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Recreational ball games are effective in improving social communication impairments among preschoolers diagnosed with autism spectrum disorder: a multi-arm controlled study

Kai Qi¹, Yufei Liu¹, Zuopeng Wang², Xuan Xiong³, Kelong Cai⁴, Yifan Xu¹, Yifan Shi⁴, Zhiyuan Sun⁴, Xiaoxiao Dong⁴ and Aiguo Chen^{5*}

Abstract

Background This study aimed to compare the effects of two 12-week training intervention experimental ball games combined with standard behavioral rehabilitation against a control group solely utilizing standard behavioral rehabilitation on social communication impairments (SCI) in preschool children with Autism Spectrum Disorder (ASD).

Methods A multi-arm controlled study design was implemented, involving 41 children diagnosed with ASD (mean age: 4.99 ± 0.76 years). 41 participants were randomized assigned to two experimental groups and a control group. The experimental group carried out ball combination training program group (BCTP) and mini-basketball training program group (MBTP) on the basis of routine behavioral rehabilitation, which underwent 12-week training interventions 5 times a week. The control group ($n = 14$) received only standard behavioral rehabilitation. Evaluations were conducted before and after interventions using the Social Responsiveness Scale, Second Edition (SRS-2).

Results The results suggest that both 12-week interventions, BCTP, and MBTP, led to significant improvements in social communication impairment among children with ASD ($p < 0.05$). Despite enhancing the overall scores on the SRS-2, these interventions displayed varying impacts across different sub-dimensions. BCTP primarily exhibited significant enhancements in social awareness and behavior pattern ($p < 0.05$), whereas MBTP significantly improved social cognition and social communication ($p < 0.05$). Both interventions showed slight improvements in social motivation.

Conclusions The utilization of recreational ball games has showed to be effective in decreasing the impairment levels of children with ASD, while the control group experienced a worsening of outcomes. This suggests that irrespective of the specific ball game strategy employed, both can be employed on a weekly basis to complement

*Correspondence:

Aiguo Chen
agchen@yzu.edu.cn

Full list of author information is available at the end of the article



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standard behavioral rehabilitation and enhance the ability to improve the quality of life for children diagnosed with ASD.

Trial registration The trial is retrospectively registered on the Chinese Clinical Trial Registry (ChiCTR1900024973; August 5, 2019).

Keywords Exercise therapies, Child, Autism spectrum disorder, Social Communication Impairment

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder, encompasses a range of early-emerging deficits in social communication and repetitive sensory-motor behaviors [1], manifests in early childhood and persists throughout one's life [2]. Based on 2020 data from the Centers for Disease Control and Prevention (CDC), the prevalence of Autism among children has risen to 1 in 36 [3], making it one of the prevalent mental disorders that significantly influence the health of children and adolescents. Social Communication Impairment (SCI), a key clinical manifestation of ASD, has long been a central focus in the rehabilitation of children with ASD [4]. Commonly characterized by difficulties in social interaction, SCI primarily encompasses persistent challenges in utilizing language and non-verbal communication, impacting the quality of family life to different extents [5, 6].

To address SCI in children with ASD, there are diverse internationally available rehabilitation approaches [7]. These approaches primarily encompass pharmacotherapy, psychotherapy, dietary interventions, music therapy, among others [8]. Despite demonstrating some effectiveness in ASD rehabilitation, the high associated costs pose challenges for many families in affording these interventions [9]. However, many researchers conduct surveys by recruiting children with autism over the age of 7 or adults with high-functioning autism, with few studies focusing on preschool children aged 3–6 with autism [10]. Research suggests that early diagnosis coupled with prompt therapy can significantly improve outcomes for both children and their families [11]. Additionally, an increasing number of researchers believe that early intervention for children with autism is highly important for mitigating the SCI [12], which also directly correlates with the intervention effectiveness for children with ASD [13]. Therefore, it is crucial to understand and manage SCI effectively in children with ASD, this can enhance their quality of life and daily functioning.

Exercise intervention, among the array of approaches for ASD, offers advantages such as cost-effectiveness, ease of implementation, and minimal side effects [14]. It has a certain positive impact [15–18]. Studies show that integrating physical exercise into autism rehabilitation effectively fosters social skills development in children with autism [19]. Moreover, diverse studies suggest that

the integration of a range of physical exercises within the ASD child population positively influences their behavior, proving to be an effective method for mitigating SCI in children with ASD [14, 20].

Among the various types of sports interventions, the number of studies using ball sports as an intervention method is increasing. As example, group-oriented sports such as mini basketball and soccer entail a need of coordinated actions among peers, including passing and receiving, covering diverse interactive scenarios and social facets [21]. These elements bear specific positive implications for augmenting the social skills of children with ASD [22]. Aligned with the expectation that group-oriented sports enhance social skills in children with ASD, a pilot study revealed that after completing a soccer intervention program, 19 children diagnosed with ASD displayed improved social abilities [23]. Moreover, research reports suggested that a 12-week mini-basketball training program group (MBTP) positively influenced the social communication impairment by preschoolers aged 3–6 diagnosed with autism spectrum disorder [24].

However, relying on a single type of sport may not be sufficient. Among various sports intervention programs, a singular and repetitive sports plan may dampen participants' interest in learning, resulting in low engagement [25]. Therefore, it is crucial to explore more comprehensive sports interventions. The diverse psycho-sociological aspects associated with various team sports, there has been a lack of research combining different team sports into a tailored training program for children with ASD [26]. For instance, integrating soccer and basketball in a Ball Combination Training Program (BCTP) could offer diverse and combined experiences for children in different environments while engaging in team sports involving balls. To the best of our knowledge, no research has explored this approach, particularly when compared to single-based ball sport games. Furthermore, there is a limited number of studies involving children with ASD in ball games from early stages and early diagnosis. Hence, both factors—the testing of BCTP and the intervention in early stages of diagnosis—present an opportunity to advance knowledge regarding the practical effects on SCI. Considering these identified needs and opportunities in the current research landscape, this study aimed to conduct a multi-arm study design involving children with

ASD. The study compares the effects of MBTP and BCTP against control groups exposed solely to standard behavioral rehabilitation for SCI.

