

Therapeutic-educational Significance of Martial Arts for Autistic Spectrum Disorders : From the Perspective of ICF Core Set

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Abstract:

Objective: This study examined the therapeutic-educational significance of martial arts for ASD from the perspective of the International Classification of Functioning, Disability and Health (ICF) core set. The goal was to expand treatment options and establish evidence-based exercise interventions.

Methods: Based on the most recent scoping review of martial arts interventions for ASD, this study analyzed previous studies in three areas related to the ICF core set: Body functions and structures, activities and participation, and contextual factors.

Results: Martial arts intervention had beneficial effects in three areas, indicating its potential to play a multifaceted role in improving the quality of life of children with ASD, such as promoting comprehensive development and social participation.

Conclusion: Given the diverse symptoms and severity of ASD, the multifaceted benefits of martial arts present a promising exercise-based treatment option. Future efforts should focus on developing evidence-based programs tailored to individual needs.

Keywords: Exercise, Physical activity, Developmental disorder, Neurodevelopmental disorder, ICF

1. Introduction

In recent years, the number of children with neurodevelopmental disorders has been increasing internationally (Boyle et al., 2011; Zablotsky et al., 2019, 2023), with a particularly marked increase

in children with Autism Spectrum Disorder (ASD) (Baio et al., 2018; Mack, 2011). ASD is a neurodevelopmental disorder with Social Communication Disorder and Repetitive/Restrictive Behavior (RRB) as core symptoms (DSM-5). Traditional interventions for children with ASD (ASDs) have focused on behavioral and psychotherapy. However, these treatments are often costly and have limited effectiveness. As a result, low-cost, side-effect-free physical activity and exercise interventions have gained attention in recent years.

Current interventions include aerobic exercises like running and swimming (Battaglia et al., 2019), team sports like basketball (Cai et al., 2020), and martial arts like Judo and Karate. In particular, martial arts has been shown by Bremer et al. (2016); Zou et al. (2017) to have a moderate to high effect size on improving core symptoms of ASD. Other recent reviews by Hosokawa et al. (2024) have shown that martial arts practice promotes multifaceted development (e.g., physical, cognitive, and socioemotional functioning) in ASDs. However, the impact of martial arts practice on the real-life situations of ASDs has not been fully discussed.

On the other hand, the therapeutic-educational significance of swimming and aquatic exercise interventions for ASDs has been examined using the International Classification of Functioning, Disability and Health (ICF) core set (Güeita-Rodríguez et al., 2019; Hosokawa et al., 2023). ICF was developed by the World Health Organization (WHO) and is a comprehensive system for assessing an individual's health status based on five items: body functions and structures, activities, participation, environmental factors, and personal factors (Figure 1).

Insert Figure 1.

The ICF core set is a framework from which items related to specific disorders such as ASD are extracted, and is a useful tool for understanding the relationship between intervention effects and real-life changes. Therefore, it is beneficial to examine the intervention effects of martial arts and its mechanism based on the ICF core set in order to clarify its therapeutic-educational significance for ASD. The purpose of this study was to evaluate the therapeutic-educational value of martial arts for ASD from the perspective of the ICF core set, ultimately broadening treatment options and establishing evidence-based exercise interventions.

2. Methods

The analysis focused on 22 articles included in a recent scoping review of martial arts interventions for ASD (Hosokawa et al., 2024) and three articles collected through an additional search (Garcia et al., 2020, 2021, 2022) (Table1).

Insert Table1.

There are three types of ICF core sets: comprehensive ICF core set, general ICF core set, and shortened ICF core set. In this study, we referred to the comprehensive ICF core set for ASD to prevent omission of information. For the purpose of convenience, the therapeutic-educational significance of martial arts for ASD was analyzed by dividing it into three areas: body functions and structures, activities and participation, and contextual factors (individual factors and environmental factors). This analysis was conducted in discussion with a physical therapist specializing in pediatrics and a university faculty member specializing in education. Items with particularly strong associations between the ICF core set and martial arts interventions are shown in < > (Table2).

Insert Table2.

3. Results and Discussion

3.1. Body functions and structures

3.1.1. Improved wake/sleep function

Because ASD is caused by structural and functional abnormalities of the brain and nervous system, patients often have some problems with wake/sleep function. For example, ASDs have difficulty regulating arousal levels and are often hyper aroused (Rogers and Ozonoff, 2005). In addition, ASDs have more than 30 minutes less total sleep time per day and 10 minutes longer sleep latency than persons with Typical Development (TDs) (Elrod and Hood, 2015). Abnormalities in wake/sleep function are involved in the occurrence of RRB and also affect the health of ASDs and those around them (Ornitz and Ritvo, 1968).

