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Original article

Effects of a school-based karate intervention on academic achievement, psychosocial functioning, and physical fitness: A multi-country cluster randomized controlled trial

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Abstract

Purpose: To examine the effects of a school-based karate intervention on academic achievement, psychosocial functioning, and physical fitness in children aged 7–8 years.

Methods: Twenty schools in 5 different European countries (2 second-grade classrooms per school) participated in a cluster randomized controlled trial (Sport at School trial). Participants were assigned to either a control group, which continued with their habitual physical education lessons, or to an intervention group, which replaced these lessons with a 1-year karate intervention (Karate Mind and Movement program). A total of 721 children (344 girls and 377 boys, 7.4 ± 0.5 years old, mean ± SD) completed the study, of which 333 and 388 were assigned to the control group and intervention group, respectively. Outcomes included academic performance (average grade), psychosocial functioning (Strengths and Difficulties Questionnaire for parents), and different markers of physical fitness (cardiorespiratory fitness, balance, and flexibility).

Results: The intervention provided small but significant benefits compared to the control group for academic achievement ($d = 0.16$; $p = 0.003$), conduct problems ($d = -0.28$; $p = 0.003$), cardiorespiratory fitness ($d = 0.36$; $p < 0.001$), and balance ($d = 0.24$; $p = 0.015$). There was a trend towards significant benefits for flexibility ($d = 0.24$; $p = 0.056$). No significant benefits were observed for other variables, including psychosocial difficulties, emotional symptoms, hyperactivity/inattention, peer problems, or prosocial behaviour (all $p > 0.05$).

Conclusion: A 1-year school-based karate intervention was effective in improving academic achievement, conduct problems, and physical fitness in primary school children. The results support the inclusion of karate during physical education lessons.

Keywords: Academic performance; Cardiorespiratory fitness; Conduct problems; Karate; Physical fitness

1. Introduction

The proportion of children meeting the levels of physical activity (PA) recommended by the World Health Organization (WHO)[1] is estimated at only 2.0%–14.7% and 9.5%–34.1% among European girls and boys, respectively.[2,3] Numerous studies have reported that PA has positive effects on different markers of physical fitness (e.g., cardiorespiratory fitness, muscle strength, and coordination) and basic motor skills in childen.[4,5] In addition, PA can benefit cognition and academic achievement, as well as social and psychological behavior (e.g., self-esteem, conduct problems, and peer problems).[6–8]

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Schools, and particularly physical education (PE) lessons, are considered key settings for promoting PA in children,[9] and indeed numerous PE-based PA interventions have been implemented.[10] In this regard, a report in 2010 by the U.S. Centers for Disease Control and Prevention concluded that PE-based PA interventions seem effective for improving academic achievement in children.[11] However, as shown in a recent meta-analysis, not all PE-based interventions exert the same effects, with greater benefits on health-related outcomes such as physical fitness found in those interventions prioritizing the quality (i.e., including teaching strategies or fitness infusion) rather than quantity (i.e., more lessons per week) of PA.[12] This could partly explain the heterogeneity found for PE-based PA interventions in primary school children, with half of studies reporting no benefits on physical fitness (particularly those not specifically designed for its improvement) and scarce or mixed evidence regarding the effects on psychosocial outcomes.[10] For this reason, improving PE quality (e.g., using trained instructors and increasing the amount of active time during PE lessons) has been highlighted as a priority.[11]

Including sports interventions during PE lessons can be a potentially effective way of increasing their quality. Recent studies suggest that participating in martial arts in particular could be beneficial for improving physical, cognitive, and psychosocial factors in children.[13,14] Primary school children practicing martial arts (karate) have been reported to present better physical fitness, working memory, visual attention, and executive function than their counterparts.[15] Moreover, Lakes and Hoyt[16] reported positive effects of a 3-month martial arts (Taekwondo) PE-based intervention on cognitive and affective self-regulation, prosocial behavior, classroom conduct, and performance on a mental math test in ~200 children of different ages (from kindergarten through fifth grade) compared with a group that performed "traditional" PE lessons; however, no measures of physical fitness and academic achievement were assessed. A non-controlled study reported improvements in physical outcomes such as balance, speed, and strength after a 10-week karate intervention in 59 primary school students, although no measures of academic achievement or psychosocial functioning were assessed.[17] Therefore, despite preliminary evidence that the benefits of martial arts on children is promising, there has been a lack of well-controlled studies (i.e., small sample sizes and/or short durations) on the feasibility and effectiveness of these interventions in an educational setting for improving academic achievement, physical fitness, and psychosocial performance.[18]

Given the paucity of research examining the effects of PE-based sports interventions (particularly those focused on martial arts) on primary school children, the aim of this study was to examine the effects of a 1-year school-based karate intervention, based on the Karate Mind and Movement program, on academic achievement, psychosocial functioning, and physical fitness in primary school children across 5 countries in the European Union.

2. Methods

2.1. Study design

The present study complies with the recommendations of the Consolidated Standards of Reporting Trials (CONSORT) statement. The Sport at School project (www.ksportatschool.eu) was co-funded by the Erasmus+ program of the European Union (567201-EPP-1-2015-2-IT-SPO-SCP). It was led by the Italian Federation of Judo, Wrestling, Karate and Martial Arts (FILJKAM) in partnership with the National Karate Federations from France, Germany, Poland, Portugal, and Spain.

A school-based karate intervention was implemented in 20 European schools (2 classrooms per school) of 5 different countries during the 2017−2018 academic year by means of a cluster randomized control trial. In March 2015, the National Karate Federations of the 5 countries involved placed an advertisement on their websites searching for schools willing to participate in the project. Each of the 5 organizing countries was asked to select 4 schools, with the aim of best representing the country's population in terms of the schools' location of (including both state and private schools) and different socioeconomic status of the students. The selected schools were located in Arnedo, Campanillas-Málaga, Alcalá de Henares, and Palencia for Spain; Braga, Vila Franca De Xira, Trofa, and Faro for Portugal; Paris, Locon-Essars, Orlèans, and Bousse for France; Börnecke, Bremen, Rhauderfehn, and Hude for Germany; and Poznań, Szczecin, Elbląg, and Łódź for Poland. Each school was asked in June 2017 to select 2 second-grade classes (i.e., children aged 7−8 years) with similar characteristics (e.g., curricular and student characteristics). During the first week of the 2017−2018 academic year, these 2 classes per school were assigned to a "control" or "intervention" group in a 1:1 ratio through simple randomization using a specific software program (www.randomizer.org).

