

Effect of Karate training on social, emotional, and executive functioning in children with autism spectrum disorder

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Abstract:

Autism spectrum disorder (ASD) is a developmental disorder that affects communication and behaviour. Previously, multiple interventions were designed to improve social-emotional and executive functioning in children with ASD. However, to date, only a few studies have examined the role of martial arts on social dysfunction and executive functioning deficits in children with ASD. Therefore, this study examined the effects of a 12-week Karate training on social-emotional and executive functioning of children (8-11 years) with ASD. Twenty-eight children were matched into pairs based on age, gender, and autism severity, and randomly allocated into an intervention (n = 14) or waitlist control group (n = 14). The intervention group performed Kata techniques training two times per week (45 min). The intervention included typically-developing children that helped facilitate the social skills, and activities targeted to train specific domains of executive functions, namely behavioural inhibition, working memory, and cognitive flexibility. At baseline and after 12 weeks, parents assessed social skills and executive functioning respectively through the Social Skills Improvement System Rating Scale and Behaviour Rating Inventory of Executive Function. After 12-week, the intervention group showed greater socio-emotional competence such as communication, cooperation and engagement, better executive functioning ability such as cognitive flexibility, inhibitory control and working memory, and a lower aggressiveness, sadness, anxiety and hyperactivity compared to the control group ($p < 0.01$; large effect size). Since ASD is a broad economic and societal problem that affects individual, family, and community levels, Karate training should be considered by autism institutions to improve individual well-being and overall health.

Key Words: working memory; cognitive flexibility; inhibitory control; social skills; behavioural problems.

Introduction

Autism spectrum disorder (ASD) is a high-prevalence neurodevelopmental condition which often results in significant impairment of social interactions and restricted, repetitive patterns of behaviour or interests, such as repeated motor movements or speech, rigidity in routines or patterns, and atypically intense preoccupations with a limited range of interests (American Psychiatric Association (APA), 2013). Deficits in social communication and social interaction span contexts and include problems with reciprocity in social-emotional interactions (e.g., theory of mind, imaginative play) and verbal and nonverbal (e.g., eye contact, facial expressions) communication (APA, 2013). Impairments associated with ASD extend beyond the individual with ASD to affect family functioning and community. Parents of children with ASD experience higher levels of stress compared to parents of children with other developmental disabilities and parents of typically-developing (TD) children experiencing a normative course of development (Estes et al., 2013; Lecavalier, Leone, & Wiltz, 2006). Furthermore, within schools, teacher stress and burnout are higher among educators of children with ASD compared to educators that do not work in special education (Jennett, Harris, & Mesibov, 2003). Thus, moving beyond the individual, family, and community levels, ASD is a broad economic and societal problem (Lavelle et al., 2014).

Another challenge, which most individuals with ASD experience, involves executive functions (EFs) (Diamond, 2013; Hill, 2004), a host of inter-related cognitive processes that drive goal-directed behaviours. The term of EFs includes the three core processes of behavioural inhibition (i.e., the control and override of behavioural urges such as maintaining social politeness), working memory (i.e., holding information in mind while mentally manipulating it, such as doing mental arithmetic), and cognitive flexibility (i.e., adjusting to changed demands such as considering ideas from a new perspective) (Diamond & Lee, 2011). More complex EFs include verbal and nonverbal fluency (i.e., generating ideas and concepts such as listing words that start with a certain letter), and planning/problem solving, and reasoning (Diamond & Lee, 2011). Both core and complex EFs continue to develop and strengthen throughout early childhood and into middle childhood (9-11 years). In terms of cognitive deficits, when compared to TD peers, children with ASD demonstrate poorer EFs (Zelazo &

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Müller, 2010), particularly poorer planning abilities and cognitive flexibility (Hill, 2004). The restricted and repetitive patterns of behaviour (RRBs; e.g., hand flapping, finger flicking, and self-injury) have been reported to be highly associated with some impairments of EFs (Ozonoff & Schetter 2007). However, there is limited research investigating the link between executive functioning and autistic symptomatology.

