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Influencing Factors and Strategies for the Development of Young Children's Operational Motor Skills from the Perspective of Healthy China

Jiajia Zhu, Mengping Yang, Jiahui Zhu

Department of Preschool Education I, Suzhou Early Childhood Education College, Suzhou, China
Email: 1583969092@qq.com

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Abstract

This study assessed the operational motor skills of 620 senior kindergarten children from a city in China using the TGMD-3 assessment tool. The results showed that children performed better in four specific skills: two-handed catching, kicking, overhand throwing, and underhand throwing. Significant differences in operational motor skills were found across age, gender, and kindergarten type (public vs. private). A clear tri-level stratification (high, medium, low) was identified in children's operational motor skill performance. Age emerged as the core predictor of skill development, and its effect was not moderated by gender. Both gender and kindergarten type showed independent predictive effects. Based on these findings, recommendations include implementing age-graded and phased physical activities; optimizing resource and activity allocation considering differences in kindergarten type; establishing a targeted, tiered intervention mechanism to enhance operational motor skills; and building a supportive environment that fosters home-kindergarten-community collaboration.

Keywords

Healthy China, Operational Motor Skills, Influencing Factors, Support Strategies

1. Introduction

The Healthy China 2030 Planning Outline proposed the "Healthy Children Initiative" to safeguard children's physical and mental health. The Five Health Promo-

tion Action Plan for Children and Adolescents (2026-2030), issued in 2025, extended the scope of health promotion to children aged 0 - 6 years, emphasizing the enhancement of children's muscle strength and motor coordination through organized physical activities, and establishing motor development as one of the key indicators for assessing children's health status (National Health Commission of the People's Republic of China, 2025). These policy initiatives indicate that children's health promotion efforts are moving toward a more systematic and evidence-based direction. Motor competence developed during early childhood serves as the foundation for physical fitness cultivation and the formation of healthy lifestyle habits (Clark & Metcalfe, 2002). Research has demonstrated that motor development positively influences children's physical, cognitive, emotional, social, and academic outcomes (Wu et al., 2023; Mao et al., 2026; Zhang et al., 2023). The establishment of well-coordinated motor abilities during this critical period contributes substantially to both physical development and long-term well-being.

Within the framework of motor development, gross motor skills can be categorized into two types based on task characteristics: (1) locomotor skills, which involve whole-body movement through space (e. g., running, jumping); and (2) operational motor skills, which involve manipulating objects through throwing, catching, striking, and related actions (Ulrich, 2000). A review of the existing literature reveals that scholarly attention to gross motor development has primarily concentrated on three areas. First, researchers have examined the overall characteristics of gross motor development and its associations with cognitive and emotional factors. Findings indicate that gross motor skills are positively correlated with prosocial behavior and negatively correlated with emotional symptoms and behavioral problems (Wang, 2024). Second, intervention studies employing sports activities as vehicles for motor skill enhancement have emerged as a research focus. Multiple experimental studies have demonstrated that activities such as mini-basketball and swimming instruction yield positive effects on gross motor skill levels (Xu, 2025). Third, investigations into individual difference variables affecting motor development have been conducted, with age being consistently identified as the most robust predictor (Yang et al., 2022; Li & Zhang, 2025). Despite the substantial contributions of existing research, several gaps warrant further exploration. Most studies have emphasized either locomotor skills or overall gross motor development, with relatively limited attention devoted specifically to operational motor skills. Furthermore, the interactive effects among multiple influencing factors remain insufficiently examined. Given that operational motor skills are closely associated with children's daily play, physical activity engagement, and motor skill acquisition, they play an irreplaceable role in cultivating hand-eye coordination, spatial-temporal judgment, and force control (Dai et al., 2017).

Given these considerations, this study focuses on senior kindergarten children as the research population, employing the object control subtest of the Test of Gross Motor Development-Third Edition (TGMD-3). Following the validation of

its reliability and validity, this study systematically investigates the developmental level of operational motor skills among senior kindergarten children, as well as the independent and interactive effects of age, gender, handedness/footedness, and kindergarten type. Additionally, cluster analysis is applied to identify group stratification characteristics in skill development. The findings are expected to provide empirical evidence for promoting motor development in young children, optimizing physical education practices, and facilitating the effective implementation of relevant policies.

2. Research Subjects and Methods

2.1. Research Subjects

This study employed a stratified cluster sampling method. A total of 25 kindergartens (14 public and 11 private) in a city were selected, and approximately 30% of children from each senior kindergarten class were randomly recruited. The initial sample consisted of 624 children, and the final valid sample comprised 620 children, including 312 males and 308 females, yielding a valid response rate of 99.4%. Among the four excluded children, two were absent on the testing day, one refused to participate, and one was unable to complete the assessment due to illness. Bunker and Sepehrnia (1989) argued that dividing age groups by year is inappropriate and that smaller time units should be used for age classification. To obtain a more precise understanding of senior kindergarten children's operational motor skills, this study divided participants into three age groups at 6-month intervals. The sample size and gender distribution for each age group are presented in Table 1.