After randomized assignment, all the pupils from the recruited second-grade classrooms (7−8 years old) were invited to participate in the Sport at School project through an online informed written consent completed by their parents or legal guardians. During the 2nd week of the 2017−2018 academic year, parents or legal guardians attended school meetings at which they were informed about the project. Only children who returned the form signed by a parent or guardian were allowed to participate in the study. Children who did not usually participate in PE lessons due to health problems or disabilities were excluded from the study and followed their usual routines. All research procedures were conducted in accordance with the Declaration of Helsinki and its later amendments and were approved by the Padova University and Complutense University of Madrid Institutional Review Board for the protection of human subjects.[19]

After the school selection phase, the karate technicians (black belt, karate-teaching certified, and experienced in karate training with children) attended a 2-week training course (40 h/week). The first training week (Rome, March 2017) included the theoretical basis of the intervention: educational psychology, neuropsychiatry, growth, and health issues in paediatric age, neurophysiology, child training, and teaching

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methodology of the program. The practical training for karate technicians was developed during a second week (Cesenatico, June 2017) at the summer training camp of FILJKAM, where children aged 5−17 years, with levels of karate skills ranging from novice to expert, performed the future intervention exercises. This training course included guidelines for the standardized assessment of study outcomes. Later, during the implementation of the program, technicians received continuous online training and advice from project coordinators, including videos and files with exercises, sessions and detailed explanations of the measurement tools and research protocols.

2.2. Intervention

During the 2017−2018 academic year, the control groups continued with habitual PE lessons (2 h/week) led by their school teacher following their standard curriculum. Specific characteristics of the activities performed by the control groups in each country are detailed in Supplementary Table 1. The intervention groups participated in the school-based karate intervention, which was implemented by the technicians in the presence of the teacher. The intervention replaced the activities that would have normally taken place in PE lessons (2 h/week). Thus, an equal amount of time was spent on PE (control) or karate (intervention) by the 2 groups. Children in both groups worked on the same elements of the standard educational curriculum, but those in the intervention group worked on these elements through karate exercises when possible. Similar exercises were performed by children in the intervention group across different schools and countries.

The intervention provided children with sensory-motor stimuli for the development of basic motor skills and cognitive performance while facilitating collaboration. An enriched environment was created in school gyms using tatamis on the floor to ensure safety and non-hazardous modular materials to facilitate specific motor actions, with materials including sponge balls, hurdles, hoops, sticks, and cones.[20] All sessions included barefoot movements aimed at developing body awareness, balance, and coordination, starting with initial bows. The main part of the session consisted of non-specific motor tasks aimed at improving cardiorespiratory fitness, strength, coordination, balance and flexibility. The final part of the session included stretching exercises, discussion about the class (e.g., feelings, difficulties) and final bows. Supplementary Table 2 provides an example of 3 full sessions performed during the academic year.

2.3. Outcomes

Outcomes, which included academic achievement, psychosocial functioning, and physical fitness, were assessed both at baseline and at the end of the intervention. Baseline assessments were performed during the first 2 weeks immediately after the randomization procedure. Post-intervention assessments were performed during the last 2 weeks of the 2017−2018 academic year. Karate technicians assessed physical fitness-related outcomes and during the assessments were accompanied by an external teacher to ensure objectivity. Academic achievement was assessed by school teachers, and psychosocial functioning variables were assessed by parents. Technicians and teachers across different schools followed the same instructions on the evaluation procedures. Parents and children from both groups performed the same tests on the same days and received the same type and amount of attention (e.g., maintaining continuous contact with teachers, receiving a T-shirt with the name of the project) so that they and their families did not know which group they or other participants belonged to. Thus, although none of the assessors was specifically blinded to the participants' conditions, parents and teachers were not involved in the study and their knowledge of the participants' condition was expected to exert little influence on the participants' assessments.

2.3.1. Academic achievement

School grades, which were reported by school teachers without guaranteeing that they were blind assessors, were used for the assessments of participants' academic achievement. Teachers assessed academic achievement following the evaluation criteria established by the curriculum of their specific country for each subject and not with standardized tests across all countries. Therefore, in order to standardize school grades across different countries, teachers were asked to transform students' grades into a scale ranging from 0 (*lowest score*) to 10 (*highest score*). A representative measure of the students' overall academic achievement was computed using the average of all school subjects. School grades from the 2016−2017 academic year were used as baseline values, and school grades from the 2017−2018 academic year were used as post-intervention values.

2.3.2. Psychosocial functioning

A parent or guardian of each participant was asked to assess their child's psychosocial difficulties using an online version of the Strengths and Difficulties Questionnaire (SDQ) for parents.[21] This is a reliable questionnaire that has been translated into the native language of and validated for each of the 5 countries participating in this study.[22,23] The SDQ is a 25-item screening questionnaire with 5 scales, each consisting of 5 items, generating scores for emotional symptoms, conduct problems, hyperactivity/inattention, peer problems, and prosocial behavior. For each item, parents had to choose between "not true", "somewhat true", or "certainly true". The first 4 problem scales were summed to generate a "total difficulties" score.

2.3.3. Physical fitness

Cardiorespiratory fitness was assessed by means of the multistage 20-m shuttle run test.[24,25] On a flat, non-slip surface, participants ran, at increasing running speeds determined by audio beep signals, back and forth continuously between 2 lines placed 20 m apart. The starting speed was 8.5 km/h and was increased every minute (stage) by 0.5 km/h until the child did not reach the lines in the required time twice in a row. The last completed stage or half-stage was considered as the child's result.

