Ge et al. BMC Public Health (2025) 25:739
https://doi.org/10.1186/s12889-025-21985-0

BMC Public Health

RESEARCH

Open Access

Evaluating the impact of motor quotient physical fitness training on health-related fitness indicators and obesity risk in children aged 7–8 years in Tianjin, China

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Abstract
This study aimed to evaluate the impact of Motor Quotient (MQ) physical fitness training on health-related fitness indicators and obesity risk in children aged 7–8 years in Tianjin, China. A total of 60 obese participants were randomly divided into an experimental group ($N=30$) and a control group ($N=30$). The intervention program focused on improving children's physical, behavioral, and task-related capabilities through structured MQ training. Key results indicated that the experimental group demonstrated significant improvements in Body Mass Index (BMI), with a reduction from 21.28 ± 1.15 kg/m^2 to 18.86 ± 1.24 kg/m^2 for boys ($p<0.001$) and from 21.04 ± 1.54 kg/m^2 to 17.47 ± 1.07 kg/m^2 for girls ($p<0.001$). Physical performance metrics improved substantially, including enhanced 2×30 m Shuttle Run times (boys: +12.97%, girls: +13.96%, both $p<0.001$) and increased Plank duration (boys: +41.36%, girls: +35.26%, both $p<0.01$), reflecting improved cardiovascular endurance and core strength. Significant gains were also observed in task-related motor skills, such as Hand-eye Coordination, Behavior Imitation, and Reaction capability (all $p<0.001$). Behavioral adaptations included higher scores in exercise behavior ($p<0.01$), while strong correlations were found between BMI and cardiovascular fitness indicators, such as the 20 m Backward Run ($r=0.974$, $p<0.001$). These findings highlight the effectiveness of MQ training in reducing obesity risk and improving multidimensional fitness outcomes. The program demonstrates significant potential as a practical and evidence-based strategy to promote health-related fitness and motor development in children.

Keywords Childhood obesity, Public health, Motor quotient, Physical fitness, Intervention

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Introduction

Childhood obesity is a major global public health challenge [1, 2]. Historically, China boasted one of the leanest populations globally; however, a concerning shift has occurred. National statistics show a progressive climb in the prevalence of overweight and obesity among school-age children in China, escalating from less than 3.0% in 1985, to 5.3% in 1995, and startlingly reaching approximately 20.0% by 2020 [3, 4]. Furthermore, recent projections depict a concerning trend, anticipating a significant increase in overweight and obesity rates among Chinese children and adolescents aged 7–18 years, with estimates reaching 32.7% by 2030 [5]. Obesity is a chronic disease with far-reaching implications. It is associated with a myriad of health problems, including cardiovascular disease, type 2 diabetes, high blood pressure, chronic liver disease, musculoskeletal problems, and a range of psychological disorders such as depression and anxiety and low self-esteem [6, 7]. Moreover, the mental well-being of children is often compromised as obesity renders them susceptible to stigmatization, social isolation, binge eating [8], discrimination and bullying [6, 9].

Tacking childhood obesity in China is a multifaceted endeavor necessitating a concerted effort among families, schools, public health agencies, healthcare providers, and government entities. In this vein, public policies and environmental interventions are pivotal in promoting healthier nutritional and physical activity choices for children [1, 4]. Among the myriad strategies, the positive impact of sports and physical fitness training on children and adolescents' metabolic activity, obesity reduction, and psychological well-being is well-documented. Exercise, a structured form of physical activity, plays a vital role in public health by preventing and treating a variety of physical conditions including obesity, metabolic, and cardiovascular diseases [10]. Physical fitness training, extended physical activity, is shown to have favorable effects on body composition, muscular fitness, cardiorespiratory fitness, and is associated with better psychological well-being, including reduced psychological distress and enhanced optimism and self-esteem in overweight/obese children [11]. Engaging in physical activity from a young age plays a significant role in preventing overweight and obesity during childhood, adolescence, and even into adulthood [12].

The concept of physical fitness entails a person's adaptability to a variety of physical activities, and it plays a significant role in aiding obesity reduction by accelerating metabolism, promoting fat burn, and reducing body fat accumulation [13]. Pursuing physical fitness through exercise can improve several metabolic risk factors independently of weight loss, offering substantial health benefits to obese and overweight individuals [14].

With the growing problem of childhood obesity in recent years, more and more research has begun to focus on the role of physical education programs in alleviating childhood obesity. According to a study published in the journal Biology [15], a structured physical education program has a significant positive impact on weight management and overall health in obese children. The study noted that regular participation in physical activity was effective in reducing the body mass index (BMI) of obese children while improving their cardiovascular health and metabolic markers. In addition, physical education programs not only work on a physical level but also bring about positive changes on a psychological and social level [8]. Obese children who participate in physical activity show higher self-esteem and self-confidence, reducing the psychological stress associated with weight problems. This overall health enhancement helps obese children to better integrate into society, enhancing their social skills and teamwork. Therefore, physical education courses provide a comprehensive health intervention program for obese children by increasing physical activity, improving metabolic function and enhancing psychological well-being. These physical education programs not only help to reduce weight but also promote the overall development of children and lay a solid foundation for their future health. Gender is an important factor influencing physical function in adolescents. Studies have shown that due to differences in developmental rates between genders, adolescents of different sexes exhibit significant differences in motor function and physical activity performance [16].

Motor Quotient (MQ) was first proposed in the 1980s and was initially used as a means of early screening for delays in motor skill development, based on the finding that motor skills are interrelated and thus allow for earlier detection of motor delays. Arnold J. et al. revised it by substituting a measure of age at attainment of optimal motor performance for the measure of optimal motor performance at screening [17]. Scientists worldwide have used this method to conduct studies on motor skills, motor performance, and related topics. Numerous studies have demonstrated a strong correlation between the Motor Quotient and the development and maintenance of motor skills, motor performance, and motor ability, and the Motor Quotient plays a critical role in understanding and improving motor skills and performance. As researchers continue to explore this relationship, it is apparent that the Motor Quotient can serve as a valuable tool for assessing and improving motor skills in diverse populations, especially for children [18, 19]. Chinese research on Motor Quotient is exemplified by Wang Zongping, who created a Motor Quotient assessment scale for Chinese children by considering the developmental characteristics of their motor skills, along with

Chinese physical education scenarios and physical fitness monitoring needs [20].

