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Effects of a school-based sport intervention on academic achievement, psychosocial functioning and motor performance: A multi-country cluster randomised controlled trial

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

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40 **Abstract**

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

44 *Methods:* Twenty schools of five different European countries (two second-
45 grade classrooms per school) participated in the present cluster randomised
46 controlled trial (*Sport at School* trial). Participants were assigned to either a
47 control group, which continued with their habitual physical education lessons, or
48 to an intervention group, which replaced these lessons by a one-year karate
49 intervention (Karate Mind and Movement program). Outcomes included
50 academic performance (average grade), psychosocial functioning (Strengths
51 and Difficulties Questionnaire for parents), and different markers of physical
52 fitness (cardiorespiratory fitness, balance and flexibility).

53 Results: Seven hundred and twenty-one children (344 girls and 377 boys,
54 7.4±0.5 years) completed the study, of which 333 and 388 were assigned to the
55 control and intervention group, respectively. The intervention provided small but
56 significant benefits compared to the control group for academic achievement
57 (d=0.16; p=0.003), conduct problems (d=-0.28; p=0.003), cardiorespiratory
58 fitness (d=0.36; p<0.001) and balance (d=0.24; p=0.015). There was a trend
59 towards significant benefits for flexibility (d=0.24; p=0.056). No significant
60 benefits were observed for other variables including psychosocial difficulties,
61 emotional symptoms, hyperactivity/inattention, peer problems or prosocial
62 behaviour (all p>0.05).

Conclusions: A one-year school-based karate intervention was effective for the improvement of academic achievement, conduct problems, and physical fitness in primary school children, which supports the inclusion of karate during physical education lessons.

Keywords: Academic performance, cardiorespiratory fitness, conduct problems, karate, physical fitness.

Introduction

The proportion of children meeting the levels of physical activity (PA) recommended by the World Health Organization[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, coordination) and basic motor skills in childen.[4,5] In addition, PA can benefit cognition and academic achievement, as well as social and psychological behaviour (e.g., self-esteem, conduct problems, peer problems).[6–8]

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 US 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 prioritising 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. Particularly, recent studies suggest that participating in martial arts 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 a better physical fitness, working memory, visual attention and executive function than their counterparts.[15] Moreover, Lakes and Hoyt reported positive effects of a 3-month martial arts (Taekwondo) PE-based intervention on cognitive and affective self-regulation, prosocial behaviour, 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; NB no measures of physical fitness and academic achievement were assessed.[16] 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 for the benefits of martial arts on children is promising, there is a lack of well-controlled studies (i.e., small sample size and/or short duration) 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 one-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 of the European Union.

Methods

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 randomised control trial. The National Karate Federations of the 5 countries involved placed an advertisement on their websites searching for schools willing to participate in the project in March 2015. Each of the 5 organising countries were asked to select 4 schools per country, with the aim to best represent the country population in terms of location, including both state and private schools with different students' socio-economic status. 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

144 select two second-grade classes (i.e., children aged 7-8 years) with similar
145 characteristics (e.g., including both curricular and students' characteristics).
146 These two classes per school were assigned to a 'control' or 'intervention' group
147 in a 1:1 ratio through simple randomization using a specific software
148 (www.randomizer.org) the first week of the 2017-2018 academic year.

149 After randomised assignment, all the pupils from the recruited second-grade
150 classrooms (7-8 years) were invited to participate in the *Sport at School* project
151 through an online informed written consent completed by their parents or legal
152 guardians. Parents or legal guardians attended to school meetings in which
153 they were informed about the project on the second week of the 2017-2018
154 academic year. Only children who returned the form signed by a parent or
155 guardian were allowed to participate in the study. Children who did not usually
156 participate in physical education lessons due to health problems or disabilities
157 were excluded from the study and followed their usual routines. All research
158 procedures were conducted in accordance to the Declaration of Helsinki and its
159 later amendments, and were approved by the corresponding Institutional
160 Review Board for the protection of human subjects.[19]

161 After the school selection phase, the karate technicians (black belt, karate
162 teaching certified and experienced in karate training with children) attended a 2-
163 week training course (40 hours/week). The first training week (Rome, March
164 2017) included the theoretical basis of the intervention: educational psychology,
165 neuropsychiatry, growth and health issues in paediatric age, neurophysiology,
166 children training, and teaching methodology of the program. The second
167 training week (Cesenatico, June 2017) was developed during the summer
168 training camp of FILJKAM where children aged from 5 to 17 years-old from

novice to karate expert levels performed the intervention exercises. This training course included guidelines for the standardised 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. Intervention

