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Original Research

The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism Spectrum Disorder

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ABSTRACT

Objectives: Autism Spectrum Disorder (ASD) is related to a dysfunction of central nervous system that most frequently appears at the age of three years old. There is no certain cure for this disorder; however, decreasing complications can produce positive life changes. Increasing physical activity is an appealing method for reducing behavioral disorders in ASD. Since Tai Chi Chuan training improves focus, attention to internal cues and balance, it seems to be an effective system for autistic children.

Materials & methods: 18 children with ASD in the age range between 6–12 years old were divided randomly into experimental and control groups. The experimental group participated in a six-week program of Tai Chi Chuan consisting of 18 sessions, limited to 60 min each. To assess motor skills, an M-ABC test was used during pre- and post-assessment. In order to analyze the data, dependent and independent T tests were used (with significance level of 0.05).

Results: Results showed a significant difference in the subscales of ball skills and balance performance ($P < 0.05$) and no significant difference in the manual agility scale ($P > 0.05$) between the two groups.

Conclusion: According to the results, it may be concluded that forms of Tai Chi Chuan improve balance and motion coordination. Moreover, this training consists of slow motion workouts with strongly focused attention, which may lead to developed control of body motions with harmony and discipline. Therefore, Tai Chi Chuan training seems to be a helpful therapeutic program to reduce motor limitations, and these benefits can be transferred to daily life in autistic children.

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1. Introduction

Primary learning and experience of motion occurs in childhood and are useful parameters for later in life. The normal growth of children follows a relatively predictable pattern; but in some cases, variables such as genetic issues, infection, injuries, poisoning, anoxia, and sensory-emotional exclusion can lead to problems in the natural growth processes of gross and fine motor skills, motor coordination, and even speech. Children with Autism Spectrum Disorder (ASD) are one of the groups faced with these growth process disorders (Baio et al., 2018). Autism is a neuro-developmental disorder that according to some sources, affects about 1 in 59 American children aged eight years, with more

prevalence in boys (at a ratio of 4:0) (Baio et al., 2018) and more intensity in girls (Frazier et al., 2014; Centers for D C P, 2015; Evans et al., 2018). In contrast, there is other research that refutes this statistic with a male-to-female odds ratio (MFOR) close to 3:1 (Loomes et al., 2017) and some even report no gender differences in social difficulties (Harrop et al., 2015), but more repetitive motor movements, communication difficulties, and inattention in males (May et al., 2016). ASD describes a heterogeneous group of neuro-developmental disorders, which may sometimes be combined with intellectual disability and cerebral palsy (Centers for D C P, 2015; Parvizi et al., 2012). A range of physical, cognitive, social, and behavioral deficits have been observed in ASD (DSM-V, 2013). Some individuals with ASD also display impaired motor coordination (MacDonald et al., 2013) and have been found to have lower overall physical activity than those without ASD (Srinivasan et al., 2014; Pan, 2008). Decreased physical activity of these individuals often leads to higher obesity rates among those with ASD (30.4% as compared to 23.6% of those without ASD) (Srinivasan et al., 2014).

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Based on these autism-related complications, interventions in autistic children would seek to decrease stereotypical and aggressive behavior while improving physical, cognitive, and social skills (Sowa and Meulenbroek, 2012). In this regard, children with ASD who are engaged in physical activity or exercise have been found to perform better academically and socially. For this reason, the use of physical activity and exercise is becoming more widely accepted as a technique to reduce stereotypical behaviors, motor disorders and total cholesterol in children with ASD (Petrus et al., 2008; Healy et al., 2018; Toscano et al., 2018). More specifically, some autistic individuals display impairments in processing sensory information. This typically causes them to present abnormal responses to sensory stimuli, such as hypersensitivity, repetitive movements (Sapey-Triomphe et al., 2019); also subtle movements, such as fine motor skills, tying shoes, and writing (Xavier et al., 2018; Bal et al., 2015). Previous studies have also recorded delayed motor skills (Pan et al., 2009) and poor motor skills (Pusponogoro et al., 2016); motor impairment with subcortical-cortical dysfunction (Paquet et al., 2019); and hypotonia (Serdarevic et al., 2017) in ASD.

