

Martial arts for health benefits in children and youth with autism spectrum disorder: a systematic review

Authors' Contribution:

- A Study Design
- B Data Collection
- C Statistical Analysis
- D Manuscript Preparation
- E Funds Collection

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Abstract

Background & Study Aim:

Available publications regarding the use of martial arts in therapy and rehabilitation are main premises to this research. The purpose of this study was the issue whether martial arts are effective in improving clinical symptoms in individuals with autism spectrum disorder (ASD) so to provide better management guidelines for treatment of ASD.

Material & Methods:

Eight electronic databases were used for literature search, including PubMed, Cochrane Library, Google Scholar, Physiotherapy Evidence Database (PEDro), ProQuest, Research Autism, and ClinicalTrials.gov. After conducting the electronic search from September 2000 to August 2016, manual searches were subsequently performed through reference lists of the relevant publications. Methodological quality of 9 eligible studies was independently evaluated by two review authors using PEDro scales and the modified Clinical Relevance Tool.

Results:

Inter-reliability for study selection was 90%. When inter-reliability for evaluating the study quality was 100%, methodological quality scores for 6 randomized controlled studies and 3 case studies ranged from 7 to 8 out of 10 and 6 out of 7, respectively. Study findings demonstrated that martial arts-based interventions (internal and external styles) had positive influence on ASD-related symptoms (e.g., social interaction/communication skills, self-regulation, memory, postural control, and cognitive function) with effect size ranging from medium to high.

Conclusions:

Martial arts are beneficial for individuals with ASD. It should be incorporated into rehabilitation program to help symptomatic management of ASD. A combination of internal and external styles of martial arts for individuals with ASD to maximize the positive effect should be examined in the future study.

Key words:

Asian martial arts • Asperger syndrome • pervasive developmental disorder • rehabilitation program

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Martial arts – *plural noun* any of various systems of combat and self-defence, e.g. judo or karate, developed especially in Japan and Korea and now usually practiced as a sport [75].

Martial Arts – are systems of fight practices (practiced in many reasons: self-defence, competition, self-improvement, physical health and fitness, mental and physical development) [76].

Baduanjin – is primarily designated as a form of medical qigong, meant to improve health (this is in contrast to religious or martial forms of qigong) [77].

Qi – literally translates as "breath", "air", or "gas", and figuratively as "material energy", "life force", or "energy flow" [78].

Qigong – (*qi gong*, *chi kung*, or *chi gung*) – (traditional Chinese: pinyin: *qigōng*; Wade-Giles: *chi gong*; literally: "Life Energy Cultivation") is a holistic system of coordinated body posture and movement, breathing, and meditation used for health, spirituality, and martial arts training. With roots in Chinese medicine, philosophy, and martial arts, **qigong** is traditionally viewed as a practice to cultivate and balance *qi* (*chi*), translated as "life energy" [79].

Kata (form) – is executed as a specified series of a variety of moves, with stepping and turning, while attempting to maintain perfect form. **Kata** displays a transition and flow from one posture and movement to another, teaching the karateka proper form and position, and encouraging them to visualize different scenarios for the use of each motion and technique in imaginary bout. There are various forms of **kata** developed through different karate styles.

Nei Yang Gong – is a mindfulness-based exercise according to a Chinese chan tradition from the Sanhuangzhai monastery [25].

DSM-IV – is the guidelines of the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition [80].

INTRODUCTION

Autism spectrum disorders (ASD) are pervasive developmental disabilities that affect approximately 1 in 68 children, characterized by severe and pervasive impairment in social interaction skills, and both verbal and non-verbal communication skills [1]. Individuals with ASD also exhibit restricted, repetitive, and stereotypic behaviour patterns, self-harm, self-centred interests, emotional outbursts, and involuntary movements such as body rocking and hand flapping [2]. These three primary clinical manifestations of ASD are usually observed before children turn three years old, and ASD are typically diagnosed in early childhood [3]. Several studies recently reported that individuals with ASD also have difficulty in fine motor skills (e.g., limited hand dexterity) as well gross motor skills such as postural control and gait [4-8].

To date, pathogenesis of ASD still remains unknown, which has led to symptomatic management of ASD not to make great progress over forty years. There have been several therapeutic methods (e.g., speech-language therapy, occupational therapy, physical therapy, and behavioural intervention) that were well documented to have relatively positive influence on maladaptive behaviours of ASD [9, 10], but they tend to be extremely intensive and time-consuming [11-13], thus the extent to which the majority of families of individuals with ASD cannot afford them. Fortunately, recent studies reported encouraging findings that exercise-based interventions or engagement in physical activities are beneficial for improving maladaptive behaviours such emotional outburst control, and decreased stereotypy. Additionally, these exercise interventions are cost-effective and more easily accessible to all individuals with ASDs than those conventional treatment settings [14-17]. According to a recent systematic review, the encouraging findings are in support of various types of exercise interventions improving the behavioural outcomes (e.g., stereotypic behaviours, social-emotional functioning, cognition and attention). Of those exercises (e.g., jogging, horse-back riding, swimming, yoga, dance, and martial arts), researchers suggest that martial arts interventions may be able to produce the greatest benefit for individuals with autism [2].

Martial arts worldwide originate from India and have been successfully disseminated since they were introduced by a Buddhist monk to Shaolin

Temple in Henan Province of China four thousand years ago. Initially, martial arts aimed to help monks receive health benefits through a combination of physical training and meditation. As time went by, practitioners according to individual needs modified and refined original movements of martial arts, which made this exercise not only benefit physical and mental health, but also became offensive and defensive combat systems. According to Theeboom and De Knop [18], Chinese martial artists were forced to migrate to surrounding countries because of the political turmoil and adhered to teaching martial arts techniques to students, which ultimately led to a variety of martial arts styles to be formed. Martial arts are generally categorized into external/hard and internal/soft styles [19, 20]. External/hard martial arts include the world's most popular kung fu (wushu), taekwondo, karate kata, judo, and aikido, which involves intensifying physical fitness such as muscular endurance and strength, flexibility, balance, agility, and speed. Internal/soft martial arts include the health-enhancing tai chi, qigong, and Baduanjin, which have shared the similar principle of cultivating inner Qi flow or energy balance in the body while physical and mental relaxation are present.