Multiple interventions were designed to improve social-emotional and executive functioning in children with ASD including speech-language therapy, occupational therapy, physical therapy and behavioural interventions (Myers & Johnson, 2007; Virues-Ortega, 2010; Yazici, & McKenzie, 2019), however, integrative approaches have been recommended to help promote an overall healthy lifestyle (Klein & Kemper, 2016) and give children with ASD opportunities for leisure activities that are social, physical, and informal (Hochhauser & Engel-Yeger, 2010). Children with ASD that participated in recreational activities were estimated by their caregivers to have a higher quality of life during late adolescence/early adulthood compared to individuals with ASD who did not participate in such activities in childhood (Billstedt, Gillberg, & Gillberg, 2011). A few studies have tested recreational programs for children with ASD and have included the examination of social-emotional skills after a swimming intervention (Pan, 2010) and after art therapy (Epp, 2008), and the examination of stereotypy (repetitive, self-stimulatory body movements) after training in karate (Bahrami, Movahedi, Marandi, & Abedi, 2012). These studies highlighted the importance of investigating children's participation in adaptive recreational programs because they have brought benefits in social communication and RRBs.

A physical activity that may be particularly effective in improving deficits in both social-emotional and executive functioning in children with ASD is martial arts training. Martial arts are traditionally distinguished by physical rigour, self-discipline, respect for others, teamwork and cognitive complexity. To date, only a few studies have examined the role of martial arts on social dysfunction (Movahedi, Bahrami, Marandi, & Abedi, 2013) and executive functioning deficits (Bahrami et al., 2012; Chan, Sze, Siu, Lau, & Cheung, 2013) in children with ASD. Kata technique training, which is a component of the Japanese martial art style of Karate, decreased social dysfunction (i.e., problem behaviours) (Movahedi et al., 2013) and reduced stereotypic behaviours (Bahrami et al., 2012), however, social-emotional skills were not examined. Furthermore, since stereotypic behaviours, which are types of RRBs, were linked to EFs, a similar approach could improve EFs. After performing the Nei Yang Gong, a mind-body exercise similar to Tai Chi, children with ASD improved self-control (Chan et al., 2013), thus, we expected that other EF domains would also be influenced by martial arts training.

Based on the limited data in the literature, we have thus investigated the effect of a 12-week Karate training on social-emotional and executive functioning in children with ASD. We hypothesized that participants trained with Kata techniques would improve social-emotional skills and decrease social dysfunctions (i.e., problem behaviours) as well as improve executive functioning abilities (i.e., inhibition, set-shifting, flexibility, organization, planning, self-monitoring, and working memory).

Materials & Methods

Participants

A total of 28 children with ASD (24 males and 4 females) ranging in age from 8 to 11 years (mean age of 9.25 ± 1.00 years) were recruited randomly from students attending one of the local autism treatment centres to participate in our study. This age range was selected because of the normative emergence of complex EFs around 8 to 9 years thus avoiding the confounding effects of the onset of puberty after around age 11 to 12. Power calculations were conducted to determine the sample size required to detect changes in the dependent measures resulting from the intervention. An a priori power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) with an assumed type I error of 0.05 and a type II error rate of 0.20 (95% statistical power) was calculated and revealed that 24 participants in total would be sufficient to observe medium 'Time x Group' interaction effects.

All children received a parent-reported clinical diagnosis of ASD based on ADOS-2 (Autism Diagnostic Observation Schedule) scores, which is a standardized, semi-structured, observational assessment of ASD (Lord et al., 2012). Consistent with 4:1 gender ratio of ASD reported by literature (Jacquemont et al., 2014), the majority of the sample was boys (85.7%, $n = 24$). ADOS-2 scores indicated that autism symptom severity in the overall sample was moderate to high (7.11 ± 1.31). Participants were screened by an experienced physician and were found eligible to participate in karate training. Parents of participating children agreed not to enrol their children in any other martial arts classes during the study and confirmed that their child did not participate in any martial arts in the past year.

After pre-intervention assessments, participants were matched into pairs based on age, gender and autism severity, and randomly allocated into an intervention group ($n = 14$; age, 9.07 ± 1.00 years; 12 males and 2 females; ADOS-2 scores, 7.07 ± 1.64) or waitlist control group ($n = 14$; age, 9.43 ± 1.02 years; 12 males and 2 females; ADOS-2 scores, 7.14 ± 0.95). The researchers were blinded to this randomisation of intervention and control group allocations. Participants of both groups were selected from the same autism institute to ensure that they receive the same treatment strategies. All participating families belonged to the middle class in terms of socioeconomic status. No children dropped out of the study. The participants' parents provided written consent to the study. The procedures followed were in accordance with the ethical standards of the responsible institutional committee on human experimentation and with the Helsinki Declaration. Children with ASD and

their families were recruited in the period from January to February 2019 and the study was conducted from March to May 2019.

