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The effects of physical exercise on fitness and emotion in Chinese preschoolers

Hua Wu^{1,2}, Hui Ruan^{1*}, Wichai Eungpinichpong^{2,3} and Wenlonog Zhou⁴

Abstract

Background The global prevalence of overweight and obesity in children under the age of five has emerged as a significant issue in recent years. Physical activity and fitness among children and adolescents have declined globally in the past few decades. Studies have indicated a link between levels of physical activity and cognitive performance in preschool children.

Methods This quasi-experimental study investigated the effects of three different types of physical education programmes on the physical fitness and emotional competence of 239 preschoolers (mean age = 5.49 ± 0.60 years, 54.4% boys) in Haikou, China. The preschoolers were grouped based on which programme they were assigned to: the “Hello Sunshine” ball skills programme (HS group), ordinary physical education (OPE group), and free play (FP group). The “Hello Sunshine” ball skills programme used both a structured curriculum design and autonomous activity selection during outdoor time., which were conducive to children’s physical fitness. The National Physical Fitness Measurement Standards Manual and the shortened version of the Social Competence and Behavior Evaluation Scale (SCBE-30) were used to assess physical fitness and emotional competence, respectively. These assessments were conducted both before and after the ten-week intervention period. The analysis utilised a mixed-effects model for physical fitness and a mixed-model ANOVA for the SCBE data.

Results The HS group and OPE group demonstrated significantly improvement in the standing long jump, 10-m shuttle run and balance beam walking than the FP group; meanwhile, only anxious-withdrawal levels showed a significant grouping effect and group-by-time interaction effect. After the intervention, both the HS group and the FP group showed significantly lower scores for anxiety compared to the OPE group, with no significant difference observed between the HS and FP groups.

Conclusions The results suggested that structured ball skills programmes may promote physical fitness and reduce anxiety. The integration of effective physical exercise programmes into preschool curricula holds the potential for promoting holistic development.

Keywords Young children, Fundamental movement skills, Physical fitness, Anxious withdrawal

*Correspondence:

Hui Ruan
huiruan@kkumail.com

¹Faculty of Physical Education, Hainan Normal University, Haikou 5771158, China

²Faculty of Associated Medical Sciences, KhonKaen University, KhonKaen 40002, Thailand

³Faculty of Associated Medical Sciences, PT Division of Physical Therapy, BNOJHP Research Center, KhonKaen University, KhonKaen 40002, Thailand

⁴Key Laboratory of Child Cognition & Behavior Development of Hainan Province, Haikou 571100, China



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Background

The early childhood stage is crucial for physical, emotional, social, and intellectual development. However, according to authoritative reports, global prevalence of overweight and obesity in children under the age of five has emerged as a significant issue in recent years, with 37 million children under the age of 5 being overweight in 2022 [1, 2]. In children, physical fitness is a significant indicator of healthy growth, development, and overall well-being, encompassing the effective coordination of various body systems to perform daily activities and maintain good health [3]. Physical fitness can be broadly categorized into health-related and performance-related components. Health-related physical fitness includes cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition. These components are critical for overall health and the prevention of diseases. Performance-related physical fitness, on the other hand, focuses on attributes such as agility, balance, coordination, power, reaction time, and speed, which are crucial for optimal performance in physical activities and sports [4].

Various countries have developed measurement methods to assess physical fitness and implemented continuous tracking to monitor changes in individuals' fitness levels. Recent data highlights that physical activity (PA) and fitness among children and adolescents have declined globally in the past few decades; in particular, cardiopulmonary endurance has demonstrated a long-term negative trend, with an overall change of about 1.5 standard deviations for both boys and girls [5, 6]. The situation in China is also concerning. Although data indicate that, over the past two decades, the physical growth and nutritional status of Chinese preschool children have notably improved, overweight and obesity are becoming increasingly prominent in this population [7]. In line with this, most preschool children's physical activities do not meet the recommended standards [8]; indeed, the 2020 Chinese National Fitness Survey revealed a downward trend in certain physical fitness indicators among preschoolers over the past decade. For example, boys showed a 1.3% decrease in jumping with both feet and a 6.6% decrease in broad jump performance, while girls showed decreases of 1.6% and 5.3%, respectively, in the same activities [9].