In contrast, Saber et al. (2021) reported improvements in the Children's Sleep Habits Questionnaire (CSHQ) measures (bedtime resistance, sleep duration, sleep anxiety, nighttime arousals, sleep paralysis, and daytime sleepiness) after a 10-week Karate intervention for ASDs aged 8-14 years. Saber et al. (2021) described the effects of martial arts on wake/sleep function as involving increased physical activity levels, improved thermoregulation, reduced anxiety and depression, and increased secretion of growth hormone, melatonin, serotonin, and others. In support of this, Chan et al. (2008) reported an improvement in self-soothing measures after a 3-month Tai Chi-like exercise program intervention for ASDs aged 16 years.

Sleep is essential for memory consolidation, stress reduction, and brain development. Therefore, improving sleep quality through physical activity and exercise is a critical component of therapeutic education for ASD. Recent studies have shown that using weighted blankets (Bolic et al., 2021) and melatonin supplementation (Rzepka-Migut and Paprocka, 2020) can be effective. Combining these approaches with increased daytime physical activity and exercise may further enhance sleep quality in ASDs.

< b110 Consciousness functions, b130 Energy and drive functions, b134 Sleep functions >

3.1.2. Improved cognitive function

ASDs exhibit a wide range of cognitive impairments, including attention, memory, and executive function. These cognitive impairments make it difficult to process audiovisual information and perform tasks, and they also impede smooth communication.

In contrast, Chan et al. (2013, 2015); McKeehan (2012) reported improvements in attention and memory after a 4-6 week interventions with Tai Chi and Mixed Martial Arts (MMA) for ASDs aged 5-17 years. Greco and Ronzi (2020); Kurniawan et al. (2022); Phung and Goldberg (2019) also reported improvements in executive function after a 6-13 week interventions with Karate and MMA for ASDs aged 8-12 years.

Physical activity/exercise activates a neural network centered on the prefrontal cortex that controls executive function through increased cerebral blood flow and release of catecholamines (dopamine, epinephrine, norepinephrine, etc.) (Meeusen and De Meirleir, 1995). Similarly, the release of Brain Derived Neurotrophic Factor (BDNF) promotes plastic neural changes such as neuronal neogenesis, dendrite proliferation, and axon elongation (Phillips et al., 2014). These neurophysiological

mechanisms are known to improve executive function acutely and chronically (Liang et al., 2022). In addition, martial arts require the following abilities: “self-control” to maintain a social attitude regardless of whether a match is won or lost, and “cognitive flexibility” in decision-making and prediction to adapt to situations during training and competition. These are subcomponents of executive function, and the unique culture and spirituality of martial arts may influence the above neurophysiological mechanisms.

< b140 Attention functions, b144 Memory functions, b164 Higher-level cognitive functions >

3.1.3. Improved sensory and motor functions

It has been noted that 80-90% of ASDs have sensory and motor-related impairments (Green et al., 2009; Schoen et al., 2009). This problem is known to interfere with participation in social activities, cause stress, and increase the risk of developing RRB (Hazen et al., 2014).

However, studies have shown that martial arts and related exercises can address these challenges. For instance, Kim et al. (2016) and Sarabzadeh et al. (2019) reported improvements in ball-handling skills and balance after 6-8 week interventions with Tai Chi and Taekwondo for ASDs aged 6-14 years. Similarly, Chan et al. (2013) observed enhancements in sensory characteristics after a 4-week intervention with Neiyangong for individuals aged 6-17 years. Additionally, Bahrami et al. (2012), Morales et al. (2021), and Tabeshian et al. (2022) documented reductions in RRBs after 8-14 week interventions with Judo, Karate, and Tai Chi for children aged 5-16 years. Structured movement learning, such as Karate kata, is known to contribute to a reduction in RRBs (Reid et al., 1988). Because sensory and motor problems and RRBs are difficult to improve with behavioral therapy, considering exercise intervention as a treatment option can be beneficial in improving the core symptoms of ASDs.

< b265 Touch function, b760 Control of voluntary movement functions >

3.1.4. Structural and functional changes in the brain and nervous system

ASD is one of the neurodevelopmental disorders and is known to have some structural and functional abnormalities in the brain and nervous system. This leads to many functional impairments as described above, and is a factor that reduces quality of life. On the other hand, evidence is accumulating that martial arts and other exercise interventions affect brain structure and function.

For instance, Chan et al. (2011, 2013, 2015) reported changes in the anterior cingulate cortex and frontal-occipital lobe activity after a 4-week Tai Chi intervention for ASDs aged 6-17 years. In China, such combinations of exercise interventions and neurological testing are commonly implemented. Yang et al. (2021) and Yu et al. (2021) observed improvements in functional connectivity within large-scale brain networks, such as the Default Mode Network (DMN) and the Executive Control Network (ECN), after a 12-week mini-basketball intervention for children with ASD aged 3-6 years. Similarly, Cai et al. (2020) reported enhanced white matter integrity in cortical-subcortical connections using a similar intervention. The structural and functional changes in the brain and nervous system after intervention indicate the potential for fundamental treatment of ASD through physical activity/exercise. It is important to continue to accumulate neurological data to explain the therapeutic-

educational significance of exercise interventions, including martial arts.