More recently, empirical evidence supports the efficacy of the external/hard martial arts (e.g., taekwondo, karate) on social interaction skills, communication, stereotypic behaviours, and balance [21-23], but individuals with ASD also experience significant improvement in self-control, memory, and cognitive function following the internal/soft martial arts (e.g., traditional qigong) [14, 24, 25]. Therefore, the purpose of this study was the issue whether martial arts are effective in improving clinical symptoms in individuals with autism spectrum disorder so to provide better management guidelines for treatment of ASD. -

MATERIAL AND METHODS

Registration

This research proposal was registered with International Prospective Register of Systematic Reviews (PROSPERO) for two main reasons: (1) avoid occurrence of unplanned duplication of systematic reviews; (2) and demonstrate transparent review process for minimizing bias of studies [26].

Search strategy

The following electronic databases were used for this review between 15 August and 16 September 2016, including PubMed, Cochrane Library, Google Scholar, Physiotherapy Evidence Database (PEDro), ProQuest, Research Autism, and ClinicalTrials.gov. After conducting the electronic search from September 2000 to August 2016, manual searches were subsequently performed through reference lists of the relevant publications. Review authors were also searching for more detailed information by communicating with autism experts. Key words used in the search process were involved with combinations of two primary aspects: (1) study participants identified with autism spectrum disorder, autistic disorder (ASD), Asperger syndrome, pervasive developmental disorder (PDD); (2) Asian martial arts (e.g., martial arts, mind-body exercise, qigong, kung fu Shaolin, wushu, karate/kata, judo, aikido, or taekwondo – one of review authors who is an expert with more than 20 years of experience in martial arts field selected the keywords relating to martial arts).

Study selection

A two-phase screening process was used for obtaining eligible studies. In the first phase, two review authors independently examined the titles and abstracts of all retrieved studies and place them into three files with name of “relevant”, “possibly relevant”, and “irrelevant”. In the secondary phase, the third review author emerged and discussed with the two same review authors to resolve disagreements about studies within the file of “possibly relevant”.

Inclusion criteria

Studies are considered eligible for inclusion if they met the following criteria: (1) experimental subjects must be human participants in the studies published in English; (2) study participants were diagnosed with autism spectrum disorder (ASD); (3) study participants were aged between 0 and 19 years old while participating in the studies; (4) intervention study was involved with using at least one type of internal/soft or external/hard martial arts as the independent variable; and (5) outcome measures includes at least stereotypic behaviours, cognition function (e.g., attention, memory) social-emotional behaviours (e.g., self-regulation, respect, or attitude), and motor abilities, suggested by a friend of one of the review authors who is a mental rehabilitation

specialist working in a rehabilitation centre in Massachusetts, USA).

Data extraction

Two review authors (LYZ and HR) independently extracted data from all studies included to create two summary tables relating to study characteristic (name of authors, year of publication, type of study design, sample size, criteria of diagnosis for ASD, age of study participants, frequency and dosage of intervention, condition of control group, and follow-up assessment) and results (outcomes of interest, use of assessment tool, results of study, and effect size). A third review author (YKS) evaluated and determined whether information within the summary tables generated from the two review authors is consistent. If not, the third review author notified the two review authors and held a discussion for dealing with inconsistent information so accurate and comprehensive information can be reported. In addition, the primary author of this systematic review contacted with the corresponding author of the official conference abstracts to obtain detailed information about the study characteristics and results if they were not reported.

Methodological quality assessment

Two assessment tools were used for the systematic analysis of study quality, based on the type of study design, including PEDro scale and Modified Clinical Relevance Tool for Case Studies. The PEDro scale was used to systematically evaluate the methodological quality of Randomized Controlled studies, including eleven items: eligibility criteria, random assignment, concealment of allocation, similar baseline, blinding of subjects, blinding of therapists, blinding of assessors, follow-up rate of 85%, intention-to-treat, between-group statistical comparison, point measures and variability. Points are only awarded when a criterion is clearly satisfied (a maximum of 10 points can be obtained without considering eligibility criteria). Study quality assessment for case studies also includes seven items: research question clearly described, research hypothesis stated, patients clearly described, intervention and treatment described, outcome measures described, effect size, and limitation identified (a maximum of seven points if all criteria are clearly satisfied).

Data analysis

The review authors used Revman 5.3 software within the Collaboration for meta-analysis if the

GARS-2 – The Gilliam Autism Rating Scale-Second Edition (GARS-2) is a screening tool for autism spectrum disorders for individuals between the ages of 3 and 22. It was designed to help differentiate those with autism from those with severe behavioural disorders as well as from those who are typically developing [81].

CBCL – Children behaviour checklist is a commonly used caregiver examination form designed to identify problem behaviours (e.g., anxiety, aggression, hyperactivity, noncompliance, social withdrawal, somatic complaints, destructive behaviour, social problems, thought problems, and attention problems) in children [82].

ADI-R – is the Autism Diagnostic Interview-Revised designed to assess the autistic symptoms with regard to social interaction, communication and repetitive/stereotypical behaviours [83].

PDD-NOS – A pervasive developmental disorder not otherwise specified (PDD-NOS) is one of the four autism spectrum disorders and also one of the five disorders classified as a pervasive developmental disorder [84].

homogeneity of outcome measures and type of martial arts from a sufficient number of randomized controlled studies exists. If the heterogeneity of intervention and outcomes in the studies included exists, a qualitative data synthesis was performed based on the guidelines for a best evidence synthesis [27]. The review authors used the value of mean and standard deviation to calculate effect size (Cohen’s d) and confidence intervals (95% CI) when applicable, with standard equations [28, 29]. To interpret the effect size, the review authors used three types of thresholds below: (1) $d \geq 0.2$ is considered small; (2) $d \geq 0.5$ is moderate; (3) $d \geq 0.8$ is considered large. The p-value of 0.05 was used as a cut-off point to determine whether statistical significance of the results exists.