Table 1. Sample size and gender distribution by age group.

Age Group	Boys		Girls		Total	
	N	%	N	%	N (%)	%
4y11m-5y4m	79	12.7	71	11.5	150	24.2
5y5m-5y10m	140	22.6	157	25.3	297	47.9
5y11m-6y4m	93	15.0	80	12.9	173	27.9
Total	312	50.3	308	49.7	620	100

2.2. Research Methods

2.2.1. Measurement Tool

The Test of Gross Motor Development (TGMD) was originally developed by Dale A. Ulrich in 1985 and revised in 2013, resulting in the third edition (TGMD-3). The revision removed the underhand rolling task from the original object control subtest and added underhand throwing and one-handed striking of a self-bounced ball (Ulrich, 2013). TGMD-3 is a standardized instrument specifically designed to assess gross motor development in children aged 3 to 10 years, com-

prising two subtests: locomotor skills and object control skills. The present study utilized only the object control subtest of the TGMD-3. This subtest includes seven gross motor tasks: two-handed striking of a stationary ball, one-handed striking of a self-bounced ball, stationary dribbling, two-handed catching, kicking, overhand throwing, and underhand throwing. Each task measures a distinct aspect of children's operational motor skills. The TGMD-3 object control subscale used in this study demonstrated satisfactory reliability and validity. The internal consistency reliability, measured by Cronbach's α, was 0.914. For test-retest reliability, 120 children were randomly selected and retested after a two-week interval; the intraclass correlation coefficient (ICC) was 0.743 (95% CI: 0.71 - 0.78). All testers received standardized training, and the inter-rater reliability ICC was greater than 0.80, indicating good scoring consistency. For construct validity, confirmatory factor analysis showed good model fit (CFI = 0.960, TLI = 0.952, RMSEA = 0.049, SRMR = 0.043). These results indicate that the scale has adequate reliability and validity for use in the present sample. Meanwhile, the TGMD-3 has been validated in multiple studies conducted with Chinese children, all of which have demonstrated satisfactory reliability and validity of the instrument in this population (Li et al., 2022).

2.2.2. Testing Procedure

Prior to testing, the participating children were divided into groups of five. To ensure that the children understood the performance criteria and could complete the tasks properly, the testers received specialized training beforehand and provided demonstrations for the children. Before the formal test, each child was given the opportunity to practice each task two to three times. During scoring, the testers stood diagonally in front of the child being assessed to ensure a clear and accurate view of the performance. The total score for operational motor skills was 27 points. In the formal test, each child performed one trial per task; a score of "1" was recorded if the task was successfully completed, and "0" was recorded if not. A higher total score indicated a higher level of operational motor skill development, whereas a lower score suggested underdevelopment or deficiency.

In addition, for tasks such as two-handed striking of a stationary ball, one-handed striking of a ball, and kicking, the testers observed the hand or foot primarily used by the child to perform the task. If a child consistently used the same hand or foot for at least three to four consecutive attempts, that side was determined to be the dominant hand or foot. Two weeks later, a subsample of 120 children (40 from each age group) was randomly selected from the initial sample for a second assessment, yielding a retest rate of 19.4%.

3. Results

3.1. Overall Level of Operational Motor Skills Development in Senior Kindergarten Children

As shown in Table 2, the maximum scores for the seven operational motor tasks

are 5, 4, 3, 3, 4, 4, and 4, respectively. Descriptive statistics of the scores for the seven test tasks are presented in Table 3. The results showed that 73.9% of the children scored 3 points or above in two-handed striking of a stationary ball, while 8.5% scored 1 point or received no score. For one-handed striking of a self-bounced ball, 75.6% of the children scored 2 points or above, whereas 24.4% scored 1 point or no score. In stationary dribbling and two-handed catching, 70.1% and 79.3% of the children scored 2 points or above, respectively, while 29.8% and 20.6% scored 1 point or no score on these two tasks. For kicking, overhand throwing, and underhand throwing, the proportions of children scoring 2 points or above were 85.4%, 83.6%, and 83.8%, respectively.

The data indicate that children performed better in four tasks: two-handed catching, kicking, overhand throwing, and underhand throwing. However, 2.9% and 6.0% of the children received no score in striking with a bat and striking with a racket, respectively, suggesting that mastery of these two tasks was relatively poor. This may be attributed to the similarity of these tasks to baseball and tennis activities, which are rarely included in early childhood physical education programs in China, resulting in children's unfamiliarity with the required movements. In addition, 6.6% of the children scored zero in stationary dribbling, which may be related to the technical specifications of the task—many children used their palms to bounce the ball rather than their fingers, as required by the standardized criteria.

Table 2. Frequency distribution of scores on operational motor skill tasks.

