± SD [95% CI])	7.48 ± 1.22 (7.28 to 7.68)	8.22 ± 1.57 (7.97 to 8.47)	**<0.001**
Psychosocial difficulties (score, mean ± SD [95% CI])	18.70 ± 5.02 (17.84 to 19.56)	18.05 ± 5.04 (17.21 to 18.89)	0.055
Emotional symptoms (score, mean ± SD [95% CI])	2.23 ± 1.88 (1.91 to 2.55)	2.17 ± 1.74 (1.88 to 2.46)	0.376
Conduct problems (score, mean ± SD [95% CI])	1.95 ± 1.62 (1.67 to 2.23)	1.91 ± 1.47 (1.66 to 2.16)	0.686
Hyperactivity/inattention (score, mean ± SD [95% CI])	4.42 ± 2.40 (4.01 to 4.83)	4.12 ± 2.61 (3.68 to 4.56)	0.103
Peers problems (score, mean ± SD [95% CI])	1.77 ± 1.85 (1.45 to 2.09)	1.53 ± 1.62 (1.26 to 1.80)	0.329
Prosocial behavior (score, mean ± SD [95% CI])	8.33 ± 1.93 (8.00 to 8.66)	8.31 ± 1.79 (8.01 to 8.61)	0.415
Overweight/Obese (%)	35, 24.6%	49, 28%	0.501
Body Mass Index (kg/m^2, mean ± SD [95% CI])	16.32 ± 2.17 (15.93 to 16.71)	16.52 ± 2.19 (16.14 to 16.90)	0.681
Physical activity level (low active, %)	86, 55.8%	87, 55.1%	0.890
Physical activity score (score, mean ± SD [95% CI])	2.70 ± 0.59 (2.60 to 2.80)	2.76 ± 0.64 (2.66 to 2.88)	0.169
Cardio-respiratory fitness (ml/kg/min, mean ± SD [95% CI])	29.4 ± 17.67 (26.02 to 32.78)	26.7 ± 10.34 (24.50 to 28.90)	0.374

Note: Data are shown as mean ±SD and 95% CI or mean %. Analyses derived from chi-squared tests and one-way ANCOVA for dichotomous and continuous variables, respectively. One-way ANCOVA analyses were adjusted for countries, schools, age, sex, and socioeconomic status. Significant p-values are in bold.
Abbreviations: CI, confidence interval; SD, standard deviation.

year school-based karate intervention, with a low rate of clinically meaningful responsiveness for SDQ (17.3%). The rate of clinically meaningful responsiveness was, however, considerably higher for academic performance (46.4%). Of note, our findings suggest that the intervention was particularly effective for improving psychosocial functioning and academic performance in children that initially presented higher psychosocial difficulties and a lower academic performance, with those classified as responders for a given outcome also presenting a greater responsiveness for the other outcome.

The benefits observed on psychosocial functioning and academic performance in the present ancillary analysis are overall in line with those reported after other school-based sport interventions.[4,6,25] These beneficial effects have also been specifically reported after martial arts interventions such as the one conducted here. For instance, Lakes and Hoyt observed beneficial effects in cognitive self-regulation, affective self-regulation, prosocial behavior, classroom conduct, and maths performance after a 3-month martial arts in children from Kindergarten to Primary School.[7] Focussing on karate interventions, Capulis and colleagues found a positive association between practicing karate-do and cognitive abilities related to academic performance such as vocabulary, understanding of qualitative and quantitative changes of things, logical thinking, and mathematical skills.[26] Moreover, positive results on resilience, self-efficacy, selective attention, and problem solving have also been reported after school-based karate interventions among children and adolescents.[8,9] These findings overall support the beneficial effects of including martial art-related activities—and particularly karate—during physical education lessons. It is worth noting, however, that the present results suggest that the proportion of children who actually obtain meaningful benefits from the intervention would be lower than previously expected, at least for SDQ scores (responsiveness rate of 17%). Research is therefore needed to confirm which children benefit more from school-based sport interventions and whether some variables related to the intervention (e.g., exercise type or dose) could be modified to maximize responsiveness.