Procedures

Before administering the tests, we required the participants' parents to precisely observe the participants at home for 7 days. After, to assess social-emotional functioning and EFs of children with ASD, we administered SSIS and BRIEF scales before intervention (baseline) and post-intervention (week 12) via an interview with the participants' parents.

Karate training has been adapted for children with ASD. The author, who has a background in Karate Shotokan and in working with children with ASD, collaborated with a team of senior martial arts instructors and program coordinators at the local martial arts academy to design the training sessions structure and content. The owner of the local martial arts academy funded the program, which was free to the families with ASD. Sessions were taught by a senior instructor and an assistant instructor, both blind for the purposes of the study, and by at least 3 typically-developing (TD) martial arts students of the academy. A key component of the adapted Karate training was the inclusion of these TD martial arts students. TD peers ranged in age from 8 to 12 years and were selected based on their instructors' overall judgment of the peer's maturity and demonstrated behaviour in class (e.g., helping others, being a good role model, etc.). TD peers were unaware of the purposes of the research study, so they were blind to which participants were in the study. Before the start of the intervention, TD peers were extensively trained by the author in how to engage with children with ASD, specifically in how to model socially appropriate behaviours in class (e.g., lining up, standing at attention, bowing), facilitate participation, and initiate and respond to social interactions. At each training session, the minimum presence of 3 TD peers was guaranteed. TD peers were not specifically assigned to any one child with ASD for the entire duration of the intervention, but the partnerships rotated each session, as martial arts traditionally encourage working with different partners to learn how to adapt and generalize skills. The TD peers volunteered their time to assist in the class; they did not receive monetary compensation but were incentivized with a free weekly ju-jitsu class.

Since the intervention was complex and the techniques were difficult over 12 weeks, it was necessary to use some strategies to motivate the ASD children to learn Kata and, thus, participate in the intervention. Meditation and breathing exercises were practised at the beginning of the training, and children were reminded to use their breathing techniques to help regulate their emotions if they became frustrated or overwhelmed. The present intervention was specifically designed to address the challenges in executive functioning faced by children with ASD by teaching multiple tools, incrementally making them more complex and challenging multiple components of EFs, and flexibly applying and generalizing the learned skills across a variety of contexts. Therefore, we used a number of attentional directing strategies including verbal exhortation, verbal augmented feedback, visual demonstration/modelling, attentional cueing, and visual cues including pictures, line, and spots drawings on the floor which gradually were disregarded (Ayers & Sariscsany, 2010) to facilitate Kata learning procedure in children with ASD. In addition, we also used a number of teaching strategies, including part practice (fractionization, segmentation and simplification), verbal instruction and verbal cues (as directing attention or prompting actions), modelling, and physical/manual guidance (Ayers & Sariscsany, 2010) to instruct basic techniques of Kata to the participants in the intervention group. A complex skill was practiced in a more simplified form by Fractionization: one or more parts of a complex skill were practiced separately; Segmentation (or progressive-part practice): one part of a target skill was practiced for a time, then a second part was added to the first part and the two were practiced together, and so on, until the entire target skill was practiced; and Simplification: the complexity of some aspect of the target skills was reduced (e.g., slow-motion practice) (Schmidt & Wrisberg, 2008). Finally, verbal exchanges between an instructor and a youth with ASD were emotionally neutral (no up and down intonations), free of jargon, and free of sarcasm and rhetoric to minimize frustration and distraction during conversations, to potentially increase learning ability (Zhang & Griffin, 2007).

Measures

To examine the effects of the intervention, two rating scales were administered to parents to assess social and executive functioning of children at pre- and post-test.