MQ seeks to elevate the importance of consistent physical activity and embed a culture of lifelong sports engagement. MQ offers a holistic understanding of an individual's physical attributes, including inherent talent, physical quality, sports psychology, and more [21].

The combination of physical training and MQ is an effective way to improve children's health and athleticism. The MQ emphasizes the comprehensive development of motor skills and physical fitness. Through physical training, children's muscle strength, endurance, agility and flexibility can be enhanced, laying the foundation for the improvement of motor quotient. For example, strength training not only significantly improves participants' muscle strength, but also significantly improves motor coordination, including balance, agility and dynamic stability. Research has shown that strength training promotes motor skill refinement and coordination by enhancing neuromuscular control and recruitment of motor units [22]. At the same time, improved MQ in turn promotes the effectiveness of physical training, making children more confident and efficient in sport. For example, when designing training programs, fun sports games can be combined with physical fitness exercises to stimulate children's interest and increase their participation. This complementary training approach not only helps to improve children's physical fitness, but also develops their interest and habits in sports, laying the foundation for lifelong sports.

Research indicates a link between obesity and deteriorating motor skills, suggesting that early interventions focusing on MQ could potentially boost children's physical activity levels and overall fitness [23, 24]. Enrichment of motor skill reserves and good motor performance can have a positive effect on children's physical activity and physical activity levels, and thus have a good intervention effect on childhood obesity [24].

Numerous studies show associations between the MQ and motor performance, physical activity, and obesity. However, there are few direct interventions for MQ and obesity. This study evaluated the effects of MQ-based physical fitness training on 7–8-year-old obese children in Tianjin, China. Through a 13-week intervention, we aimed to explore the effects on physical performance indicators to reveal the potential of physical training in mitigating the risk of childhood obesity. This study creates a fun physical activity program with a motivational quotient and observes the intervention effects from a motor quotient perspective on obese children to elucidate the potential of physical fitness training in reducing childhood obesity. This provides support for the application of physical fitness training program in childhood obesity intervention, with important theoretical and practical implications.

Materials and methods

Research object

This study employed a stratified random sampling method. Height and weight measurements were conducted using a free-standing stadiometer. The research focuses on the body mass index (BMI) calculation method and the overweight and obesity thresholds for school-age children, as defined in the Chinese health industry standard WS/T586-2018 "Screening for Overweight and Obesity in School-Age Children and Adolescents," issued on February 23, 2018 [25]. For boys aged 7, the obesity threshold for BMI is set at 17.7, while for girls of the same age, it is 17.5. At the age of 8, these thresholds rise to 19.7 for boys and 19.4 for girls. The detailed process of stratified random sampling was as follows: (1) The researchers divided the obese children into groups of boys and girls according to gender. Then, 15 boys and 15 girls were randomly selected from each group using a random number generator to ensure that the sample was balanced in terms of gender. (2) The researchers used SPSS to generate random numbers. Each obese child was assigned a unique number and then sorted according to the order of the size of the random numbers, selecting the top 15 boys (mean BMI = 21.3 kg/m^2) and the top 15 girls (mean BMI = 21.1 kg/m^2) into the experimental and control groups. (3) The list of 60 obese children screened was validated to ensure that they met the inclusion criteria for the study. Children with other chronic diseases or unfit for physical activity were excluded. (4) The 60 obese children were randomly divided into an experimental group and a control group of 30 children each. The experimental group underwent MQ physical training for 13 weeks, while the control group participated in regular physical activities at school. Considering the subject children's normal participation in physical fitness monitoring and physical education classes at school, the study conducted individual interviews with parents about the health status of the subject children to ascertain that the subject children had no other health problems.

Ethics approval

Informed consent was obtained from all participants before the study. The research adhered to the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Tianjin Normal University, China (Approval No. 2023102301) on October 23rd, 2023. Consent forms were signed by the parents or guardians of all child participants, agreeing to their involvement in the study, with all information being treated with strict confidentiality.

Intervention

The course training occurs four times weekly, incorporating MQ elements into its exercise methods. In planning the content and intensity of MQ fitness training, we referenced the CDC's requirements for effective modes and intensities of physical activity for 7- to 8-year-old [26], used moderate- or vigorous-intensity aerobic exercise, and controlled the overall session load density with target heart rate measurements in the trials [27], all of which were conducted under instructor supervision and in a safe environment. The physical fitness training program consists of four distinct parts.

The first section, the warm-up exercise, spans 10 min and includes various activities such as running exercises and simple stretching under the supervision of a physical fitness coach.

The second segment, lasting 20 min, is dedicated to sports quality exercise. This part concentrates on teaching children's various sports skills, including basketball, volleyball, soccer, and shot-put. It also aims to boost their basic physical fitness, encompassing strength, speed, endurance, and multiple sensory abilities like agility, balance, and coordination.

(c) The third part involves team sports games, occupying 10 min.
(d) The final section, spanning 5 min, consists of relaxation activities. In this section, the physical fitness coach leads children stretching and relaxing their entire body muscles.

Subjects in the experimental group completed an 8-week MQ physical fitness program, with four sessions per week, each lasting at least 45 min. The collective practice density should not be lower than 75%, while the individual practice density should be maintained at no less than 50%. The control group followed the regular physical education curriculum of the school, which was designed in accordance with the Compulsory Education Physical Education and Health Curriculum Standards (2022 Edition) [28].

Experimental group subjects were instructed not to engage in any other training during the 13-week experiment, which included 2 weeks of screening, 1 week of pre-experiment, 1 week of pre-test, 8 weeks of intervention, and 1 week of post-test. The physical education instructors involved in the intervention were blinded to the specific research hypotheses and received training solely on the exercise intervention protocols. The project has established a collaborative relationship with the school where the experiment was conducted. After obtaining explicit consent from the guardians of the participants, the school coordinated the scheduling to ensure the smooth progress of the study and the full participation of the subjects. To enhance the motivation and compliance of the participants, the project team provided small gifts to those who fully participated in the intervention on a weekly basis.