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Balance was assessed by means of the Y-Balance test, which is a reliable and valid test widely used to assess dynamic postural control and balance.[26] This test involves maintaining single-legged balance whilst simultaneously reaching as far as possible with the most distal part of the contralateral foot in 3 directions: anterior, posterolateral, and posteromedial. Participants performed 3 trials in each direction, and the greatest distance attained for each of the 3 directions for each of the 2 legs was used to compute an average. This average was then divided by the participant's height and was used as an overall indicator of the child's balance.

Flexibility was assessed by means of the frontal split test, which has been used in different studies to measure hip abductor flexibility.[27] For this test, children placed their backs to a wall, whilst maintaining their trunk perpendicular to the origin of an angle protractor printed on a mat. They were asked to separate their 2 legs up to the maximal amplitude possible, with legs straight while the angle was measured.

2.4. Covariates

To account for their potential influence on study outcomes, the following baseline variables were included as covariates: age, sex, weight category, PA level, and socioeconomic status.

The exact age at baseline was calculated using the children's birthdates in order to avoid the relative age effect in academic achievement and physical fitness.[28,29] Height, weight and body mass index (BMI) were measured using standard procedures, and age- and sex-specific BMI percentiles were determined as recommended by the WHO for the classification of children into 1 of 2 weight categories: overweight/obese or not overweight/obese.[30]

The Physical Activity Questionnaire for Children (PAQ-C) was administered to measure children's PA levels during a regular week. PAQ-C is a validated, self-administered 7-day recall assessment questionnaire comprising 10 items related to the frequency of PA at school, at home, and during leisure time. The PAQ-C has been translated into the native language of and validated for each of the 5 participating countries. A summary score from 1 to 5 is obtained for the PAQ-C, where 5 represents a high PA level.[31] In the present study, children were classified into "low-active" or "active" according the PAQ-C cut-off points.[32]

To assess participants' socioeconomic status, parents answered the Q1009 question from the Short Questionnaire Rotation A (SQR-A).[33] This questionnaire has been translated into the native language of and validated for each of the participating countries.[34] Parents' level of education was assessed using a 7-point scale (1 = *no formal schooling*, 2 = *less than primary school*, 3 = *primary school*, 4 = *secondary school*, 5 = *high school (or equivalent)*, 6 = *college/pre-university/university*, 7 = *post-graduate degree*), and the highest level reported from either the mother, the father or the legal guardian was used for analyses.

2.5. Statistical analysis

Based on previous research reporting the effects of PE-based exercise interventions on markers of physical fitness and academic achievement (effect size 0.23−0.24),[12] a sample of 470 children was deemed appropriate to determine significant between-group differences (one-tailed $\alpha < 0.05$, power > 80% (computed with G*power; Version 3.1.9.2; Universität Düsseldorf, Düsseldorf, Germany)), which increased up to a minimum of 560 children (280 per group) after accounting for ~20% of drop-outs.

Descriptive statistics are reported as mean ± SD, percentage (%) or median and interquartile range (IQR) for continuous, dichotomous, and ordinal variables, respectively. Baseline differences between groups were examined using independent student t tests (or Mann-Whitney U test when not normally distributed) or chi-square tests (χ^2) for continuous and dichotomous variables, respectively. The effects of the school-based karate intervention on study outcomes were assessed using linear mixed models with random intercepts for participants and for schools within countries in order to adjust for cluster effects (repeated covariance type = AutoRegressive(1): Heterogeneus; random effects covariance type = AutoRegressive(1): Heterogeneus; estimation = restricted maximum likelihood). Although not of primary interest, the following covariates were included because they could potentially influence the study outcomes: age, sex, weight category, PA level, and socioeconomic status. Intervention results are presented as unstandardized beta coefficients (B) and are presented along with effect sizes (Cohen's d, obtained from dividing the adjusted estimated marginal means by the pooled standard deviation).[35] In order to assess whether changes in fitness might partly explain the improvement observed in other variables, we performed a preliminary analysis on the association (Pearson's correlation coefficient) between the enhancement (presented in %) of those outcomes that improved significantly after the intervention with the improvement of fitness-related variables. We did not impute missing data; thus, only available data were used for analysis for each variable. Sensitivity analyses that included only those participants with complete data at both baseline and post-intervention were performed using linear mixed models and repeated measures of covariance. Analyses were performed using SPSS Statistics (Version 25.0; IBM Corp., Armonk, NY, USA), and statistical significance level was set at $p < 0.05$.

3. Results

A flowchart of study participants is shown in Fig. 1. From a total of 759 eligible children, 26 did not provide informed consent to participate and 12 left the school during the study period. Thus, a total of 721 children (344 girls and 377 boys) eventually completed the study; 388 participants belonged to the intervention group and 333 to the control group (descriptive characteristics are shown in Table 1). Groups were similar for most baseline variables (e.g., age, sex, anthropometrical variables, and PA levels), but the intervention group presented with a higher socioeconomic status ($p < 0.05$) (Table 1). No