Given that positive changes are observed when these individuals are engaged in physical activity and also multidimensional complications reported by other researchers; a form of exercise that combines balance and mental stimulation, such as Tai Chi Chuan, seems to be a potentially effective therapeutic intervention for individuals with ASD (Gatts, 2008). Tai Chi Chuan training is focused on promoting balance capability, proprioceptive functions, and body awareness, all of which may help improve cognition, balance, and behavioral problems in autistic individuals (Gatts, 2008). Furthermore, the major parts of a Tai Chi Chuan schedule include some slow motions and gait training combined with repetitive sit-to-stand movements, balance, relaxation and mind stimulation tasks, and sensory-motor exercises to work on better integration of the left-right brain hemispheres and increased environmental perception (Chan and Sze, 2013). This training method also involves sets of soft and chain-like transitional movements, which could lead to increased tolerance thresholds and decrease anxiety in autistic individuals (Chan, 2013). For all of these compelling reasons outlined above, Tai Chi Chuan can be confidently expected to be a therapeutic method to improving many of the challenges caused by ASD.

To briefly review previous findings, it should be stated that Berkeley et al. (2001) have found that 73% of autism subjects demonstrated delays in basic and gross motor function, based on the Ulrich test; Ozonoff et al. (2008) stated significant delay of gross skill growth in children with ASD; Green et al. (2009), by using M-ABC test (The Movement Assessment Battery for Children), reported that 79% of autistic children have shown clear movement disorders; Lang et al. (2010) concluded that basic motor skills were observed to be significantly weak in high-functioning autistic children (HFA). Apart from these studies, the effectiveness of physical activity on maladaptive patterns of behavior has been proven useful (Petrus et al., 2008; Duffy et al., 2017), as have its positive effects on social behavior, communication skills, interactions, sensory skills (Sowa and Meulenbroek, 2011; Zhao and Chen, 2018), and reduction of stereotypical behavior has been reported too (Liu et al., 2016). From the perspective of the physical benefits of exercise, Cetin et al. (2018) reported improved balance control and functional mobility in children with congenital sensorineural hearing loss. Zheng et al. (2015) discovered improved cardiovascular fitness in healthy adults by using Tai Chi Chuan, and the effects of Tai Chi Chuan training over a period of 8 weeks revealed that patients with type 2 diabetes experienced a decrease in blood glucose levels (Wang et al., 2008). Moreover, recovery from chronic obstructive pulmonary disease (Yan et al., 2013) enhanced balance in patients with multiple sclerosis (Azimzadeh et al., 2015),

and recovery of sleep quality in patients with major depressive disorder (Ma et al., 2016) has been demonstrated in Tai Chi-based rehabilitations. In particular, this training may lead to improved sensory and mental performance. As a result, the active response capability of the body would increase, and the body can react to verbal messages with more accurate responses.

As previously demonstrated, it is worth bearing in mind that some autistic individuals are unsociable (Li et al., 2018), have low verbal capabilities and poor eye contact. They also might be weak in terms of motor function and balance maintenance, and have reduced awareness of their arms and legs (Moraes et al., 2017). Accordingly, to overcome each of these disabilities, the present study should focus specifically on Tai Chi Chuan-induced benefits in individuals with ASD. Given that the aim of a practice course with Tai Chi Chuan is identified as enhancing combined physical and psychological development, and a range of multidimensional complications are confirmed in ASD, it would be worthwhile to assess existing hypotheses and trends that target long term and risk-free therapeutic approaches in the autistic community. Furthermore, performing the forms of Tai Chi Chuan can methodically engage the right and left hemispheres of the brain and activate the inner explosive force for action without contracting muscle tension (Chan and Sze, 2013). For these reasons, it seems to be a completely appropriate method to meet the basic needs of autistic children in treatment particularly as it has less of an effect on body temperature; a matter that should be considered early in every therapeutic program for these individuals due to their high level of basal body temperature (BBT). Therefore, this study aimed to investigate the effectiveness of basic Tai Chi Chuan forms to improve motor function problems in children with ASD.