Result measurement and evaluation indicators

The evaluation system in this study is based on the Newell model [20]. A consensus among twelve field experts confirmed that the scale's content is relatively independent and effectively represents the development of motor abilities in children. The scale encompasses multiple dimensions, including physical fitness (e.g., strength, endurance, speed, flexibility, and agility), motor skills (both fundamental and specialized), sports psychology (e.g., motivation, self-confidence, and teamwork), and behavioral performance (e.g., exercise habits and attitudes). The scale was developed through a structured process involving theoretical foundation, item design, sample testing, data analysis, and optimization, exhibiting strong reliability and validity with internal consistency reliability coefficients (Cronbach's Alpha) ranging from 0.6 to 0.8 across different age groups and genders. The measurement scale comprises three dimensions: Body Quotient, Behavioral Quotient, and Task Quotient, with an accompanying distribution map of MQ tasks and measurement indicators.

The body quotient dimension integrates various references, such as the Chinese student physical health standards, FITNESSGRAM, ACSM exercise testing, and exercise prescription guidelines. It comprises seven testing indicators: BMI, strength, speed, endurance, agility, flexibility, and balance. The behavioral quotient dimension employs a questionnaire specifically designed for 7-8-year-old children, created by the research team. This questionnaire, drawing from resources like the International Physical Activity Scale [29], Exercise Behavior Scale [30], and Exercise Attitudes and Beliefs Scale [31]. For the questionnaire comprises 20 questions, high correlation coefficients—0.93 for exercise behavior, 0.93 for exercise psychology, and 0.97 for living labor—indicate the questionnaire's high reliability. In the task quotient dimension, the action development test is based on the Peabody motor development scale [32] and the assessment for the development of large muscle groups, among others.

Statistical analysis

Descriptive statistics were utilized to present the anthropometric data and task quotient test results, including mean values, standard deviation, minimum, and maximum. The normality of the BMI distribution in obese children was initially confirmed. An independent samples t-test, post-hoc Anova analysis was conducted to investigate gender differences within the sample. Subsequently, the pre- and post-intervention task quotient indicators for both genders were analyzed to assess the intervention's effectiveness and identify potential gender-based disparities. Additionally, a correlation analysis using Pearson's coefficient was performed to explore the relationship between BMI and motor quotient indicators. All analyses were conducted with a significance level set at $p < 0.05$, using SPSS 29.0 software.

Results

Comparison of test results between two groups of children before and after the experiment

The present study investigated the effects of intervention on children's physical, behavioral, and task-related capabilities through a comprehensive assessment framework. Statistical analysis using independent t-tests revealed significant differences between the experimental ($N = 30$) and control groups ($N = 30$) across multiple dimensions (Table 1). In terms of Body Quotient indicators, the experimental group demonstrated substantial improvements post-intervention. Body Mass Index (BMI) showed a significant reduction in the experimental group (18.16 ± 1.34 kg/m²) compared to the control group (21.14 ± 1.2 kg/m²; t = 9.044, $p < 0.01$). Physical performance metrics exhibited notable enhancements, including 2 × 30 m shuttle run (experimental: 21.22 ± 1.53 vs. control: 23.99 ± 1.2; t = 7.821, $p < 0.01$), plank exercise duration (experimental: 18.03 ± 4.58 vs. control: 13.04 ± 3.65; t=-4.67, $p < 0.01$), sit and reach flexibility (experimental: 3.27 ± 1.21 vs. control: 2.53 ± 1.40; t=-2.197, $p < 0.05$), and 20 m backward run (experimental: 22.86 ± 1.57 vs. control: 24.20 ± 0.95; t = 4.005, $p < 0.01$). Regarding Behavioral Quotient measurements, significant improvements were observed in exercise behavior (experimental: 23.93 ± 2.38 vs. control: 22.50 ± 0.94; t=-3.072, $p < 0.01$) and living labor capabilities (experimental: 11.07 ± 0.91 vs. control: 11.53 ± 0.63; t = 2.316, $p < 0.05$). These findings suggest enhanced behavioral adaptation and motor learning outcomes in the experimental group. Task Quotient analysis revealed significant advancements in multiple domains. The experimental group showed superior performance in arm-up squat (4.00 ± 0.59 vs. 2.67 ± 0.48; t=-9.633, $p < 0.01$), hand-eye coordination (3.97 ± 0.67 vs. 3.00 ± 0.53; t=-6.227, $p < 0.01$), behavior imitation (3.97 ± 1.03 vs. 3.03 ± 0.41; t=-4.592, $p < 0.01$), specialized skills (3.70 ± 0.53 vs. 2.93 ± 0.52; t=-5.624, $p < 0.01$), and reaction capability (3.40 ± 0.86 vs. 2.67 ± 0.61; t=-3.832, $p < 0.01$). Notably, several parameters including one-minute rope skipping, throw solid balls, exercise psychology, ball handling, lunge squat, and dynamic context showed no statistically significant differences between groups ($p > 0.05$). These findings collectively demonstrate that the intervention protocol effectively enhanced multiple aspects of physical