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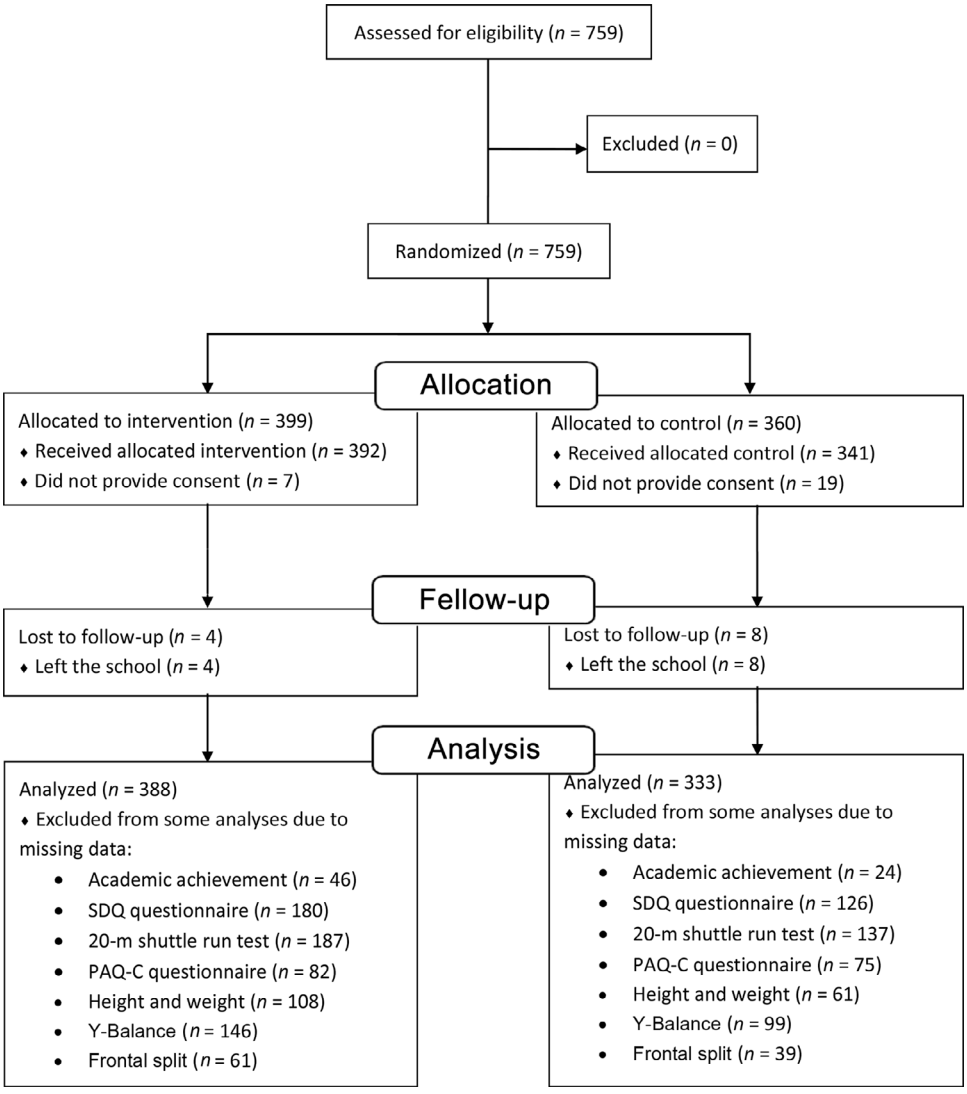

Fig. 1. Flow diagram of study participants in the study. PAQ-C = Physical Activity Questionnaire for Children; SDQ = Strengths and Difficulties Questionnaire.

adverse events were reported during habitual PE lessons or during intervention sessions.

The effects of the school-based karate intervention on study outcomes are reported in Table 2. The intervention provided small but significant benefits over the control group for academic achievement ($B = 0.20$, $d = 0.16$, $p = 0.003$), conduct problems ($B = -0.41$, $d = -0.28$, $p = 0.003$), cardiorespiratory fitness ($B = 0.53$, $d = 0.36$, $p < 0.001$) and balance ($B = 1.68$, $d = 0.24$, $p = 0.015$), and a non-significant trend toward a beneficial effect was also observed for flexibility ($B = 9.16$, $d = 0.24$, $p = 0.056$). No significant between-group differences were found for the remaining outcomes. These findings remained significant in sensitivity analyses (Supplementary Tables 3 and 4). No significant associations were found between the improvement on fitness-related markers and the improvement on the remaining outcomes (i.e., marks and conduct problems) (data not shown).

4. Discussion

The present study shows that a 1-year school-based karate intervention, when compared with usual PE lessons, resulted in improved academic achievement, cardiorespiratory fitness, and balance, as well as reduced conduct problems, among European 2nd-grade children from 5 different countries and 20 different primary schools. To the best of our knowledge, this is one of the largest randomized controlled trials assessing the effect of sport-specific PE lessons on academic achievement, psychosocial functioning, and physical fitness in children from different countries.

In our study, the small but significant benefits observed for academic achievement (greater increase in overall marks compared with the marks attained in the previous academic year) are in line with the results observed for other school-based interventions, and our results reinforce previous findings that PA has beneficial effects on academic and cognitive performance in

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Table 1
Children's demographic and physical characteristics at baseline by group.

Variable	*n*	Control baseline	*n*	Intervention baseline	Differences *p* value
Age (year; mean ± SD (min−max))	297	7.4 ± 0.4 (6.6−9.3)	329	7.4 ± 0.5 (5.8−9.8)	0.556
Sex (girls, %)	333	47.1%	388	48.2%	0.779
Overweight/obese (%)	282	29.8%	317	26.5%	0.371
PA level (low active, %)	266	56.0%	312	55.4%	0.891
SES (median (IQR); min−max)	271	5 (4−6); 1−7	308	5 (4−6); 1−7	0.014
Height (cm; mean ± SD (min−max))	291	126.5 ± 6.0 (111-143)	334	126.5 ± 6.6 (111−149)	0.945
Weight (kg; mean ± SD (min−max))	283	26.9 ± 5.3 (17.0−50.5)	321	26.4 ± 5.5 (18.4−55.1)	0.343
BMI (kg/m^2; mean ± SD (min−max))	282	16.7 ± 2.3 (12.6−28.2)	317	16.4 ± 2.3 (13.0−26.4)	0.182
PA (score; mean ± SD (min−max))	266	2.7 ± 0.6 (1.2−4.4)	312	2.7 ± 0.6 (0.7−4.5)	0.390

Note: *n* represents the number of participants whose data were used to calculate this value. Sex was available in all the participantes, but other variables had missing data.
Abbreviations: BMI = body mass index; IQR = interquartile range; PA = physical activity; SES = socioeconomic status.