<s110 Structure of brain >

3.2. Activities and participation

3.2.1. Attention control and information processing

ASDs are characterized by attention impairments such as difficulty switching attention and hyper focusing on details (Reed and McCarthy, 2012; Smith and Milne, 2009). This is thought to be related to inhibition of social information processing, such as difficulties with face recognition and reduced sensitivity to human movement (Todorova et al., 2019).

In contrast, McKeehan (2012) reported beneficial effects on attention and concentration improvement after a 6-week MMA intervention for ASDs aged 10-12 years.

In martial arts practice and training, participants are expected to pay attention to and gather information from the visual and verbal instructions of their instructor in order to acquire skills. The opportunity to repeatedly imitate and reproduce perceived information in order to adapt to quick changes in the situation during the match may have contributed to the improvement of attention and concentration in ASD.

< d110 Watching, d115 Listening, d130 Copying, d138 Acquiring information, d155 Acquiring skills, d160 Focusing attention, d161 Maintaining attention >

3.2.2. Executing tasks and management of behavior

The executive function is a brain function involved in planning and decision-making by controlling attention, emotion, and memory. Executive function affects the performance of nonconventional behaviors and complex tasks, and a reduction in this function is suspected in ASDs (Hill, 2004).

In contrast, Greco and Ronzi (2020); Kurniawan et al. (2022); Phung and Goldberg (2019) reported improvements in executive function after a 6-13 week interventions with Karate and MMA for ASDs aged 5-17 years. In particular, Greco and Ronzi, (2020); Phung and Goldberg, (2019) reported improvements in several subcomponents, including behavioral regulation, emotion regulation, and global executive functioning composite.

Difficulties with daily tasks, such as self-care or using public transportation, can increase the caregiving burden on families and caregivers. Thus, improving task execution and behavioral management through interventions may enhance the quality of life for both ASDs and those around them.

< d210 Undertaking a single task, d220 Undertaking multiple tasks, d230 Carrying out daily routine, d250 Managing one's own behavior >

3.2.3. Promotion of mental and physical health

According to Stanish et al. (2017), only 14% of ASDs meet the National Physical Activity Plan Alliance (NPAPA) recommended amount of physical activity. Furthermore, Tyler et al. (2014) reported that individuals with ASD spend approximately 20% more time in sedentary behaviors compared to those with TD. As a result, the rates of obesity and overweight in ASDs are 1.4 to 2 times

higher than in TDs, posing a significant risk for cardiovascular diseases (Pan, 2008; Phillips et al., 2014; Danielsen et al., 2011).

Although not included in the review by Hosokawa et al. (2024), Garcia et al. (2020) reported a significant increase in time spent in moderate-to-vigorous physical activity (MVPA) that was maintained after an 8-week Judo intervention for ASDs aged 8-17 years.

Regular 150 minutes of MVPA per week is known to reduce the risk of developing cardiovascular disease, type 2 diabetes, metabolic syndrome, and cancer (Bishop et al., 2022). Martial arts are suitable for lifelong practice because they do not necessarily require a high level of physical ability or interpersonal practice. Thus, the practice of martial arts as a lifelong sport is considered to contribute to the improvement of physical health through an increase in physical activity.

ASDs have sensory and motor impairments in addition to the core symptoms, and are therefore susceptible to physical and social stress. In addition, prolonged exposure to stress risks secondary disorders such as anxiety and depression.

In contrast, Renziehausen et al. (2022) reported a decrease in salivary cortisol levels, a type of stress marker, after a 10-week Judo intervention for ASDs aged 8-17 years.

Physical activity/exercise is listed as one of the emotion-focused stress coping methods because it has the effect of distracting you and reducing anxiety and stress. Therefore, regular physical activity/exercise is considered to contribute to the maintenance and promotion of mental health as well as physical health.

< d240 Handling stress and other psychological demands, d570 Looking after one's health, d571 Looking after one's safety, d880 Engagement in play, d910 Community life, d920 Recreation and leisure >

3.2.4. Acquisition of social communication skills

ASDs have unique communication styles such as echolalia and the crane symptom, and may have difficulty with verbal and nonverbal communication. Problems with daily conversation and communication have a significant impact on a person's long-term lifestyle, including participation in social activities, further education, and employment.