Studies have indicated a positive link between physical fitness and levels of PA [10] and cognitive performance [11, 12] in preschool children. Furthermore, cognitive, emotional, and social competencies do not exist in isolation but rather coalesce and develop in tandem throughout the lifespan and create strong academic and health outcomes [13]. Emotional competence encompasses the capacity to recognise, comprehend, express, and manage emotions [14]. Research findings have indicated that emotional competence during the preschool years plays a

significant role in fostering social competence and carries long-lasting implications [15]. Research has shown that age and gender can significantly impact children's social competence, behavior problems, and emotional regulation, with preschool boys generally being more aggressive and having poorer social skills compared to girls [16], and social competence improving progressively with age [17]. The early development of social and emotional skills is a crucial factor in predicting academic preparedness and future achievement in education [18, 19]. Moreover, nurturing children's social and emotional competence not only enhances their cognitive abilities but also fosters positive attitudes towards school and improves student behaviour [20, 21]. In the conceptual model of Health through Sport [22], engagement in sports is positively associated with individual psychological, social, and societal well-being. On the other hand, previous studies have found that physical exercise influences emotional competence through various neurobiological mechanisms, including the release of mood-regulating neurotransmitters and the enhancement of neuroplasticity [23–25]. Neuroimaging evidence found improved cognitive function [26] and positive social interactions during PA [27], which may further support the development of emotional competence. In contrast, certain evidence suggested that children with limited motor abilities experience social and emotional challenges, such as elevated levels of anxiety and depression, and that these problems appear as early as age four [28, 29].

Kindergarten, recognised as a pivotal environment for promoting PA, offers significant advantages and has the potential to generate numerous public health benefits [30]. Recent research suggests that policies implemented in kindergartens can have an impact on children's participation in PA, the duration of outdoor activities, and the strategies employed by teachers to encourage PA [30, 31]. In the past, intervention studies have primarily been focused on interventions at kindergartens [32, 33], joint family-kindergarten programmes [34], and multifaceted kindergarten-family-community programmes [35]. These studies have employed specific types of intervention methods, including strength-dominated exercise [36], ball skills [37] and mixed physical exercises [33, 38, 39] to explore the effects of exercise programmes on children's physical and motor domains. However, two recent systematic reviews have reported that methodologies of existing studies reporting the positive effects of body-oriented interventions on social-emotional competencies, such as empathy and social interaction, were of limited high methodological quality (such as the implementation of blinding) [40, 41].

In China, due to variations in kindergartens' specific characteristics and requirements for facilities, teachers, and premises, there are three main forms of preschool

physical education. These include unique sports-oriented curricula designed by kindergartens themselves (i.e., a kindergarten provides a range of specialised sports and physical education programmes, capitalising on school resources, favourable geography, and teachers' expertise, e.g. national football characteristic kindergarten), the adoption of general physical education materials (i.e., some ordinary public kindergartens in China adopt the unified physical education textbooks of each province and city), and free play (i.e., PA time is dominated by children's free play) [42]. During the pandemic, kindergartens adapted their PA programmes to ensure the safety and well-being of children. Activities now focus on individual play and movement, with an emphasis on maintaining social distancing. Notably, outdoor activities that used balls as a medium were a fun way to engage in physical exercise, such as throwing, catching, and kicking exercises. These activities help children enhance their PA participation, motor skills, and spatial awareness while maintaining a safe distance. Especially noteworthy is that ball skills reflect the ability to control objects and are a part of fundamental movement skills [43]. Evidence suggests that the comprehensive development of fundamental movement skills in childhood, particularly ball skills, is considered crucial for acquiring more intricate movement patterns and increasing the likelihood of successful participation in both team and individual sports [44, 45]. For instance, "SKIP" (Successful Kinesthetic Instruction for Preschoolers) [46] and "CHAMP" (Children's Health Activity Motor Programme) [37] emphasise the development of ball skills to enhance these capabilities. Given the potential health effects of implementing physical education in kindergartens, this study explored the impact of a ball skill-based programme, "Hello Sunshine", on physical fitness and emotional competence in preschool children. Specifically, it was hypothesised that three different models of physical education programmes for preschoolers, the "Hello Sunshine" programme, traditional physical education, and free play activities would enhance the children's physical fitness and emotional competence; however, it was also hypothesised that the "Hello Sunshine" programme would have a more significant impact on enhancing physical fitness and emotional competence

in preschool children than traditional physical education and free play activities.

Methods

Study design and population

This study was designed as a quasi-experimental trial with a ten-week physical exercise programme intervention, and pre- and post-intervention assessments. The pre-registration research protocol obtained approval from the Ethics Committee for Human Research at Khan Kaen University, demonstrating adherence to the ethical standards outlined in the Declaration of Helsinki (Ethical approval number: HE642100), and was registered with the Chinese Clinical Trial Registry (ChiCTR ChiCTR2000035414) on 8 October 2020.