Table 1 T test results of two groups of children before and after the experiment

Test Indicators		Before the Experiment					After the Experiment				
		Control Group (*N* = 30)	Experimental Group (*N* = 30)	F	t	*p*	Control Group (*N* = 30)	Experimental Group (*N* = 30)	F	t	*p*
Body Quotient	BMI(kg/m²)	21.27 ± 1.27	21.16 ± 1.34	0.058	0.326	0.746	21.14 ± 1.2	18.16 ± 1.34	0.147	9.044	0.000**
	2×30m Shuttle Run	24.30 ± 1.26	24.53 ± 1.48	0.242	-0.630	0.531	23.99 ± 1.2	21.22 ± 1.53	0.503	7.821	0.000**
	Plank	13.10 ± 3.73	13.02 ± 4.58	0.857	0.071	0.944	13.04 ± 3.65	18.03 ± 4.58	1.494	-4.67	0.000**
	One-minute Rope Skipping	22.80 ± 5.12	23.13 ± 5.70	0.040	-0.238	0.812	23.53 ± 5.03	25.8 ± 5.07	0.021	-1.738	0.088
	Sit and Reach	2.60 ± 1.63	2.48 ± 2.19	1.571	0.241	0.811	2.53 ± 1.40	3.27 ± 1.21	0.092	-2.197	0.032*
	Throw Solid Balls	2.30 ± 0.43	2.30 ± 2.19	0.000	0.000	1.000	2.42 ± 0.45	2.44 ± 0.40	0.323	-0.183	0.855
	20m Backward Run	24.33 ± 1.17	24.27 ± 0.96	1.443	0.205	0.838	24.20 ± 0.95	22.86 ± 1.57	4.468	4.005	0.000**
Behavioral Quotient	Exercise Behavior	22.37 ± 1.17	24.27 ± 0.96	0.001	0.309	0.758	22.50 ± 0.94	23.93 ± 2.38	26.498	-3.072	0.004**
	Exercise Psychology	22.63 ± 0.93	22.67 ± 1.09	0.595	-0.127	0.899	22.63 ± 0.56	22.13 ± 1.43	12.040	1.783	0.083
	Living Labor	11.37 ± 0.81	11.23 ± 1.01	1.360	0.566	0.574	11.53 ± 0.63	11.07 ± 0.91	3.425	2.316	0.024*
Task Quotient	Arm-up Squat	2.87 ± 0.51	2.93 ± 0.52	0.125	-0.502	0.617	2.67 ± 0.48	4.00 ± 0.59	1.450	-9.633	0.000**
	Ball Handling	1.67 ± 0.48	1.60 ± 0.50	1.069	0.528	0.599	1.77 ± 0.50	1.67 ± 0.66	4.960	0.659	0.513
	Hand-eye Coordination	3.17 ± 0.53	3.33 ± 0.88	8.119	-0.885	0.380	3.00 ± 0.53	3.97 ± 0.67	2.325	-6.227	0.000**
	Behavior Imitation	3.10 ± 0.61	3.20 ± 0.76	4.245	-0.562	0.576	3.03 ± 0.41	3.97 ± 1.03	27.485	-4.592	0.000**
	Specialized Skills	2.70 ± 0.47	2.70 ± 0.53	0.683	0.000	1.000	2.93 ± 0.52	3.70 ± 0.53	3.128	-5.624	0.000**
	Lunge Squat	1.93 ± 0.52	1.70 ± 0.47	1.728	1.892	0.073	2.10 ± 0.55	1.97 ± 0.49	0.929	0.994	0.325
	Dynamic Context	1.67 ± 0.55	1.60 ± 0.56	0.326	0.465	0.644	1.73 ± 0.58	1.53 ± 0.57	0.473	1.342	0.185
	Reaction	2.40 ± 0.50	2.40 ± 0.81	6.197	0.000	1.000	2.67 ± 0.61	3.40 ± 0.86	3.896	-3.832	0.000**

Note: *p<0.05, **p<0.01

Table 2 Post-hoc Anova result between two groups before and after the experiment

	Test Indicators	F	p
Body Quotient	**BMI**	41.373	< 0.001**
	2 × 30 m Shuttle Run	37.900	< 0.001**
	Plank	10.732	< 0.001**
	One-minute Rope Skipping	2.010	0.116
	Sit and Reach	1.521	0.213
	Throw Solid Balls	0.902	0.443
	20 m Backward Run	10.544	< 0.001**
Behavioral Quotient	**Exercise Behavior**	7.627	< 0.001**
	Exercise Psychology	1.781	0.155
	Living Labor	1.633	0.186
Task Quotient	**Arm-up Squat**	39.110	< 0.001**
	Ball Handling	0.485	0.694
	Hand-eye Coordination	11.993	< 0.001**
	Behavior Imitation	10.297	< 0.001**
	Specialized Skills	25.418	< 0.001**
	Lunge Squat	3.229	0.025*
	Dynamic Context	0.693	0.558
	Reaction	13.339	< 0.001**

Note: *p<0.05, **p<0.01

fitness, behavioral adaptation, and task-specific performance capabilities, particularly in areas requiring complex motor control and coordination. The results provide compelling evidence for the efficacy of the implemented intervention strategy in improving children's overall physical and behavioral development.

The post-hoc ANOVA analysis revealed significant differences between the two groups across multiple dimensions (Table 2). In terms of Body Quotient, significant differences were observed in BMI (F = 41.373, $p < 0.001$), 2 × 30 m Shuttle Run (F = 37.900, $p < 0.001$), Plank (F = 10.732, $p < 0.001$), and 20 m Backward Run (F = 10.544, $p < 0.001$). However, One-minute Rope Skipping, Sit and Reach, and Throw Solid Balls showed no significant differences between groups ($p > 0.05$). Within the Behavioral Quotient category, Exercise Behavior demonstrated significant differences (F = 7.627, $p < 0.001$), while Exercise Psychology and Living Labor showed no significant differences between groups ($p > 0.05$). The Task Quotient analysis revealed significant differences in several parameters: Arm-up Squat (F = 39.11, $p < 0.001$), Hand-eye Coordination (F = 11.993, $p < 0.001$), Behavior Imitation (F = 10.297, $p < 0.001$), Specialized Skills (F = 25.418, $p < 0.001$), and Reaction (F = 13.339, $p < 0.001$). Lunge Squat showed moderate significance (F = 3.229, $p < 0.05$), while Ball Handling and Dynamic Context showed no significant differences between groups ($p > 0.05$).

Comparison of test results for children of different genders

Table 3 presents the MQ Indicator Test results for boys in the experimental group after the intervention ($N = 15$). Significant improvements were observed in several key indicators. The Body Mass Index (BMI) decreased from 21.28 ± 1.15 kg/m² before the experiment to 18.86 ± 1.24 kg/m² afterwards, representing a reduction of 11.40% ($p < 0.001$). The 2 × 30 m Shuttle Run time improved significantly, with the average time dropping from 23.69 ± 0.68 to 20.62 ± 0.99, a 12.97% increase in performance (t = 11.152, $p < 0.001$). Additionally, the Plank performance showed a notable increase from 13.34 ± 4.46 to 18.86 ± 5.85, demonstrating a 41.36% improvement

Table 3 MQ Indicator Test results of boys in the Experimental Group after the experiment($N = 15$)