2. Materials & methods

The research participants were 18 autistic children between the ages of 6 and 12, who had undergone prolonged treatment for at least one year (see Table 1). First, a general physician and psychologist examined the physical and mental conditions of all volunteer participants; then, the parents of selected children were asked to allow their children to participate in primary educational meetings, and written consent was obtained from all participants prior to initiating any research activity. Entry criteria: 1-Autistic children between 6 and 12 years of age; 2-written agreement with the research processes; 3-undergoing prolonged treatment for at least one year in an autism center; 4-absence of mental retardation and malnutrition; 5-having physical and cognitive ability, and interest in participating in the intervention program; 6-having no absence from more than two training sessions per month during intervention. Meanwhile, each participant who had not complied with the aforementioned criteria was excluded from the research process (see Fig. 1).

After identifying participants who met the necessary criteria, a random number table was used to choose the final subjects. The Gilliam Autism Rating Scale-second edition (GARS2) was also used to measure the degree of Autism Spectrum Disorder in subjects.

Table 1
Participants' demographic information (N = 18).

GROUPS	Autism rate	Age	Sex	Number		
				Age 3-6	Age 7-10	Age 11-16
Tai chi	68.97 ± 8.15	8.88 ± 1.76	Male	1	5	1
			Female	0	2	0
Control	69.1 ± 7.04	8.22 ± 1.92	Male	1	5	1
			Female	1	1	0

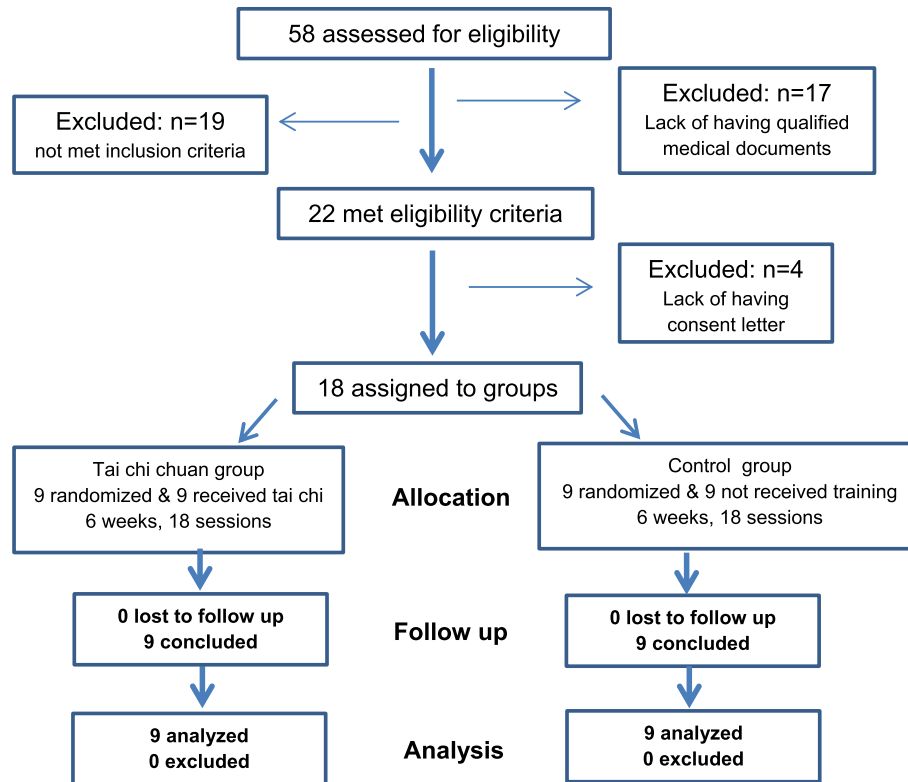


Fig. 1. Consort flow chart.