Table 2
Effects of a school-based karate intervention on academic achievement, psychosocial functioning and physical fitness.

Outcome	Control			Intervention			Differences	
	n	Baseline	Post-intervention	*n*	Baseline	Post-intervention	*B*(95%CI)	*p* value
Academic performance (grade)	309	8.13 (7.97 to 8.28)	8.39 (8.25 to 8.53)	342	7.98 (7.84 to 8.12)	8.45 (8.32 to 8.58)	0.20 (0.07 to 0.34)	**0.003**
Psychosocial difficulties (score)	207	18.25 (17.62 to 18.88)	17.67 (16.97 to 18.37)	208	18.26 (17.67 to 18.86)	17.27 (16.62 to 17.96)	−0.41 (−1.22 to 0.40)	0.322
Emotional symptoms (score)	207	2.28 (2.04 to 2.52)	1.99 (1.70 to 2.31)	208	2.18 (1.96 to 2.41)	2.05 (1.78 to 2.31)	0.16 (−0.19 to 0.50)	0.381
Conduct problems (score)	207	1.79 (1.58 to 1.99)	1.72 (1.52 to 1.99)	208	1.91 (1.72 to 2.10)	1.43 (1.24 to 1.63)	−0.41 (−0.68 to -0.14)	**0.003**
Hyperactivity/inattention (score)	207	4.17 (3.86 to 4.40)	3.89 (3.54 to 4.19)	208	4.20 (3.91 to 4.49)	3.85 (3.54 to 4.16)	-0.05 (−0.44 to 0.33)	0.784
Peers problems (score)	207	1.46 (1.26 to 1.65)	1.34 (1.13 to 1.54)	208	1.61 (1.42 to 1.79)	1.42 (1.22 to 1.61)	−0.07 (−0.35 to 0.21)	0.622
Prosocial behaviour (score)	207	8.43 (8.22 to 8.64)	8.65 (8.43 to 8.87)	208	8.40 (8.19 to 8.60)	8.62 (8.42 to 8.82)	-0.00 (−0.33 to 0.33)	0.992
Cardiorespiratory fitness (min)	196	2.76 (2.58 to 2.93)	3.39 (3.15 to 3.63)	201	2.69 (2.52 to 2.86)	3.86 (3.63 to 4.10)	0.53 (0.25 to 0.82)	<**0.001**
Balance (total score)	234	38.38 (37.39 to 39.38)	41.27 (40.40 to 42.14)	242	38.26 (37.30 to 39.21)	42.82 (41.98 to 43.67)	1.68 (0.32 to 3.03)	**0.015**
Flexibility (degrees)	294	125.91 (118.94 to 132.89)	122.15 (120.39 to 123.91)	327	119.78 (113.37 to 126.19)	125.17 (123.54 to 126.80)	9.16 (−0.22 to 18.54)	0.056

Notes: Data are shown as estimated marginal means and 95%CI after adjustment for clustering effects of schools within countries and controlling for covariates (age, sex, weight category, physical activity level and socioeconomic status). *B* corresponds to the unstandardized difference between groups in the change from baseline to post-intervention. Significant *p* values are in bold font. Raw (non-adjusted) means and SD are available as Supplementary Table 5.
Abbreviation: 95%CI = 95% confidence interval.

children.[36−38] Given that both groups in our study performed some level of PA during PE lessons but that the intervention group participated in a sport-specific intervention, the present findings particularly support the importance of improving the quality of PE lessons.[12] Some benefits have also been specifically reported for martial arts interventions such as the one conducted in our study. For instance, Lakes and Hoyt[16] observed improved performance on a mental math test after a 3-month martial arts intervention among children of different ages (from kindergarten to fifth grade). Similarly, a mixed martial arts intervention combined with mindfulness induced improved academic achievement (including work completion, persistence with work, listening and focusing in class, improved group work, and decreased test anxiety) among high-school students.[39] Although this research is promising, additional research is needed to confirm the practical relevance of the small improvements observed in academic achievement.

A number of underlying mechanisms have been suggested as potential mediators of the benefits of PA/sports interventions on cognition, notably reductions in anxiety levels, increases in the neuroelectric activity of the cerebral cortex, exercise-induced increases in neurotrophins (e.g., brain-derived neurotrophic factor), and increases of hippocampal blood flow.[40−43] Given that both groups in our study performed some level of PA during PE lessons, it can be hypothesized that the greater improvement in both academic achievement and physical fitness observed for the intervention group might be due to an increase in the quality of PE (e.g., higher intensity and/or time spent exercising) compared with traditional PE lessons. Indeed, the intervention proved more

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effective for increasing cardiorespiratory fitness than did traditional PE lessons, and increases in cardiorespiratory fitness have been positively associated with the development of distinctive brain regions that are in turn associated with greater academic performance in children.[44] Thus, PE-based interventions aimed at improving physical fitness might be the cornerstone for improving academic achievement. In this regard, it must be noted that our preliminary analyses revealed no associations between improvement in fitness-related outcomes and the benefits observed on academic achievement or psychosocial functioning. Therefore, further research is warranted to elucidate whether other factors apart from fitness changes (e.g., the improvement of psychosocial factors due to active participation in karate lessons) might play a role in improving academic achievement.

