Research Paper

Comparing the Influence of an Aqua-based Versus a Mindfulness-based Kata Techniques Training on Sleep Habits and Stereotypic Behaviors in Children With Autism

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ABSTRACT

Objective: The present study aims to compare the effectiveness of aquatic and karate training programs on sleep habits and stereotypic behaviors in children with autism spectrum disorder (ASD).

Methods: This research was a quasi-experimental study with a pre-test/post-test design, with two intervention groups and one control group. The statistical population included all boys with ASD who were a member of the Autism Institute in Rasht City, Iran, in 2019. Of whom 30 individuals were selected using the purposive sampling method. Thirty children with autism (8–14 years) were randomly divided into karate exercise (n=10), aquatic training (n=10), and wait list control (n=10) conditions. The training groups practiced for 10 weeks, two sessions of 60 minutes per week. Karate exercises involved mindfulness Taikyoku Jodan Kata, consisting of blocking, punching, sticking, and kicking moves against an imaginary opponent. Aquatic training was a group intervention, including orientation training, basic swimming skills, and free swimming. Children's sleep habits questionnaire (CSHQ, 2000) and stereotype subscale of the Gilliam autism rating scale (GARS-2, 2006) were completed by parents during pre-and post-intervention. Analysis of variance for repeated measures was utilized for data analysis.

Results: The results indicated that both training interventions have a significant positive effect on stereotypic behaviors compared to the pre-intervention and control groups (P<0.01). We also found that the aquatic exercise group obtained better scores (P<0.001) and two subscale scores (sleep anxiety (P<0.001) and Parasomnias (P<0.05)) than the kata techniques training group, but no significant group effects were observed regarding the other subscales.

Conclusion: It is recommended to provide a suitable environment at school or institute for children with ASD to participate in physical activities, such as aquatic and karate exercises to alleviate repetitive behaviors. Furthermore, it is suggested to use aqua-based training as a complementary approach in the field of improving common problems, such as the sleep habits of children with ASD.

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Highlights

● The improvement of stereotypic behaviors was more in the aquatic group than kata and control groups.

● Aquatic exercise leads to better scores in bedtime resistance than other groups.

● The kata techniques group attained lower scores in sleep duration than other groups.

● The evidence supports exercise interventions, such as aquatic and kata training programs as influential interventions to impact behavioral and sleep disturbances for children with autism spectrum disorder (ASD).

Plain Language Summary

Physical activity-based interventions are effective to improve repetitive behaviors and sleep problems in children with ASD. Because aqua-based exercises and mindfulness-based kata techniques training depend on different inputs (as mentioned above), it may be recommended that aquatic training and kata exercises may influence in another way on problems of children with ASD. Therefore, we compared two types of physical activity programs (kata techniques of karate and aquatic training) to improve stereotypic behaviors and sleep habits in children with ASD. The first result of this study is the value of using kata techniques exercises. Due to the sameness between stereotypic behaviors and kata exercises, educators and trainers should note that kata techniques may give adequate support to children with ASD and reduce restricted behaviors. In addition, kata techniques training can change hormone levels and have a favorable regulatory effect on sleep quality. Another result involves the focus on using aquatic exercise as a beneficial alternative for children with ASD. The results suggest that when children with ASD participate in aquatic exercise, stereotypic behaviors and sleep regulation problems decrease. Exercise in the water environment gives consistent somatosensory input in children with ASD and provides enjoyable physical activities.

Introduction

Autism spectrum disorders (ASDs) are multi-factorial disorders that appear in early childhood and are characterized by persistent deficits of social interaction, as well as repetitive and restricted behaviors (Sefen et al., 2020). In 2019, it has been estimated that the prevalence of ASD changed into 10 for every 10 000 among Iranian children (Mohammadi et al., 2019).

Since ASDs are classified as sensory disorders, stereotypical behaviors associated with ASD are considered to be attempts to seek sensory feedback from the individual. These behaviors are self-stimulating, non-purposeful, and repetitive and can take the shape of hand and body rocking, toe on foot, weaving objects, sniffing, and running objects over one's peripheral imaginative and prescient. It is essential to reduce these behaviors because they are often troublesome, reduce attention, and interfere with activities of daily living (Sharma et al., 2018). Usually, as stereotyped behaviors decrease, maladaptive behaviors also decline because the child can concentrate more on tasks (Liu et al., 2016).