However, numerous studies have demonstrated improvements in social communication skills following martial arts interventions. For example, Bahrami et al. (2016), Calinog et al. (2021), Greco and Ronzi (2020), Morales et al. (2021), Movahedi et al. (2013), Phung and Goldberg (2021), and Polak et al. (2019) reported enhancements in social interaction, emotional regulation, and related measures after 7-14 weeks of training in Judo, Karate, Taekwondo, Aikido, and MMA for ASDs aged 5-16 years. Social communication disorder is one of the core symptoms of ASD, so it is of great academic interest, and many researchers are considering the mechanism of improvement by martial arts from their own standpoints. Bahrami et al. (2016); Movahedi et al. (2013) examined the mechanisms from a neurophysiological perspective, including the secretion of neurotransmitters such as oxytocin, serotonin, and BDNF and the associated plastic neural changes. Morales et al. (2021) believe that sensory input through body contact and touch in Judo assisted the formation of self-awareness and body schemes, and promoted the formation of attachment to others. Greco and Ronzi

(2020); Phung and Goldberg (2021) found that many important social communication skills were learned through pair or group-based partner practice in Karate and MMA, including nonverbal communication such as imitation, eye contact, and gestures; verbal communication such as conversation; and sequencing.

As described above, many hypotheses have been proposed regarding the mechanisms by which martial arts practice improve social communication in ASDs. These intervention studies combined different patterns of instructional methods, such as simultaneous instruction by a teacher and individual practice with TDs. Therefore, it is likely that an intervention designed to gradually increase interpersonal interactions produced complex social interactions that affected the social communication of the ASDs.

< d310 Communicating with - receiving - spoken messages, d315 Communicating with - receiving - nonverbal messages, d330 Speaking, d335 Producing nonverbal messages, d350 Conversation, d360 Using communication devices and techniques, d710 Basic interpersonal interactions, d720 Complex interpersonal interactions, d730 Relating with strangers, d740 Formal relationships, d750 Informal social relationships >

3.3. Contextual factor

3.3.1. Support and cooperation of familiar people

In addition to core symptoms, ASDs have sensory and motor impairments that present high barriers to participation in social activities. Therefore, planned and strategic motivation is necessary for participation in social activities.

Although not included in the review by Hosokawa et al. (2024), Garcia et al. (2022) reported a 15-week Judo intervention and reported that participation with family members improved program participation and retention. In another exercise intervention study, Chu and Pan (2012) reported a 16-week swimming and aquatic exercise intervention and reported that peer and sibling support facilitated learning.

Thus, support and cooperation of those close to the ASDs may motivate participation in social activities and contribute to the effectiveness of learning. In addition, family participation in common activities is thought to promote understanding of disability and to provide opportunities for growth together.

< e310 Immediate family, e315 Extended family, e320 Friends, e325 Acquaintances, peers, colleagues, neighbors and community members, e330 People in positions of authority, e410 Individual attitudes of immediate family members, e415 Individual attitudes of extended family members, e420 Individual attitudes of friends, e425 Individual attitudes of acquaintances, peers, colleagues, neighbors and community members, e430 Individual attitudes of people in positions of authority >

3.3.2. Acquisition of social attitudes and norms

As noted above, ASDs have high barriers to participation in social activities, which may limit their opportunities to learn social attitudes and norms. The ability to exhibit self-control, to express emotions appropriately, and to respect the opinions of others are essential for building interpersonal

relationships and participating in social activities.

In contrast, Chan et al. (2013) reported improvements in self-control scores after a 4-week intervention with Tai Chi for ASDs aged 6-17 years. Additionally, Li et al. (2022), although not included in the review by Hosokawa et al. (2024), observed enhancements in social attitudes and behaviors through routine movements commonly practiced in martial arts.

Martial arts culture values courtesy and etiquette more than the result of a match. This is highly compatible with ASDs' preference for structured environments and behaviors and may be effective in learning social attitudes and norms.

< e460 Social attitudes, e465 Social norms, practices and ideologies >

3.3.3. Limitations

The results of this study rely on the most recent scoping review and are not based on rigorous statistical analysis. Thus, caution must be exercised in generalizing the results. There are also issues regarding the studies analyzed, such as the limited number of articles, the short duration of the intervention, the lack of continuous follow-up, and the lack of studies involving adults. Therefore, future long-term studies that include more diverse age groups are needed.

4. Conclusion

This study examined the therapeutic-educational significance of martial arts for children with ASDs based on the ICF core set. The results showed beneficial effects from previous studies in three areas: body functions and structures, activities and participation, and contextual factors, indicating the possibility of a multifaceted role in improving the quality of life of ASDs, such as promoting comprehensive development and social participation (Figure 2). Because symptoms and severity of ASD are varied, the multifaceted effects of martial arts are promising as an exercise-based treatment option for ASD. In the future, it is necessary to continue to accumulate intervention studies and develop evidence-based intervention programs to adapt to individual needs.

Insert Figure 2.