The positive effect of the intervention on children's conduct problems are also consistent with previous research assessing the effects of general PA interventions, as well as with other PE interventions aimed at improving self-control, such as play fighting and martial arts.[16,45–50] For instance, Greco et al.[51] observed an improved resilience and self-efficacy after a 12-week intervention among high school students that focused on karate and psychoeducational activities. These findings suggest that including martial arts activities, particularly karate, during PE lessons may have the potential to reduce children's conduct problems (including having a hot temper, obedience difficulties, fighting with other children, lying, cheating, and stealing). Moreover, having conduct problems in childhood has been shown to be related to violent and antisocial behaviors later in life, and it could therefore be hypothesized that a karate-based PA intervention decreases future conduct problems.[52] It must be noted, however, that in our study no benefits were observed on other psychosocial variables such as emotional symptoms, hyperactivity/inattention, peer problems or prosocial behavior, which is in line with previous studies assessing the effects of other PA interventions.[53,54]

Our results also show that the karate intervention increased different markers of physical fitness. These findings are in line with previous research. For instance, Kriemler and colleagues[55] reported that a school-based PA intervention improved physical fitness, PA levels, and body composition in children aged ~7 years. Moreover, the benefits on physical fitness, but not on PA levels or body composition, were still observed after a 3-year follow-up.[56] Meta-analytical evidence also supports the beneficial effects of school-based PA interventions on physical fitness among children and adolescents, although the dose of PA seems to be a major mediator of the benefits.[57] The findings that our karate intervention was positively associated with greater benefits for cardiorespiratory fitness are consistent with the results of other studies that have observed PE quality.[12,58] In addition, our study suggests that the inclusion of martial arts during PE lessons might be effective for improving children's balance and flexibility, which is in line with the benefits observed for these variables in other studies assessing the effects of martial arts among young people and adults.[59,60] These results are of major relevance, particularly given that poor physical fitness during childhood has been associated with a greater incidence of cardiometabolic conditions (e.g., obesity and metabolic syndrome) later in life.[61–63]

Strengths of this study include the use of a cluster-randomized design, the large sample size analyzed, the study's relatively long duration (a complete academic year) and its inclusion of children from multiple countries, all of which reinforce its generalizability to different educational contexts. In addition, all assessment instruments have been shown to be reliable, were translated into each country's native language and were validated for each country. However, some limitations should be acknowledged. Although we aimed at selecting different schools from each country in order to enhance the generalisability of our findings, we cannot confirm that our findings are actually applicable to all children across different countries. Furthermore, participants in our study were slightly more active (with the prevalence of active individuals in our study ranging between 36% and 56%, depending on the country) than their counterparts in their respective countries (according to the WHO,[64] the prevalence of active individuals in general ranges between 22% and 38% for the analyzed countries). This difference in activity levels may have partially affected the representativeness of our sample. Despite randomization, significant differences between the intervention and control groups were observed at baseline for socioeconomic status, but this variable was included as a covariate in statistical analyses. Moreover, the lack of blinding of the participants and outcome assessors could be viewed as a cause for potential bias. Additionally, the diverse PE curricula across countries and the potential differences in teachers' preferences could have hindered the standardization of the activities of the control group. Notwithstanding, we considered this to be a potential influence and adjusted for schools and countries in order to minimize any cluster effects (e.g., influence of differences between control interventions, learning environments, and teachers' characteristics). Moreover, although the karate intervention was expected to be more intense than the activities performed by the control group, intensity was not monitored (e.g., through rating of perceived exertion or heart rate) during the study, so we could not discern whether the observed improvements were due to a higher exercise intensity or to a higher specificity/variability of the exercises performed. A low response rate was observed for some tests, such as the multistage 20-m shuttle run test, due to the children not being allowed to perform the shuttle run test by the Portuguese government. Internet connection problems in some schools and homes hindered completion of some parents' and children's questionnaires. Finally, additional evidence is needed to elucidate whether our karate intervention was more enjoyable for children than the traditional PE lessons, and whether the karate intervention provided superior benefits on other outcomes, such as muscular strength, velocity-agility, and body composition.

5. Conclusion

Our randomized controlled trial using a multi-country cluster shows that the inclusion of a 1-year school-based karate

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intervention drawing on the Karate Mind and Movement program during PE lessons helped to improve the quality of the lessons. Our intervention was more effective than traditional PE lessons in improving academic achievement, conduct problems, and physical fitness (as reflected by improvements in cardiorespiratory fitness and balance) among primary school children. Consequently, including karate activities during PE lessons may be a promising alternative for the enhancement of relevant functions related to learning, behavior, and health among this population.

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Authors' contributions

TP, EG and OMQ conceived the original idea, designed the study, acquired the data, performed the statistical analyses, interpreted the data, and drafted the manuscript; EG acquired the data, interpreted the data, and drafted the manuscript; PLV interpreted the data and drafted the manuscript; SJB conceived the original idea, designed the study, performed the statistical analyses, and interpreted the data; PA and MML conceived the original idea and designed the study; AP conceived the original idea, designed the study, and acquired the data. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interest

The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jshs.2021.10.006.