RESULTS

Study selection

Authors initially retrieved 321 articles. According to titles and abstracts of the articles, we identified and removed 189 duplicates, which resulted in the remaining articles of 132. Following the full-text review of the remaining articles against the inclusion criteria, 123 articles were excluded: irrelevant studies (n = 58), non-martial arts intervention (n = 34), review articles (n = 15), unable to retrieve detailed information (n = 9), and medical qigong massage (n = 7). After excluding the 123 articles, we have the final number of 9 articles in this review. An inter-rater agreement (e.g. 90%) for the screening of articles was obtained between the two authors.

Methodological quality assessment for included studies

The inter-rater reliability for methodology quality assessment within the ten included studies was 90%. A third party emerged to resolve a disagreement between the first two review authors (LYZ and YKS) about one included study. The methodological quality assessment for RCTs [21, 23, 25, 30, 31] and case studies [22, 24, 32] are presented in Table 1 and Table 2, respectively. With regard to the study quality assessment for six RCTs, three studies scored seven out of ten and another three scored eight out of ten, indicating acceptable to high quality. More specifically, given that most of the included RCTs lacked reporting items (subject blinded, therapist blinded, and intention-to-treat analysis) of the PEDro scale, points were taken away from a total score of 10. With regard to the study quality assessment for three case studies with pre-test – post-test design, the three included studies scored six out of seven, indicating high quality [22, 24, 32]. Because all the three case studies lacked reporting effect size, one point was deducted.

Study characteristics

The study characteristics of the included studies are presented in Table 3. Among the nine studies, six were randomized controlled trials (RCTs) [21, 22, 25, 30, 31, 33] and three were case studies (pre-experimental design with pre-test – post-test on one to two participants only) [22, 29, 32]. These included studies were conducted in three different countries (China, USA, and Iran) and then published between 2008 and

Table 1. Criteria (without eligibility criteria) were used to calculate the total PEDro score (0 = does not meet the criteria; 1 = meet the criteria).

Study	Eligibility criteria	Random allocation	Concealed allocation	Similar at baseline	Subject blinded	Therapists blinded	Assessor blinded	<15% dropouts	Intention-to-treat analysis	Between group comparisons	Points measures and variability	Total
Bahrami et al. [21] 2012	1	1	1	1	0	0	1	1	1	1	1	8/10
Chan et al. [25] 2013	1	1	1	1	0	0	1	1	0	1	1	7/10
Movaheidi et al. [23] 2013	1	1	1	1	0	0	1	1	0	1	1	7/10
Chan et al. [30] 2015	1	1	1	1	0	0	1	1	0	1	1	7/10
Bahrami et al. [33] 2016	1	1	1	1	0	0	1	1	1	1	1	8/10
Kim et al. [31] 2016	1	1	1	1	0	0	1	1	1	1	1	8/10

Table 2. Criteria (without eligibility criteria) were used to calculate the total PEDro score (0 = does not meet the criteria; 1 = meet the criteria).

Study	Purposed stated	Hypothesis stated	Patients described	Intervention and treatment described	Outcome measure described	Effect size	Limitation identified	Total
Chan et al. [24] 2008	1	1	1	1	1	0	1	6/7
Chan et al. [32] 2011	1	1	1	1	1	0	1	6/7
McKeehan [22] 2013	1	1	1	1	1	0	1	6/7

2016, indicating martial arts as an intervention program is a young, rapidly expanding scientific field. The studies occurred at different settings, including home [29, 32], private martial arts studio [22,31], university wellness centre [21, 23, 25, 30, 33].

A total of 209 participants with ASD (PDD-NOS = 3, Asperger = 1, autism = 205) in the 9 included studies, but only 5% were female, which is consistent with the male to female ratio within the ASD population (American Psychiatric Association, 2013). Standard diagnosis criteria were used by health professionals (clinical psychologist, physician, and researcher) to evaluate and confirm whether participants belonged to ASD, involving DSM-IV, GARS-2, CBCL, ADI-R. With regard to each study, sample size ranged from one to fifty-five and attrition percentage ranged from zero to 26.67%. Study participants ranged in age between five and seventeen. There were two main types of martial arts used in the 9 studies included in this review: internal (Shaolin Qigong, Dejian Qigong, and Nei Yang Gong Qigong) and external style (karate kata, taekwondo, and jiu-jitsu). Relatively large variability was reported for the intervention frequency and duration across studies. Specifically, martial arts intervention length ranged one to eight months, with each session ranging from 15 to 75 minutes for one to six sessions weekly. All martial arts sessions were implemented by experienced martial arts instructors under the guidance of the authors based on one-to-one and group instruction (an instructor-to-at least twenty participant ratio) when the control group either carried out original lifestyle or progressive muscle relaxation technique. Follow-up assessment was only reported in three included studies [21, 23, 33].

Summary of evidence

Authors of the included studies utilized diverse reliable and valid instruments to measure behavioural outcomes. We classified outcome measures into social-emotional function, stereotypy, and cognitive function (Table 4).

Social-emotional function: McKeehan [22] conducted two independent case studies to investigate whether the combined external martial arts (jiu-jitsu, Muay Tai) were effective in social skills as measured by multiple methods (GARS-2, behavioural observation, parents' interviews, and instructor interview) in two boys with ASD. Alpha demonstrated significant improvement in social skills (before participating in the study, he had no experience in martial arts and Bravo maintained the lasting improvement in the same outcome (one-year experience of martial arts before voluntarily participating in this research project). In addition to the mentioned-above case studies, researchers also designed two RCTs to investigate the effects of kata training on social function in individuals with ASD. Movaheidi et al [23] found a significant decrease (a relatively large effect size: $d = 1.43$) of social dysfunction (the social interaction subscale of GARS-2) in the kata group between baseline and week 14 ($t_{(12)} = 6.17$, $p < 0.001$), whereas no significant change was observed in the control group ($t_{(12)} = 0.62$, $p = 0.55$). Bahrami et al [33] investigated whether kata training was effective in alleviating the severity of communication dysfunction as measured by the communication subscale of GARS-2. After 12-week kata intervention period, a significant decrease (6.18) (a relatively moderate effect size: $d = 0.62$) was observed with regard to average communication deficit scores in the kata group from baseline to week 14 ($t_{(10)} = 6.7$, $p < 0.001$), whereas no

Table 3. The study characteristics (SMD: Shaolin mind-body exercise; CBCL: Children behavior Checklist; CI: conventional intervention; NA: not applicable).