Preschoolers from grades K2-K3 in three different types of kindergartens (sports-focused, ordinary public, and non-profit private kindergartens) in the centre of Haikou City, China participated in the study. Each kindergarten class was considered an experimental unit, and children were selected from two classes in the K2 and K3 grades. The eligibility criteria for the children were as follows: (1) to be in good health and typically developing, (2) 4–6 years old, (3) no additional sports club training, and (4) primary caregiver provided informed consent. Children with known learning and physical disabilities, motor delays, and medical or psychological diagnoses were excluded.

Participants

WinPepi software was utilised and referenced Westendorp et al. [47] to calculate the sample size. A significance level of 5%, power of 80%, confidence level of 95%, and dropout rate of 20% were utilized in the study. Initially, 249 preschool children were recruited and divided into three groups of 83 based on their respective kindergarten physical education models. However, ten children were excluded from the analysis due to missing or outlier data for one or more outcome variables. Therefore, data from 239 preschool children (mean age and sex) were included in the statistical analysis. Detailed demographic and anthropometric data were presented in Table 1.

Intervention

All three preschool groups participated in 30-minute physical education classes. The K2 group attended one class per week, while the K3 group attended two classes per week. Additionally, all groups had 30-minute outdoor classes every day, five days a week, throughout the ten-week intervention period. Apart from physical education and outdoor classes, the daily activities of the students in the three groups were similar.

Table 1 Demographic characteristics

	HS group (n = 79)	OPE group (n = 80)	FP group (n = 80)	Total (n = 239)
Gender (male/ female)	40 / 39	43 / 37	47 / 33	130 / 109
Age	5.38 ± 0.52	5.48 ± 0.67	5.59 ± 0.58	5.49 ± 0.60
Height (cm)	112.9 ± 6.46	117.68 ± 8.28	112.64 ± 5.42	114.41 ± 7.18
Weight (kg)	19.94 ± 3.79	20.59 ± 4.07	19.63 ± 2.92	20.05 ± 3.63
BMI (kg/m ²)	15.65 ± 2.29	15.39 ± 2.01	15.49 ± 2.22	15.51 ± 2.17

Note HS: Hello Sunshine; OPE: ordinary physical education; FP: free play

Hello sunshine group (HS group)

“Hello Sunshine” followed a structured, age-based curriculum focused on ball skills. This curriculum is a school-based programme collaboratively developed by physical education experts and experienced PE teachers from the kindergarten. It was created by upgrading and expanding the kindergarten’s existing sports curriculum, which included basketball and football and had been successfully implemented for three years. The upgraded curriculum incorporated additional ball activities, such as badminton, table tennis, and handball. During the 10-week intervention, this enhanced curriculum was used to teach children various ball skills in physical education (PE) classes. These sessions included “ball sense,” dribbling, passing, and gameplay. Outdoor classes featured both pre-set ball skills and optional area ball games. Skilled PE teachers guided the children through predetermined game scenarios during PE classes, where they demonstrated and explained basic ball skills and knowledge through games or stories. During the outdoor class time, the children had a high level of autonomy and could explore various ball-game stations independently. Each class was organised with a structure comprising a 5-minute warm-up, a 20–25-minute exercise session, and a 5-minute cool-down activity. Outdoor time allows for a significant level of autonomy. Apart from the optional ball skills activity once a week (K2) or twice a week (K3), participants could choose their exercise area during the remaining outdoor time, including options like the equipment area or bicycle zone. More details on how this programme may be implemented are available elsewhere [48].

Ordinary physical education (OPE group)

In the OPE group, PE classes were taught by a dedicated PE teacher who followed a specific kindergarten textbook. This textbook covered various themes related to health and physical activity, such as fundamental movement skills, and exercises promoting overall physical fitness. The outdoor class time for this group was the same as that of the HS group; however, the children were allowed to engage in free play in different areas.

Free play group (FP group)

In the FP group, preschoolers had the opportunity to freely play using various playground facilities, such as slides and sandboxes, under the supervision of kindergarten teachers who did not have a PE background.

Outcome measures

To assess physical fitness and emotional competence, a preschool physical fitness test battery and a teacher-reported questionnaire on children’s emotional competence were used [49]. All measurements were conducted

in the respective kindergartens. A team of trained and experienced researchers followed the standard operating procedures for the tests.

Physical fitness measures

The National Physical Fitness Measurement Standards Manual [50] was used; the physical fitness testing battery included anthropometric data (height, weight), sit and reach test, the standing long jump test, the double-leg timed hop test, the 10-m shuttle run, balance beam walking, and tennis ball throwing. Each participant is tested twice for each item, and the best result is recorded.

(1) Sit and reach test: This test measures the flexibility of the lower back and hamstrings, which is the ability of these muscle groups to stretch and allow a range of motion. Participants sit on the floor with legs extended straight ahead and reach forward as far as possible, keeping the knees straight. The distance reached is recorded.