During the 2017-18 academic year, the control group continued with habitual PE lessons (2 hour/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 File 1. The intervention group participated in the school-based karate intervention. This was implemented by the technicians with the teacher's presence and replaced the activities that would have normally taken place in PE lessons (2 hours/week). Thus, an equal amount of time was spent on PE (control) or karate (intervention) by the two 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 (e.g., gymnastic exercises such as somersaults, balance tasks, or jumps), but also included some karate-specific motor skills (representative examples of the different exercises performed can be seen see in Supplementary Videos 1 and 2). The final part of the session included stretching exercises, discussion about the class (e.g., feelings, difficulties), and final bows. Supplementary Table 4 provides an example of three full sessions performed along the academic year.

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 two weeks immediately after the randomisation procedure. Post-intervention assessments were performed during the last two weeks of the 2017-2018 academic year. Karate technicians assessed physical fitness-related outcomes, and 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 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 the group they or other participants belonged to. Thus, although none of the assessors was specifically blinded to participants' conditions, parents and teachers were not involved in the study and therefore knowledge of participants' condition was expected to exert little influence on their assessments.

3.1 Academic achievement

School grades - reported by school teachers without guaranteeing if they were blind assessors - were used for the assessments of participants' academic achievement. Teachers assessed academic achievement following the evaluation criteria established on the curriculum of their country for each subject and not with standardized tests across all countries. Therefore, in order to standardise 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 those of the 2017-2018 academic year were used as post-intervention values.

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 and validated in the native language of the 5 countries participating in this study.[22,23] The SDQ is a 25-item screening questionnaire

242 with 5 scales, each consisting of 5 items, generating scores for emotional
243 symptoms, conduct problems, hyperactivity/inattention, peer problems, and
244 prosocial behaviour. For each item, parents had to choose between 'not true',
245 'somewhat true' or 'certainly true'. The first four problem scales were summed to
246 generate a ‘total difficulties’ score.

247 3.3. Physical fitness

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

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

264 Flexibility was assessed by means of the frontal split test, which has been used
265 in different studies to measure hip abductor flexibility.[27] For this test, children

laid their backs to the wall, whilst maintaining the trunk perpendicular to the origin of an angle protractor printed on a mat. They were asked to separate the lower limbs up to the maximal amplitude possible with legs straight while the angle was measured.

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 the 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 2 weight categories: overweight/obese or not.[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 compounded by ten items about the frequency of PA at school, at home, and during leisure time, being validated and translated in the languages of the 5 participating countries. A summary score from 1 to 5 is obtained, where 5 represents high PA levels.[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 and validated in the languages 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 or the father was used for analyses.

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 Gpower 3.1.9.2, Universität 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 ± standard deviation (SD), percentages (%) 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 = AR(1): Heterogeneus; random effects covariance type = AR(1): Heterogeneus; estimation = restricted

maximum likelihood). Although not of primary interest, the following covariates were included as they could potentially influence the study outcomes: age, sex, weight category, PA level and socioeconomic status. Intervention results are presented as unstandardized beta coefficients (β), and are presented along with effect sizes (Cohen's d, obtained from adjusted estimated marginal means).[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 (as a %) of those outcomes that improved significantly after the intervention with the improvement of fitness-related variables. We did not impute missing data and, thus, only available data was used for analysis for each variable. Sensitivity analyses were performed including only those participants with complete data both at baseline and post-intervention for all outcomes. Analyses were performed using IBM IPSS Statistics (version 25, Armonk, NY) and statistical significance level was set at $p < 0.05$.

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; of which 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, PA levels), but the intervention group presented with a higher socioeconomic status ($p<0.05$) (**Table 1**). No adverse

events were reported during neither habitual PE lessons nor 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 (β=0.20, d=0.16, p=0.003), conduct problems (β=-0.41, d=-0.28, p=0.003), cardiorespiratory fitness (β=0.53, d=0.36, p<0.001) and balance (β=1.68, d=0.24, p=0.015), and a non-significant trend toward a beneficial effect was also observed for flexibility (β=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 including only those participants with complete data for all outcomes (Supplementary Table 2). 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).