Methods

Study design and experimental approach

This study employed a multi-arm study design. Participants were randomly assigned into groups, with children from a development center in Yangzhou city as the control group and those from an educational institution in Yangzhou as the experimental group. The experimental group received 12 weeks of BCTP and MBTP intervention on top of the regular behavioral rehabilitation offered by the institution; the control group received only the regular behavioral rehabilitation intervention. While the experimental group underwent the sports intervention, the control group continued with their regular educational activities. All participants underwent a standardized Applied Behavior Analysis (ABA) rehabilitation program. Upon expressing their willingness to participate voluntarily, participants were screened against eligibility criteria. Assessments were carried out by an evaluator blinded to the intervention. The same evaluator conducted the second assessment. The study was not blinded to participants and therapists.

Ethical aspects

The present study employed a 3×2 mixed experimental design, where group (experimental and control) served as the between-subjects factor, and time (baseline and posttest) served as the within-subjects factor. This study received ethics approval from the Ethics and Human Protection Committee of the Affiliated Hospital of Yangzhou University, and the study was registered with the Chinese Clinical Trial Registry (ChiCTR1900024973). Informed consent was obtained from the parents or guardians of all participants. The study adhered to the ethical standards outlined in the Declaration of Helsinki.

Participants

The a priori sample size was determined using an effect size of 0.35 (medium effect size), with a significance level of 0.05 and a power of 0.95, considering the repeated measures ANOVA with a within-between interaction. The test was conducted using G*Power software (version 3.1.9.6, Universität Düsseldorf: Psychologie – HHU), resulting in a recommended number of 36 participants.

Volunteers were screened against the following eligibility criteria: (i) having a clinical diagnosis of ASD; (ii) not having injuries or motor ability that would hinder participation in physical exercise; (iii) having medical clearance to participate in physical exercise; (iv) attending at least 90% of the training sessions; and (v) participating in both assessment moments. Participants were excluded if

any of the following conditions were present: (1) they had engaged in basketball training or regular physical exercise within the past 6 months; (2) they had other mental illnesses in addition to autism; (3) they had a complex neurological disorder (e.g., epilepsy, phenylketonuria, fragile X syndrome, tuberous sclerosis, etc.); (4) they had visual or auditory disorders; (5) they had a medical history of head trauma; (6) they had any medical condition that might limit participation in the exercise intervention.

After 109 volunteers expressed interest in participating, all of whom were from a development center in Yangzhou city and an educational institution in Yangzhou, screening resulted in 41 participants who were ultimately analyzed (Fig. 1). Initially, twenty ASD children were assigned to the BCTP group, twenty-three ASD children were assigned to the MBTP group, and twenty ASD children were assigned to the control group. Notably, six participants withdrew during the experiment: four due to transferring schools mid-study and two due to prolonged illness. Additionally, sixteen participants missed one of the assessments, resulting in a total of forty-one participants included in the final analysis (Fig. 1).

Intervention programs

The intervention programs were conducted over 12 consecutive weeks, with a frequency of 5 sessions per week, totaling 60 training sessions per group. They are divided into three training stages, as outlined in Fig. 2. Each training session lasted between 40 and 45 min, as outlined in Fig. 3. The training content of BCTP is shown in Table 1, and the training content of MBTP is shown in Table 2. Throughout the intervention, the children participated in exercises at a moderate intensity, aiming to maintain a mean heart rate between 128 and 148 beats per minute, monitored using the POLAR M430 heart rate monitor. The training sessions were led by two physical education teachers with expertise in working with autistic populations. At least one parent of the participating children was required to join the class and accompany their child during the training session. The intervention was implemented as prescribed and supervised by the healthcare providers biweekly.

Both experimental groups received standard behavioral rehabilitation, as did the control group, which solely received standard behavioral rehabilitation. This included Applied Behavior Analysis, structured teaching methods (Treatment and Education of Autistic and related Communication Handicapped Children), Communication and Social Skills Training, Parent Training and Involvement, Positive Reinforcement and Rewards, and Structured Play and Socialization. These interventions were conducted by expert technicians who were not part of the research team.