(2) Standing long jump test: This test assesses explosive leg strength, defined as the ability of the leg muscles to exert maximum force in a short period of time. It is measured by the distance a participant can jump forward from a standing position.

(3) Double-leg timed hop test: This test evaluates lower body strength and power, which involves the ability of the leg muscles to generate force repeatedly over a period of time. Participants perform consecutive hops on both legs over ten soft blocks spaced 0.5 m apart on a flat surface. The total time taken to complete the hops is recorded from the start signal until both feet land past the tenth block.

10-m shuttle run: This test measures agility and speed, defined as the ability to change direction quickly and move rapidly. Participants run back and forth between two lines set 10 m apart as quickly as possible, touch an object with their hand at return line, then turn and sprint back to the starting line. The total time to complete a set number of shuttles is recorded.

Balance beam walking: This test assesses balance and coordination, the abilities to maintain body stability and control movements smoothly. Participants walk across a narrow beam without stepping off, and the time taken to complete the walk is recorded.

Tennis ball throwing test: This test measures upper body coordination and strength, defined as the ability of the upper body muscles to work together to produce a forceful and precise movement. Participants throw a tennis ball as far as possible from a designated point, and the distance the ball is thrown is recorded.

Emotional competence measures

The shortened version of the Social Competence and Behavior Evaluation Scale (SCBE-30) was used to measure the participants’ levels of emotional competency,

which developed by LaFreniere and Jean in 1996, the SCBE-30 comprises 30 items, each scored on a 6-point Likert scale, where 1 represents 'never' and 6 represents 'always' [51]. The scale includes three subdomains: social competence, anger aggression, and anxious withdrawal, and scoring for each subscale was calculated by summing the scores of specific items related to that factor. It has shown strong inter-rater and test-retest reliability, as well as strong internal consistency and temporal stability [51]. In this study, the Chinese version of the SCBE-30 [49] filled out for each child individually by their teacher. The scale exhibited strong internal consistency, with Cronbach's α values of 0.91 for the social competence dimension, 0.88 for the anger-aggression dimension, 0.91 for anxious withdrawal, and an overall Cronbach's α value of 0.92.

Procedure

Kindergarten students were recruited at the beginning of the school term in March 2022. The teacher placed an informed consent form in each student's backpack for parents to review. These forms included detailed information about the study's purpose, procedures, potential risks and benefits, and the confidentiality of the collected data. Contact information for the researchers was also provided, allowing parents to ask any additional questions. Researchers and teachers then screened the children whose parents returned the signed consent forms.

All measures were conducted within the kindergartens over a span of two weeks. For the physical fitness assessments, children were tested individually by trained researchers in a designated area within the kindergarten to minimize distractions. Prior to the testing, all children participated in approximately 5 min warm-up routine included light aerobic exercises, dynamic stretching. Each test was demonstrated by the researchers before the children performed them to ensure they understood the procedures. Adequate rest was provided between tests to ensure the children's comfort and optimal performance. For the emotional competence assessment, teachers completed the SCBE-30 questionnaire based on their observations of the children over the previous month. Teachers filled out the questionnaires in a quiet setting, free from interruptions, to ensure they could provide thoughtful and accurate responses. Researchers were available to clarify any questions regarding the questionnaire to ensure consistency in the responses.

Data collection and analysis

Analyses were performed using IBM SPSS (version 25.0; IBM, Armonk, NJ, USA). A normality study was conducted, and further descriptive statistics were obtained. Intragroup comparisons were performed using paired t-tests or Wilcoxon paired-sample tests based on the

data distribution or scoring criteria. The raw data of the physical fitness tests were analysed using a longitudinal model, employing a mixed-effects model (with gender, age, height, weight, and baseline data as covariates), and forest plots were created using the R programming language (R4.2.1). Using age and gender as covariates, a 3 (HS, OPE, and FP) \times 2 (baseline and after 10 weeks) mixed-model ANOVA comparison was employed for the SCBE data, considering the absence of baseline differences between the groups. The effect size, denoted by Partial η^2 ($p\eta^2$), was utilised to quantify the magnitude of the effect, with small (0.01), medium (0.06), and large (0.14) classifications.