Test Indicators		Before the Experiment	After the Experiment	t	p	Significant Increase Rate
Body Quotient	**BMI(kg/m²)**	21.287 ± 1.146	18.86 ± 1.243	19.753	0.000**	-11.40%
	2 × 30 m Shuttle Run	23.693 ± 0.682	20.62 ± 0.986	11.152	0.000**	12.97%
	Plank	13.347 ± 4.457	18.867 ± 5.847	-4.403	0.001**	41.36%
	One-minute Rope Skipping	24.467 ± 5.939	28.333 ± 4.169	-2.591	0.021*	15.80%
	Sit and Reach	1.533 ± 2.214	3.407 ± 1.499	-3.622	0.003**	122.24%
	Throw Solid Balls	2.367 ± 0.564	2.34 ± 0.414	0.156	0.879	
	20 m Backward Run	24.827 ± 0.811	23.593 ± 1.425	5.486	0.000**	4.97%
Behavioral Quotient	**Exercise Behavior**	22.8 ± 0.862	25 ± 2.45	-3.696	0.002**	9.65%
	Exercise Psychology	22.933 ± 0.799	22.4 ± 1.682	1.258	0.229	
	Living Labor	11.267 ± 1.033	11.067 ± 1.033	0.509	0.619	
Task Quotient	**Arm-up Squat**	3.067 ± 0.258	4.133 ± 0.64	-5.87	0.000**	34.76%
	Ball Handling	1.6 ± 0.507	1.733 ± 0.594	-0.564	0.582	
	Hand-eye Coordination	3.4 ± 0.633	4.4 ± 0.507	-4.583	0.000**	29.41%
	Behavior Imitation	3.533 ± 0.516	4.133 ± 1.06	-1.964	0.07	
	Specialized Skills	2.667 ± 0.488	3.733 ± 0.458	-16	0.000**	39.97%
	Lunge Squat	1.933 ± 0.258	2.067 ± 0.458	-1	0.334	
	Dynamic Context	1.533 ± 0.516	1.6 ± 0.507	-0.323	0.751	
	Reaction	2.467 ± 0.834	3.467 ± 0.916	-3.623	0.003**	40.54%

Note: *p<0.05, **p<0.01

(t=-4.403, $p=0.001$). Furthermore, the One-minute Rope Skipping improved by 15.80% ($p=0.021$), and the Sit and Reach test indicated a remarkable enhancement of 122.24% ($p=0.003$). Similarly, Table 4 illustrates the MQ Indicator Test results for girls in the experimental group ($N=15$). The average BMI decreased significantly from 21.04 ± 1.54 kg/m² to 17.47 ± 1.07 kg/m², marking a substantial 16.98% reduction (t = 5.802, $p<0.001$). The 2 × 30 m Shuttle Run times also demonstrated significant improvement, decreasing from 25.36 ± 1.60 to 21.82 ± 1.76, yielding a 13.96% enhancement (t = 5.338, $p<0.001$). Additionally, the performance in the Plank was notably enhanced, increasing by 35.26% (t=-2.989, $p=0.010$). A significant improvement was noted in the Throw Solid Balls test, with scores rising by 13.39% ($p=0.008$). These results indicate that the intervention program was effective in enhancing various physical performance indicators for both boys and girls in the experimental group.

Analysis of association factors for the effect of the MQ training program on BMI values in obese children

The correlation analysis revealed significant associations between Movement Quotient (MQ) training factors and Body Mass Index (BMI) among obese children. Within the Body Quotient domain, cardiovascular endurance indicators demonstrated strong positive correlations (Table 5). In the Body Quotient dimension, One-minute Rope skipping demonstrated a strong positive correlation with BMI across all participants ($r=0.968$, $p<0.001$), with similar strong correlations observed in both boys ($r=0.947$, $p<0.001$) and girls ($r=0.984$, $p<0.001$). The 20 m Backward Run also showed a robust positive correlation with BMI ($r=0.974$, $p<0.001$), maintaining consistency across gender groups (boys: $r=0.988$, $p<0.001$; girls: $r=0.947$, $p<0.001$). Conversely, the 2 × 30 m Shuttle Run exhibited a weak negative correlation with BMI in the total sample (r=-0.352, $p<0.05$). Regarding the Behavioral Quotient, Exercise Behaviors demonstrated a moderate to strong positive correlation with BMI in the total sample ($r=0.681$, $p<0.001$) and particularly among boys ($r=0.732$, $p<0.001$), while no significant correlation was found among girls ($p>0.05$). Within the Task Quotient category, several indicators showed significant correlations: Hand-eye Coordination ($r=0.922$, $p<0.001$), Behavior Imitation ($r=0.796$, $p<0.001$), and Arm-up Squat ($r=0.425$, $p<0.05$) all demonstrated positive correlations with BMI in the total sample. Notably, these correlations remained consistent across gender groups for Hand-eye Coordination (boys: $r=0.889$, girls: $r=0.916$, both $p<0.001$) and Behavior Imitation (boys: $r=0.856$, girls: $r=0.838$, both $p<0.001$). Other indicators within the Task Quotient dimension, such as Ball Handling, Specialized Skills, and Dynamic Context, showed no significant correlations with BMI (all $p>0.05$).

Discussion

Childhood obesity remains a critical global public health issue, particularly due to its long-term health risks and rising prevalence. This study highlights the significance of Motor Quotient (MQ) physical fitness training as an effective intervention for improving health-related fitness indicators in obese children aged 7–8 years. By demonstrating significant improvements in key fitness metrics

Table 4 MQ Indicator Test results of girls in the Experimental Group after the experiment($N=15$)