Social Skills Improvement System Rating Scale (SSIS-RS). It is used to evaluate social skills (e.g., takes turns in conversations) and problem behaviours (e.g., force others to act against their will) across multiple reporters, including parents, teachers, and children themselves in different contexts such as home, school, and the community (Gresham & Elliot, 2008). The SSIS-RS has been validated for use with preschool children up to the age of 18 and showed high internal consistency and test-retest reliability (Gresham, Elliott, Vance, & Cook, 2011). In this study, each item (46 for social skills and 33 for problem behaviours) on the SSIS was rated by parents on a 4-point frequency scale (from 0 = Never to 3 = Almost always) based on their perception of the frequency of the behaviour in children. The SSIS-RS raw scores were converted to standard scores per scoring instructions. Standard scores were loaded on two scales (social skills and problem behaviours). Higher scores on the social skills scale (SSS) indicate greater social competence (e.g. communication, cooperation, assertion, responsibility, empathy, engagement, and self-control). Higher scores on the problem behaviours scale (PBS) indicate more problem behaviours (e.g. internalizing, externalizing, bullying, hyperactivity/inattention and autism spectrum). The SSIS-RS typically takes approximately 10 – 25 minutes to complete and it was given to

parents both at pre-test and post-test. The internal consistency level was high, determined by a Cronbach's alpha of 0.90.

Behaviour Rating Inventory of Executive Function (BRIEF). It is an 86-item parent and teacher rating scale designed to assess executive functioning and self-regulation in children and adolescents ages 5 – 18 years (Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF takes 10 – 15 minutes to complete. Parents were given the BRIEF at pre- and post-test and reported on children's functioning on three indexes of EFs, with each index consisting of multiple clinical scales: Behaviour Regulation Index (BRI; scales: inhibit, self-monitor), Emotion Regulation Index (ERI; scales: shift, emotional control), and Cognitive Regulation Index (CRI; scales: initiate, working memory, plan/organize, task-monitor, organization of materials). The three indexes were combined according to the scoring instructions to yield a Global Executive Composite (GEC) score. Higher scores indicate poorer executive functioning on all the scales, indexes and composite scores. The BRIEF has high internal consistency and test-retest reliability (Gioia et al., 2000). In this study, the internal consistency level was high, determined by a Cronbach's alpha of 0.88.

Intervention

The Karate intervention consisted of performing the Heian Shodan kata (Shotokan style). Kata is a choreographed sequence of movements consisting of combinations of blocks, punches and kicks, performed as though defending against imaginary opponents (Nakayama, 1979). Previous studies have chosen this kata (Bahrami et al., 2012; Movahedi et al., 2013) as it is among the first to be taught; however, we have used a substantially different research design and intervention program.

The overall intervention consisted of 24 training sessions for 12 weeks, performed in the afternoon; this schedule resulted in training taking place two times per week with each training session lasting 45 minutes, yielding a targeted total of 1080 minutes of intervention time. The duration and intensity of the intervention were modelled on a prior study that implemented a martial arts intervention with TD children (Lakes & Hoyt, 2004), to increase the likelihood of the children being able to complete the full intervention.

In the first 4 weeks, before introducing Heian Shodan Kata to students, they were required to become familiar with the concepts of the individual hand and foot motions, the basic stances, the basic kicking techniques, and the processes involved in advancing, retreating, and turning the body about in a stable fashion (Redmond, 2008). These basic technical skills are learned through the Kihon practise that allows one to acquire offensive and defensive technical abilities performing with proper breathing and posture. Behaviour inhibition was used to attend to the instructor's demonstrations. These sessions also practised working memory, as the children had to remember the different rules that they learned and move different parts of their bodies following the rules. In weeks 5-8 of the intervention, participants extended these skills and learned the Heian Shodan Kata characterized by its use of the down block, the upper block, the middle-level stepping punch, the sword hand block and the fact that every technique takes one step to complete. This period emphasized working memory along with behavioural inhibition and cognitive flexibility. Behaviour inhibition was taught when working with a partner so that children did not hit or kick their partner with excessive force as one would when practising with a pad. Children also were taught cognitive flexibility when asked to mentally manipulate what was previously learned to accommodate the new information as it was presented.

In weeks 9-12 of the intervention, participants combined all their learned skills, which consisted of highly detailed, multi-step techniques, which required the active use of the three core EFs through learning Heian Shodan Kata. Contents of the training sessions were shown in Table 1.