Discussion

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

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 those observed with other school-based interventions and reinforce the beneficial effects of PA on academic and cognitive performance in children.[36–38] Particularly, given that both groups performed some level of PA during PE lessons but the intervention group participated on a sport-specific intervention, the present findings support the importance of improving the quality of PE lessons.[12] Some benefits have also been specifically reported for martial arts interventions such as that conducted here. For instance, Lakes et al. observed an improved performance during a mental math test after a 3-month martial arts intervention in children of different ages (from kindergarten up to fifth grade).[16] Similarly, a mixed martial arts intervention combined with mindfulness induced improved academic achievement (including work completion, persist with work, listen and focus in class, improved group work and decreased test anxiety) in high-school students.[39] Although promising, further research is needed to confirm the practical relevance of the small improvements in academic achievement observed.

A number of underlying mechanisms have been suggested as potential mediators of these 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 the present 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 (e.g., higher intensity and/or time spent exercising) of PE compared with traditional lessons. Indeed, the intervention proved effective for increasing cardiorespiratory fitness (more than 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 the improvement of fitness-related outcomes and the benefits observed on academic achievement or psychosocial functioning, and therefore further research is warranted to elucidate whether other factors apart from fitness changes (e.g., the improvement of psychosocial factors due to the active participation in karate lessons) might play a role.

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, or others including play fighting or martial arts interventions.[16,45–50] For instance, Greco, Cataldi and Fischetti observed an improved resilience and self-efficacy after a 12-week intervention among high school students that performed karate and psychoeducational activities.[51] These findings suggest that including martial arts activities – and particularly karate – during PE lessons may have the potential to reduce children's conduct problems (which include items such as hot temper, obedience, fights with other children, lies or cheats,

411 and steal). Moreover, conduct problems in childhood are related to violent and
412 antisocial behaviours later in life, and it could therefore be hypothesised that a
413 karate-based PA intervention might decrease future conduct problems.[52] It must
414 be noted, however, that no benefits were observed on other psychosocial
415 variables such as emotional symptoms, hyperactivity/inattention, peer problems
416 or prosocial behaviour, which is in line with previous studies assessing the
417 effects of other PA interventions.[53,54]

418 The present results also show that the karate intervention increased different
419 markers of physical fitness. These findings are in line with previous research.
420 For instance, Kriemler and colleagues reported that a school-based PA
421 intervention improved physical fitness, PA levels and body composition in
422 children aged ~7 years.[55] Moreover, the benefits on physical fitness, but not
423 those on PA levels or body composition, were still observed after a 3-year
424 follow-up.[56] Meta-analytical evidence also supports the beneficial effects of
425 school-based PA interventions on physical fitness in children and adolescents,
426 although the dose of PA seems to be a major mediator of the benefits.[57] Our
427 results are consistent with those of other authors that observed PE quality –
428 which was supposed to be improved with the karate intervention – is positively
429 associated with greater benefits on cardiorespiratory fitness.[12,58] In addition, our
430 study suggests that the inclusion of martial arts during PE lessons might be
431 effective for the improvement of children's balance and flexibility, which is in line
432 with the benefits observed for these variables in other studies assessing the
433 effects of martial arts in young and adults.[59,60] These results are of major
434 relevance, particularly given that a poor physical fitness during childhood is

associated with a greater incidence of cardiometabolic conditions (e.g., obesity, metabolic syndrome) later in life.[61–63]

Strengths of this study include the use of a cluster-randomised design, the large sample size analysed, its relatively long duration (a whole academic year) and its multi-country nature, which reinforces its generalisability among different educational contexts. In addition, all assessment instruments were reliable, validated and translated into each country's native language. Some limitations should however be acknowledged. Although we aimed at selecting different schools from each country to enhance the generalisability of our findings, we cannot confirm whether our findings are actually applicable to all children across different countries. Furthermore, the participants of the present study were slightly more active (with the prevalence of active individuals ranging between 36 and 56% depending on the country) than their counterparts in their respective countries (prevalence of active individuals ranging between 22 and 38% for the analysed countries attending to the WHO),[64] which might partially affect the representativeness of our sample. Despite randomisation, 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 participants and outcomes' assessors could be viewed as a potential bias. Additionally, the diverse PE curricula across countries and potential differences in teachers' preferences hindered the standardisation of the activities of the control group. Notwithstanding, we considered this potential influence and adjusted for schools and countries to minimize any cluster effects (e.g., influence of differences between control interventions, learning environments, 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 during the study (e.g., through rating of perceived exertion or heart rate), so we cannot 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-metre shuttle run test and parents' and children's questionnaires, due to the children not being allowed to perform the multistage 20-metre shuttle run test by the Portuguese government, as well as having internet connection problems in some schools/homes that hindered the completion of questionnaires. Finally, evidence is still needed to elucidate whether a karate intervention is more enjoyable for children than traditional PE lessons, or whether the former provides superior benefits on other outcomes such as muscular strength, velocity-agility, or body composition.