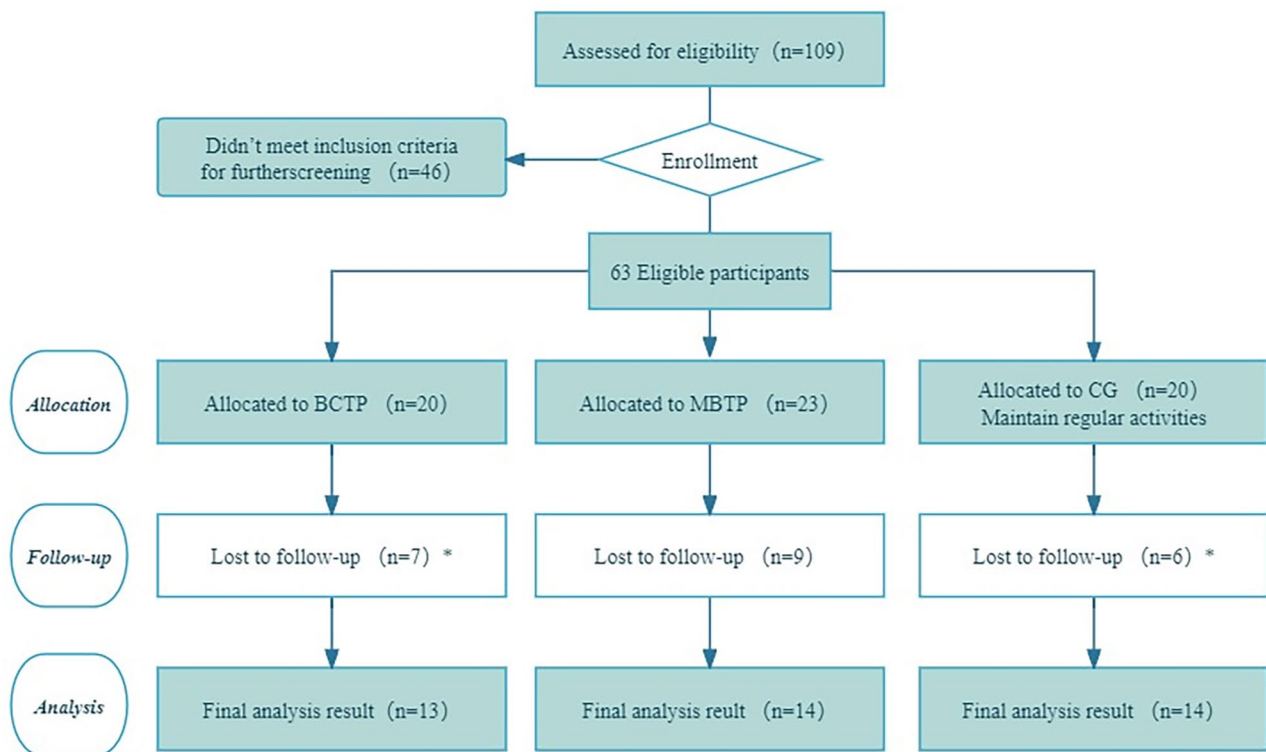


Fig. 1 Participant flow characteristics. * Twenty-two children's parents did not finish the assessment in the post-test

Evaluation procedures

The evaluation procedures were conducted by the same researcher specialized in administering questionnaires. Each questionnaire was administered individually in a quiet room, ensuring confidentiality. Demographic information including age, sex, body mass, height, and body mass index was obtained during the pretest.

Finally, the Social Responsiveness Scales Second Edition (SRS-2) was applied [27]. The validation of the Chinese Mandarin version of the SRS has been previously confirmed, as has its reliability [28]. A previous study revealed that, in terms of its structure, it is both feasible and holds the potential to provide important insights into the biology of autistic syndromes [29]. The SRS-2 consists of a total of 65 items and covers 5 subscales, specifically: Social Awareness (8 items), Social Cognition (12 items), Social Communication (22 items), Social Motivation (11 items), and Behavior Pattern (12 items). According to the requirements of the scale: it is filled out by parents or teachers of autistic patients, while in this study, it was required that the parents of the participants fill it out, and the same person was responsible for the assessment before and after the experimental intervention. The quantified scoring of the SRS-2 includes both the total score of the scale and the scores of the 5 subscales, where higher scores indicate a more severe degree of social communication impairment.

Confounding variables

The autism severity level of participants was confirmed using the Childhood Autism Rating Scale (CARS) [30]. The scale has been confirmed as an effective and valid diagnostic instrument for assessing ASD cases [31]. The scale assesses various aspects of a child's behavior, communication, and social interaction through both direct observation and information provided by caregivers. Comprising 15 items, it evaluates behaviors including emotional response, verbal and non-verbal communication, and social relationships. Each item is rated on a scale ranging from one to four, with higher scores indicating more pronounced symptoms related to autism [30]. The assessment was conducted independently by a clinician, and a comprehensive clinical assessment report is subsequently provided.

Research has indicated that dietary behavior [32, 33] and sleep disturbances may also be related to the severity of core ASD symptoms [34]. To avoid heterogeneity among participants, these factors were considered as confounding variables and analyzed accordingly.

Sleep problems were assessed using the Children's Sleep Habits Questionnaire (CSHQ) [35], a parent-reported questionnaire designed as a screening instrument for sleep disorders. It has been validated for preschool children with ASD and has a high degree of correspondence [36]. The CSHQ consists of 33 items covering various aspects of sleep behavior, including