Results

Effects of physical education on physical fitness among the three groups

The statistical differences in physical fitness parameters from pre- to the post-test among the children in the three groups were shown in Table 2. Significant improvements in pre-post differences were found for the HS, OPE and FP groups in standing long jump, and 10-m shuttle run. In addition, the HS group showed significant improvements in tennis ball throwing ($p < 0.05$), while the FP group demonstrated a significant increase in sit-and-reach test. The model showed that the HS group performed better than the FP group ($p < 0.05$) and had a small-to-medium effect size (0.036–0.121) in all tests except the sit and reach item ($F = 1.093$, $p = 0.337$). In addition, the HS group performed better than the FP group in tennis ball throwing ($F = 4.52$, $p = 0.012$). Both HS and OPE groups exhibited significantly greater improvements compared to FP group in the standing long jump ($F = 16.449$, $p < 0.001$), 10-m shuttle run ($F = 15.117$, $p < 0.001$), and balance beam walking ($F = 11.378$, $p < 0.001$) (Fig. 1).

Effects of physical education on emotional competence among the three groups

The SCBE results demonstrated no significant differences in the mean values of social competence [$F_{(2, 236)} = 2.772$, $p = 0.065$], anger aggression [$F_{(2, 236)} = 2.717$, $p = 0.068$], and anxious withdrawal [$F_{(2, 236)} = 3.037$, $p = 0.05$] among the three groups of children in their baseline level tests. Further analysis of the results showed no significant changes in the main effect of time in the three dimensions before and after the intervention ($p > 0.05$). The main effect of grouping was found on anger aggression [$F_{(2, 236)} = 3.801$, $p = 0.024$, Partial $\eta^2 = 0.031$] and anxious-withdrawal [$F_{(2, 236)} = 4.278$, $p = 0.015$, Partial $\eta^2 = 0.035$], with significant differences in scores among the three groups after the intervention; however, the corresponding interaction between grouping and time were not significant. Meanwhile, the results of the anxious-withdrawal levels showed an obvious grouping effect [$F_{(2, 236)} = 4.278$,

Table 2 Physical fitness of the children at pre-and post-test

		Pre-test (Mean ± SD)	Post-test Mean ± SD	Mean difference (95% CI)	P	Cohen'sd
Sit and reach (cm)	HS	10.26 ± 5.30	9.44 ± 5.15	-0.82 (-1.70, 0.05)	0.063	0.21
	OPE	8.94 ± 4.84	9.03 ± 4.88	0.09 (-0.77, 0.95)	0.831	0.02
Standing long jump (cm)	FP	7.35 ± 5.87	8.81 ± 4.22	1.47 (0.39, 2.54)	0.008*	0.30
	HS	96.40 ± 17.03	99.14 ± 17.75	2.74 (0.14, 5.34)	0.039*	0.23
	OPE	93.59 ± 18.20	98.24 ± 17.27	4.65 (1.47, 7.83)	0.005**	0.33
	FP	89.71 ± 18.21	85.71 ± 18.39	-4 (-6.9, -1.11)	0.007**	0.31
Double-leg timed hop(s)	HS	6.29 ± 1.51	5.50 ± 1.10	-0.79 (-1.07, -0.52)	<0.001**	0.65
	OPE	5.84 ± 1.20	5.87 ± 1.37	0.03 (-0.26, 0.33)	0.823	0.03
	FP	6.60 ± 1.80	6.22 ± 1.43	-0.39 (-0.73, -0.05)	0.024*	0.26
	HS	7.51 ± 0.76	7.23 ± 0.80	-0.29 (-0.48, -0.09)	0.004*	0.32
10-m shuttle run (s)	OPE	7.72 ± 0.86	7.41 ± 1.06	-0.32 (-0.60, -1.77)	0.026*	0.25
	FP	7.28 ± 0.96	7.91 ± 1.02	0.63 (0.35, 0.90)	<0.001**	0.51
Balance beam walking(s)	HS	6.77 ± 3.96	5.38 ± 2.11	-1.40 (-2.26, -0.53)	0.002*	0.36
	OPE	7.52 ± 3.85	5.05 ± 2.23	-2.47 (-3.16, -1.77)	<0.001**	0.79
	FP	6.15 ± 2.72	5.98 ± 2.26	-0.18 (-0.57, 0.22)	0.379	0.10
	HS	5.48 ± 1.90	6.03 ± 2.12	0.56 (0.18, 0.93)	0.004**	0.33
Tennis ball throwing (m)	OPE	5.67 ± 1.97	5.71 ± 2.10	0.04 (-0.40, 0.47)	0.868	0.02
	FP	5.99 ± 2.19	5.58 ± 2.22	-0.40 (0.87, 0.06)	0.087	0.19

Note: *p < 0.05, **p < 0.01. HS: Hello Sunshine group; OPE: ordinary physical education group; FP: free play group