Author(s) [reference] Year	Study design	Sample size (attrition%), gender	Age (year) M (SD)	Diagnosis criteria; autism severity M (SD)	Intervention frequency and duration	Follow- up test
Chan et al. [24] 2008	Single subject	1 female	a girl was at age of 16	At age of three, he was first diagnosed of having autistic tendency with normal intelligence level at a local Hospital. Formal diagnosis of ASD (Asperger's disorder) was confirmed by a clinical psychologist through DSM-IV-TR.	Traditional Chinese internal martial arts/Qigong consisted of two parts: Tribrachic Body Pathway Relaxation Technique (TBRT) and Dejian Mind- Body Intervention (DMBI). Daily practice for three months.	NA
Chan et al. [32] 2011	Single- subject	1 male	A boy was at age of nine	Diagnosis criteria were not exactly mentioned, but KY is a right-handed boy with mental retardation and autism. He demonstrated delayed sensory, language, motor, and social development when he turn two years old.	Firstly, he experienced CI /functional communication training with behavioral modification techniques, with 30-minute sessions weekly for one years. After one-month of no treatment, He started to experience SMD for eight months: 15-minute weekly sessions during the first month, and then 15-minute monthly sessions for the subsequent seven months.	NA
Bahrami et al. [21] 2012	RCT	N =30, including 26 males and 4 females, none of participants dropped out	5 to 16 years 9.13 (3.27)	DSM-IV; Kata: 42. 53 (18.65) Control:47.27 (19.53)	Kata (n = 15): four 60-minute sessions weekly for 14 weeks (one-to-one instruction); Control (n = 15): keep original lifestyle in the matched group according to age, gender, and autism severity.	30 days
Chan et al. [25] 2013	RCT	N = 46 (13%), six children dropped out, so only forty children left for data analysis, including 36 males and 4 females.	6 to 17 years NYG Qigong: 12.42 (3.25) PMR: 11.28 (3.90)	Formal diagnosis of ASD was confirmed by a clinical psychologist through DSM-IV-TR; ADI-R was used to assess the autistic symptoms with regard to social interaction [NYG 24.6(4.64) and PMR 23.2 (4.48)], communication [NYG 18.65 (4.06) and PMR 19.2 (4.25)] and repetitive/stereotypical behaviors [NYG 6.6 (2.6) and PMR 6.45 (2.94); Autistic disorder (92.5%) and PDD-NOS (7.5%).	NYG (n = 20): two 60-minute sessions weekly for four weeks (group training instruction); PMR (n = 20): two 60-minute sessions weekly for four weeks on the same day of a week (group training instruction).	NA
McKeehan [22] 2013	Two independent Case studies	N = 2 males	8 – 15 years Alpha: 10 years old; Bravo: 12 years old.	Exact diagnosis tool was not reported, but author used GARS-2 and CBCL to confirm that two boys had high probability of autism. Alpha showed typical symptoms, including ritualistic behaviors, avoiding eye contact, frequently emotional outburst, repetitive pattern. The standard sum score in the GARS-2 was 44, indicating that he presented high probability of autism. Bravo presented milder form of autism.	Two children with autism were assigned to 75-minute external martial arts intervention weekly for six weeks.	NA
Movahedi et al. [23] 2013	RCT	N =30 (13%), including 26 males and 4 females, but four participants dropped out because of being unable to complete the assessment	5 – 16 years 9.13(3.27)	DSM-IV; Kata: 46.31 (17.03) Control: 44.77(19.73)	Kata (n = 13): four 60-minute sessions weekly for 14 weeks (one-to-one instruction); Control (n = 13): matched according to age, gender, autism severity; keep original lifestyle.	30 days
Chan et al. [30] 2015	RCT	N = 55 (12.7%), seven withdrew before post-test because of personal reasons. The final participants included 44 male and 4 female children.	5 to17 years NFT Qigong: 11.88 (4.07) PMR: 11.04 (3.33) Control: 9.61 (3.35)	Formal diagnosis of ASD was confirmed by clinical psychologist through DSM-IV-TR; ADI-R was used to assess the autistic symptoms with regard to social interaction [NGT 23.39(4.67); PMR 23.06 (7.05); Control 20.15 (6.50)], communication [NGT 18.94 (4.33); PMR 17.59 (5.78); control 20.77 (4.38)], repetitive/ stereotypical behaviors [NGT 6.5 (2.9); PMR 6.53 (2.81); control 7 (2.86)]. Autistic disorder (85.4%) and PDD-NOS (14.6%).	NGT (n = 18): 65% of the children practiced NGT at least 6 days weekly for 5 to 45-minute daily; the remaining children practiced 3-5 days weekly for 5-25 minute daily; one-month intervention PMR (n = 17): PMR lasted approximately 20 minutes during group training; plus, home practice – half of the children practiced PMR at least six 20-minute sessions weekly, while the other half practiced 1 to 5 days weekly for one month. Control (n = 13): keep daily routine. In summary, the average practice duration between the two training was similar.	NA
Bahrami et al. [33] 2016	RCT	N = 30; None of the participants dropped out, but eight children were not included for data analysis because of not being able to perform verbal communication.	5 to 16 years 9.13 (3.27)	DSM-IV; Kata: 42. 53 (18.65) Control:47.27 (19.53)	Kata (n = 15): four 60-minute sessions weekly for 14 weeks (one-to-one instruction); Control (n = 15): keep original lifestyle in the matched group according to age, gender, and autism severity.	30 days
Kim et al. [31] 2016	RCT	N = 14, including 13 females and 1 males;	8 to 14 years TKD: 10.25 (2.38) Control: 10 (2.83)	Formal diagnosis of ASD was confirmed by a physician.	TKD (n = 8): two 50-minute sessions weekly for eight weeks (one-to-one instruction); Control (n = 6): keep daily routine	NA