In this regard, our results show that responders for either psychosocial functioning or academic performance were those children who initially had more psychosocial difficulties or attained a worse GPA, respectively. Thus, the intervention applied here seems particularly beneficial for those children with a wider margin for improvement. Similarly, McClelland, Pitt, and Stein reported that

TABLE 3 Effects of a school-based karate intervention in responders and non-responders for the Strength and Difficulties Questionnaire (SDQ)

	SDQ responders			SDQ non-responders			Differences
Outcome	**N**	**Pre-test**	**Post-test**	**N**	**Pre-test**	**Post-test**	***p*-value**
Academic performance (GPA, mean ± SD [95% CI])	34	7.49 ± 1.30 (7.05 to 7.93)	8.05 ± 1.42 (7.57 to 8.53)	165	8.12 ± 1.52 (7.89 to 8.35)	8.47 ± 1.53 (8.24 to 8.70)	**0.045**
Body mass index (kg/m^2, mean ± SD [95% CI])	32	16.46 ± 2.68 (15.53 to 17.39)	16.61 ± 2.55 (15.73 to 17.49)	138	16.60 ± 2.01 (16.26 to 16.94)	16.70 ± 2.08 (16.35 to 17.05)	0.788
Physical activity level (score, mean ± SD [95% CI])	32	2.72 ± 0.51 (2.54 to 2.90)	2.85 ± 0.57 (2.65 to 3.05)	161	2.71 ± 0.64 (2.61 to 2.81)	2.81 ± 0.58 (2.72 to 2.90)	0.849
Cardio-respiratory fitness (ml/kg/min, mean ± SD [95% CI])	18	22.9 ± 8.55 (18.65 to 27.15)	33.9 ± 11.20 (28.33 to 39.47)	88	28.4 ± 12.20 (25.85 to 30.95)	40.6 ± 15.62 (37.34 to 43.86)	0.577

Note: Data are shown as mean ± SD and 95% CI after controlling for countries, schools, age, sex, and socioeconomic status in repeated measures ANCOVA. Significant p-values are in bold.

Abbreviation: GPA, grade point average; CI, confidence interval.

children who participated in a 12-week physical training program enhanced their academic performance compared to those from the control group, with those children in the lowest percentile of academic performance obtaining the greatest benefits, especially in reading and maths.[27]

Moreover, our results show an interrelation between SDQ scores and GPA. In the same line, Petrie and Russell reported that higher levels of life stress and anxiety were associated with lower GPA among university athletes.[28] In addition, evidence suggests a direct relationship between learning disorders and psychosocial difficulties in children because of their underlying problems on executive functions[29,30] Our results also suggest that improvements in psychosocial functioning were associated with greater improvements in academic performance, which is overall in line with the concomitant benefits on both psychosocial functioning and academic performance previously reported in children with attention deficit hyperactivity disorder, behavioral and social problems, or learning difficulties.[31,32] For instance, Gapin and Etnier found a relationship between higher children's engagement in regular physical activity and greater academic performance in children with attention deficit hyperactivity disorder.[33]

Interestingly, no differences between responders and non-responders were observed neither at baseline nor in the change induced by the intervention for other variables such as body mass index, physical activity levels, or cardiorespiratory fitness, which have been traditionally thought to mediate, at least partially, exercise benefits on cognitive performance and psychosocial functioning in children.[34,35] Thus, other variables apart from the abovementioned ones might explain the benefits observed with the present intervention, although research is warranted to confirm whether additional improvements might have been observed with more demanding interventions (e.g., interventions focused on improving cardiorespiratory fitness), particularly given that in the present ancillary analysis the intervention was implemented during the two hours of physical education, without adding any extra hours of physical activity.

The major strengths of this ancillary analysis are that it is, to the best of our knowledge, the first one to analyze individual responsiveness after a school-based sport intervention, as well as its large sample size from 5 European countries and long duration (a whole academic year). Some limitations should, however, be acknowledged. The thresholds used to determine responsiveness might not necessarily correspond to clinically relevant improvements in psychosocial functioning and academic performance, although we implemented widely accepted methods for this purpose.[21-23] Also, the potential confounding effect of random within-subject variations (e.g.,

TABLE 4 Effects of a school-based karate intervention between responders and non-responders for academic performance