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Figures and Tables

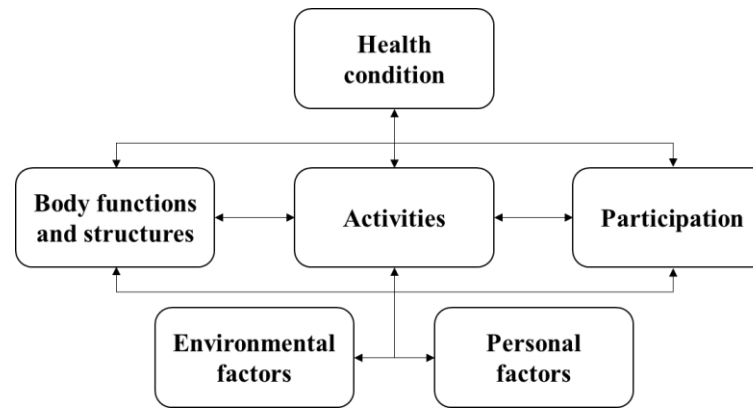


Figure1. ICF model

Table1. List of analyzed articles

	Authors & Year Country Study design	Sample size(males) Age Intervention method(Special note) Intervention time, frequency, and duration	Summery
Judo	Garcia et al. (2020) USA Pre-post	n=14(12) 8-17 years old <u>Judo program</u> 45 minutes *1 time per week *8 weeks	Garcia et al. (2019) conducted an 8-week intervention with a judo program for 14 Persons with ASD (ASDs) (8-17 years old). The results showed a significant increase in the percentage of moderate to vigorous physical activity (MVPA) as measured by Actigraph.
	Garcia et al. (2021) USA Pre-post	n=9(8) 15-18 years old <u>Judo program(Partially online instruction^{†1})</u> 45 minutes *2 time per week *7 weeks	Garcia et al. (2021) conducted a 7-week intervention with in-person and remote judo program for nine ASDs (15-18 years old). The results showed that semi-structured interviews revealed advantages and disadvantages of remote instruction.
	Garcia et al. (2022) USA Pre-post	n=17(9) 6-19 years old <u>Judo program(Partially online instruction^{†1})</u> 45 minutes *1 time per week *15 weeks	Garcia et al. (2022) conducted a 15-week intervention with a judo program divided 17 ASDs (6-19 years old) into family and child-only classes. The results showed that the family class had significantly higher attendance and retention rates than the child-only class.
	Morales et al. (2021) Spain Pre-post	n=11(7) 9-13 years old <u>Judo program</u> 75 minutes *1 time per week *8 weeks	Morales et al. (2021) conducted an 8-week intervention with a judo program for 11 ASDs (9-13 years old). The results showed significant improvements in the Gilliam Autism Rating Scale-Third Edition (GARS-3) subscales of sedentary behavior, social interaction, social communication, and emotional response.
	Renziehausen et al. (2022) USA non-RCT	n=12(8) 8-17 years old <u>Judo program</u> 45 minutes *2 times per week *10 weeks	Renziehausen et al. (2022) conducted a 10-week intervention with a judo program for 12 ASDs (8-17 years old). The results showed a decreasing trend in salivary cortisol levels after the first round of sessions.
	Rivera et al. (2020) USA Pre-post	n=25(22) 8-17years old <u>Judo program</u> 45 minutes *1 time per week *8 weeks	Rivera et al. (2020) conducted an 8-week intervention with a judo program for 25 ASDs (8-17 years old). The results showed that while the Abnormal Behavior Checklist (ABC) did not show significant improvement, approximately 78% of the parents observed improvements in social skills and self-esteem in semi-structured interviews.
	Tomey (2017) USA Pre-post	n=5(NA) 8-11 years old <u>Judo program</u> 50 minutes *2 times per week *5 weeks	Tomey (2017) conducted a 5-week intervention with a judo program for five ASDs (8-11 years old). The results showed that qualitative outcomes, such as positive opinions of the program and increased confidence, were observed through the semi-structured interviews.