Children with ASD also experience other challenges, aside from the two main features. Experts have implied several associated problems along with two main symptoms. According to previous studies, many children with ASD suffer from sleep disturbances, which are much more common than in other developmental disorders, as well as in typically developing children with a prevalence of 57% (Galli et al., 2022). Sleep disturbances may detrimentally impact behavior, depression, anxiety, and disorders in cognitive functions; and if left untreated, lead to complications, such as attention deficit, memory, and learning disorders in children with ASD (Adib Saber et al., 2019).

Given the impact of stereotypic behaviors and sleep disturbances on daily functions and life quality in children with ASD and their families, researchers in different fields of behavioral, psychological, and medical sciences tried to acquire beneficial interventions to decrease its difficulties. Physical activity-based interventions are accepted to be effective for ameliorating repetitive behaviors (Adib Saber et al., 2019; Ansari et al., 2020; Liu et al., 2016; Marzouki et al., 2022; Tarr et al., 2020), and sleep problems (Adib Saber et al., 2019; Brand et al., 2015; Kanupka et al., 2018; Lawson & Little, 2017; Liu et al., 2016; Oriel et al., 2016) in children with ASD.

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Martial arts are a special and mindfulness-based form of physical activity, depending on visual and somatosensory signals, and are very popular among children and adolescents (Gubbels et al., 2016). Studies have evaluated the effect of various types of martial arts on different problems in ASD, such as behavioral (Phung & Goldberg, 2019), social (Bell et al., 2016; Movahedi etall., 2013), communication, and balance deficits (Kim et al., 2016) in ASD populations. The results identified improvement in core and associated issues of children with ASD. Karate training, a Japanese form of martial arts, is usually subdivided into Kihon, Kata, and Kumite. Blocking, punching, sticking, and kicking techniques are arranged in a logical order in the kata of karate (Bahrami et al., 2012). Kata is recognized as an execution of combat movements without physical contact and with a crucial meditative component. This system integrates mind, body, and spirit because its practice demands constant attention and focus on the execution of movements (Naves-Bittencourt et al., 2015). Bahrami et al. investigated the effects of Kata techniques of karate on the stereotypic behaviors of children with ASD. They found that the stereotypic behaviors decreased after 14 weeks of training. However, the effectiveness of karate training programs on the improvement of sleep habits and stereotypic behaviors of children with ASD has been infrequently studied (Bahrami et al., 2012).

Aqua-based activities, another form of physical activity depending on somatosensory signals, are a relatively inexpensive, potentially safe, and enjoyable option for children with disabilities, including ASD (Ansari et al., 2021). Aquatic exercises have a myriad of extraordinary advantages for the body and mind that can raise the quality of life for children with ASD (Bella, 2019). Unique properties of water, including immersion, hydrostatic pressure and water temperature may provide a recreational environment and sensory input to improve social behaviors (Azimigarosi et al., 2020), stereotypic behaviors (Adib Saber et al., 2019) and sleep habits (Kanupka et al., 2018; Lawson & Little, 2017; Oriel et al., 2016) in children with ASD. Despite these advantages, it seems crucial to investigate the effect of different forms of aquatic training to improve sleep habits as well as stereotypic behaviors in children with ASD.

Although some studies have suggested the beneficial effects of aquatic and martial arts training interventions in children with ASD, there is a lack of data regarding the impact of kata techniques of karate training on sleep habits in this population. Moreover, to our knowledge, no study has compared the influence of a mindfulness-based and an aqua-based intervention to improve the core and associated deficits of children with ASD. Since aquatic and kata techniques exercises depend on various information (as mentioned above), it may be recommended that they may variously affect the problems of children with ASD. Therefore, this study was conducted to compare the consequences of these two types of exercise activities on sleep habits and stereotypic behaviors of children with ASD to figure out which of these exercises is the best intervention to improve them.