Table 4. Summary of study results (NA: not applicable)

Author(s) [reference] Year	Outcome measures	Results	Conclusion	Effect Size (d)
Chan et al. [24] 2008	Control of emotional outbursts, control of repetitive thoughts and behaviors, and psychological and occupational functioning were measured using weekly frequency of temper outbursts, maximum time duration persisted (minute) in an episode of outburst, and daily maximum number of times reporting the same event. The mother of this girl helped to keep record of her emotional and behavioral problems.	After three-month Qigong intervention, the girl demonstrated a significant decrease in mean frequency of temper outbursts ranging from seven to one, maximum time duration persisted (minutes) in an episode of outburst ranging from 60 to 2, and daily maximum number of times reporting the same event ranging from four to one.	Three-month traditional Chinese Qigong had positive influence on improving temper tantrum and repetitive behaviors, faster self-claiming process, and problem-solving and psychosocial functioning.	NA
Chan et al. [32] 2011	Neuropsychological and neurophysiological measures were assessed before and after 12-month CI and after one month of no-CI and after 8-month SMB. The assessment after one month of no CI represented the pre-assessment of SMD. Memory and inhibition was measured using the Honk Kong List Learning Test; inhibitory control and cognitive flexibility was measured using the Children's Color Trails Test; overall executive functioning and inhibitory control were measured using Patient's rating on the Behavior Rating Inventory of Executive Function. In addition, underlying neural mechanism were recorded using EEG Cordance intensity and global brain state.	1. he showed significant improvement after 1-month SMB with a decrease in Intrusion score from nine to zero; he showed significantly positive effect on inhibitory control and cognitive flexibility measures (from "severely impaired" to "low average to average"); his behavioral regulation from his mother's rating showed significant improvement after 8-month SMB (from "moderately impaired" to "borderline" in overall executive functioning and low average in inhibitory control); his emotional outburst frequency reduced from more than five times weekly to two times weekly after 1-month SMD; after 8-month SMD, he has become patient, calm while unexpected events took place. 2. he showed significant memory improvement from "the severely impaired" to "the low-average to average level" after 8-month SMB. More specifically, he was able to master 19 words after 1-month SMB; during 20-minute delayed recall and recognition tests, he demonstrated the better accuracy of recalling and discriminating target words, with 71% and 92%, respectively. 3. for the neurophysiological measures, he demonstrated elevated Theta Cordance and more concordant brain state. Positive effects on these neuropsychological and neurophysiological measures were not observed after 1-year CI.	SMB as an alternative therapy could be incorporated into rehabilitation program to improve the cognitive functions and alternating the brain activity in children with low functioning autism.	NA
Bahrami et al. [21] 2012	Stereotypic behavior was measured using the stereotypy subscale of GARS-2	A significant interaction between group and time was observed, $F_{(1,28)} = 22.09$, $p < 0.001$; a significant decrease (5.33) of stereotypy scores on average in the kata group from baseline to week 14 ($t_{(14)} = 5.94$, $p < 0.001$), whereas no significant change was observed in the control group ($t_{(14)} = 1.10$, $p = 0.29$); a slightly increase (0.87) on stereotypy scores in the kata group from week 14 to follow-up test, but was not significant [$t_{(14)} = -0.9$, $p = 0.38$].	14 weeks of Kata training is effective for consistently reducing stereotypy in children with ASD.	0.93
Chan et al. [25] 2013	Self-control was measured using the three standardized neuropsychological tests, namely Tower of London Test, the Children's Color Trails Test, and the Five Point Test; Child's behavioral changes in daily life were measured using standardized questionnaires through parental interviews; The underlying neural mechanism was assessed by collecting the brain EEG signals during an inhibitory-control task before and after intervention.	1. the three standardized neuropsychological tests 1.1 with regard to the frequency of rule violation in the TOLDX, a significant difference on average reduction between NYG (-8.53) and PMR (-2.82) existed, $t_{(34)} = 2.45$, $p = 0.019$; NYG demonstrated greater reduction in the impulsivity than the PMR, $t_{(33)} = -2.27$, $p = 0.03$; 1.2 With regard to the CCTT-T2, NYG group showed a significant reduction (-17.29) in average completion time, $t_{(17)} 3.53$, $p = 0.11$, whereas no significant reduction was observed in the PMR group. 1.3 With regard to FPT, both NYG and PMR demonstrated significant improvement, but NGY group demonstrated greater effect size (0.80) than PMR (0.63). 2. self-control related daily behavioral problem 2.1 Parents of NYG group reported significant improvement in three subscales: sociability, $t_{(19)} = 3.06$, $p = 0.006$; sensory/cognitive awareness, $t_{(18)} = 2.11$, $p = 0.049$; and health/physical behavior, $t_{(18)} = 2.87$, $p = 0.01$; 2.1 parents of NYG group reported significant improvement in two subscales: temper outbursts, $t_{(28)} = 2.36$, $p = 0.026$; obsessive behaviors, $t_{(28)} = 1.9$, $p = 0.068$. 3. Brain activity in the anterior Cingulate Cortex 3.1 after four-week intervention, NYG group demonstrated significantly enhanced activity in the rostral ACC region during the No-go condition, $t = 0.30$, $p = 0.02$, where PMR did not report a significant change in activity in the ACC	Four-week NYG had a positive effect in enhancing the self-control of children with autism spectrum disorders. This cognitive improvement coincided with significantly enhanced brain activity in the anterior cingulate cortex in the NTG group, but the encouraging finding was not observed in the PMR group.	In the TOLDX, the frequency of rule violation (0.84) and The initial time of controlling impulsivity (0.77), the completion time of the CCTT-T2 (0.83), and FPT (0.80) Sociability (0.68), sensory/cognitive awareness (0.49), and health/physical behavior (0.66); Temper outburst (0.86) and obsessive behavior (0.69); Brain activity (NA)
McKeehan [22] 2013	Focus, attention, and social skills were mainly measured using five point Likert scale. In addition, multiple behavioral observations, parent interviews, and instructor interview were also conducted to collection information of symptomatic outcomes.	Alpha demonstrated significant improvement in social skills, physical ability, respect, and overall attitude (he did not have any experience in martial art program). Due to one-year experience of practicing martial arts before attending this research project, Bravo maintained the original gain in the same outcome variables.	External martial arts may be beneficial for children with autism.	NA