Conclusion

The present multi-country cluster randomised controlled trial shows that the inclusion of a one-year school-based karate intervention based on the *Karate Mind and Movement* program during PE lessons might help to improve PE lessons' quality, as it is more effective for the improvement of academic achievement, conduct problems, and physical fitness (as reflected by improvements in cardiorespiratory fitness and balance) among primary school children than traditional PE lessons. Consequently, including karate activities during PE lessons may be a promising alternative to enhance relevant functions for learning, behaviour and health in this population.

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Authors' contributions

PA, OMQ, TP, AP, SB, MML conceived the original idea and designed the study; TP, OMQ, AP and EG acquired the data; OMQ, TP and SB performed the statistical analyses; TP, OMQ, PLV, SB and EG interpreted the data. TP, PLV, EG and OMQ drafted the manuscript; All the authors gave final approval of the final version and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

The authors declare that they have no competing interests'.

Data statement

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

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740 **Fig. 1.** Flow diagram of study participants through the study.

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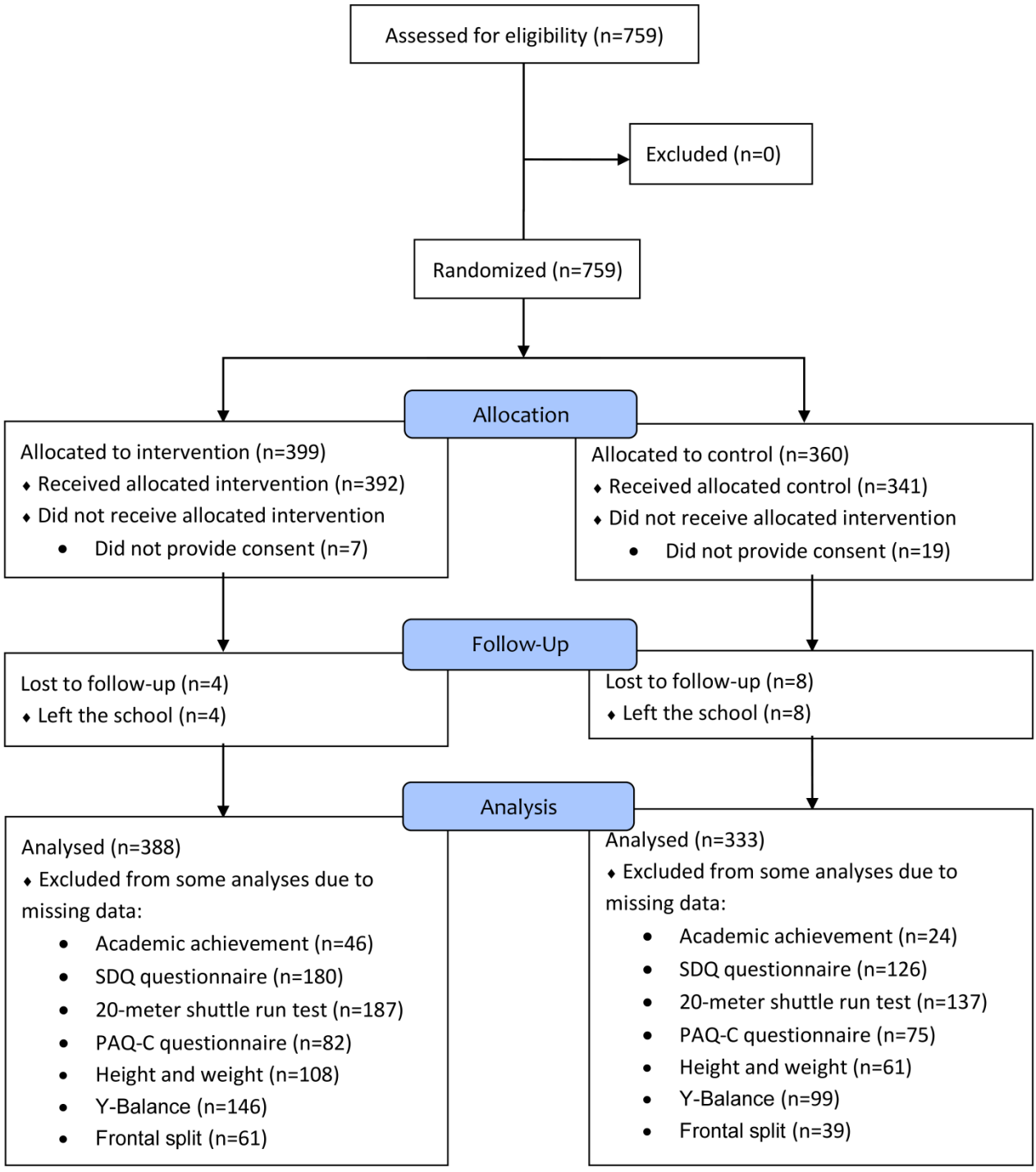