Materials and Methods

This research was a quasi-experimental study with a pre-test/post-test design, with two intervention groups and one control group. The statistical population included 56 children aged 8-14 years with a clinical diagnosis of ASD from the Autism Love Rain Institute (Rasht City, Iran) who were recruited from April to July of 2019.

The inclusion criteria included ASD diagnosed by a psychiatrist based on full diagnostic and statistical manual of mental disorders, fifth edition (DSM-5) for ASD criteria, having autism severity 1 and 2 based on Gilliam autism rating scale (GARS-2), male gender aged 8–14 years, intelligence quotient (IQ) between 55 to 70 (according to the Wechsler intelligence quotient test and based on their medical records), no change in medication use or diet habits during the study, and ability to perform the desired exercise interventions. The exclusion criteria included having complex medical comorbidity in addition to ASD or any other developmental disorders. Meanwhile, if each of the participants was absent for more than two sessions in the intervention sessions, they were excluded from the study.

Finally, thirty boys with ASD participated in the study and were randomly separated into three groups, including a kata techniques group (n=10), an aquatic training group (n=10), and a control group (n=10) using a stratified randomization procedure within the agency. An experienced physician screened all children to be eligible to participate in the exercise protocols.

Owens et al. (2000) developed the short form of the children's sleep habits questionnaire (CSHQ) and used it to quantify sleep problems in the participants at the beginning and the end of the study. It has 33 item guardian-reported questions with eight subscales that demonstrate clinically considerable sleep problems in school-aged children. Respondents demonstrated the recurrence of every sleep behavior on average during the last normal week on a 3-point scale, usually (weekly 5–7 times), sometimes (weekly 2–4 times), or rarely (weekly 0–1

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time). The higher the score, the more prominent sleep issues (Owens et al., 2000). To assess the reliability, the α coefficient was calculated as 0.75 for the total score, 0.68 for resistance, 0.7 for sleep onset delay, 0.7 for sleep duration, 0.61 for sleep anxiety, 0.64 for night wakening, 0.68 for Parasomnias, 0.64 for sleep-disordered, and 0.71 for daytime sleepiness (Adib Saber et al., 2019).

We also utilized the stereotype subscale of the GARS-2 developed by Gilliam, a 14-item informant, to make sense of changes in participants' stereotype severity. GARS-2 has been used in past studies (Adib Saber et al., 2019). Unique, quantifiable, and observable restricted and repetitive behaviors can be more precisely expressed by the stereotype subscale. It includes observations, and parent or teacher interviews, and the examiner completes questions according to their interpretation. For each item, the parent (or teacher) is requested to select one of four choices using objective frequency-based ratings of four points that the best way possible to exhibit the child's special stereotypical behavior (0: Indicates that the behavior was never observed, and 3: Indicates that the behavior frequently observed). Higher scores indicate a higher level of stereotypes. According to the frequency of occurrence of each stereotyped behavior under routine situations in 6 hours, caregivers reply to rate the child's behavior. In this study, the total raw score of this subscale was considered. The α coefficient was calculated as 0.81 for the total score, and 0.74 for the stereotype subscale (Emad et al., 2023).

The aquatic exercise program was performed in the Arsen swimming pool in Rasht City. It was developed based on the previous study (Kolachahi et al., 2020). It included 20 sessions (10 weeks) and two sessions every week (60 minutes per session). Five trained and certified instructors with prior experience teaching swimming to children with ASD exercised with participants according to the schedule of the study in a child-to-trainer 2:1 ratio. Each session included warm-up (5 minutes), orientation training (15 minutes), basic swimming skills (20 minutes), free swimming (15 minutes), and cool down (5 minutes). The aquatic exercise was administered from 3 PM to 4 PM (Sundays and Thursdays). Two certified lifeguards were present for all aquatic exercise sessions (Table 1).