...Table 4. Summary of study results (NA: not applicable)

Author(s) [reference] Year	Outcome measures	Results	Conclusion	Effect Size (d)
Movahedi et al. [23] 2013	Social behavior was measured using the social interaction subscale of GARS-2	A significant interaction between group and time was observed, $F_{(2,48)} = 14.91$, $p < 0.001$, $\eta^2 = 0.38$; a significant decrease of social dysfunction in the Kata group between baseline and week 14 ($t_{(12)} = 6.17$, $p < 0.001$), whereas no significant change was observed in the control group ($t_{(12)} = 0.62$, $p = 0.55$); a slightly increase on social dysfunction score (1.69 point) was observed from week 14 to follow-up test in the kata, but was not significant ($t_{(12)} = -1.65$, $p = 0.13$).	14 weeks of kata training is effective for consistently improving social interaction skill in children with ASD.	1.43
Chan et al. [30] 2015	EEG signals were collected while participants performed a computerized visual memory task during the memory encoding phase, including memory function measures (semantic clustering score, visual scanning score, and total recall score) and EEG measures (Theta Coherence and Theta Source Activity).	1. Performance and memory retrieval strategy: NGT showed greater enhancement in semantic clustering scores in the randomized condition ($F_{(2,45)} = 4.29$, $p = 0.02$) and in total recall ($F_{(2,45)} = 5.38$, $p = 0.008$) and visual scanning scores ($F_{(2,45)} = 3.38$, $p = 0.04$) in the organized condition, in comparison with the two other groups. 2. Frontoposterior Theta Coherence during memory encoding: NGT showed significant improvement of theta coherence in certain frontoposterior connections, including intra-left frontoposterior coherence ($t = 1.85$, $p = 0.04$) in the randomized condition and intra-left and intra-right frontoposterior coherence ($t = 2.58$ and 2.67 , $p = 0.02$ and 0.01) and inter-left-to-right and inter-right-to-left frontoposterior coherence ($t = 2.74$ and 2.57 , $p = 0.01$) in the organized condition. 3. Theta Source Activity in the neural network underlying memory encoding: NGT showed significantly elevated theta source activity in the bilateral prefrontal cortex, the left parietal cortex, and the medial and inferior temporal cortex in the randomized condition (t maximum = 2.18 ; $p < 0.05$). Particularly, elevated source activity was more pronounced and bilateral during the organized condition (t maximum = 3.02 ; $p < 0.05$).	NGT is a beneficial method contributing to better memory through applying more effective and flexible strategies in children with ASD. Through one-month NGT training, children showed the use of a more efficient neural network for memory processing.	1. medium effect size; 2. NA 3. NA
Bahrami et al. [33] 2016	The severity of communication deficits was measured using the communication subscale of GARS-2.	A significant interaction between group and time was observed, ($F_{(1,20)} = 22.35$, $p = 0.000$); a significant decrease (6.18) was observed with regard to average communication deficit scores in the kata group from baseline to week 14 ($t_{(10)} = 6.7$, $p < 0.001$), whereas no significant change was observed in the control group ($t_{(10)} = 0.72$, $p = 0.49$); no significant changes with regard to the communication deficit score in the kata group from week 14 to follow-up test, ($t_{(10)} = -0.83$, $p = 0.43$).	14 weeks of Kata training has played a role in consistently reducing communication deficits.	0.62
Kim et al. [31] 2016	Postural control was measured using the NeuroCom Balance Master, including the double leg stance, the single leg stance, and the step-quick-turn test. Pediatric Balance Scale was used to measure functional balance performance.	TKD group showed significant improvement with decrease of postural sway in the right leg with eye closed condition, $F_{(1,12)} = 4.974$, $p = 0.046$ when significant improvement in the control group was not observed; TKD group showed significant decrease of postural sway in single leg (left leg with eyes open condition) after 8-week intervention ($t_{(7)} = 3.24$, $p = 0.014$), whereas no significant difference was observed in the control group between baseline and week 8.	Postural control for teenage with ASD improved following 8-week TKD training.	1.06

significant change was observed in the control group ($t_{(10)} = 0.72$, $p = 0.49$).

Self-control problems (e.g., emotional outbursts and repetitive/rigid/impulsive behaviours) are also clinical manifestations of ASD, which generally contributes to negative effect on social interaction [34-37]. Therefore, we categorized self-control capability into this subsection in this review. The oldest study examining the effect of internal martial arts (Tribrachi Body Pathway Relaxation Technique and Dejian Mind-Body Intervention) on self-control capability took place in Hong Kong, China [24]. This case study involved a girl with Asperger's disorder who was at age of 16. Her emotional outbursts frequently occurred. According to the description of her mother, if she had difficulty in switching

computer or television, she would irritable by continuously yelling until the problem was solved by her family members. After three-month qigong intervention, the girl demonstrated a significant decrease in mean frequency of temper outbursts ranging from seven to one, maximum time duration persisted (minutes) in an episode of outburst ranging from 60 to 2, and daily maximum number of times reporting the same event ranging from four to one. To be warranted to make more definitive conclusions regarding the effect of the internal martial arts on improving self-control capability, Chan et al. [25] further obtained a relatively large sample size ($n = 46$ individuals with ASD aged six to seventeen) and randomly equally assigned them into either internal martial arts (Nei Yang Gong) or conventional progressive muscle relaxation (PMR) technique. After 4-week

intervention period, participants in the internal martial arts group demonstrated significantly greater improvement in self-control than those of the PMR group (for more detailed results of multiple indicators; please see Table 4).