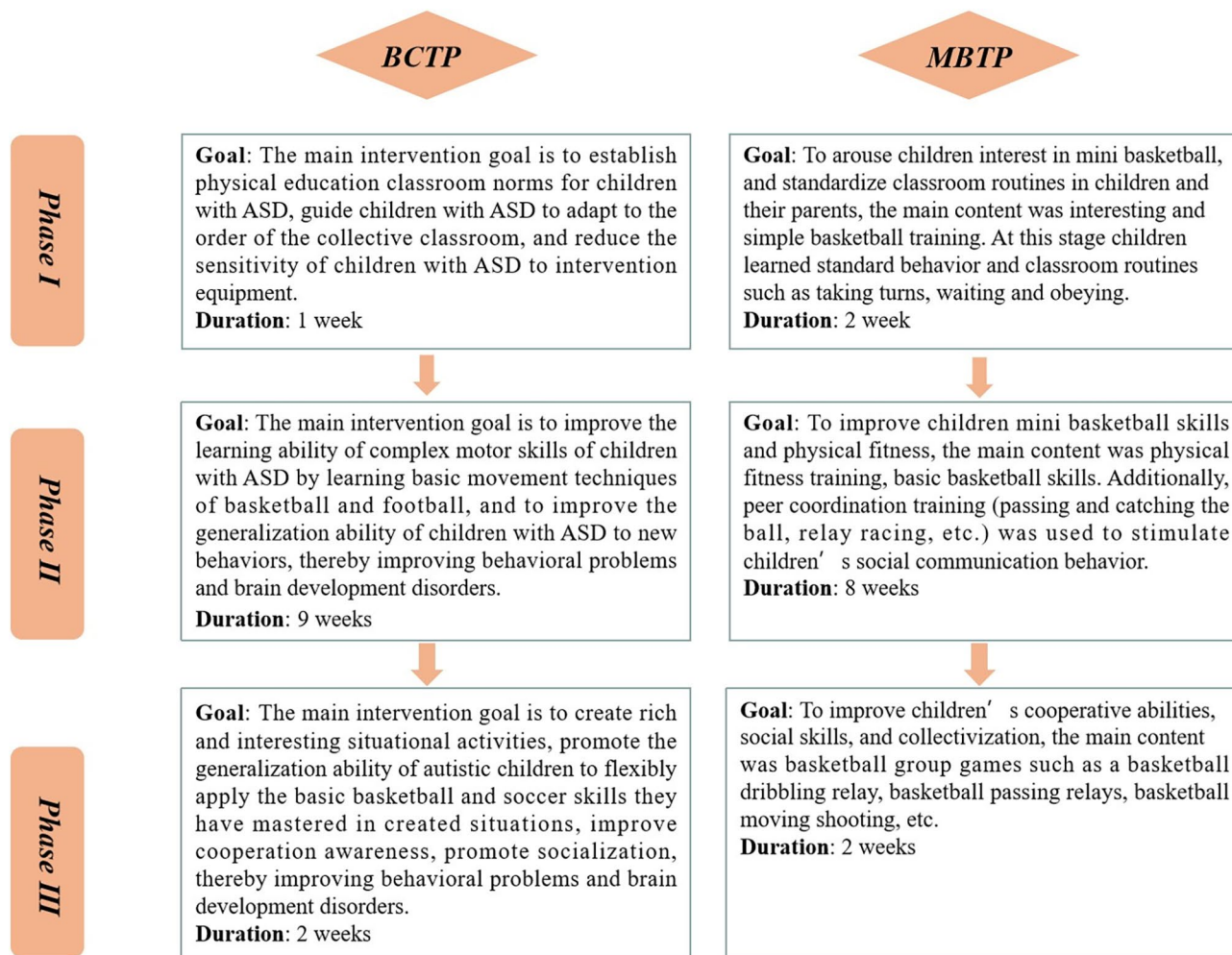


Fig. 2 Goal and duration of intervention for the three stages of BCTP and MBTP

bedtime resistance, sleep onset delay, sleep duration, night waking, and daytime sleepiness. Caregivers report on their child's sleep habits over the preceding week, rating each item on a Likert scale.

The children's eating style was assessed by a parent-report Child Eating Behavior Questionnaire (CEBQ) [37]. The scale comprises 35 items grouped into eight subscales, including food responsiveness, enjoyment of food, satiety responsiveness, emotional overeating, and desire to drink. Caregivers report on their child's eating behaviors, providing insights into aspects such as food preferences, appetite regulation, and emotional eating tendencies.

Statistical analysis

Initially, SPSS 26.0 (IBM, Armonk, NY, USA) software was used to perform an independent samples t-test and chi-square tests to three participant groups assess the homogeneity of demographic characteristics (age, BMI, sex), and CARS, CSHQ, CEBQ. This aimed to identify

any differences in baseline demographic and behavioral characteristics. Whereafter, a repeated measures analysis of variance (ANOVA) was employed to scrutinize the impact of a 12-week BCTP and MBTP on SRS-2 scale scores in children with ASD. The partial eta-squared (η_p^2) value served to indicate effect size. In the event of a significant time \times group interaction, a subsequent simple effect analysis would be conducted. $P < 0.05$ were statistically significant.

Results

Demographic characteristics

To ensure the study's integrity, demographic characteristics (age, gender, BMI) and diagnostic reports (CARS, CSHQ, CEBQ) were taken into account as potential influencers on the SCI of children with ASD before the experiment commenced. Hence, controlling these factors throughout the research process and conducting differential tests on all participants was deemed necessary to avoid any influence on the experimental outcomes.