The kata techniques program was held at Ansar Sports Club in Rasht City. It consisted of 20 sessions (10 weeks) and two sessions every week (60 minutes per session), based on AdibSaber et al's study. The kata techniques program was instructed by five certified instructors (with 5 previous experience playing sessions) in a child-to-

trainer of 2:1 ratio. Each session included a warm-up (10 minutes), the main body of training (45 minutes), and cooldown (5 minutes). Participants performed Taikyoku Jodan Kata techniques, including a series of explosive blocking, punching, sticking, and kicking moves administered in a predetermined order against an imaginary opponent in multiple directions in space. The Taikyoku term means the direction of 19 movements with a crucial meditative component and constant focus on each movement, which has its meaning and purpose (AdibSaber et al., 2021). Each session was held between 5 PM and 7 PM (Saturdays and Wednesdays) (Table 2).

One parent/guardian was present at all training sessions to help when needed. All children completed the trial in full. Participants in the control group did not receive the intervention. Throughout the study, they were requested to maintain their daily programs and treatments.

Analyses were conducted using SPSS software, version 26. Table 3 presents the descriptive analysis of participants' age and severity of autism as the Mean±SD. Shapiro-Wilk and Leven's tests were utilized to control the normality and homogeneity of variances of the data, respectively. We used repeated measures analyses of variance. Effect sizes were reported as partial eta squared (η_p^2), with $0.059 > \eta_p^2 > 0.01$, $0.139 > \eta_p^2 > 0.06$, and $\eta_p^2 > 0.14$ indicating small (S), medium (M), and large (L) effect sizes, respectively (Bosco et al., 2015). The effect sizes for the within groups effect sizes were calculated using Cohen's d and classified as small ($0.20 \leq 0.50$), moderate ($0.50 \leq 0.80$), and large (≥ 0.80) (Cohen, 1988). $P < 0.05$ were considered statistically significant.

Results

In total, 30 ASD children (mean age 10.56±1.94 and autism severity 38.83±5.62) were recruited for this study. Table 1 presents the participants' age and autism severity, as well as, research variables for the three research groups at baseline and post-intervention. No statistically significant difference was observed in age, severity of autism, and research variables in the three groups, at baseline.

The results showed that stereotypic behaviors improved over time from pre to post-test in both exercise groups (significant time effect with large effect sizes), compared to the control group (small effect sizes; Table 4) ($P < 0.001$, F=86.631). Moreover, a significant group× time interaction was observed for stereotypic behaviors (with large effect sizes) ($P = 0.001$, F=26.928).

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Table 1. Aquatic exercise program (adapted from Kolachahi et al. (2020)

Program Activity	Length (m)	Content	Goal
Warm-up	5	Walking clockwise and counterclockwise, running in place, jumping jacks, blowing bubbles and reciprocal arm and leg movements	Warm-up and water adjustment
Orientation training	15	Sagittal, transversal, and longitudinal rotation	Water orientation
Basic swimming skills	20	Breathing, floating, and stroke skills	Swimming skills
Free swim	15	Group activities: Ball toss and catch, cross through hula-hoop, red light/green light, allowed to play pool toys, noodles, and kickboards	Communication and social interaction
Cool down	5	The same as warm-up	

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Single effect size calculations (Table 5) showed that in both intervention groups, mean differences from pre- to post-assessment were large (d=1.057 and d=0.510, respectively), while in the control group, mean differences from pre- to post-assessment were small (d=0.025).

The results showed that the total score of sleep habits improved over time from baseline to post-intervention in both exercise groups (significant time effect with large effect sizes), compared to the control group (small effect sizes; Table 4) (P<0.001, F=192.98). Moreover, a significant group×time interaction was observed for stereotypic behaviors (with large effect sizes) (P<0.001, F=55.337). Compared to the control group, both physical exercise groups had lower total scores (significant group effect with large effect sizes) (P<0.001, F=5.598).

Single effect size calculations (Table 5) showed that in both intervention groups, mean differences from pre- to post-assessment were large (d=3.185 and d=3.510, respectively), while in the control group, mean differences from pre- to post-assessment were small (d=0.095).

Over time, the scores of all subscales improved from baseline to post-intervention in both exercise groups (significant time effect with medium to large effect sizes), compared to the control group (small to medium effect sizes; Table 4). Moreover, a significant group × time interaction was observed for all subscales (with

large effect sizes), except sleep onset delay (with small effect sizes) (P>0.05, F=0.018). Compared to the control group, both physical exercise groups had lower scores in two subscales (sleep anxiety and Parasomnias; significant group effect with large effect sizes) (P<0.001, F=9.808; P<0.05, F=3.434, respectively).