Stereotypic behaviours: A randomized controlled study was conducted to examine the effects of 14 weeks of external martial arts (kata training) on stereotypic behaviour (the stereotypy subscale of GARS-2) in children with ASD [21]. According to Bahrami et al. [21], the findings indicated a significant decrease (5.33) (effect size: $d = 0.93$) of stereotypy scores on average in the kata group from baseline to week 14 ($t_{(14)} = 5.94$, $p < 0.001$), whereas no significant change was observed in the control group ($t_{(14)} = 1.10$, $p = 0.29$). In addition to the stereotyped patterns of body movement, individuals with ASD also experience repetitive thoughts and behaviours. According to Chan [24], a female teenager with Asperger's disorder who was at age of 16 demonstrated improved ability in regulating her repetitive thoughts and behaviours. More specifically, after a 3-month internal martial arts intervention period, if unhappy event happened to her, she would only call her mother and to talk about the event only once, rather than repetitively ruminating a minimum of two to three times within the day of even occurred before intervention. In addition, individuals with ASD generally experience difficulties performing fundamental motor skills (e.g., walking, running, and jumping), which may be due to poor balance ability [6, 38].

Given that a small number of studies examining the effectiveness of martial arts on stereotypic behaviours, therefore we added balance measure in this subsection. Kim et al [31] measured balance performance in 14 individuals with ASD before and after an eight-week taekwondo (TKD) intervention, with multiple instruments containing NeuroCom Balance Master, single- and double-leg balance, step-quick-turn test, and Paediatric Balance Scale. TKD group showed significant improvement with decrease of postural sway in the right leg with eye closed condition, $F_{(1,12)} = 4.974$, $p = 0.046$ when significant improvement in the control group was not observed; TKD group showed significant decrease of postural sway in single leg (left leg with eyes open condition) after 8-week intervention ($t_{(7)} = 3.24$, $p = 0.014$), whereas no significant difference was observed in the control group between baseline

and week 8. Magnitude of effectiveness of martial arts intervention on balance performance was reflected as a large effect size of 1.06.

Cognitive dysfunction: as clinical manifestations of ASD emerges in individuals with ASD, including inflexible thinking, impaired memory, and lack of attention, which directly affects academic achievement and occupational performance. Two different case studies found that individuals with ASD receiving 6 or 12-week martial arts demonstrated better attention [22, 24]. Particularly, Chan et al [24] emphasized that a 16-year old female with Asperger's disorder receiving 3-month internal martial arts was able to hold herself accountable for reading books due to better attention. In addition, there were two studies, one with a randomized controlled design and another with case study, conducted to examine whether internal martial arts were effective in enhancing memory function [30, 32]. Both the studies found that internal martial arts had the beneficial effect on improving memory functions in individuals with ASD (Table 4 presenting the detailed information about the effectiveness of the internal martial arts on multiple specific indicators).

DISCUSSION

The independently peer-reviewed process finally resulted in 9 eligible studies. The findings of the present systematic review support the effectiveness of martial arts for individuals with ASD, which is consistent with a few systematic reviews summarizing the results in relation to the influence of exercise interventions on behavioural outcomes or specific indicators (e.g., stereotypic behaviours, self-regulation capability, memory, balance) [2, 39-41]. However, given that a relatively small number of studies were included for final analysis and advent effect regarding martial arts was not reported in most of the included studies, a conclusive claim regarding the effectiveness of martial arts for symptomatic management in individuals with ASD should be made carefully.

Individuals with ASD experience social dysfunction associated with verbal and non-verbal communicative behaviours. Specifically, the manifestations of social deficits are associated with

inadequate eye contact and emotional expression through body, having difficulty in asking and responding to questions, and failure to share affective experience or achievements with other individuals [34, 42, 43], and high tendency of emotional outbursts [36, 44]. These social deficits have been identified to negatively affect academic and occupational success [45], psychological wellbeing (e.g., bad mood, anxiety) [46], independence learning capability [47], and engaging in exchanging a variety of ideas and perspectives with others [48, 49]. In this review, the findings of all six included studies consistently demonstrated after experiencing martial arts-based training individuals with ASD receiving substantial improvement on social emotional function-related outcomes, including social interaction/skills [22, 50], communicative function [33], and self-control of emotional outburst [24, 25].

The findings of this review regarding the social interaction improvement following martial arts-based intervention are consistent with an extensive number of studies examining other types of physical exercises for other healthy or special populations such as individuals with developmental disabilities [51-53]. Individuals with ASD experiencing the beneficial effects following martial arts-based intervention may be attributed to two main reasons. First, exercise and sport participation is in fact a platform that allows individuals to socialize with each other, which can improve self-esteem, self-confidence, and self-competence [54, 55]. These psychological outcomes are crucial materials for intensifying social cohesion, social connections, social, recreational, and friendship networks [56]. More persuasive explanation regarding the consistent improvement of social dysfunction is associated with neurochemical mechanism. Research findings indicated that neurotransmitters (e.g., oxytocin and serotonin) modulating complex social emotional behaviours [57-59] were not sufficiently produced in individuals with ASD [4-6, 60]. Fortunately, exercise-based interventions have been shown to have the positive effect on the central oxytocinergic and serotonergic systems such as synthesis and metabolism of oxytocin and serotonin [61, 62]. Thus, martial arts belong to one of exercise-based interventions, which possibly contributes to improving synthesis and metabolism of the neurotransmitters.