	Academic performance responders			Academic performance non-responders			Differences
Outcome	**N**	**Pre-test**	**Post-test**	**N**	**Pre-test**	**Post-test**	**p-value**
Psychosocial difficulties (score, mean ± SD [95% CI])	90	18.90 ± 4.75 (17.92 to 19.88)	17.43 ± 5.48 (16.30 to 18.56)	112	18.12 ± 4.85 (17.22 to 19.02)	17.41 ± 5.03 (16.48 to 18.34)	0.059
Emotional symptoms (score, mean ± SD [95% CI])	90	2.19 ± 1.80 (1.82 to 2.56)	2.04 ± 2.00 (1.63 to 2.45)	112	2.23 ± 1.71 (1.91 to 2.55)	2.07 ± 1.94 (1.71 to 2.43)	0.652
Conduct problems (score, mean ± SD [95% CI])	90	2.00 ± 1.66 (1.66 to 2.34)	1.39 ± 1.40 (1.10 to 1.68)	112	1.89 ± 1.32 (1.65 to 2.13)	1.48 ± 1.39 (1.22 to 1.74)	0.188
Hyperactivity/inattention (score, mean ± SD [95% CI])	90	4.43 ± 2.27 (3.96 to 4.90)	3.84 ± 2.54 (3.32 to 4.36)	112	4.09 ± 2.50 (3.63 to 4.55)	3.96 ± 2.50 (3.50 to 4.42)	0.080
Peers problems (score, mean ± SD [95% CI])	90	1.67 ± 1.62 (1.34 to 2.00)	1.59 ± 1.84 (1.21 to 1.97)	112	1.58 ± 1.67 (1.27 to 1.89)	1.37 ± 1.58 (1.08 to 1.66)	0.586
Prosocial behavior (score, mean ± SD [95% CI])	90	8.61 ± 1.65 (8.27 to 8.95)	8.57 ± 1.66 (8.23 to 8.91)	112	8.32 ± 1.74 (8.00 to 8.64)	8.54 ± 1.61 (8.24 to 8.84)	0.074
Body mass index (kg/m^2, mean ± SD [95% CI])	117	16.33 ± 2.18 (15.93 to 16.73)	16.36 ± 2.16 (15.97 to 16.75)	126	16.47 ± 2.03 (16.12 to 16.82)	16.70 ± 2.04 (16.34 to 17.06)	0.330
Physical activity level (score, mean ± SD [95% CI])	128	2.70 ± 0.59 (2.60 to 2.80)	2.87 ± 0.63 (2.76 to 2.98)	141	2.78 ± 0.64 (2.67 to 2.89)	2.83 ± 0.60 (2.73 to 2.93)	0.326
Cardio-respiratory fitness (ml/kg/min, mean ± SD [95% CI])	83	32.9 ± 17.96 (29.04 to 36.76)	43.3 ± 18.26 (39.37 to 47.23)	79	27.3 ± 10.09 (25.07 to 29.53)	37.6 ± 14.00 (34.51 to 40.61)	0.626

Note: Data are shown as mean ± SD and 95% CI after controlling for countries, schools, age, sex and socioeconomic status in repeated measures ANCOVA. Significant p-values are in bold.

Abbreviation: GPA, grade point average; CI, confidence interval.

due to biological variations or to reliability issues) or a regression-to-the-mean effect should not be disregarded.[24] Furthermore, our results are not necessarily generalizable to children with other ages, from other countries, or with a different socioeconomic status.

5 | PERSPECTIVE

The present ancillary analysis shows that the inclusion of a one-year school-based karate intervention applied during physical education lessons is particularly effective for inducing meaningful improvement in academic performance (46% of responders), albeit a lower responsiveness rate was observed for psychosocial functioning (17% of responders). Of note, the intervention was particularly effective in those children with greater psychosocial difficulties and lower academic performance, and the improvement of one outcome (e.g., psychosocial functioning) was associated with greater improvements in the other outcome (e.g., academic performance). School-based karate lessons may therefore be a promising alternative to enhance relevant functions for learning and behavior in those children with more psychosocial difficulties and lower academic performance. Efforts are needed to design interventions that maximize responsiveness among all children, including those that did not response to the present intervention (i.e., those with average or good psychosocial functioning and academic achievement at baseline).

School-based karate lessons may therefore be a promising alternative to enhance relevant functions for learning and behavior in those children with more psychosocial difficulties and lower academic performance. Efforts are needed to design interventions that maximize responsiveness among all children, including those that did not response to the present intervention (i.e., those with average or good academic achievement and psychosocial functioning at baseline).

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CONFLICT OF INTERESTS

The authors have no conflict of interests to declare.

DATA AVAILABILITY STATEMENT

Data will be made available upon reasonable request to the corresponding author.

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