References

1. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behavior. *Br J Sports Med* 2020;**54**:1451–62.
2. World Health Organization. *Global recommendations on physical activity for health*. Available at: https://apps.who.int/iris/bitstream/handle/10665/44399/9789241599979_eng.pdf?sequence=1. [accessed 25.01.2021].
3. Konstabel K, Veidebaum T, Verbestel V, et al. Objectively measured physical activity in European children: The IDEFICS study. *Int J Obes (Lond)* 2014;**38**(Suppl. 2):S135–43.
4. García-Hermoso A, Alonso-Martinez AM, Ramírez-Vélez R, Izquierdo M. Effects of exercise intervention on health-related physical fitness and blood pressure in preschool children: A systematic review and meta-analysis of randomized controlled trials. *Sport Med* 2020;**50**:187–203.
5. Nilsen AKO, Anderssen SA, Johannessen K, et al. Bi-directional prospective associations between objectively measured physical activity and fundamental motor skills in children: A two-year follow-up. *Int J Behav Nutr Phys Act* 2020;**17**:1. doi:10.1186/s12966-019-0902-6.
6. Andermo S, Hallgren M, Nguyen TT, et al. School-related physical activity interventions and mental health among children: A systematic review and meta- analysis. *Sport Med Open* 2020;**6**:25. doi:10.1186/s40798-020-00254-x.
7. Erickson KI, Hillman C, Stillman CM, et al. Physical activity, cognition, and brain outcomes: A review of the 2018 physical activity guidelines. *Med Sci Sports Exerc* 2019;**51**:1242–51.
8. Gao Z, Hannan P, Xiang P, Stodden DF, Valdez VE. Video game-based exercise, latino children's physical health, and academic achievement. *Am J Prev Med* 2013;**44**(Suppl. 3):S240–6.
9. Naylor PJ, Mckay HA. Prevention in the first place: Schools a setting for action on physical inactivity. *Br J Sports Med* 2009;**43**:10–3.
10. Errisuriz VL, Golaszewski NM, Born K, Bartholomew JB. Systematic review of physical education-based physical activity interventions among elementary school children. *J Prim Prev* 2018;**39**:303–27.
11. Centers for Disease Control and Prevention. *The association between school-based physical activity, including physical education, and academic performance*. Atlanta, GA: U.S. Department of Health and Human Services; 2010.
12. García-Hermoso A, Alonso-Martínez AM, Ramírez-Vélez R, Pérez-Sousa MÁ, Ramírez-Campillo R, Izquierdo M. Association of physical education with improvement of health-related physical fitness outcomes and fundamental motor skills among youths: A systematic review and meta-analysis. *JAMA Pediatr* 2020;**174**:e200223. doi:10.1001/jamapediatrics.2020.0223.
13. Fabio RA, Towey GE. Cognitive and personality factors in the regular practice of martial arts. *J Sports Med Phys Fitness* 2018;**58**:933–43.
14. Gutierrez-Garcia C, Astrain I, Izquierdo E, Gomez-Alonso MT, Yague JM. Effects of judo participation in children: A systematic review. *Ido Mov Cult* 2018;**18**:63–73.
15. Alesi M, Bianco A, Padulo J, et al. Motor and cognitive development: The role of karate. *Muscles Ligaments Tendons J* 2014;**4**:114–20.
16. Lakes KD, Hoyt WT. Promoting self-regulation through school-based martial arts training. *Appl Dev Psychol* 2004;**25**:283–302.
17. Rutkowski T, Sobiech KA, Chwałczyńska A. The effect of karate training on changes in physical fitness in school-age children with normal and abnormal body weight. *Physiother Q* 2019;**27**:28–33.
18. Diamond A, Lee K. Interventions shown to aid executive function development in children 4 to 12 years old. *Science* 2011;**333**:959–64.
19. The World Medical Association. *Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects.* Available at: https://www.wma.net/wp-content/uploads/2018/07/DoH-Oct2008.pdf. [accessed 07.04.2016].
20. Aschieri P. Education in the third millenium. Movement, sport, nutrition and health. (Educazione nel 3° millennio. Progetto Sport a Scuola FIJLKAM). *Athlon* 2015;**34**:7–12. [In Italian].
21. Goodman R. The strengths and difficulties questionnaire: A research note. *J Child Psychol Psychiatry* 1997;**38**:581–6.
22. Goodman R, Meltzer H, Bailey V. The strengths and difficulties questionnaire: A pilot study on the validity of the self-report version. *Eur Child Adolesc Psychiatry* 1998;**7**:125–30.
23. Marzocchi GM, Capron C, Di Pietro M, et al. The use of the Strengths and Difficulties Questionnaire (SDQ) in Southern European countries. *Eur Child Adolesc Psychiatry* 2004;**13**(Suppl. 2):S40–46.
24. Léger L, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci* 1988;**6**:93–101.
25. Mahar MT, Guerieri AM, Hanna MS, Kemble CD. Estimation of aerobic fitness from 20-m multistage shuttle run test performance. *Am J Prev Med* 2011;**41**(Suppl. 2):S117–23.
26. Faigenbaum AD, Myer GD, Fernandez IP, et al. Feasibility and reliability of dynamic postural control measures in first through fifth grades. *Int J Sports Phys Ther* 2014;**9**:140–8.
27. Guillot A, Tolleron C, Collet C. Does motor imagery enhance stretching and flexibility? *J Sports Sci* 2010;**28**:291–8.
28. Cupeiro R, Rojo-Tirado MA, Cadenas-Sanchez C, et al. The relative age effect on physical fitness in preschool children. *J Sports Sci* 2020;**38**:1506–15.