Self-control problems (e.g., emotional outburst, repetitive/obsessive behavioural) are clinical manifestations in individuals with ASD. In this review, two studies (a case study and a randomized controlled design) indicated that internal martial arts were effective in improving self-control capability in individuals with ASD, which is convincingly supported by a recently published review study in *Science* (traditional internal martial arts were more effective in improving executive control than standard physical education-based or modern martial arts) [63]. The consistent findings of this review may be attributed to the fact that traditional internal martial arts were developed according to the principles of Chinese Chan and Buddhism emphasizing peaceful mind for anger and distress relief [64]. In addition, for the neural mechanism perspective, participants in the internal martial arts demonstrated the enhanced brain EEG activity in the anterior cingulate cortex mediating self-control, whereas the PMR group did not.

Restricted, repetitive, self-stimulatory, and stereotyped patterns of behaviour are one of three main characteristics of ASD [1]. Stereotypic behaviours may be associated with verbal or nonverbal, fine, or gross motor skill-based, and simple or complex. The commonly emerged stereotypy involves body movements such as hand flapping, body rocking, persistently lining up toys, spinning objects, self-harmful behaviours (head banging and facing slapping) [65-67]. According to Bahrami et al [21], individuals with ASD demonstrated significantly decreased stereotypy (roughly 43%) following 14-week external martial arts intervention. A decrease in repetitive thoughts and acts in a girl with Asperger's disorder was also observed following three-month internal martial arts intervention [24]. Because of stereotypic behaviour measures did not take place immediately after martial arts training, fatigue contributing to decreased stereotypic behaviour seems unexplainable. Kata as one of forms of karate contains a variety of body movements similar to stereotypic behaviours, which may produce a "replacement effect." According to Lang et al. [39], individuals with ASD experienced movement skill stimulation through participating in exercise and sport: If these movement patterns were similar to stereotypic behaviours and repetitively practiced, which may lead to decreased stereotypic behaviour, with greater similarity producing greater reduction in stereotypic

behaviours. For example, arm flapping is one of the most common stereotypic behaviours in individuals with ASD, which is an indispensable movement of martial arts that are required to repetitively practice. In addition, optimal stimulation theory and homeostatic theory [68] are possibly utilized to explain the decreased stereotypic behaviours. The optimal arousal level is critical of an organism to maintain homeostatic functional state. Unfortunately, individuals with ASD are encountering arousal level deficit, thus a compensatory effort such as self-stimulation is needed for restoring functional homeostasis. Exercise-based intervention as a self-stimulatory method has been shown to have the beneficial effect on facilitating optimal arousal level [69, 70]. Therefore, in this review, kata training could be a substitute that individuals with ASD need to either increase or decrease arousal level in order to replace his/her stereotypic behaviours.

In addition to social communication and interaction, stereotypic behaviour, multiple recent studies reported that individuals with ASD demonstrated worse capability of performing fundamental motor skills (walking, running, and jumping) than normal peers [5-7, 38]. Kim et al [31] hypothesized that individuals with ASD experiencing difficulty in performing fundamental motor skills may be attributed to the poor balance, then to examine whether external martial arts (TKD) was effective in improving balance performance for better fundamental motor skills. Following two 50-minute TKD sessions weekly for eight weeks, eight children with ASD demonstrated significant improvement on multiple balance measures, whereas six individuals with ASD in the control did not. The improved balance performance in eight children with ASD following the eight-week TKD intervention are relatively easy to be explained because TKD is a lower limb dominant external martial arts that requires practitioners to perform a variety of kicking with single leg support while physical body is moving.

Individuals with ASD also experience abnormalities in relation to cognitive function [71-74]. The cognitive dysfunction involves inflexible thinking, impaired memory, and lack of attention, which greatly hinder individuals with ASD to obtain academic and occupational success [30]. In this review, four studies involved using martial arts to intervene individuals with ASD and indicated that martial arts-based intervention was effective

in improving cognitive dysfunction [22, 24, 30, 32]. More specifically, both internal and external martial arts have been shown to have the positive effect on improving attention in two case studies [22-24]. The attention improvement (e.g., on-task behaviour) may be partially due to friendly instruction such as martial arts instructors incorporate visual, auditory, and kinaesthetic cues into their instructions, which may make individuals with ASD develop the ability to pay attention to tasks (e.g., being able to pay attention to reading books). Following internal martial arts intervention, enhanced executive and memory function was observed in a case study and a RCT, which is attributed to the fact that the internal martial arts potentially modulating neural functional connectivity underlying memory processing [30, 32]. In this review, the internal martial arts enhancing executive and memory functions were consistent with previous studies examining the effects of the same internal martial arts on the same outcome measures in patients with other neurological disorders [25, 30, 32] and older adults with lower memory functions.

LIMITATION AND RECOMMENDATION

Although the existing evidence supports the beneficial effect of martial arts on social-emotional function, stereotypic behaviours, and cognitive function, this review still has limitation. First, the present review only containing nine studies in English language was to systematically evaluate the effects of martial arts on symptom-related outcomes in individuals with ASD, regardless of taking into account other non-English studies on the similar topic. Second, due to the limited number of studies regarding martial arts-based intervention, the present review did not separately evaluate the effects of two different styles of martial arts (internal and external martial arts) on the specific symptom-related outcome despite the existing evidence of this review indicated that internal martial arts tend to improve cognitive function, but external martial arts are likely to enhance social-emotional function and stereotypic behaviours. Third, the heterogeneity of sample size, symptom-related outcomes, intervention frequency and duration, and experimental designs are more likely to produce difficulties in identifying significant difference and summarize overall research findings.

Whether the combined martial arts (internal and external styles) are more beneficial for symptom-related outcomes in individuals with ASD that still remain unclear, thus researchers should further explore a combination of internal and external martial arts.

CONCLUSIONS

The present systematic review demonstrated that martial arts (internal and external styles) had positive influence on ASD-related symptoms (e.g., social interaction/communication skills, self-regulation, memory, postural control, and cognitive function) with effect size ranging from medium to high. Therefore, martial arts are potentially

beneficial for individuals with ASD, particularly for children and teenagers. It may be suitable to be considered as a rehabilitation program to help symptomatic management of ASD. A combination of internal and external styles of martial arts for individuals with ASD to maximize the positive effect should be further examined with a great sample size following a follow-up assessment.

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