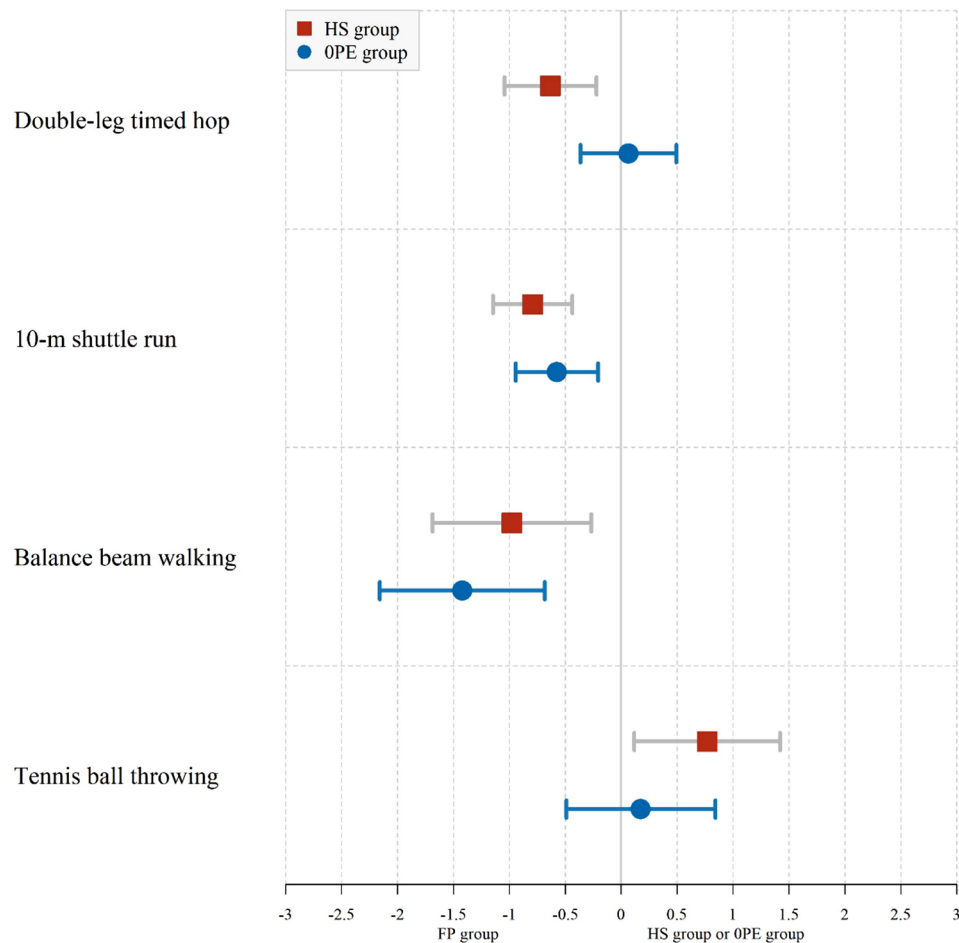


Fig. 1 Effects of the HS and OPE groups on physical fitness parameters compared to FP group, Sex, age, height, weight, and baseline values were adjusted as covariates. Data were presented as mean between-group differences with 95% confidence intervals (Note Double-leg timed hop, 10-m shuttle run, and Balance beam walking are compared based on timing (s), while Tennis ball throwing is compared based on distance (m). No significant differences were found in the three groups of sit-and-reach tests, so they were not shown in the figure. The wide confidence interval of the standing long jump results also affected the overall image quality and was not displayed)

$p=0.015$, $Partial\eta^2=0.035$], with a significant interaction effect observed between the grouping and time [$F_{(2, 236)}=7.802$, $p=0.001$, $Partial\eta^2=0.063$] (Table 3). Multiple comparisons indicated that there were no significant differences in anxiety scores among the groups before the intervention. However, after the intervention, both the HS group ($p=0.02$) and the FP group ($p<0.001$) showed significantly lower scores compared to the OPE group, with no significant difference observed between the HS and FP groups (Table 4).

Discussion

The preschool stage is widely recognised as a crucial period for implementing interventions aimed at promoting PA participation [52], owing to the strong plasticity of young children. It is believed that increasing PA levels during early childhood not only improves children's health and motor skills but also promotes healthy and active lifestyles in the longer term [53]. The vast majority

of children spend approximately eight hours per day in daycare (mainly kindergartens) [54]. As key intervention environments for PA participation, kindergartens have many advantages and can produce a wide range of public health benefits. This quasi-experimental study explored the effects of the HS intervention curriculum on children's physical fitness and emotional competence and compared them with the effects of the interventions in the OPE and FP groups.