GARS2 consists of a norm-referenced test, which assists teachers and clinicians in accurately assessing the severity of ASD in individuals aged 3–22 years (Montgomery et al., 2008). The final qualified subjects were subsequently divided into the experimental and control groups. The experimental group participated in a six-week training program consisting of 60-minute Tai Chi Chuan workouts for three days per week. This protocol was designed to reinforce fundamental skills such as balance, physical fitness, body awareness, neural control, and proprioceptive coordination. Each training session consisted of a 10-min warm-up, 40 min practicing basic Tai Chi Chuan forms, and a 10-min cool-down. The control group did not carry out any regular exercise training during the study period. This training protocol was designed by a qualified Tai Chi Chuan instructor and was based on the subjects' ability. Six simple and fundamental forms of Yang style were chosen from the original 24 forms, which were much easier and more comprehensible compared to the longer forms. During the training program, subjects were asked to imitate the instructor's movements and postures. Since the main focus of trainings was on breathing, mind and relaxation, the progress of each subject was monitored in each session. The experimental group subjects were also provided with an audiovisual-based instructional DVD containing Tai Chi movements with music. The assessment of the motor skill performances of subjects was performed via M-ABC-2 test before and after the training program. The validity and reliability of this test are verified (Green et al., 2009; Wagner et al., 2011; Schoemaker et al., 2012) with an internal consistency of 0.90, test-retest reliability of 0.97 (WUANG et al., 2012), and kappa statistic coefficient range of 0.92–0.98 (Henderson, 1992). The functional part of MABC-2 contains a total of eight tasks in each of three age ranges: 3–6, 7–10, and 11–16 years. Tasks in three specific areas are as follows; 1-manual dexterity (three tasks: speed of movement, motor coordination of hands, and hand-eye coordination); 2-ball skills (two

tasks: throwing & catching); and 3-static and dynamic balance (three tasks). Each task is scored from 0 to 5; total scores range between a score of 0 and 40, which is generated from the eight tasks (high scores representing greater impairment). This test is an evaluative tool that could be used to identify children who are significantly behind their peers in motor skill development. Significantly, each task's raw score can be converted to a percentile score to determine a child's motor delay compared to their age-matched norms. These percentile scores are described as a traffic-light scoring system, including a red zone, amber zone, and green zone. A percentile score <5 is classified in the red zone, indicating a significant movement difficulty; a percentile score between 5 and 15 are classified in the amber zone, representing the child is at risk of movement difficulty; and, percentile score >15 is classified in the green zone, indicating no movement difficulty detected. Ultimately, quantitative data of this study were analyzed using IBM SPSS version 20 software, and the statistical examination was performed by dependent and independent T-test at the significance level of $P < 0.05$.

3. Results

According to Table 2, a significant difference was observed in ball skills ($P < 0.001$) and balance variables ($P < 0.001$) between the groups; also, a noticeable difference was observed between pre-test and post-test scores of ball skills ($P < 0.001$) and balance ($P < 0.001$) variables in the experimental group; whereas no significant difference was reported between pre-test and post-test scores in these variables in the control group (see Table 2, dependent *t*-test). In regards to the manual dexterity variable, no considerable difference was seen between groups ($P = 0.95$); likewise, there was no significant difference between pre-test and post-test scores in the experimental ($P = 0.76$) and control ($P = 0.16$) groups based on

Table 2

Pre-test and post-test comparison of motor skills between the groups.

Variables	Groups	Pre-test	Post-test	Mean difference	Dependent T	Sig	Independent T	Sig
manual dexterity	Tai chi	57.03 ± 13.27	56.66 ± 10.92	-0.37	0.31	0.76	0.06	0.95
	Control	55.55 ± 14.24	56.29 ± 14.47	0.74	-1.51	0.16		
ball skills	Tai chi	58.33 ± 9.01	30 ± 7.50	-28.33	11.33	<0.001	-9.24	< 0.001
	Control	60 ± 8.29	62.77 ± 7.54	2.77	-1.64	0.13		
balance	Tai chi	60.73 ± 12.66	14.81 ± 6.26	-45.92	10.60	<0.001	-14.37	< 0.001
	Control	62.58 ± 10.10	64.81 ± 8.35	2.23	-2.30	0.05		
Total	Tai chi	58.75 ± 6.49	34.30 ± 3.48	-24.45	13.53	<0.001	-9.95	< 0.001
	Control	59.30 ± 8.70	61.38 ± 7.38	2.08	-3.53	0.008		