Single effect size calculations (Table 5) showed that in both intervention groups, mean differences from pre- to post-assessment were medium to large, while in the control group, mean differences from pre- to post-assessment were small to medium.

Discussion

This study was conducted to compare the effectiveness of aquatic and karate training programs on sleep habits and stereotypic behaviors in children with ASD aged 8-14 years. The results showed that both aqua-based exercises and mindfulness-based kata techniques of karate during 10 consecutive weeks had positive impacts on stereotypic behaviors and sleep habits among children with ASD aged 8-14 years compared to the control group.

Two hypotheses were formulated and each of these is now explained in turn. Our first hypothesis was that an improvement in stereotypic behaviors after kata of karate and aquatic exercise programs was observed in

Table 2. Mindfulness-based Kata techniques, adapted from AdibSaber et al. (2021)

Program Activity	Length (m)	Content	Goal
Warm-up	10	Jogging, stretching movements	Warm-up
Main body	45	Gōjū-ryū Watanabe Kata techniques (blocking, punching, sticking, and kicking)	Fighting against an imaginary opponent in multiple directions
Cool down	5	The same as warm-up	Cool down

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Table 3. Descriptive statistics research variables at baseline and post-intervention in three research groups

Variables		Mean±SD					
		Time Points					
		Baseline			Post-intervention		
		Aquatic Exercise (n=10)	Karate Techniques (n=10)	Control (n=10)	Aquatic Exercise (n=10)	Karate Exercise (n=10)	Control (n=10)
Age (y)		10.70±1.88	10.60±2.06	10.40±2.06	-	-	-
Autism severity		38.9±6.24	37.6±5.52	40.1±5.39	-	-	-
Research Variables	Stereotypic behaviors	12.60±3.50	13.10±4.70	12.10±3.90	8.90±2.76	10.70±4.66	12.20±3.93
CSHQ Score	Total score	68.40±4.74	66.90±4.33	68.00±7.30	53.30±4.16	51.70±3.19	68.70±8.00
	Resistance	13.40±2.41	12.30±1.70	13.30±2.54	11.00±1.49	10.60±1.42	13.00±2.74
	Sleep onset delay	2.10±0.316	2.10±0.31	2.20±0.42	2.50±0.52	2.60±0.51	2.50±0.52
	Sleep duration	6.80±1.31	7.00±1.49	7.00±1.54	5.40±1.77	4.70±1.33	7.01±1.76
	Sleep anxiety	10.60±1.17	10.40±1.17	10.70±1.41	7.50±1.26	7.50±1.43	11.00±1.41
	Night wakening	6.50±1.58	6.70±1.76	6.40±1.71	4.00±0.94	4.40±1.34	6.50±1.50
	Parasomnias	11.30±1.76	11.50±1.84	11.41±1.71	8.50±1.26	8.50±1.58	11.39±1.57
	Sleep disordered	5.00±1.49	5.80±1.03	5.30±1.33	4.00±1.05	4.20±1.032	5.40±1.26
	Daytime sleepiness	12.70±2.16	11.10±2.33	11.70±2.21	10.40±2.17	9.20±1.22	11.90±1.66

CSHQ: Children's sleep habits questionnaire.

children with ASD, and it was partly upheld. The results showed that participants of both aquatic and kata techniques training demonstrated a substantial decrease in stereotypic behaviors. Our results are consistent with the results of previous studies that showed decreased levels of stereotypic behaviors following kata training (Bahrami et al., 2012) and swimming (Azimigarosi et al., 2020) among children with ASD.

Previous studies suggested that repetitive behaviors occur because they produce pleasurable states for individuals with ASD; then, physical exercises can improve stereotypes due to the similarity of physical stimulation acquired through stereotypes (Lang et al., 2010). Kata of karate includes various movements that are similar to various repetitive and restricted behaviors. Hence, performing kata techniques with ASD children may give them adequate support so that they do not have to engage in stereotypes. Kata is a combination of sequential and various movements that get a similar fortification to stereotypic behaviors, may give adequate support to children with ASD, replace them with restricted behaviors, and can reduce them (Bahrami et al., 2012).