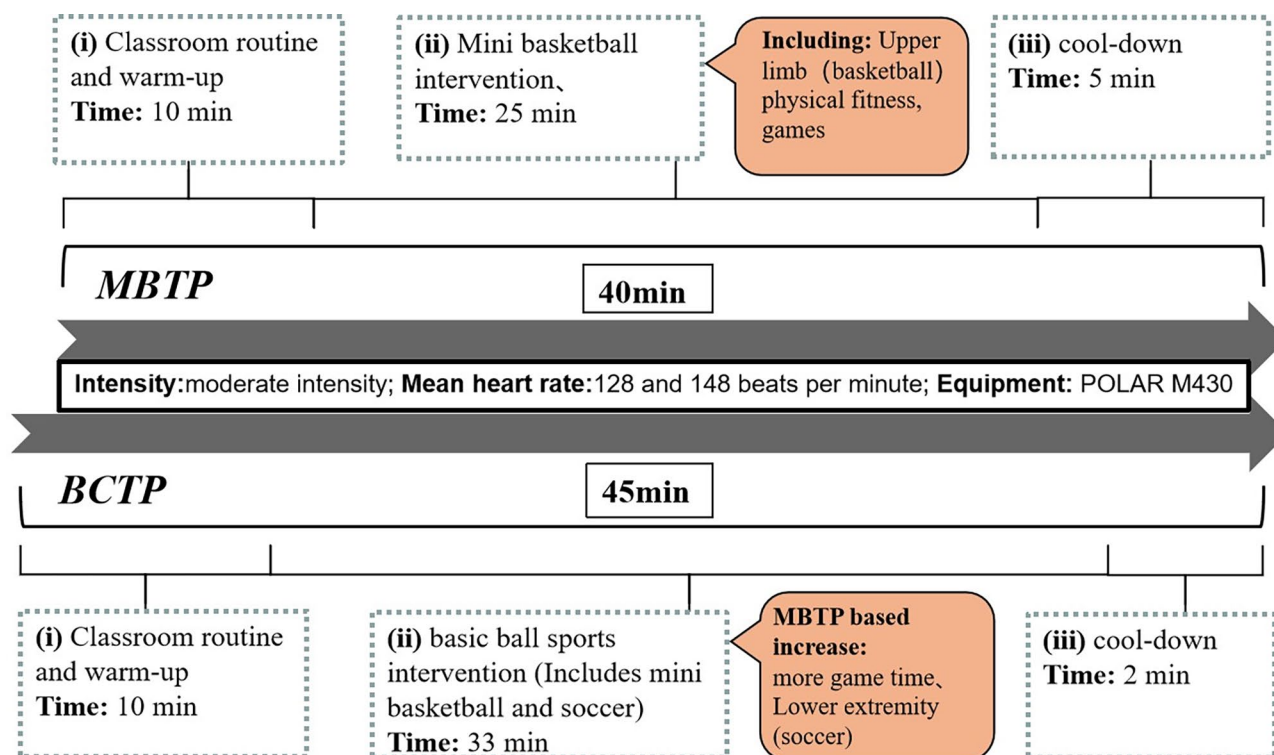


Fig. 3 BCTP and MBTP single intervention procedure

The chi-square test did not demonstrate any differences among the three groups of participants concerning sex ($\chi^2=1.372$, $p>0.05$). Similarly, the single-factor variance analysis for age [$F_{(2,38)}=2.247$, $p>0.05$], BMI [$F_{(2,38)}=0.770$, $p>0.05$], CARS, CSHQ [$F_{(2,38)}=2.275$, $p>0.05$], and CEBQ [$F_{(2,38)}=0.156$, $p>0.05$] indicated no significant differences. These findings explain a homogeneity in demographic indicators, symptom severity, sleep patterns, and dietary habits among the three groups of preschool children with ASD (Table 3).

Three groups of SCI before and after intervention

The analysis results of the total scores and scores on the 5 sub-dimensions of SRS-2 for the three groups are presented in Fig. 4. The study revealed a statistically significant time \times group interaction in the total score of the SRS-2 ($F_{(2,38)}=7.484$, $p<0.01$, $\eta_p^2=0.283$), and in the scores of social awareness ($F_{(2,38)}=3.32$, $p<0.05$, $\eta_p^2=0.149$), social cognition ($F_{(2,38)}=3.239$, $p<0.05$, $\eta_p^2=0.146$), social communication ($F_{(2,38)}=4.777$, $p<0.05$, $\eta_p^2=0.201$), and behavior pattern ($F_{(2,38)}=5.993$, $p<0.01$, $\eta_p^2=0.240$). Accordingly, we performed further simple effect analyses on the five outcomes mentioned above. The results indicated that there were no statistical differences in the baseline scores of the total SRS-2 score and the scores of the subscales between the experimental and control groups ($p>0.05$). Our findings also revealed significant decreases in the scores of the BCTP group on

the SRS-2 total scores, as well as its social awareness and behavior pattern subscales ($p<0.05$). The post-test SRS-2 total scores, as well as its social cognition and social communication of the MBTP group significantly decreased compared to the pre-test total scores ($p<0.05$). Conversely, the control group exhibited a significant increase in scores on the SRS-2 total score, behavior pattern ($p<0.05$). This demonstrates the continuous deterioration of social communication impairment among ASD children in the control group due to the absence of an intervention through the training program. These findings indicate that the BCTP could improve SCI of participants, particularly in the domains of social awareness and behavior pattern. The MBTP could improve SCI of participants, particularly in the domains of social cognition and social communication.

No statistical difference was found in the scores for the social motivation subscale ($F_{(2,38)}=1.319$, $p>0.05$, $\eta_p^2=0.065$) in the time \times group interaction, suggesting that the two experimental groups did not result in improvements in social motivation. Table 4 describes the SRS-2 outcomes between groups.

Discussion

The current research has showed that ball-games training is effective in complementing standard behavioral rehabilitation. Preschool children with ASD significantly benefited from both the BCTP and the MBTP in their SCI.

Table 1 Intervention program description for ball combination training program (BCTP).

Week Number	Days Per Week	Work Duration (min)	Practice phase	Training Drills
1	5	45	PhaseI	Assemble the team(2 min)、warm up(8 min)、Sports intervention (mini-basketball tactile desensitization, small basketball visual desensitization, physical fitness exercises (return running with the ball, etc.), sports games (high-five passing games, etc.))(33 min)、relaxation(2 min)
2	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
3	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
4	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
5	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
6	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
7	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic mini-basketball skills learning (such as passing, dribbling, shooting, etc.), physical fitness exercises, sports games (jumping jacks + two-handed dribbling, seeing who can react faster, etc.))(33 min)、relaxation(2 min)
8	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic technical learning of football (such as kicking a spot kick, alternating feet on the ball and dribbling with the inside of the foot, etc.), physical fitness exercises, sports games (such as spot dribbling and one-foot dribbling around obstacles, etc.))(33 min)、relaxation(2 min)
9	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (basic technical learning of football (such as kicking a spot kick, alternating feet on the ball and dribbling with the inside of the foot, etc.), physical fitness exercises, sports games (such as spot dribbling and one-foot dribbling around obstacles, etc.))(33 min)、relaxation(2 min)
10	5	45	PhaseII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (Integrate 2–9 weeks of mini-basketball and soccer skills learning)(33 min)、relaxation(2 min)
11	5	45	PhaseIII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (combine the basic movement techniques of mini-basketball and football to design group sports games, such as relay throwing and catching, dribbling relay games, small circle shooting and large circle jumping games, etc.)(33 min)、relaxation(2 min)
12	5	45	PhaseIII	Assemble the team(2 min)、warm up(8 min)、Sports intervention (combine the basic movement techniques of mini-basketball and football to design group sports games, such as relay throwing and catching, dribbling relay games, small circle shooting and large circle jumping games, etc.)(33 min)、relaxation(2 min)

Min: minutes

Conversely, those who underwent only standard behavioral rehabilitation (control group) actually experienced worsened outcomes over the 12-week period of this experiment. Furthermore, BCTP appears to be particularly promising for significantly enhancing social communication impairment, social awareness, and behavior patterns in preschool children with ASD. Although no significant changes were observed in other sub-dimensions, they all showed an improving trend. MBTP was notably effective in significantly improving social communication impairment, social cognition, and social communication in preschool children with ASD. Similarly, although no significant changes were detected in other sub-dimensions, they all displayed an improving

trend. The observed effectiveness of both BCTP and MBTP can be attributed to several underlying mechanisms. For BCTP, the combination of soccer and basketball involves a variety of motor skills that require both individual and team-based actions. These activities likely stimulate different brain regions associated with motor planning, coordination, and social cognition. The structured yet dynamic nature of these sports also provides a controlled environment where children can practice social interactions and receive immediate feedback from peers and coaches, thereby reinforcing positive social behaviors and reducing repetitive, stereotyped behaviors. Similarly, MBTP focuses on basketball skills which involve significant social interaction and coordination.