Test Indicators		Before the Experiment	After the Experiment	t	*p*	Significant Increase Rate
Body Quotient	**BMI(kg/m²)**	21.04 ± 1.542	17.467 ± 1.068	5.802	0.000**	-16.98%
	2 × 30 m Shuttle Run	25.36 ± 1.599	21.82 ± 1.759	5.338	0.000**	13.96%
	Plank	12.707 ± 4.83	17.187 ± 2.779	-2.989	0.01*	35.26%
	One-minute Rope Skipping	21.8 ± 5.308	23.267 ± 4.713	-0.721	0.483	
	Sit and Reach	3.42 ± 1.766	3.133 ± 0.853	0.496	0.627	
	Throw Solid Balls	2.24 ± 0.22	2.54 ± 0.372	-3.059	0.008**	13.39%
Behavioral Quotient	**20 m Backward Run**	23.713 ± 0.76	22.127 ± 1.381	4.047	0.001**	6.69%
	Exercise Behavior	21.733 ± 1.438	22.867 ± 1.807	-1.568	0.139	
	Exercise Psychology	22.4 ± 1.298	21.867 ± 1.126	1.169	0.262	
Task Quotient	**Living Labor**	11.2 ± 1.014	11.067 ± 0.799	0.435	0.670	
	Arm-up Squat	2.8 ± 0.676	3.867 ± 0.516	-4.000	0.001**	38.11%
	Ball Handling	1.6 ± 0.507	1.6 ± 0.737	0.000	1.000	
	Hand-eye Coordination	3.267 ± 1.1	3.533 ± 0.516	-0.695	0.499	
	Behavior Imitation	2.867 ± 0.834	3.8 ± 1.014	-2.064	0.058	
	Specialized Skills	2.733 ± 0.594	3.667 ± 0.617	-4.09	0.001**	34.17%
	Lunge Squat	1.467 ± 0.516	1.867 ± 0.516	-1.871	0.082	
	Dynamic Context	1.667 ± 0.617	1.467 ± 0.64	0.823	0.424	
	Reaction	2.333a ± 0.817	3.333a ± 0.817	-	-	

Note: *$p<0.05$, **$p<0.01$

Table 5 Pearson correlation analysis of MQ training factors and BMI in obese children

Test Indicators with BMI		Pearson Correlation			Sig.		
		Total	Boys	Girls	Total	Boys	Girls
Body Quotient	**2×30 m Shuttle Run**	-0.352*	-0.098	-0.254	0.028	0.364	0.181
	Plank	0.099	0.042	-0.103	0.302	0.441	0.358
	One-minute Rope skipping	0.968**	0.947**	0.984**	0.000	0.000	0.000
	Sit and Reach	0.195	0.128	0.233	0.151	0.325	0.202
	Throw Solid Balls	-0.009	0.174	0.126	0.482	0.267	0.327
	20 m Backward Run	0.974**	0.988**	0.947**	0.000	0.000	0.000
Behavioral Quotient	**Exercise Behaviors**	0.681**	0.732**	0.349	0.000	0.001	0.101
	Exercise Psychology	0.094	0.128	-0.242	0.310	0.325	0.193
	Living Labor	-0.006	-0.131	0.179	0.487	0.320	0.262
Task Quotient	**Arm-up Squat**	0.425*	0.537*	0.121	0.010	0.019	0.334
	Ball Handling	-0.006	0.207	-0.336	0.486	0.229	0.110
	Hand-eye Coordination	0.922**	0.889**	0.916**	0.000	0.000	0.000
	Behavior Imitation	0.796**	0.856**	0.838**	0.000	0.000	0.000
	Specialized Skills	-0.122	-0.083	-0.278	0.261	0.385	0.158
	Lunge Squat	0.124	0.156	-0.125	0.257	0.290	0.328
	Dynamic Context	0.008	0.154	-0.268	0.482	0.292	0.167
	Reaction	-0.101	0.215	-0.109	0.298	0.221	0.349

Note: *$p<0.05$, **$p<0.01$

such as agility, strength, and flexibility after a structured 13-week MQ program, this research underscores its practical implications for combating childhood obesity within school environments. Theoretically, it contributes new insights into the relationship between targeted fitness programs and obesity-related health variables, offering a valuable framework for early intervention strategies in similar populations. These findings emphasize the need for further research with larger samples to explore the long-term impact and scalability of MQ training in diverse educational settings.

Designing MQ training programs to improve physical fitness in obese children

Obesity among children has emerged as a serious public health threat, increasing morbidity risk while simultaneously diminishing quality of life. Studies demonstrate the devastating consequences of sedentary lifestyles on this population's physical development, with numerous reports documenting its negative influence. Studies confirming its detrimental impact both physically and psychosocially are numerous. Zongping Wang's Motor Quotient (MQ) training program serves as the cornerstone for improving physical fitness of obese children. This program stresses the significance of recognizing and developing students' motor quotient to unlock their athletic potential, advocating the necessity of consistent physical activity as part of an overall sports culture that honors life-long participation [20]. The MQ Training program represents an innovative solution to increase multidimensional physical fitness while decreasing child obesity. Optimizing the design and delivery of such programs merits further discussion, particularly as regards meeting the unique needs of obese pediatric cohorts. A key design principle should be targeting specific aspects of fitness that have been most compromised due to obesity. Obese children tend to show reduced strength, motor skills, agility, flexibility and cardiovascular endurance compared with their leaner peers [33, 34]. Combining continuous aerobic activity to increase peak VO2, along with resistance training, motor skills exercises, and stretching as part of an integrated fitness approach offers a strategic way of combatting obesity-related fitness deficits [35]. Beyond fitness outcomes, MQ programming must address the negative psychosocial correlates of pediatric obesity to maximize adherence and health benefits. Obese children are disproportionately prone to low self-efficacy, negative body image, and peer victimization, all of which militate against participation in physical activity [36]. Sensitively structured sessions that focus on enjoyment, inclusion, and cooperation can overcome these barriers, as can family-based initiatives to cultivate support [37]. Key design considerations of MQ obesity interventions for MQ cohorts should center around optimizing training frequency, intensity and duration - though no consensus exists as of yet regarding optimal sessions for obese cohorts, it appears 3–5 weekly 30- to 60-minute training sessions may provide the greatest return [38]. Moderate-to-vigorous intensity, eliciting 60–90% of maximal heart rate, prevents overexertion while stimulating cardiorespiratory and metabolic adaptations [39]. Such programming parameters help to strike a balance between efficacy and feasibility. In this context, the Motor Quotient (MQ) training program, as highlighted by Zongping Wang, emphasizes the recognition of the motor quotient to enhance the athletic potential of Chinese children, emphasize the importance of regular physical activity, and promote a culture of lifelong sports participation. The design of the training program within the MQ paradigm was carefully tailored to address both the physical fitness and MQ assessments. The physical fitness assessment consisted of a series of seven observational measures, namely body mass index (BMI), a 2 × 30 m shuttle run, a one-minute jump rope, a plank hold, a seated forward bend, an in-place medicine ball throw, and a 20 m backward run. These tests were carefully selected to provide a comprehensive assessment of the children's physical abilities, such as strength, speed, endurance, coordination, and flexibility, thus providing a nuanced understanding of their fitness profiles [40]. Recent research by Xu et al. has described a nonlinear relationship between weight status and physical fitness, showing that both underweight and obese children and adolescents have lower levels of physical fitness compared to their normal weight counterparts, underscoring the complexity of the relationship between body composition and physical performance [41]. The MQ training program is not monolithic, but rather consists of a variety of modalities, including both dynamic and isometric exercises, carefully curated to enhance coordination and agility. This multifaceted approach has borne fruit, as evidenced by significant improvements in lower extremity, upper extremity, and core strength. Accompanying these physical improvements were observable gains in coordination and agility, which may collectively contribute to increased physical fitness and enriched quality of life for the obese pediatric cohort. These findings lend credence to the proposition that integrated training methodologies are instrumental in mitigating the challenges posed by childhood obesity.