Beneficial effects on physical fitness

The results of the present study showed significant improvements in most of physical fitness measures after ten -weeks physical exercise intervention, with the HS and OPE groups showing better results than FP group in terms of explosive leg power (standing long jump), agility and speed (10-m shuttle run), and dynamic balance (balance beam walking), and HS group having a longer tennis throwing distance compared to the other groups. This

Table 3 Comparison of SCBE score in three groups before and after the intervention

Variable	Time effect			Group effect			A group-by-time interaction effect				
	Pre-Test ^a Mean ± SE	Post-Test ^b Mean ± SE	F	p	Partialη ²	F	p	Partialη ²	F	p	Partialη ²
SCBE subset											
Social Competence											
HS Group	4.19 ± 0.09	4.28 ± 0.09	0.933	0.335	0.004	3.006	0.051	0.025	0.287	0.751	0.002
OPE Group	3.94 ± 0.09	4.04 ± 0.09									
FP Group	3.88 ± 0.09	4.04 ± 0.09									
Anger Aggression											
HS Group	1.89 ± 0.07	1.83 ± 0.06	2.969	0.086	0.013	3.801	0.024*	0.031	1.473	0.231	0.012
OPE Group	2.06 ± 0.07	2.03 ± 0.06									
FP Group	2.15 ± 0.07	2.04 ± 0.06									
Anxious-withdrawal											
HS Group	1.99 ± 0.08	1.93 ± 0.07	0.171	0.680	0.001	4.278	0.015*	0.035	7.802	0.001**	0.063
OPE Group	2.24 ± 0.08	2.19 ± 0.07									
FP Group	2.24 ± 0.08	1.81 ± 0.07									

Note^a age and gender as Covariates in the model; ^bp < 0.05; ** p < 0.01; HS: Hello Sunshine; OPE: ordinary physical education; FP: free play

result concurs with previous studies, wherein structured PA course interventions improved physical fitness. In a quasi-experimental study, after a nine-month structured multi-sport programme (60 min of basic/gross and fine motor skills and ball play-based exercises twice a week), children showed sustained improvements in physical fitness, particularly strength, speed, agility, and flexibility [38]. Another study of a 30-minute PA intervention and PA homework for 4-to-5 years old children over one academic year discovered improvements in static balance (single-leg stance), explosive leg strength (standing long jump), jumping coordination, and agility during the follow-up period [55]. Wang et al. [33] compared the effects of a 16-week programme among our physical exercise interventions on physical fitness of children aged 4–5 years and found that the ball games and multiple activity groups had an advantage over the basic movements group and rhythm activities group in terms of improving physical fitness. As suggested by similar studies, diverse PA modules and structured multi-sport programmes have demonstrated notable benefits in enhancing physical fitness in preschoolers when compared to free play or regular PA [38, 56]. This study explored the effect of the “Hello Sunshine” programme, a ball skills-based programme that teaches children a variety of motor skills and encourages them to repeatedly practice them. Abundant research evidence supports a significant positive correlation between fundamental movement skills and cardiovascular health, as well as muscle strength and endurance [57, 58]. Strong evidence indicates a positive association between fundamental movement skills proficiency and PA levels in children and adolescents [59]. Considering the Stodden’s classic conceptual model [60], the development of motor skill competence is regarded as a primary underlying mechanism for promoting engagement in PA and fitness, which partly explains why the HS group improved their performance on most physical tests more than the other groups. However, we also found that the lower back and legs flexibility did not change significantly in HS and OPE groups except for the FP group, indicating a need for targeted exercises to improve flexibility.

Beneficial effects on emotional competence

Based on previous research, this study controlled for age and gender variables to provide a clearer understanding of how the interventions impacted the children’s emotional competence and social behavior. Intragroup comparisons showed no significant effects in social competence, anger aggression, and anxiety withdrawal in the three groups after the intervention compared with baseline data. However, anger aggression in the HS group was significantly lower than in the FP group after intervention. Further, the anxious-withdrawal score was significantly different among the three groups, with the

Table 4 Multiple comparisons in the means of anxious-withdrawal score in three groups between pre-and post-test

Time	(i) group	(j) group	Mean difference (I-J)	Std. error	p^b	95% confidence interval for difference ^b	
Pre-test	HS	OPE	-0.246	0.113	0.09	-0.52	0.03
		FP	-0.249	0.114	0.09	-0.52	0.03
	OPE	HS	0.246	0.113	0.09	-0.03	0.52
		FP	-0.003	0.112	1	-0.27	0.27
	FP	HS	0.249	0.114	0.09	-0.03	0.52
		OPE	0.003	0.112	1	-0.27	0.27
Post-test	HS	OPE	-0.260*	0.097	0.02*	-0.50	-0.03
		FP	0.117	0.098	0.7	-0.12	0.35
	OPE	HS	0.260*	0.097	0.02*	0.03	0.50
		FP	0.378*	0.097	<0.001**	0.14	0.61
	FP	HS	-0.117	0.098	0.7	-0.35	0.12
		OPE	-0.378*	0.097	<0.001**	-0.61	-0.14