Table 2 The characteristics of Mini-basketball Training Program (MBTP).

Week Number	Days Per Week	Work Duration (min)	Practice phase	Training Drills
1	5	Work Duration (min)	Phase I	Assemble the team(2 min)、warm up(8 min)、Sports intervention (mini-basketball tactile desensitization, mini-basketball visual desensitization, upper limb throwing ball movement learning, physical fitness training (holding the ball and jumping in circles, holding the ball and running relay, running over obstacles, etc.))(25 min)、relaxation(5 min)
2	5	40	Phase I	Assemble the team(2 min)、warm up(8 min)、Sports intervention (mini-basketball tactile desensitization, small basketball visual desensitization, upper limb throwing ball movement learning, physical fitness training (holding the ball and jumping in circles, holding the ball and running relay, running over obstacles, etc.))(25 min)、relaxation(5 min)
3	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
4	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
5	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
6	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
7	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
8	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
9	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
10	5	40	Phase II	Assemble the team(2 min)、warm up(8 min)、Sports intervention (familiarity with the nature of the ball, children and parents working together on passing exercises and chest-passing and catching on the spot, etc., physical fitness training (holding the ball in circles with both feet, holding the ball and running back and forth in relay races, etc.))(25 min)、relaxation(5 min)
11	5	40	Phase III	Assemble the team(2 min)、warm up(8 min)、Sports intervention (review of passing, catching, dribbling and shooting, group mini-basketball games (hand pushing bocce ball, holding the ball and running relay, etc.), relay throwing and catching and dribbling relay competitions, etc., physical fitness training (double holding the ball) Hops, standing on one foot and hopping on one foot, running back and forth, sit-ups, etc.))(25 min)、relaxation(5 min)
12	5	40	Phase III	Assemble the team(2 min)、warm up(8 min)、Sports intervention (review of passing, catching, dribbling and shooting, group mini-basketball games (hand pushing bocce ball, holding the ball and running relay, etc.), relay throwing and catching and dribbling relay competitions, etc., physical fitness training (double holding the ball) Hops, standing on one foot and hopping on one foot, running back and forth, sit-ups, etc.))(25 min)、relaxation(5 min)

Min: minutes

The repetitive practice of these skills can enhance neural plasticity, leading to improvements in areas of the brain associated with social cognition and communication. Moreover, the group-based nature of both interventions promotes peer modeling and social learning, where

children observe and imitate appropriate social behaviors from their peers, further enhancing their social skills.

While both BCTP and MBTP demonstrated significant positive effects on the manifestation of SCI in children with ASD, their impacts varied across different

Table 3 Participant demographic characteristics (mean ± standard deviation)

Variable	BCTP Goup	MBTP Group	Control Group	χ ²	F	P
N	13	14	14	-	-	-
Gender (boys/girls)	10/3	12/2	13/1	1.372	-	0.504
Age (years)	5.23 ± 0.89	5.04 ± 0.66	4.71 ± 0.75	-	2.247	0.12
BMI (height/weight ²)	16.62 ± 2.63	15.69 ± 1.38	16.18 ± 1.95	-	0.770	0.47
CARS	35.62 ± 5.41	40.50 ± 6.54	41.07 ± 7.79	-	2.685	0.081
CSHQ	61.77 ± 11.76	56.29 ± 5.18	55.50 ± 6.72	-	2.275	0.117
CEBQ	49.85 ± 16.76	53.36 ± 9.43	51.64 ± 20.74	-	0.156	0.856

x̄ Mean. SD Standard deviation

CARS: Childhood Autism Rating Scale; CSHQ: Children’s Sleep Habits Questionnaire; CEBQ: Child Eating Behavior Questionnaire; BCTP: the ball combination training program group; MBTP: mini-basketball training program group