Table 1. Twelve-week program followed by the intervention group (2 d·wk⁻¹)

Duration (time)	Contents of each training session
5 min	<ul style="list-style-type: none"> Line up, stand at attention, bow and pay respects to the instructor. Sit in meditation (breathing exercises), focus claps.
15 min	<ul style="list-style-type: none"> Warm-up activities: exercises including jogging, jumping, etc. Stretching activities: Achilles' tendon/calf stretches, skier's stretches, quadriceps stretches, back stretches, etc. Basic technical skills (i.e., Kihon)
20 min	<ul style="list-style-type: none"> Main activity (i.e., Heian Shodan Kata) Increasingly complex (over the 12 weeks of the intervention) combinations of Heian Shodan: <ol style="list-style-type: none"> Application of stepping punches following blocks which remove any obstructing limbs, and the use of blocking as attacking; Sequences of the down block, the upper block, the middle-level stepping punch, the sword hand block. Practise back-and-forth with TD peers.
5 min	<ul style="list-style-type: none"> Cooldown, social game (e.g., red light-green light to practise starting and stopping one's body, dodgeball)

Data analysis

Statistical analyses were carried out using SAS JMP® Statistics (Version <14.3>, SAS Institute Inc., Cary, NC, USA, 2018). Data were presented as group mean values and standard deviations and checked for assumptions of normality and homogeneity of variances. An independent sample *t*-test was used to evaluate group differences at baseline. A two-way ANOVA (group (intervention/control) × time (pre/post-intervention)), with repeated measures on the time dimension, was conducted to examine the effect of karate training on all dependent variables. When ‘Group x Time’ interactions reached the level of significance, group-specific post hoc tests (i.e., paired *t*-tests) were conducted to identify the significant comparisons.

Partial eta squared (η^2_p) was used to estimate the magnitude of the difference within each group and interpreted using the following criteria: small ($\eta^2_p < 0.06$), medium ($0.06 \leq \eta^2_p < 0.14$), large ($\eta^2_p \geq 0.14$). Effect sizes for the pairwise comparisons were determined by Cohen’s *d* and interpreted as small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$) and large ($d \geq 0.80$) (Cohen, 1992). The standardized Cronbach’s alpha coefficient (Cohen, Manion, & Morrison, 2011) was used as a measure of the reliability of the psychological tests (reliable: $0.70 \leq \alpha < 0.80$; highly reliable: $0.80 \leq \alpha \leq 0.90$). Statistical significance was set at $p < 0.05$.

Results

All participants received the treatment conditions as allocated and the adherence to the intervention was 92.3 % (22.15 actual sessions / 24 intended sessions). Furthermore, all parents reported wanting to continue the Karate training program after the intervention and solicited agreement to start the program for those who were part of the waitlist control group. We found no significant differences between groups at baseline in age ($t(26) = -0.94, p = 0.357$) and autism symptom severity ($t(26) = -0.14, p = 0.889$). Pre- and post-intervention results for all dependent measures are presented in Table 2.

Table 2. Changes in social and executive functioning of ASD children over 12-week Karate intervention.

	Intervention group (n = 14)			Waitlist Control group (n = 14)		
	Pre-test	Post-test	Δ	Pre-test	Post-test	Δ
Social Skills Improvement System Rating Scale (SSIS-RS)						
Social Skills	64.1 (8.0)	73.0 (8.6)†*	8.9 (3.1)	66.5 (7.1)	65.7 (7.4)	-0.8 (1.5)
Problem Behaviours	119.6 (10.8)	111.6 (9.1)†*	-8.0 (3.1)	120.3 (10.7)	122.9 (10.3)*	2.6 (2.2)
Executive Function: Behaviour Rating Inventory (BRIEF)						
Behaviour Regulation	72.4 (9.0)	68.7 (8.1)†*	-3.6 (2.7)	73.0 (8.9)	73.5 (8.8)	0.5 (0.9)
Emotion Regulation	69.9 (8.6)	66.4 (7.4)†*	-3.5 (2.1)	72.5 (9.2)	73.1 (8.8)	0.6 (1.3)
Cognitive Regulation	69.9 (7.4)	67.6 (8.4)†*	-2.3 (1.5)	70.4 (9.2)	70.8 (10.1)	0.4 (3.1)
Global Executive Functioning Composite	75.1 (7.5)	71.9 (8.3)†*	-3.2 (3.3)	75.9 (7.4)	76.4 (7.2)	0.5 (1.0)

Notes. Scores are presented as mean (± SD); Δ: pre- to post-training changes; †Significant ‘Group x Time’ interaction: significant effect of the intervention ($p < 0.05$). *Significantly different from pre-test ($p < 0.05$).