Note: scores are illustrated in percentages (%), and a higher score indicates more motor disorders.

dependent *t*-test results. Finally, the total mean-based results interestingly represent a noticeable difference between pre-test and post-test in both experimental ($P < 0.001$) and control (0.008) groups, which significantly show that control group results were in a negative direction and their motor skill disorders significantly increased in the post-test, compared to the pre-test stage (see Fig. 2).

4. Discussion

The results showed improved motor skills in children with ASD, under the influence of six weeks Tai Chi Chuan training. The training program appears to improve balance and ball skills, whereas it does not appear to be a useful method to positively affect manual dexterity in autistic children. These findings are consistent with several previous studies that have found that exercise has a beneficial effect on autistic children (Ferguson, 2010; Duronjic and Valkova, 2010), as participation in taekwondo training may enhance balance in healthy individuals (Pons et al., 2013) and even in children with developmental coordination disorders (Fong et al., 2013). In some studies, the effectiveness of physical activity on maladaptive behaviors has been reported (Petrus et al., 2008); likewise, its effects on social behavior, communication skills, sensory regulation (Sowa and Meulenbroek, 2011; Zhao and Chen, 2018), and decreasing stereotypical behavior (Liu et al., 2016) have been abundantly demonstrated. Regarding the Tai Chi Chuan-induced benefits on health, the present study is in agreement with Zhang et al. (2018), which reported improved mental health in college students; and with Alsubiheen et al. (2017), which found

improved nerve conduction, balance, and walking stability following a Tai Chi Chuan intervention. Furthermore, our findings approximately match those of several studies that have shown the benefits of Tai Chi Chuan in improving motor function in patients with Parkinson's disease (Yang et al., 2014), recovery from chronic obstructive pulmonary disease (Yan et al., 2013), balance improvement in multiple sclerosis patients (Azimzadeh et al., 2015), and recovery of sleep quality in patients with major depressive disorder (MDD) (Ma et al., 2016). Consistent with our results, other studies have also shown the effectiveness of yoga training programs on reducing the severity of autism symptoms (Sotoodeh et al., 2017; Brausch, 2018) and neuroenhancement of memory in autistic children (Chan et al., 2015). A recent review article also concluded that traditional martial arts including a form of mind-body exercise may be more effective in improving executive control and attention to a greater extent than standard physical exercise (Diamond and Lee, 2011; Johnstone and Marí-Beffa, 2018) or even the effects of modern martial arts on improving executive function (EF) (Lima et al., 2017). The effectiveness of traditional martial arts seems to be related to their concurrent emphasis on physical adaptation training, self-control, discipline, and character development (e.g., respect, responsibility, and perseverance), which tend to mostly focus on the executive function. Similarly, Tai Chi Chuan training was employed to recover autism-related motor limitations in the present study; based upon the principles of Chinese mind-body exercises. In our Tai Chi Chuan program, the subjects were also guided to practice with a peaceful mind to decrease anger and distress. This case may explain the distinctive effects of this exercise on enhanced self-control. Notably, the