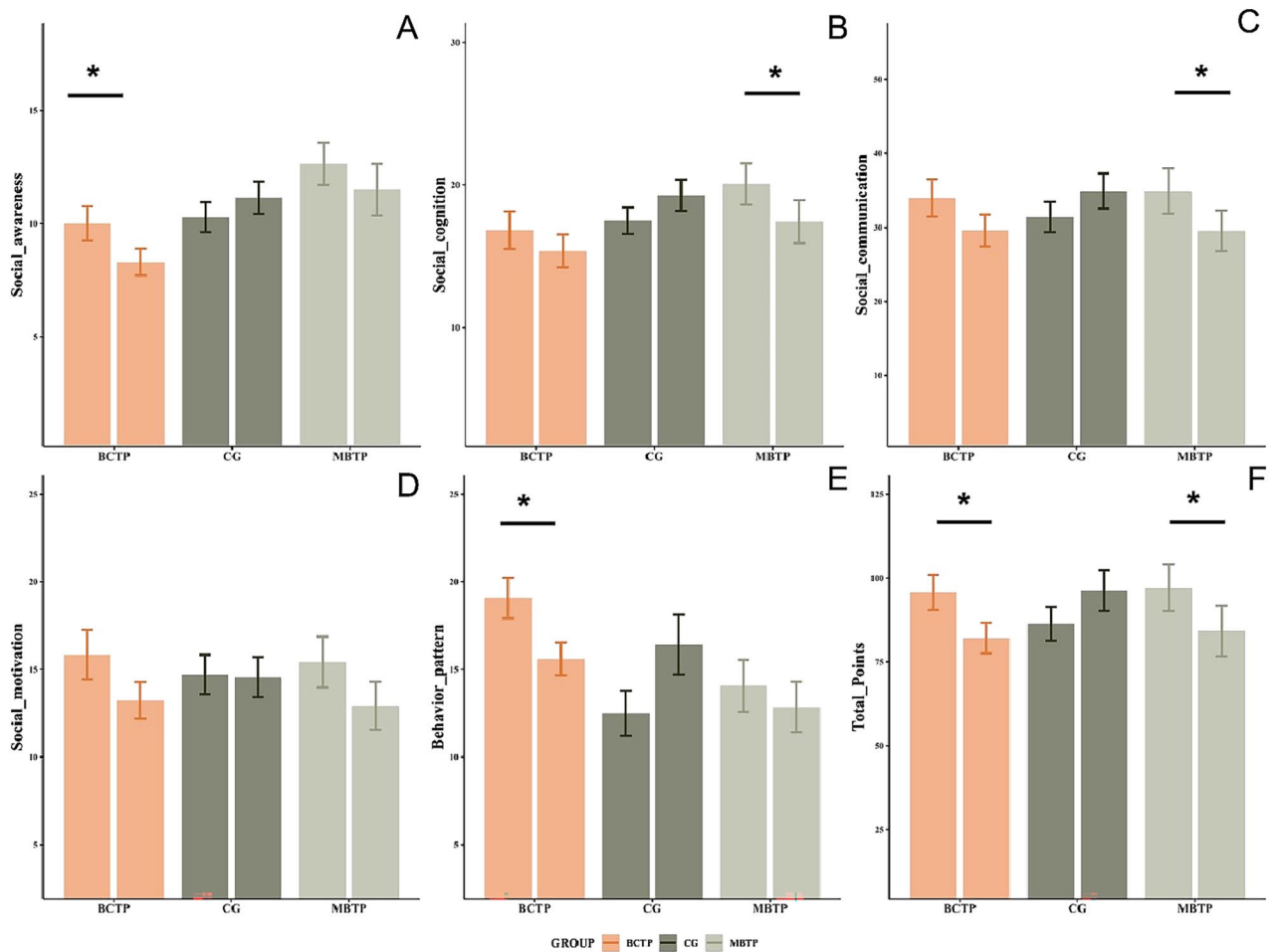


Fig. 4 Performances for SRS-2 subscales at particular time points and for three groups. * $p < 0.05$

sub-dimensions. Overall, our results align with previous systematic reviews, supporting a tendency for research articles to highlight the positive aspects of sports, particularly game-based approaches, in enhancing social skills among children with autism [38, 39]. These activities usually involve teamwork and communication, allowing for interaction with peers [38]. Participating in play and competitions with other children could assist autistic

children in learning collaboration, communication, and forming friendships [40].

While individual sports activities such as aquatic swimming [41], ballet dance [42], Kata techniques [43], horseback riding [44] have been shown to enhance self-control, concentration capabilities, self-confidence and independence as well as social cognition, behavior, and communication skills in children with ASD, incorporating

Table 4 The SRS-2 performances (mean \pm standard deviation)

Variable	BCTP Goup(n = 13)		MBTP Group(n = 14)		Control Group(n = 14)	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Social awareness	10.00 \pm 2.74	8.31 \pm 2.14	12.64 \pm 3.52	11.50 \pm 4.26	10.29 \pm 2.46	11.14 \pm 2.66
Social cognition	16.85 \pm 4.76	15.38 \pm 4.15	20.07 \pm 5.46	17.43 \pm 5.64	17.50 \pm 3.48	19.29 \pm 4.07
Social communication	34.00 \pm 9.05	29.62 \pm 7.75	34.93 \pm 11.40	29.57 \pm 10.27	31.43 \pm 7.66	34.93 \pm 8.88
Social motivation	15.85 \pm 5.10	14.57 \pm 4.29	15.43 \pm 5.42	12.93 \pm 5.14	14.71 \pm 4.20	14.57 \pm 4.29
Behavior pattern	19.08 \pm 4.15	15.62 \pm 3.38	14.07 \pm 5.57	12.86 \pm 5.41	12.50 \pm 4.86	16.43 \pm 6.38
SRS-2 Total Points	95.77 \pm 18.89	82.15 \pm 16.54	97.14 \pm 25.87	84.29 \pm 28.26	86.43 \pm 18.90	96.36 \pm 22.86

\bar{x} Mean, SD Standard deviation. Numbers presented are F statistics showing the tests of the interaction effect of group and time. η_p^2 : Partial eta-squared represents the effect size SRS-2: Social Responsiveness Scale Second Edition; BCTP: the ball combination training program group; MBTP: mini-basketball training program group

collective sports activities can offer different benefits. The interactive processes, collaboration, and communication required in such team sports can promote factors that individual sports alone may not be able to foster in social level [45]. For instance, in our ball-game training interventions, a particular emphasis was placed on stimulating and improving communication skills, thereby enhancing social interactions among children with ASD, similar to a previous study [46]. Furthermore, the ball-game interventions implemented in our study were designed to create conducive environments for enhancing the self-esteem, confidence, and self-competence of children with ASD. Throughout our sports intervention, we encouraged children to thoroughly learn movements to boost their confidence. Additionally, we instilled basic etiquette among program participants, including greetings with peers, parents, and teachers.

Employing ball-game interventions may pose challenges, such as offering fewer opportunities for individualized training compared to individual sports [14, 47] since individual sports can aid in circumventing communication challenges [48], and mitigating interpersonal conflicts among peers [49] which are commonly observed in group interventions. Considering the two training methods in our study (BCTP and MBTP), both were conducted in a team or group format, involving significant activity imitation and game elements in teaching. This approach not only sparked the learning interest of children with ASD but also effectively enhanced SCI and improved behavioral issues in autistic children. Unlike other individual sports interventions, the BCTP intervention combines a more comprehensive range of training content, including both ball sports and related physical training, thereby enriching the teaching content. Similarly, the MBTP is designed based on the development of preschool children and the specific characteristics of ASD children's movements, featuring tasks of varying difficulties, which also enrich the teaching content. The two training approaches in our study differ in content, resulting in varying intervention effects on different sub-dimensions of social communication impairment.