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Karate	Bahrami et al. (2012) Iran <i>RCT</i>	n=30(24) 5-16 years old <u>Karate kata program(Heian Shodan ^{†2})</u> <i>30-90 minutes *4 times per week *14 weeks</i>	Bahrami et al. (2012) divided 30 ASDs (5-16 years old) into an intervention group and a control group, and conducted a 14-week intervention with a Karate kata (Heian Shodan) program for the intervention group. They reported that the intervention group showed significant improvement in the GARS-2 subscale of stereotyped behavior compared to the control group, and that this effect was maintained one month after the intervention.
	Bahrami et al. (2016) Iran <i>RCT</i>	n=30(26) 5-16 years old <u>Karate kata program(Heian Shodan ^{†2})</u> <i>30-90 minutes *4 times per week *14 weeks</i>	Bahrami et al. (2016) divided 30 ASDs (5-16 years old) into an intervention group and a control group, and conducted a 14-week intervention with a Karate kata (Heian Shodan) program for the intervention group. They reported that the intervention group showed significant improvement in the GARS-2 subscale of social communication, compared to the control group, and that this effect was maintained one month after the intervention.
	Greco & Ronzi (2020) Italy <i>RCT</i>	n=28(24) 8-11 years old <u>Karate kata program(Heian Shodan ^{†2})</u> <i>45 minutes *2 times per week *12 weeks</i>	Greco and Ronzi (2020) divided 28 ASDs (8-11 years old) into an intervention group and a wait-list control group, and conducted a 12-week intervention with a Karate kata (Heian Shodan) program for the intervention group. They reported that the intervention group showed significant improvement on two subscales of the Social Skills Improvement System Rating Scale (SSIS-RS) and on four subscales of the Behavior Rating Inventory of Executive Function (BRIEF).
	Kurniawan et al. (2022) Indonesia <i>Pre-post</i>	n=4(4) 8-12 years old <u>Karate kata program</u> <i>30-45 minutes *3 times per week *6 weeks</i>	Kurniawan et al. (2022) conducted a 6-week intervention with a Karate kata program for four ASDs (8-12 years old). The results showed a trend toward improvement in socio-emotional dysfunction and executive dysfunction, as indicated by questionnaires developed based on ICD-10 and DSM-IV.
	Movahedi et al. (2013) Iran <i>RCT</i>	n=26(22) 5-16 years old <u>Karate kata program(Heian Shodan ^{†2})</u> <i>30-90 minutes *4 times per week *14 weeks</i>	Movahedi et al. (2013) divided 26 ASDs (5-16 years old) into an intervention group and a control group, and conducted a 14-week intervention with a Karate kata (Heian Shodan) program for the intervention group. They reported that the intervention group showed significant improvement in the GARS-2 subscale of social interaction, compared to the control group, and that this effect was maintained one month after the intervention.
	Saber et al. (2021) Iran <i>RCT</i>	n=20(20) 8-14 years old <u>Karate kata program</u> <i>60 minutes *2 times per week *10 weeks</i>	Saber et al. (2021) divided 20 ASDs (8-14 years old) into an experimental group and a control group, and conducted a 10-week intervention with a Karate kata program for the experimental group. They reported that the experimental group showed significant improvements in the Children's Sleep Habits Questionnaire (CSHQ) subscales of bedtime resistance, sleep duration, sleep anxiety, nighttime arousal, side sleep, and daytime sleepiness.
Traditional Chinese martial arts	Chan et al. (2008) China <i>Case study</i>	n=1(0) 16 years old <u>Dejian Mind-Body Intervention ^{†3}</u> <i>every day before bed *3month</i>	Chan et al. (2008) reported that the Triarchic Bodypathway Relaxation Technique (TBRT) and Dejian Mind-Body Intervention (DMBI) for one ASDs improved in tantrums, repetitive behaviors, and self-soothing.
	Chan et al. (2011) China <i>Case study</i>	n=1(1) 9 years old <u>Dejian Mind-Body Intervention ^{†3}</u> <i>15 minutes *1 time per week or month</i>	Chan et al. (2011) reported that Dejian Mind-Body Intervention (DMBI) for one ASDs improved memory and executive function, as well as brain activity in the frontal-occipital lobes.
	Chan et al. (2013) China <i>RCT</i>	n=40(36) 6-17 years old <u>Neiyangong-based program ^{†4}</u> <i>60 minutes *2 times per week *4weeks</i>	Chan et al. (2013) divided 40 ASDs (6-17 years old) into experimental group and control groups, and conducted a 4-week intervention with a Neiyangong-based program for the experimental group. They reported that the experimental group showed improvement their performance on neuropsychological assessments related to self-control, as well as significantly increased activity in the anterior cingulate cortex during the Go/No-go task.