Overall, MQ training program represents an innovative paradigm shift in its approach to childhood obesity by going beyond traditional exercise programs to foster holistic development of physical and motor skills. Empirical evidence collected so far supports expansion and continuation of such programs to bring significant and long-lasting improvements in children with obesity's health trajectories.

The effect of MQ training programs on BMI in obese children

According to the results of this study, exercise program has shown some effect in improving children's BMI, as well as potentially having a positive impact on children's cognitive and learning abilities at that age.

This study suggests that training methods based on basic motor skills such as running backwards, jumping rope and throwing a solid ball may be more advantageous in improving children's physical and mental ability to perform specific movements, but there is a lack of direct evidence that these methods are more effective than other training programs. This is because interventions in relevant studies typically include multiple training modalities, and the effectiveness of each training method has not been compared individually.

These activities focus on fundamental motor skills crucial for children's physical development, making them more accessible and impactful in this age group (Table 5). In contrast, team-based, rule-bound programs like the Lucky Spin, which require a deeper understanding and processing of information and rely on collaborative efforts, may not be as effective within the constraints of limited classroom practice. Research indicates that insufficient physical activity, especially in conjunction with obesity, can lead to poor health-related fitness and reduced confidence in participating in sports and physical activities [42, 43]. However, enhancing motor skills through tailored physical activities can boost a child's motivation for physical engagement, often accompanied by improved self-esteem and enjoyment [44].

The impact of various exercise interventions on Body Mass Index (BMI) in obese children highlights the efficacy of activities that focus on enhancing fundamental motor skills appropriate for their age group. The study showed that individual exercises, such as the 20 m backward run and the one-minute rope skipping, significantly outperformed multiple program combinations. These exercises, which require singular execution, place high demands on specific physical attributes that are crucial at this developmental stage. The importance of various types of exercises, including weight lifting and aerobic exercise, in positively impacting BMI is well established [45]. This is further supported by a pilot randomized controlled trial, which found that either caloric restriction alone or combined with rope-skipping exercise significantly reduced weight, BMI, PBF, and BFM in young adults over eight weeks [46]. This underscores the role of targeted exercise in improving cardiometabolic health. In the context of this study, the one-minute rope skipping, which demands power and agility, effectively exercised these attributes, leading to significant effects in test outcomes. This suggests that the observed reduction in BMI among obese children is not solely due to a particular exercise, but rather the overall enhancement of physical qualities such as muscular strength and coordination. By engaging in rope skipping, children were able to improve these skills comprehensively, which in turn facilitated greater proficiency in activities requiring strength and coordination. This not only contributed to weight management but also aided in lowering BMI. In summary, the key to reducing BMI in obese children lies in advancing their physical capacities through targeted training that

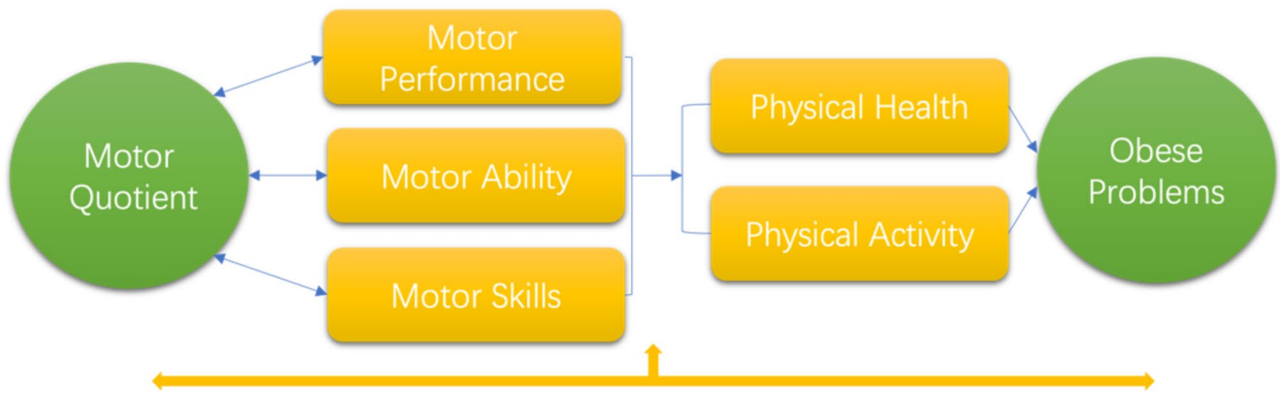

Fig. 1 Relation between motor quotient and obese problems

focuses on essential motor skills and attributes, rather than merely participating in specific types of exercises.

Regarding BMI calculations, they were derived directly from height and weight measurements in the study. The minimal changes in height observed among most children during the intervention period suggest that BMI changes were primarily due to weight fluctuations. Research indicates that obese children often have poorer physical coordination due to their excess weight, which can impede their ability to engage effectively in physical activities [47]. Moreover, while physical activity is crucial for developing basic motor skills in younger children, the association between BMI and these skills, or physical activity levels, may not be as pronounced in preschoolers [48]. Regression and correlation analyses in the study showed that exercises focusing on a single physical quality had a more significant impact on BMI than those involving multiple qualities. This is likely because exercises demanding multiple skills require synchronized mastery of diverse physical capacities, which can vary in development among obese children. In our study, we also found that behavioral tasks were significantly correlated with BMI, which is consistent with previous findings in the category of motor performance. Obese children's motor skills and performance can be compromised to some extent due to body shape limitations [34], which can adversely affect sports participation and increased physical activity in obese children.(Fig. 1).