On the other hand, aquatic exercise may be a beneficial alternative for children with ASD. Exercise in the water environment reduces inappropriate behaviors and gives consistent somatosensory input in children with ASD due to the reduced effect of gravity and decreased secondary disorders in this population. Aquatic activity is also believed to provide an additional sensory stimulus that reduces stereotypic behaviors in children (Oriel et al., 2016).

While repetitive and stereotypic behaviors are reduced immediately after kata (Bahrami et al., 2012) and aquatic exercise (Adib Saber et al., 2019) programs; to date, the comparison of advantageous effects of two types of physical activity (aqua-based and land-based training) in children with ASD has not been studied. These results revealed no significant group effects regarding stereotypic behaviors. Although a greater improvement was observed in stereotyped behaviors in the aquatic training group than in the karate group, this difference was not statistically significant. These results may also be elucidated by optimal stimulation theory and homeostatic theory. These theories are supported by a model of behavioral distur-

Table 4. Inferential statistics of the research variables with the factors time, group, and the time×group-interaction

Variables		Time		Group		Time × Group	
		F	η_p^2	F	η_p^2	F	η_p^2
Autism severity	Stereotypic behaviors	86.631***	0.762 (L)	0.362	0.700 (L)	26.928***	0.666 (L)
CSHQ	Total sleep score	192.98***	0.877(L)	8.598***	0.389 (L)	55.337***	0.804 (L)
	Resistance	26.162***	0.492 (L)	1.869	0.122 (M)	4.635*	0.256 (L)
	Sleep onset delay	11.782**	0.304 (L)	0.085	0.006 (S)	0.245	0.018 (S)
	Sleep duration	16.994***	0.386 (L)	2.356	0.149 (L)	5.003*	0.270 (L)
	Sleep anxiety	47.239***	0.636 (L)	9.808***	0.421 (L)	15.877***	0.540 (L)
	Night wakening	45.703***	0.629 (L)	2.103	0.135 (M)	12.993***	0.490 (L)
	Parasomnias	44.787***	0.624 (L)	3.434*	0.203 (L)	11.237***	0.454 (L)
	Sleep disordered	17.971***	0.400 (L)	1.539	0.102 (M)	6.412**	0.322 (L)
	Daytime sleepiness	18.321***	0.404 (L)	2.417	0.152 (L)	6.195**	0.315 (L)

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Abbreviations: CSHQ: Children's sleep habits questionnaire; S: Small effect size; M: Medium effect size; L: Large effect size.

*P<0.05; **P<0.01; ***P<0.001.

bances that may explain the fact that stereotypic and restricted behaviors are reduced following physical exercise programs. It states that the presence of a particular level of arousal adjusts stimulation in an organism. Physical exercise interventions probably facilitate stimulation modulation to optimal levels (Bahrami et al., 2012).

Our second hypothesis was that aquatic exercise and kata of karate training can positively influence sleep habits, and find out which of these physical activities are more efficient. This was partly confirmed. Our results indicated that in the following 10 weeks, both exercise interventions (karate and aquatic training) resulted in a significant improvement and all subscales scores of sleep habits in children with ASD. Consequently, considering sleep habits scores, we found that the aquatic exercise group obtained better scores and two subscale scores (sleep anxiety and Parasomnias) than the kata techniques training group; but no significant group effects were observed regarding the other subscales.

Our results are consistent with the results of previous studies that found improved levels of sleep-related problems following physical activity among children with ASD (Kanupka et al., 2018; Lawson & Little, 2017; Oriel et al., 2016). They concluded that a positive relationship is observed between physical activity and sleep patterns in children with ASD.

Unhealthy and inadequate sleep will not only cause problems for a child with ASD with behavior problems and daily functioning but also for other family members who care for the child during sleeplessness. It can be stated that many variables may affect sleep, including biological, psychological, mood, and developmental characteristics of the child, social environment, and cultural factors (Oriel et al., 2016), and sleep disorders in children with ASD are linked with physiological, behavioral, and sensory sensitivity complications (Reynoldset al., 2012). The biopsychosocial model provides a conceptual framework for further understanding children with ASD having sleep disorders. This model suggests that certain factors are involved in ASD that may underlie many prevalent sleep problems, including biological disorders (autism gene, clock gene) that affect circadian rhythms and melatonin levels, the relationship between the main features of ASD and sleep problems, and the relationship between sleep disorders and psychiatric disorders (e.g. anxiety, depression) (Lawson & Little, 2017).