BCTP intervention improved the social awareness and behavior pattern of children with ASD. Social awareness refers to the perception of others' emotional states and social environments, including understanding others' emotional expressions, attending to others' gaze, and facial expressions [50]. During BCTP classes, teachers and parents adapt teaching methods in real-time based on the condition of children with ASD, engaging attention, completing assigned tasks. Additionally, in the later stages of the 12-week BCTP, football-related actions were incorporated to make it more appealing. Consequently, this improved the emotional stability, reduced distractions, increased learning interest in children with ASD, ultimately enhancing their social awareness and behavioral manners. It is important to recognize that individual differences among children with ASD can significantly influence the outcomes of interventions like BCTP and MBTP. For example, children with higher baseline social skills may benefit more rapidly from group-based interventions due to their existing ability to engage in social interactions, whereas children with more severe symptoms may require additional support and a longer adjustment period. Moreover, the role of individual preferences and interests should not be underestimated. Some children may naturally gravitate towards specific sports or activities, which can enhance their motivation and engagement in the intervention. Tailoring the interventions to accommodate these individual preferences could lead to more effective and personalized rehabilitation outcomes. Future studies should consider these individual differences by incorporating personalized assessments and adapting interventions accordingly. This approach would ensure that each child receives the most appropriate and effective support, thereby maximizing the potential benefits of the intervention. MBTP improved the social cognition and social communication of children with ASD. Social cognition involves the understanding and thinking abilities related to social situations, including comprehending social rules, inferring others' intentions and emotions, as well as understanding non-verbal aspects of social communication

[51]. Social communication refers to the ability to engage in social interactions, including establishing and maintaining friendships, sharing interests and experiences, and collaborating and interacting with others [7]. In the 12-week MBTP classroom teaching, teachers included a significant amount of action imitation activities while teaching basic basketball skills to children with ASD. The gaming part involved role-playing elements where ASD children imagined themselves as relevant characters to complete the game. Consequently, there was more cooperation and interaction among ASD children and their peers, thus enhancing their social cognition and social communication.

Despite the significant findings observed, this study is not without limitations. It has two main limitations. Firstly, the SRS-2 scale data were collected based on parental reports. While the SRS-2 is an authoritative scale used to assess children's social communication disorders, results from parental reports may be subjective, introducing the possibility of self-report bias. Furthermore, this study lacks a comparison to individual sports, which could provide alternative outcomes. Therefore, future research should consider conducting such comparisons.

Our study suggests that game-based training interventions for preschool children with ASD were effective in improving SCI, and they offered significant benefits compared to continuing with standard behavioral rehabilitation alone. Consequently, it is recommended, despite the study's limitations, that ball-based training interventions be implemented in children with ASD, regardless of the type of games used. While different programs may show varying effectiveness across sub-dimensions, they can all help children develop social skills and enhance emotional cognition and expression, enabling better interaction with others. However, it is also recommended to conduct individual and continuous evaluations for cases needing specific adjustments to the programs. Therefore, interventions and future research should consider individual responses to interventions and be ready to implement alternative or complementary approaches during the programs to enhance the likelihood of success.

Conclusions

Our multi-arm controlled study suggests that ball-game training interventions effectively enhance the SCI of children with ASD, significantly exceeding the effectiveness of standard behavioral rehabilitation alone. This study emphasizes the positive impact of BCTP on the social communication impairment of preschool children with ASD, further supporting the evidence of MBTP's effectiveness in improving social communication impairment in the same group. The effects of BCTP and MBTP on various dimensions of motor impairments in preschool children with ASD vary, allowing for personalized

exercise interventions tailored to different subtypes of preschool children with ASD. These research findings contribute to a deeper understanding of the relationship between physical sports and social communication impairment in children with ASD. They establish a practical foundation for utilizing physical sports to improve the social communication impairment and other behavioral symptoms of children with ASD in educational and medical practices.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13102-024-00957-8>.

Supplementary Material 1

Acknowledgements

The authors would like to express their gratitude to all the children who participated in this study, teachers and parents of children for their support, and research assistants who helped with data collection and other contributions. In addition, special thanks to Professor Chen Aiguo of Nanjing Sport Institute and the Gdansk Institute of Physical Education for their support.

Author contributions

K.Q., Y.L., Z.W., X.X., K.C., Y.X., Y.S., Z.S., X.D., A.C. wrote the main manuscript text and K.Q. prepared Fig. 1. Y.L. prepared Fig. 2. All authors reviewed the manuscript.

Funding

This research was supported by grants from the National Natural Science Foundation of China (31771243), the National Social Science Foundation of China (23ATY008).

Data availability

The anonymized dataset used for analysis will be made available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Ethics and Human Protection Committee of the Affiliated Hospital of Yangzhou University, and the study was registered with the Chinese Clinical Trial Registry (ChiCTR1900024973). Informed consent was obtained from the parents or guardians of all participants.

Consent for publication

No applicable.

Competing interests

The authors declare no competing interests.

Statement

The design and reporting of this study adhere to the principles of the CONSORT guidelines. We have followed the CONSORT flow diagram and checklist to ensure that all relevant information has been fully disclosed.

Author details

¹Gdansk University of Physical Education and Sport, Gdansk 80-336, Poland

²Jiamusi University, Jiamusi, Heilongjiang 154007, China

³Nanjing University, Nanjing, Jiangsu 210008, China

⁴Yangzhou University, Yangzhou, Jiangsu 225009, China

⁵Nanjing Sport Institute, Nanjing, Jiangsu 210014, China

Received: 2 May 2024 / Accepted: 1 August 2024

Published online: 22 August 2024

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