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29. Bedard K, Dhuey E. The persistence of early childhood maturity: International evidence of long-run age effects. *Q J Econ* 2006;**121**:1437–72.
30. World Health Organization. *BMI-for-age (5–19 years).* Available at: https://www.who.int/growthref/who2007_bmi_for_age/en/. [accessed 15.12.2016].
31. Kowalski K, Crocker P, Faulkner R. Validation of the physical activity questionnaire for older children. *Pediatr Exerc Sci* 1997;**9**:174–86.
32. Voss C, Ogunleye AA, Sandercock GR. Physical activity questionnaire for children and adolescents: English norms and cut-points. *Pediatr Int* 2013;**55**:498–507.
33. World Health Organization. *World health survey instruments and related documents.* Available at: https://www.who.int/healthinfo/survey/instruments/en/. [accessed 22.01.2017].
34. Üstün TB, Chatterji S, Villanueva M, et al. *WHO multi-country survey study on health and responsiveness*. Geneva: World Health Organization; 2001.
35. Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. New York, NY: Routledge; 1988.
36. Mavilidi MF, Drew R, Morgan PJ, Lubans DR, Schmidt M, Riley N. Effects of different types of classroom physical activity breaks on children's on-task behavior, academic achievement and cognition. *Acta Paediatr* 2020;**109**:158–65.
37. Gall S, Adams L, Joubert N, et al. Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighborhoods: A cluster randomized control trial. *PLoS One* 2018;**13**:e0206908. doi:10.1371/journal.pone.0206908.
38. Singh AS, Saliasi E, van den Berg V, et al. Effects of physical activity interventions on cognitive and academic performance in children and adolescents: A novel combination of a systematic review and recommendations from an expert panel. *Br J Sport Med* 2019;**53**:640–7.
39. Milligan K, Cosme R, Wolfe Miscio M, et al. Integrating mindfulness into mixed martial arts training to enhance academic, social, and emotional outcomes for at-risk high school students: A qualitative exploration. *Contemp Sch Psychol* 2017;**21**:335–46.
40. Chaddock-Heyman L, Erickson KI, Chappell MA, et al. Aerobic fitness is associated with greater hippocampal cerebral blood flow in children. *Dev Cogn Neurosci* 2016;**20**:52–8.
41. Lubans D, Richards J, Hillman C, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics* 2016;**138**:e20161642. doi:10.1542/peds.2016-1642.
42. Jeon YK, Ha CH. The effect of exercise intensity on brain derived neurotrophic factor and memory in adolescents. *Environ Health Prev Med* 2017;**22**:27. doi:10.1186/s12199-017-0643-6.
43. Lippi G, Mattiuzzi C, Sanchis-Gomar F. Updated overview on interplay between physical exercise, neurotrophins, and cognitive function in humans. *J Sport Health Sci* 2020;**9**:74–81.
44. Esteban-Cornejo I, Cadenas-Sanchez C, Contreras-Rodriguez O, et al. A whole brain volumetric approach in overweight/obese children: Examining the association with different physical fitness components and academic performance. The ActiveBrains project. *Neuroimage* 2017;**159**:346–54.
45. Haydicky J, Wiener J, Badali P, Milligan K, Ducharme JM. Evaluation of a mindfulness-based intervention for adolescents with learning disabilities and co-occurring ADHD and anxiety. *Mindfulness* 2012;**3**:151–64.
46. Hinkley T, Teychenne M, Downing KL, Ball K, Salmon J, Hesketh KD. Early childhood physical activity, sedentary behaviors and psychosocial well-being: A systematic review. *Prev Med* 2014;**62**:182–92.
47. Spruit A, Assink M, van Vugt E, van der Put C, Stams GJ. The effects of physical activity interventions on psychosocial outcomes in adolescents: A meta-analytic review. *Clin Psychol Rev* 2016;**45**:56–71.
48. Pesce C, Lakes KD, Stodden DF, Marchetti R. Fostering self-control development with a designed intervention in physical education: A two-year class-randomized trial. *Child Dev*. 2020. doi:10.1111/cdev.13445.
49. Carraro A, Gobbi E. Play fighting to cope with children aggression: A study in primary school. *J Phys Educ Sport* 2018;**18**:1455. doi:10.7752/jpes.2018.03215.
50. Carraro A, Gobbi E, Moè A. Brief report: Play fighting to curb self-reported aggression in young adolescents. *J Adolesc* 2014;**37**:1303–7.
51. Greco G, Cataldi S, Fischetti F. Karate as anti-bullying strategy by improvement resilience and self-efficacy in school-age youth. *J Phys Educ Sport* 2019;**19**:1863–70.
52. Galán CA, Wang FL, Shaw DS, Forbes EE. Early childhood trajectories of conduct problems and hyperactivity/attention problems: Predicting adolescent and adult antisocial behavior and internalizing problems. *J Clin Child Adolesc Psychol* 2020;**49**:200–14.
53. Bell SL, Audrey S, Gunnell D, Cooper A, Campbell R. The relationship between physical activity, mental wellbeing and symptoms of mental health disorder in adolescents: A cohort study. *Int J Behav Nutr Phys Act* 2019;**16**:138. doi:10.1186/s12966-019-0901-7.
54. Hartman E, Ketelaar D, Lu C, Corpeleijn E. Objectively measured physical activity and psychosocial functioning in young children: The GECKO Drenthe cohort. *J Sports Sci* 2019;**37**:2198–204.
55. Kriemler S, Zahner L, Schindler C, et al. Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: Cluster randomised controlled trial. *BMJ* 2010;**340**:c785. doi:10.1136/bmj.c785.
56. Meyer U, Schindler C, Zahner L, et al. Long-term effect of a school-based physical activity program (KISS) on fitness and adiposity in children: A cluster-randomized controlled trial. *PLoS One* 2014;**9**:e87929. doi:10.1371/journal.pone.0087929.
57. Sun C, Pezic A, Tikellis G, et al. Effects of school-based interventions for direct delivery of physical activity on fitness and cardiometabolic markers in children and adolescents: A systematic review of randomized controlled trials. *Obes Rev* 2013;**14**:818–38.
58. Li Y, Wang S, Yu Y, et al. Associations among physical education, activity-related healthy lifestyle practices, and cardiorespiratory fitness of chinese youth associations among physical education, activity-related healthy lifestyle. *Res Q Exerc Sport* 2019;**90**:123–32.
59. Fallahi Farrash F, Sheikhhoseini R, Babakhani F. Effect of 8 weeks of functional exercise on soft surfaces on the balance and electromyographic activity of the muscles of female taekwondo athletes. *Women Heal Bull* 2020;**7**:19–25.
60. Abdullah AG, Nandiyanto ABD, Widiaty I, et al. *Proceedings of the 4th International Conference on Sport Science, Health, and Physical Education*. New York, NY: Atlantis Press; 2019.
61. Schmidt MD, Magnussen CG, Rees E, Dwyer T, Venn AJ. Childhood fitness reduces the long-term cardiometabolic risks associated with childhood obesity. *Int J Obes(Lond)* 2016;**40**:1134–40.
62. Mintjens S, Menting MD, Daams JG, van Poppel MNM, Roseboom TJ, Gemke RJBJ. Cardiorespiratory fitness in childhood and adolescence affects future cardiovascular risk factors: A systematic review of longitudinal studies. *Sport Med* 2018;**48**:2577–605.
63. García-Hermoso A, Ramírez-Vélez R, García-Alonso Y, Alonso-Martínez A, Izquierdo M. Association of cardiorespiratory fitness levels during youth with health risk later in life: A systematic review and meta-analysis. *JAMA Pediatr* 2020;**174**:952–60.
64. World Health Organization. *Physical activity country factsheets.* Available at: https://www.euro.who.int/en/health-topics/disease-prevention/physical-activity/data-and-statistics/physical-activity-fact-sheets/physical-activity-country-factsheets. [accessed 14.12.2020].

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