	Chan et al. (2015) China <i>RCT</i>	n=31(29) 5-17 years old <u>Neiyangong-based program</u> ^{†4} 60 minutes *2 times per week *4weeks	Chan et al. (2015) divided 31 ASDs (5-17 years old) into three groups: a Neiyangong training (NGT) group, a progressive muscle relaxation training (PMR) group, and a control group, and conducted a 4-week intervention with a Neiyangong-based program for the NGT group. They reported that the NGT group showed improvement in memory function and accompanying changes in brain activity between the frontal and occipital lobes.
	Sarabzadeh et al. (2019) Iran <i>RCT</i>	n=18(14) 6-12 years old <u>Tai Chi program(Yang style</u> ^{†5}) 60 minutes *3 times per week *6 weeks	Sarabzadeh et al. (2019) divided 18 ASDs (6-12 years old) into experimental group and control group, and conducted a 6-week intervention with a Tai Chi program for the experimental group. They reported that the experimental group showed significant improvement in the performance on the ball skills and balance subscales of the M-ABC.
	Tabeshian et al. (2021) Iran <i>RCT</i>	n=23(19) 6-12 years old <u>Tai Chi program(Yang style</u> ^{†5}) 45 minutes *3 times per week *12 weeks	Tabeshian et al. (2022) divided 23 ASDs (6-12 years old) into intervention group and control group, and conducted a 12-week intervention with Yang style Tai Chi program for the intervention group. They reported that the intervention group showed significant improvements in the GARS-2 subscale of sedentary behavior, which were maintained one month after the intervention.
Taekwondo	Calinog et al. (2021) USA <i>Pre-post</i>	n=3(NA) 7-8 years old <u>Taekwondo-based program</u> 45 minutes *1 time per week *7 weeks	Calinog et al. (2021) conducted a 7-week intervention with a Taekwondo-based program for three ASDs (7-8 years old). The results showed a trend toward improvement in the Autism Social Skills Profile-2 (ASSP-2) subscales of Social/Emotional Reciprocity (SER), Social Participation/Avoidance (SPA), and Detrimental Social Behaviors (DSB).
	Kim et al. (2016) USA <i>non-RCT</i>	n=14(13) 8-14 years old <u>Taekwondo-based program</u> 50 minutes *2 times per week *8 weeks	Kim et al. (2016) divided 14 ASDs (8-14 years old) into an intervention group and a control group, and conducted an 8-week intervention with a Taekwondo-based program for the intervention group. They reported that intervention group showed significant improvements in dynamic and static balance in the one-leg standing position with closed eyes and coasted state.
Aikido	Polak et al. (2019) Poland <i>Case study</i>	n=1(1) 12 years old <u>Aikido camps</u> 90 minutes *2 times per day *10 days	Polak et al. (2019) reported improved social interactions with peers for one ASD (12 years old) who attended five 10-day Aikido camps held between 2013 and 2017.
Mixed martial arts (MMA)	McKeehan (2012) USA <i>Pre-post</i>	n=2(2) 10-12 years old <u>Mixed Martial Arts program</u> 6 weeks	McKeehan (2012) conducted a 6-week intervention with a mixed martial arts (MMA) program for two ASDs (10-12 years old). The results showed beneficial effects on cognitive functions such as attention and concentration, as well as on psychological and social functions.
	Phung & Goldberg (2019) USA <i>RCT</i>	n=34(28) 8-11 years old <u>Mixed Martial Arts program</u> 45 minutes *2 times per week *13 weeks	Phung & Goldberg (2019) divided 34 ASDs (8-11 years old) into an MMA group and a wait-list control group, and conducted a 13-week intervention with MMA program for the MMA group. They reported that the MMA group showed significant improvements in the BRIEF-2 subscales of behavioral control, emotional control, and composite executive control, compared to the wait-list control group.
	Phung & Goldberg (2021) USA <i>RCT</i>	n=34(28) 8-11 years old <u>Mixed Martial Arts program</u> 45 minutes *2 times per week *13 weeks	Phung & Goldberg (2021) divided 34 ASDs (8-11 years old) into an MMA group and wait-list control groups, and conducted a 13-week intervention with MMA program for the MMA group. They reported that the MMA group showed tended to improvement in the SSIS-RS subscale of social skills and problem behaviors, compared to the wait-list control group.

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† 1 : In these studies, online Judo instruction by ZOOM was used in some of the interventions due to the influence of COVID-19.

† 2 : Heian shodan is one of the first kata practiced by beginners in Shotokan karate.

† 3 : DMBI is a mind-body conditioning method based on traditional Chinese martial arts, Zen practice, and medical approaches that originated in the Shaolin Temple.

† 4 : Nei Yang Gong is part of DMBI and consists of smooth, slow movements similar to tai chi.

† 5 : The Yang style is a representative form of tai chi chuan, and six basic movements were practiced in these studies.