A two-factor repeated measures ANOVA found significant ‘Time x Group’ interactions for Social Skills Scale ($F_{1,26} = 110.60, p < 0.001, \eta^2_p = 0.81$), Problem Behaviours Scale ($F_{1,26} = 108.52, p < 0.001, \eta^2_p = 0.81$), Behaviour Regulation Index ($F_{1,26} = 29.27, p < 0.001, \eta^2_p = 0.53$), Emotion Regulation Index ($F_{1,26} = 37.77, p < 0.001, \eta^2_p = 0.59$), Cognitive Regulation Index ($F_{1,26} = 8.47, p = 0.007, \eta^2_p = 0.25$) and Global Executive Functioning Composite ($F_{1,26} = 16.32, p < 0.001, \eta^2_p = 0.39$). Statistical analysis detected large effect sizes for all significant interactions ($\eta^2_p \geq 0.14$).

As for the intervention group, the post-hoc analyses revealed a significant increase in score from pre- to post-test in the Social Skills Scale ($t(13) = 10.69, p < 0.001, d = 2.85$), whereas significant decreases in scores were found in the Problem Behaviours Scale ($t(13) = -9.77, p < 0.001, d = 2.64$), Behaviour Regulation Index ($t(13) = -5.04, p < 0.001, d = 1.36$), Emotion Regulation Index ($t(13) = -6.12, p < 0.001, d = 1.63$), Cognitive Regulation Index ($t(13) = -5.74, p < 0.001, d = 1.54$) and Global Executive Functioning Composite ($t(13) = -3.66, p = 0.003, d = 0.97$). Significant differences from pre- to post-intervention were relevant as effect size was found to be large ($d \geq 0.80$).

No significant changes were found for the control group in all dependent measures ($p > 0.05$) except for the Problem Behaviours Scale ($t(13) = 4.29, p < 0.001, d = 1.22$) that showed a significant increase in the score with a large effect size.

Discussion & Conclusions

The purpose of this study was to examine the impact of karate training on the social-emotional and executive functioning in children with ASD aged 8-11 years. Following 12-week Kata techniques training, participants improved social skills and EF deficits and decreased problem behaviours. Furthermore, adherence to treatment was high (92.3%) and an important indicator of its efficacy resided in the desire of all parents to have their children continue with practise karate after the intervention. Our findings confirm the study of Movahedi et al. (2013) that found a decrease in social dysfunctions (i.e., problem behaviours) after children with ASD received 14-week Kata techniques training; they also reported an improvement in social skills, which had not been examined previously. Also, the increased executive functioning in children with ASD is consistent with Bahrami et al. (2012) and Chan et al. (2013) that found decreased stereotypic behaviours and improved self-control, respectively. However, the current study extends their results as the measures of executive functioning suggest that cognitive flexibility and working memory were also challenged and worked during Karate training.

Previous studies demonstrated that physical exercise decreases social dysfunctions in children with ASD (Bass, Duchowny, & Llabre, 2009; Pan, 2010), however this study extended the results and showed a significant reduction in problem behaviours with a large effect size, that is: externalizing problems, such as aggressive acts and poor temper control; internalizing problems, such as sadness and anxiety; and hyperactivity, such as fidgeting and impulsive acts. Furthermore, the findings of the present study extended the results of Movahedi et al. (2013) by also measuring and finding an improvement in social-emotional skills. Children with ASD showed greater social competence after the intervention regarding communication, cooperation, assertion, responsibility, empathy, engagement, and self-control, confirming the results of the few existing studies (Epp, 2008; Pan, 2010). Movahedi et al. (2013) also suggested that the attendance of other children and adult instructors created a cohesive community that allowed for more opportunities to practise social skills. In fact, in the present study, participants engaged in dynamic interactions with typically-developing (TD) children in the class through the practising of the Kata techniques. The Kata consisted of movements that were slow, controlled and focused on form and rhythm of the technique; ASD children learned about their movements and also the movements of their partners. The dynamic interaction of “partner-drilling” in the context of martial arts requires the use and practise of social skills that are critical in all interpersonal interactions: eye contact, verbal communication, and non-verbal communication (e.g., gestures). In this study, the partner-drilling may have provided opportunities to develop more complex social skills in children with ASD, as TD children were experts in not only typical social behaviours, but also were experts in the martial arts techniques. However, this was a limitation in the study of Movahedi et al. (2013) because they did not differentiate between the roles of peers with ASD and the adult instructors. The improvements in ASD children in social skills and problem behaviours are consistent with a previous peer-mediated intervention (Laushey & Heflin, 2000), which found that children with ASD increased social skills when learning from TD peers, but our study extends current studies to include ASD children.