Swimming is an aerobic exercise that is interesting for all ages, especially children, providing cardiovascular benefits, and putting less stress on the joints than other activities (Oriel et al., 2016). In addition to the physiological benefits, the psychosocial benefits of water activities include improving mood, self-esteem, body image, and reducing anxiety. In addition, children with

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Table 5. Effect sizes for mean comparisons from baseline to study completion, separately for the groups

Variables		Effect Sizes: Cohen's d		
		Pre-post: Aquatic	Pre-post: Karate	Pre-post: Control
Autism Severity	Stereotypic behaviors	1.057 (L)	0.510 (L)	0.025 (S)
CSHQ	Total sleep score	3.185 (L)	3.510 (L)	0.095 (S)
	Resistance	0.995 (L)	0.764 (M)	0.118 (S)
	Sleep onset delay	1.265 (L)	1.612 (L)	0.714 (M)
	Sleep duration	1.068 (L)	1.543 (L)	0.006 (S)
	Sleep anxiety	2.649 (L)	2.478 (L)	0.212 (S)
	Night wakening	1.582 (L)	1.306 (L)	0.058 (S)
	Parasomnias	1.590 (L)	1.630 (L)	0.011 (S)
	Sleep disordered	0.671 (M)	1.553 (L)	0.075 (S)
	Daytime sleepiness	1.064 (L)	0.815 (L)	0.090 (S)

Abbreviations: CSHQ: Children's sleep habits questionnaire; S: Small effect size; M: Medium effect size; L: Large effect size.

ASD suffer from sensory sensitivity; therefore, they can enjoy swimming as the water provides proprioceptive sensory input (Lawson & Little, 2017).

Enough research is not conducted in the field of studying the effect of kata techniques training on sleep habits. In addition to the possibility of fatigue associated with physical activity, at least, three other possible causes exist. First, kata techniques training can promote physiological adaptations in blood pressure, heart rate, and circulating levels of cortisol and α-amylase, and psychological adaptations, including changes in sleep quality (Naves-Bittencourt et al., 2015). Second, the increase in sleep waves is directly related to the energy metabolism of the brain, and it decreases dramatically during sleep. Third, it is believed that increased physical activity can improve sleep by increasing growth hormone secretion (Brand et al., 2015). However, in the present study, it was impossible to measure neuroendocrine processes. Also, physical activity leads to biological and biochemical changes, including changes in central body temperature, which stimulates the anterior hypothalamus, and increases sleep quality. In addition, changes in hormone levels due to physical activity, including melatonin, cytokines, prolactin, and prostaglandin D2, have a favorable regulatory effect on sleep quality (Azarniveh & Khormizi, 2016).

Conclusion

Ten weeks of kata techniques and aquatic exercises contributed to sleep and behavior improvements among children with ASD. Considering the simplicity and lower cost of physical exercise than other treatment interventions, karate, and swimming may be joyful options in the physical exercise curriculum to improve the behavioral and sleep problems of ASD children.

One of the strengths of this research is the existence of a control group. However, the present study has some limitations. First, the number of participants was small. Second, we only used the CSHQ, the stereotypy subscale of Gilliam's autism rating scale (GARS-2), and parents' reports to collect information about behavioral and sleep disturbances. This can limit the objective understanding of sleep improvement and may be biased.

It is recommended that future studies focus on using objective measures of sleep (e.g. actigraphy) to monitor sleep and movement throughout the night and a cross-over study to reduce covariates. It is also suggested to provide a suitable environment at school or institute for children with ASD to participate in physical activities, such as aquatic and karate exercises to alleviate common problems, such as sleep disturbances and repetitive behaviors.

Ethical Considerations

Compliance with ethical guidelines

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Authors' contributions

Conflict of interest

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