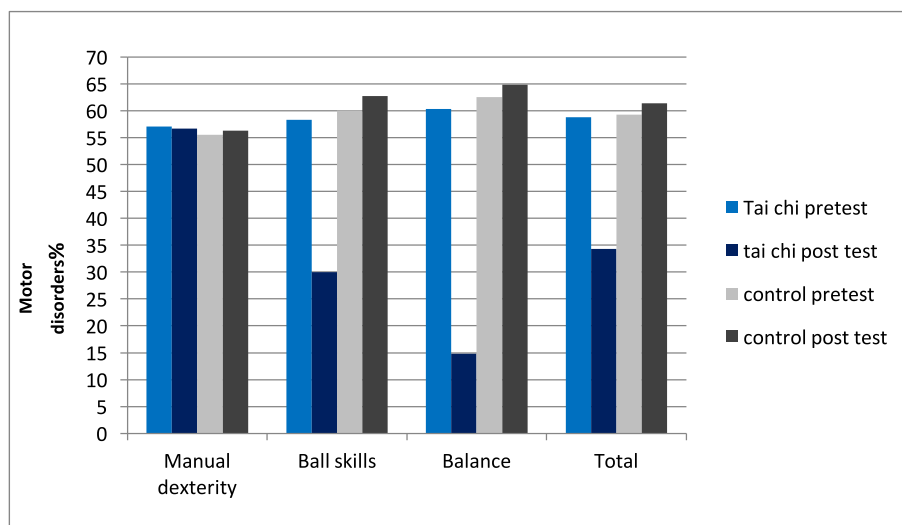


Fig. 2. Pretest and Posttest Comparison of Motor Skills between the Experimental and Control groups. Scores are illustrated in percentages (%), and a higher percentage indicates more motor disorders.

improvement of brain activity (Agam et al., 2010; Chan et al., 2011, 2014; Chan et al., 2011a,b) and inhibitory control (Chan et al., 2012) has been reported in autistic children by practicing Tai Chi Chuan. As proven, inhibitory control deficits plays an important role in ASD or ADHD; therefore, exercise with mind-physical interactions similar Tai Chi Chuan seems to be helpful to recover these multi-dimensional deficits of inhibitory responses in three different areas including motor, attentional and behavioral levels. For these compelling benefits, much evidence demonstrates that mind-body techniques like Tai Chi Chuan are used by up to 30% of people with Autism Spectrum Disorder (Hourston and Atchley, 2017), which could be linked to many different aspects of ASD as a part of therapy (NaraSiNgharao et al., 2017). Other evidence has recently found that children with ASD may achieve better behavior control, including the ability to sit for a long period of time, through the Tai Chi Chuan intervention (NaraSiNgharao et al., 2017). More specifically, it is noteworthy that an aspect of Tai Chi Chuan that is similar to the nature of yoga, could allow autistic children to shift their attention away from destructive external stimuli and toward their own body movements (Deorari and Bhardqaj, 2014). As expected, this feature of Tai Chi Chuan would allow the child to focus on internal factors, which might be regulated more easily than other factors that are less easily manipulated. Accordingly, it was found that autistic children were better able to self-regulate and cope with change after undergoing this training program (Deorari and Bhardqaj, 2014). In addition to these effects, enhanced memory and self-synchronization of EEG signals were reported under influence of a mind-body exercise, which seem to be related to the enhanced functional network; the same factor that mediates the relationship between executive control and memory process (Sauseng et al., 2005). Despite these Tai Chi Chuan-induced neural adaptations (Chan et al., 2013) being only tentatively connected to the subject of the present study, it would appear that these effects on neuro-cognitive enhancement and CNS connectivity can be transferred to more organized and better maintenance of information during memory processing, and subsequent improvement of neuromuscular coordination in motor skills in autistic children. That is why these neural changes could be considered as one of the possible justifications to support the results of present study. The most likely reason for Tai Chi Chuan-induced benefits might also be justified by the factors of increased physical fitness, fundamental skills, motor coordination, self-confidence, and interacting well with others by means of exercises more focused on body awareness, such as walking on balance planks. Some studies have stated that balance/spark exercises such as those performed in Tai Chi Chuan, may promote fundamental motor skills (FMS) by use of the integrating factor-based tasks, including practice opportunity and interacting with the environment (Akbari, 2013; Najafabadi et al., 2018). Furthermore, this training seems to lead to an improvement in sensory and conscious performance; as a result, the active response capability of the body rises, and the body responds to verbal messages more accurately. These are some neural alterations in multisensory function which could form part of a secure support regime to reinforce weak senses in children with ASD. On the other hand, as proven by other studies, toe walking creates muscle compression in most autistic children; accordingly, the full-body stretching routine in Tai Chi Chuan program may be useful for eliminating muscle cramps, skeletal abnormalities, and to develop balance in autistic children.