The effect of school physical education on childhood obesity

In recent years, research has shown that methods such as High Intensity Interval Training (HIIT) and Tabata training in school physical education programs have significant potential to improve childhood obesity. These training methods are not only effective in reducing body fat in obese children, but also in improving their overall health. Tabata training, a high-intensity interval training method that alternates short bursts of high-intensity exercise with brief periods of rest, has been shown to have a significant effect on improving body composition and health-related fitness in obese children. For example, a study by Domaradzki et al. (2020) [49] demonstrated that Tabata training significantly reduced body weight, body fat percentage, and waist-to-hip ratio in overweight adolescents, while improving their aerobic capacity. A study by Popowczak et al. (2022) [50] also found that 10 weeks of Tabata training significantly improved body fat percentage and cardiovascular efficiency in 16-year-old middle school students. These findings suggest that Tabata training is not only effective in reducing body fat in obese children, but also in improving their overall health. In addition to Tabata training, other forms of high-intensity interval training (HIIT) have also shown positive effects on obese children. A systematic review and meta-analysis by Costigan et al. (2015) [51] showed that HIIT had significant effects in improving cardiorespiratory endurance and body fat in adolescents. In particular, for overweight and obese children, HIIT significantly reduced body fat percentage while improving cardiorespiratory fitness. These findings further confirm the effectiveness of HIIT in improving health-related fitness in obese children. Despite the significant potential of HIIT and Tabata training to improve the health of obese children, there are still some challenges to its implementation in school physical education program. For example, Liu et al.'s (2024) [52] systematic review and meta-analysis noted that HIIT interventions in school physical education curricula have deficiencies in process evaluation, with many studies under-reporting details of the intervention process. This may have affected the accurate assessment and replication of intervention effects. Therefore, future studies need to focus more on process evaluation, including the implementation of the intervention, mechanisms of influence and contextual factors, in order to improve the feasibility and effectiveness of the intervention. In addition, research should also focus on the potential impact of these training methods on children's mental health, such as self-esteem, anxiety and depression. By considering both physical and mental health together, the potential of these training methods in improving childhood obesity can be more fully assessed. Research should also focus on the individualization of training methods and gender differences to ensure that training programs are better adapted to the needs of different children.

In this study, we identified three major limitations. First, sample size limitations had an impact on our findings. As this study was part of an exercise participation intervention study under the MQ perspective, obese subjects participated in the MQ physical education program with normal weight subjects. This setting was designed to assess the variability of the intervention effects of the MQ physical education program on different weight groups. Although we have found the effectiveness of the intervention on BMI, Behavioral task, etc. in obese children in our study, to assess the effectiveness of the intervention more accurately for a group of obese children in future studies, we plan to implement a more customized MQ obesity intervention training program or curriculum design in a larger sample group. Second, the limitations of the assessment instruments are also a noteworthy issue. In monitoring weight changes in obese children, we only used BMI as a measurement tool due to operational limitations. Thirdly, as the interventions in this study included multiple means of exercise and the effectiveness of each means of exercise was not compared individually, it was not possible to directly demonstrate that a single means of exercise (e.g., running backwards, skipping rope, solid ball, etc.) was more effective than a combination of exercises. In future studies, further stratified analyses should be done to compare the effects of different combinations of exercise programs on the BMI of obese children to assess the independent effect of single exercise.

In addition, we only used target heart rate as an indicator of training intensity during the intervention. To obtain more comprehensive assessment results, future studies should consider incorporating relevant physiological indicators such as maximal oxygen uptake and motor function for more comprehensive monitoring and assessment of intervention effects.

Conclusions

The results of the study indicate that Motor Quotient (MQ) Physical Fitness Training exerts a pronounced positive effect on health-related fitness parameters and mitigates obesity risk in children aged 7–8 years. This is substantiated by marked reductions in Body Mass Index (BMI) as well as significant enhancements in cardiovascular endurance, core muscular strength, and motor coordination. Furthermore, the study reveals significant correlations between BMI and key health indicators, including cardiovascular endurance and motor skills, validating the positive intervention effects of MQ training on childhood obesity and comprehensive physical development. These results not only expand the theoretical framework of Motor Quotient in children's health promotion but also provide robust evidence for implementing structured, scientific physical training programs. This study offers valuable insights and practical solutions for obesity prevention and health promotion, contributing significantly to both theoretical advancement and practical applications in the field of children's physical development.

Acknowledgements
This study was supported by Tianjin Education Science Planning (General) Project, China and Ministry of Education Humanities and Social Sciences Projects, China. We would like to express our sincere appreciation to Hongwu Liu for his assistance during the project implementation, to Chao Song for her support in structuring the logic and writing process, to Xuepeng Guo for his valuable input to the manuscript drafting, and to Weipeng Zhang for his support in the statistical methods used in this study.

Author contributions
Conceptualization, Sha Ge, Song Chao, Hongwu Liu and Xuepeng Guo; methodology, Sha Ge and Hongwu Liu; software, Hongwu Liu and Xuepeng Guo; validation Sha Ge and Hongwu Liu; formal analysis Sha Ge and Hongwu Liu; investigation, Hongwu Liu and Xuepeng Guo; resources, Sha Ge and Hongwu Liu; data curation, Hongwu Liu and Xuepeng Guo, data analysis, Sha Ge, Hongwu Liu and Weipeng Zhang; writing, original draft preparation, Sha Ge and Song Chao; writing, review and editing, Sha Ge.

Funding
This research was funded by Tianjin Education Science Planning (General) Project, China—Intervention Study on the Tripartite Relationship between Community, School, and Family in Youth Sports Participation of Urban Adolescences, grant number CLE210087. And also supported by Ministry of Education Humanities and Social Sciences Projects, China: Influence of Parents' PA Behavior on Adolescents' PA Participation from a Family Environment Perspective (No. 20YJC8900204).

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki, and the protocol received approval from the Ethics Committee of Tianjin Normal University, China (Approval No. 2023102301) on October 23rd, 2023.

Consent for publication
Informed consent was obtained from all subjects involved in the study.

Competing interests
The authors declare no competing interests.

Received: 30 April 2024 / Accepted: 17 February 2025
Published online: 22 February 2025

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