Table2. ICF core set for ASD

Category	No.	Contents	Relation*	Category	No.	Contents	Relation*
Body functions and structures	b110	Consciousness functions	3.1.1	Activities and participation	d571	Looking after one's safety	3.2.3.
	b114	Orientation functions			d620	Acquisition of goods and services	
	b117	Intellectual functions			d630	Preparing meals	
	b122	Global psychosocial functions			d640	Doing housework	
	b125	Dispositions and intra-personal funtions			d650	Caring for household objects	
	b126	Temperament and personality functions			d660	Assisting others	
	b130	Energy and drive functions	3.1.1		d710	Basic interpersonal interactions	3.2.4.
	b134	Sleep functions	3.1.1		d720	Complex interpersonal interactions	
	b140	Attention functions	3.1.2.		d730	Relating with strangers	
	b144	Memory functions			d740	Formal relationships	
	b147	Psychomotor functions			d750	Informal social relationships	
	b152	Emotional functions			d760	Family relationships	
	b156	Perceptual functions			d770	Intimate relationships	
	b160	Thought functions			d820	School education	
	b164	Higher-level cognitive functions	3.1.2.		d825	Vocational training	
	b167	Mental functions of language			d830	Higher education	
	b265	Touch function	3.1.3.		d845	Acquiring, keeping and terminating a job	
	b270	Sensory functions related to temperature and other stimuli			d850	Remunerative employment	
	b330	Fluency and rhythm of speech functions			d860	Basic economic transactions	
	b760	Control of voluntary movement functions	3.1.3.		d865	Complex economic transactions	
b765	Involuntary movement functions		d870	Economic self-sufficiency			
s110	Structure of brain	3.1.4.	d880	Engagement in play	3.2.3.		
Activities and participation	d110	Watching	3.2.1.	Contextual factor		d910	Community life
	d115	Listening				d920	Recreation and leisure
	d130	Copying				d940	Human rights
	d132	Acquiring information			e110	Products or substances for personal consumption	
	d137	Acquiring concepts			e115	Products and technology for personal use in daily living	
	d140	Learning to read			e125	Products and technology for communication	
	d145	Learning to write			e130	Products and technology for education	
	d155	Acquiring skills	3.2.1.		e240	Light	
	d160	Focusing attention			e250	Sound	
	d161	Directing attention			e310	Immediate family	3.3.1.
	d163	Thinking			e315	Extended family	
	d166	Reading			e320	Friends	
	d170	Writing			e325	Acquaintances, peers colleagues, neighbours and community members	
	d175	Solving problems			e330	People in positions of authority	
	d177	Making decisions			e340	Personal care providers and personal assistants	
	d210	Undertaking a single task	3.2.2.		e355	Health professionals	
	d220	Undertaking multiple tasks			e360	Other professionals	
	d230	Carrying out daily routine			e410	Individual attitudes of immediate family members	3.3.1.
	d240	Handling stress and other psychological demands	3.2.3.		e415	Individual attitudes of extended family members	
	d250	Managing one's own behaviour	3.2.2.		e420	Individual attitudes of friends	
	d310	Communicating with - receiving - spoken messages	3.2.4.		e425	Individual attitudes of acquaintances, peers colleagues, neighbours and community members	
	d315	Communicating with - receiving - nonverbal messages			e430	Individual attitudes of people in positions of authority	
	d330	Speaking			e450	Individual attitudes of health professionals	
	d331	Pre-talking			e455	Individual attitudes of other professionals	
	d335	Producing nonverbal messages	3.2.4.		e460	Societal attitudes	3.3.2.
	d350	Conversation			e465	Social norms, practices and ideologies	
	d360	Using communication devices and techniques			e525	Housing services, systems and policies	
	d470	Using transportation				e535	Communication services, systems and policies
	d475	Driving			e550	Legal services, systems and policies	
	d510	Washing oneself			e560	Media services, systems and policies	
	d520	Caring for body parts			e570	Social security services, systems and policies	
	d530	Toileting			e575	General social support services, systems and policies	
	d540	Dressing			e580	Health services, systems and policies	
	d550	Eating			e585	Education and training services, systems and policie	
	d570	Looking after one's health	3.2.3.		e590	Labour and employment services, systems and policies	

※Relevant sections of the text.

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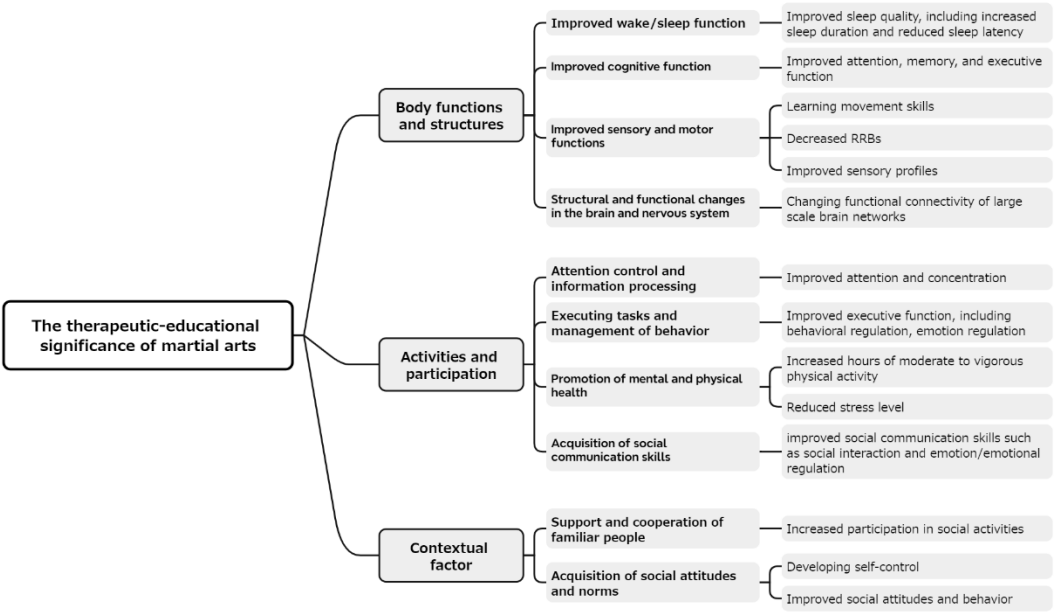


Figure2. Summary of the results and discussion in this study