To date, only two studies have implemented a martial arts intervention to address executive functioning deficits in children with ASD. Bahrami et al. (2012) examined the plasticity of stereotypic behaviours, which are types of RRBs and the results indicated that participants that received 14-week Kata intervention demonstrated reduced stereotypic behaviours both at post-test and at one-month follow-up compared to the baseline assessment. Chan et al. (2013) found lower daily behaviour problems and improvements in self-control, in children with ASD following 4-week Nei Yang Gong, a mind-body exercise similar to Tai Chi. Our findings confirm previous results (Bahrami et al., 2012; Chan et al., 2013) because Kata techniques intervention, which consisted of exercises that utilized increasingly complex cognitive processes, improved behaviour, emotion and cognitive regulation. Behaviour and emotion regulation are components of self-regulation, whereas cognitive regulation includes subcomponents such as planning and organizing. Also, Lakes & Hoyts (2004) found that self-regulation was improved after martial arts training in TD children, but our study extends results in ASD children. Previous research has suggested that executive dysfunction may be related to RRBs frequently exhibited by individuals with ASD (Boyd, McBee, Holtzclaw, Baranek, & Bodfish, 2009; Kenworthy et al., 2014; Lopez, Lincoln, Ozonoff, & Lai, 2005; South, Ozonoff, & McMahon, 2007). RRBs were associated with multiple executive processes including behavioural inhibition (Boyd et al., 2009), working memory, and cognitive flexibility (Kenworthy et al., 2014; Lopez et al., 2005; South et al., 2007). Research with TD children suggests that exercise can lead to improvements in executive functioning (Best, 2010). In this study, results have extended improvement also in children with ASD most likely because the Kata contains a variety of movements that are similar to a variety of stereotypic motor mannerisms. It is known that body movement that reproduces a given motor stereotypy used by children with ASD is an effective means to reduce the stereotypic behaviour (Reid, Factor, Freeman, & Sherman, 1988).

The limitations of this study should be recognized. First, we did not consider gender differences as the number of females was rather limited. It would be necessary, however, to study any differences after intervention as in a previous study the females showed greater EF problems than males and markedly worse adaptive daily living skills (White et al., 2017). Second, the parents in the study were not blind to the condition their child was assigned, thus reporter bias is possible on the parent-report measures. Parents may have been inclined to report improvement due to their direct knowledge of their child's participation. Third, the present study relied only on

parental reports of social-emotional and executive functioning and did not include supplemental laboratory performance measures; future work, which combines laboratory and informant-based measures, is needed for a more in-depth investigation. Finally, it was not possible to isolate the components of the Karate intervention to determine whether partner-drilling or the inclusion of TD peers were most responsible for the observed effects; further studies are needed to clarify this question.

Despite some limitations, this study has many strengths. It incorporated a novel approach to the investigation of social-emotional skills and EFs in children with ASD performed Kata techniques. Furthermore, this study provided a considerable contribution to ASD research, as there is limited research that has investigated the link between executive functioning and autistic symptomology, tested recreational programs for children with ASD and have included the examination of social-emotional skills. Finally, the contemporary enhancement of social and executive functioning shown by children with ASD after Karate training confirms that executive functioning is associated with socialization and communication in ASD (Joseph & Tager-Flusberg, 2004; Kenworthy et al., 2014). However, except for the theory of mind research, less work has been done exploring the relations between EFs and social and communicative symptoms of ASD and the majority of studies have used archival clinical data without control groups to confirm that the link between EFs and autistic symptomology is specific to ASD. Therefore, our research work was important for the high scientific relevance of the findings (large effect size) and rigorosity of research design (i.e., randomised-controlled), as there are many programs in the literature aimed at families with ASD, but only a few are empirically supported.

In conclusion, we found that school-aged children with ASD that participated in Karate training program, consisted by Kata techniques performed through dynamic interactions with TD children, showed improved social-emotional skills and executive functioning performance, and lowered behavioural problems. Therefore, after a 12-week intervention, children with ASD showed greater socio-emotional competence such as communication, cooperation and engagement, better executive functioning ability such as cognitive flexibility, inhibitory control and working memory and a lower aggressiveness, sadness, anxiety and hyperactivity. Since ASD is a broad economic and societal problem that affects individual, family, and community levels, autism institutions should seriously consider Karate training to improve individual well-being and overall health.

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