To summarize our findings regarding the subscale of manual dexterity, this training program failed to improve manual skills in the experimental group, which may suggest that a longer training program is needed to improve manual factors. Also, more hand tasks seem to be needed to improve neuromuscular coordination. In this regard, there have been research studies that reported the

improvement of manual dexterity induced by mind-body exercises in autistic children (Ferguson, 2010; Duronjic and Valkova, 2010), or even in Parkinson's disease patients (Mateos-Toset et al., 2016), which are in contrast with the present results; however, the different training models must be considered because those studies implemented their training protocols based on functional hand tasks with the aim of improving delicate skills.

According to the results of ball skills test, the present study found that these scores, including throwing and catching skills, developed as a result of the six weeks of Tai Chi Chuan intervention in the experimental group. The most likely explanation for the child's progress in ball carrying ability might be related to promote physical fitness factors, including muscular strength, balance, body and environmental awareness, flexibility, and especially coordination and attention span. Catching and throwing are manipulative skills, which require tracking the ball and propelling it towards a target. Environment, education, and personal activities seem to have impressive effects on the growth of fundamental motor skills. In this respect, research shows that the dexterity skills of autistic children could be affected by the mode of training program (Akbari, 2013), which means that repetitive training and experience can positively affect motor coordination. Therefore, more structural practice is needed for better motor coordination (Kosari et al., 2012). Other studies have also proved the beneficial effects of mind-body exercises in autistic children (Ferguson et al., 2010; Duronjic and Valkova, 2009; Kosari et al., 2012; Liu and Breslin, 2013; Liu et al., 2016; Brausch, 2018; Toscano et al., 2018), all of which are in agreement with the present finding.

Regarding the result of the balance subscale, an improved performance in dynamic and static balance tests was observed in the experimental group following the six weeks of Tai Chi Chuan intervention. This result is in agreement with the findings of Pons et al. (2013), Fong et al. (2013), Akbari et al. (2013), Kim et al. (2016), Brausch et al. (2018) and Cetin et al. (2018). Balance and environmental awareness are the most important factors in action and movement. Some researchers suggest that a full interaction between neural and biomechanical mechanisms would provide appropriate balance. The components that might cause the balance progress in this study can be summarized as follows: 1-cooperation of postural muscular responses; 2-better efficiency in vision, vestibular and somatosensory systems; 3-adaptive systems; 4-improved muscular strength and range of motion; and 5-better physical structure. All these possible correlations seem to be linked with the achieved result of the balance test in autistic children.

5. Conclusion

As shown above, a Tai Chi Chuan training program may improve hand-foot coordination, muscular tone, sensory homogeneity, body awareness, and particularly self-confidence in autistic children. Since Tai Chi Chuan engages both the right and left hemispheres during training, it can improve autistic children's skills and movements, and finally may assist them in recovering from many of the disabilities caused by ASD. Generally, maintaining an active and healthy lifestyle through daily exercise can be a key element in improving the quality of life in these children. This was not specifically evaluated by the present study; however, improvement of daily motor skills is likely to be a primary factor that may subsequently promote the quality of life in children with ASD. Accordingly, further research is needed to evaluate the quality of life and its related factors after Tai Chi Chuan intervention.

In conclusion, it is suggested that participation in exercise activities, especially those which focus on improving balance, seems to be a reliable therapeutic method in children with ASD. It is also

worth bearing in mind that the improvement of motor skills in the present study is not the only possible advantage since Tai Chi Chuan training may additionally present new promising approaches in rehabilitation to ameliorate dependency, physical fitness, body control, and sociability in autistic children. In sum, it can be confidently recommended to all relevant coaches and therapists to consider Tai Chi Chuan forms as a primary choice for rehabilitation programs in children with ASD.

Conflicts of interest

The Authors have no conflict of interest to disclose regarding the present manuscript.

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