Note^b Adjustment for multiple comparisons: Bonferroni; * $p < 0.05$; HS: Hello Sunshine; OPE: ordinary physical education; FP: free play

scores of the HS and FP groups showing a significant decrease compared to the OPE group. Previous research has focused on the impact of interventions on young children's social competence and socio-emotional competence; for example, studies have reported that structured play-based activities during recess have a positive impact on the development of preschool children's social skills [61, 62] and that physical training has a significant positive effect on preschoolers' social skill level [63, 64]; on the other hand, social-emotional competence refers to emotional and social competence working together towards adaptive behaviour [65]. No significant changes in social competence were found in this study, which may be due to insufficient intervention time, or excessive emphasis on safe social distancing in both teaching strategies and the daily health care atmosphere during the pandemic, which affected children's social development. Rodrigues et al.'s [41] systemic review suggested that there was an absence of research evidence on the effects of exercise on anger/aggression and anxiety/withdrawal, and highlighted that of all the body-oriented interventions, play programmes received the most research attention and exhibited the highest efficacy in fostering social-emotional development. Free play is a prevalent form of play that enables children to explore their bodies and experience emotional changes [41]. In contrast, pretend play, which involves children taking on different roles and scenarios, is thought to develop emotion comprehension and regulation and prosocial behaviour [66, 67]. Pretend play is considered an activity that is more often engaged in by 5-year-olds in the context of free play [66]. In our FP group, free play, including pretend play and other spontaneous activities, was the main form of physical activity for children and occurred in a more relaxed environment, which may be beneficial for reducing anxiety and withdrawal. However, similar to Chinkesh et al.'s study [68], structured group games in

the HS groups also improved emotional abilities. It has been proposed that motor skill levels in infancy and early childhood predict anxiety levels during the school-age period [69]. Children with higher levels of motor skills may exhibit greater self-belief. The research further indicates that motor skills intervention can enhance children's self-beliefs, consequently reducing psychological issues such as anxiety [70]. This, to some extent, explains the potential reasons behind the HS intervention.

Broadly, this study compared three mainstream PE models in Chinese preschools to evaluate their impact on child physical health and emotional competence development. The strengths of this study included its quasi-experimental design, which allowed for a more controlled comparison of the different interventions, reflecting real-world applicability. Additionally, the comprehensive assessment of both physical fitness and emotional competence provided a holistic view of the children's development. Moreover, focusing on a preschool population highlighted the critical period for development and underscored the potential long-term benefits of early physical education interventions. However, several limitations must be addressed: (1) the subjective scale (SCBE-30) can be influenced by social desirability biases or inaccurate perceptions; (2) the study did not extensively account for potential confounding factors that may influence the outcomes, such as prior exposure to physical education or variations in teaching quality among different educators; (3) the long-term sustainability and durability of the observed benefits have not been thoroughly explored; and (4) this study focuses on a specific region in China, it may be limited in generalisability to other populations or settings. Long-term follow-up studies would provide more insight into the lasting effects of the intervention and reveal the underlying mechanism. Additionally, investigating the integration of effective physical

exercise programmes into preschool curricula holds the potential for promoting holistic development.

Conclusions

In summary, this study compared three mainstream physical education models in Chinese preschools, focusing on the efficacy of the “Hello Sunshine” physical education program. The results indicate that structured ball skills training not only promotes physical health but also significantly reduces anxiety in children. This finding underscores the potential of integrating effective physical exercise programs into preschool curricula to foster holistic development.

Abbreviations

PA	Physical activity
FMS	Fundamental movement skills
PE	Physical education
HS group	“Hello Sunshine” programme group
OPE group	Ordinary physical education group
FP	Free play group
SCBE	Social competence and behavior evaluation scale

Supplementary Information

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Supplementary Material 1

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Author contributions

H.W.: conceptualization, methodology, writing—original draft; H.R.: preparation, data curation; W.E.: conceptualization, reviewing; W.L.: investigation and data collection. All authors have read and agreed to the published version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data availability

The data are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Institutional Review Board Statement: We confirm that informed consent was obtained from the legally authorized representatives (LARs) or next of kin of all minors (less than 16 years of age) who participated in the study. The LARs or next of kin were provided with detailed information about the study, including its purpose, procedures, risks, and benefits, and gave their

voluntary and informed consent on behalf of the minors. All LARs or next of kin were informed that participation in the study was entirely voluntary and that they could withdraw their consent at any time. The study was conducted in accordance with the Declaration of Helsinki and approved by KhonKaen University Ethics Committee for Human Research (HE642100).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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