742 **Table 1.** Children's demographic and physical characteristics at baseline by group.

Variables	Control (n = 333)	Intervention (n = 388)	p-value
Age, years (mean [95% CI])	7.4 (7.4 to 7.5)	7.4 (7.4 to 7.5)	0.556
Sex, girls (%)	48.2%	47.1%	0.787
Overweight/obese (%)	31.2 %	29.3 %	0.592
Physical activity level, low active (%)	55.8 %	55.4 %	0.939
Socioeconomic status (median [IQR])	5 (4-6)	6 (4-6)	0.020
Height, cm (mean [95% CI])	127 (126 to 127)	127 (126 to 127)	0.815
Weight, kg (mean [95% CI])	26.9 (26.2 to 27.5)	26.5 (25.9 to 27.1)	0.343
Body mass index, kg/m^2 (mean [95% CI])	16.7 (16.4 to 16.9)	16.5 (16.2 to 16.7)	0.183
Physical activity, score (mean [95% CI])	2.7 (2.6 to 2.8)	2.7 (2.7 to 2.8)	0.390

743 Abbreviations: CI = confidence interval; IQR = interquartile range.

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	β (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	18.2 (17.6 to 18.9)	17.7 (17.0 to 18.4)	208	18.3 (17.7 to 18.9)	17.3 (16.6 to 18.0)	-0.41 (-1.22 to 0.40)	0.322
Emotional symptoms (score)	207	2.3 (2.0 to 2.5)	2.0 (1.7 to 2.3)	208	2.2 (2.0 to 2.4)	2.0 (1.8 to 2.3)	0.16 (-0.19 to 0.50)	0.381
Conduct problems (score)	207	1.8 (1.6 to 2.0)	1.7 (1.5 to 1.9)	208	1.9 (1.7 to 2.1)	1.4 (1.2 to 1.6)	-0.41 (-0.68 to -0.14)	**0.003**
Hyperactivity/inattention (score)	207	4.2 (3.9 to 4.4)	3.9 (3.5 to 4.2)	208	4.2 (3.9 to 4.5)	3.8 (3.5 to 4.2)	-0.05 (-0.44 to 0.33)	0.784
Peers problems (score)	207	1.5 (1.3 to 1.7)	1.3 (1.1 to 1.5)	208	1.6 (1.4 to 1.8)	1.4 (1.2 to 1.6)	-0.07 (-0.35 to 0.21)	0.622
Prosocial behaviour (score)	207	8.4 (8.2 to 8.6)	8.6 (8.4 to 8.9)	208	8.4 (8.2 to 8.6)	8.6 (8.4 to 8.8)	-0.00 (-0.33 to 0.33)	0.992
Cardiorespiratory fitness (min)	196	2.8 (2.6 to 2.9)	3.4 (3.2 to 3.6)	201	2.7 (2.5 to 2.9)	3.9 (3.6 to 4.1)	0.53 (0.25 to 0.82)	**<0.001**
Balance (total score)	234	38.4 (37.4 to 39.4)	41.3 (40.4 to 42.1)	242	38.3 (37.3 to 39.2)	42.8 (42.0 to 43.7)	1.68 (0.32 to 3.03)	**0.015**
Flexibility (degrees)	294	125 (118 to 132)	122 (120 to 123)	327	119 (113 to 126)	125 (123 to 126)	9.16 (-0.22 to 18.54)	0.056

Data are shown as estimated marginal means and 95% confidence intervals (CI) after adjustment for clustering effects of schools within countries and controlling for covariates (age, sex, weight category, physical activity level and socioeconomic status). β 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 File 3.