Test Item	Percentage of Children Scoring at Each Score Level (%)					
	0 points	1 points	2 points	3 points	4 points	5 points
Two-handed striking of a stationary ball	2.9	5.6	17.6	29.2	33.7	11.0
One-handed striking of a self-bounced ball	6.0	18.4	40.5	29.8	5.3	/
Stationary dribbling	6.6	23.2	33.2	36.9	/	/
Two-handed catching	2.4	18.2	48.2	31.1	/	/
Kicking	1.0	13.7	36.8	34.7	13.9	/
Overhand throwing	1.8	14.7	32.3	36.5	14.8	/
Underhand throwing	1.5	14.7	29.5	36.9	17.4	/

Note: "/" indicates that no child received a score at that level.

3.2. Differential Analysis of Operational Motor Skills Scores among Senior Kindergarten Children

3.2.1. Age-Based Differences in Operational Motor Skills

This study examined operational motor skill performance across three age groups of senior kindergarten children. One-way ANOVA revealed highly significant differences among age groups in both individual task scores and the total score (*p*

< 0.001). Further post hoc comparisons using the Least Significant Difference (LSD) method showed that children aged 5y11m-6y4m scored significantly higher than those aged 5y5m-5y10m in both the total operational motor skills score and all individual task scores (*p* < 0.001), and children aged 5y5m-5y10m scored significantly higher than those aged 4y11m-5y4m (*p* < 0.001). These results indicate a stepwise increasing trend across the three age groups. This finding is consistent with the results reported by Ma (2007).

Table 3. Analysis of variance in operational motor skills scores across age groups.

Test Item	Age Group			F	p	LSD
	4y11m-5y4m (a)	5y5m-5y10m (b)	5y11m-6y4m (c)			
Two-handed striking of a stationary ball	1.87	3.37	3.99	239.70	0.000***	a < b < c
One-handed striking of a self-bounced ball	1.04	2.14	2.95	324.49	0.000***	a < b < c
Stationary dribbling	1.10	2.08	2.66	180.98	0.000***	a < b < c
Two-handed catching	1.36	2.12	2.64	176.47	0.000***	a < b < c
Kicking	1.69	2.50	3.09	128.47	0.000***	a < b < c
Overhand throwing	1.69	2.43	3.25	156.31	0.000***	a < b < c
Underhand throwing	2.13	2.48	2.99	34.78	0.000***	a < b < c
Total operational motor skills score	10.89	17.13	21.57	688.84	0.000***	a < b < c

Note: *p* < 0.05; **p* < 0.01; ***p* < 0.001 (same below).

3.2.2. Gender-Based Differences in Operational Motor Skills

As shown in Table 4, significant gender differences were observed in operational motor skills among senior kindergarten children, specifically in one-handed striking, two-handed catching, kicking, and the total score, with boys significantly outperforming girls in these three tasks as well as in the overall score. In terms of mean scores, boys also scored higher than girls in overhand throwing and underhand throwing. This finding is consistent with the results of Li Jing's study, which reported that preschool boys outperformed girls in object control skills (Li et al., 2019). Compared to girls, boys exhibited significantly higher levels of total physical activity, greater range of movement, and more diverse activity content, resulting in an overall higher level of gross motor development (Shao, 2020). The observed gender differences are primarily attributable to sociocultural factors (LeGear et al., 2012).

3.2.3. Differences in Operational Motor Skills by Handedness and Footedness

A review of the literature revealed that, compared with commonly examined variables such as age and gender, handedness/footedness—an individual characteristic reflecting neural motor lateralization—has received relatively limited attention

in studies of gross motor development in young children. In the present study, 26 children were identified as left-handed/left-footed, while 594 children were right-handed/right-footed. The results showed no significant difference in the total operational motor skills score between children with different dominant hand/foot preferences. However, an examination of individual task scores revealed that left-handed/left-footed children scored higher than their right-handed/right-footed peers on the task of "one-handed striking of a self-bounced ball".

Table 4. Analysis of gender differences in operational motor skills scores.

Test Item	Gender		T	*p*
	Boys	Girls		
Two-handed striking of a stationary ball	3.14	3.22	−0.836	0.403
One-handed striking of a self-bounced ball	2.21	2.00	2.711	0.007**
Stationary dribbling	2.00	2.01	−0.044	0.965
Two-handed catching	2.20	1.96	3.914	0.000***
Kicking	2.64	2.29	4.764	0.000***
Overhand throwing	2.55	2.41	1.863	0.063
Underhand throwing	2.60	2.49	1.374	0.170
Total operational motor skills score	17.34	16.37	2.605	0.009**

From a neurophysiological perspective, this difference may be attributed to the distinct neural pathways controlling the two sides of the body. Neurobiological research indicates that for right-handed individuals, performing a right-hand action involves a contralateral transmission pathway: left hemisphere → right hemisphere → right hand. In contrast, for left-handed individuals, the pathway is more direct, involving an ipsilateral route: right hemisphere → left hand (Xie & Zhang, 2000). Theoretically, this more direct transmission may confer a speed advantage in information processing and motor execution for the dominant hand. In addition to potential processing speed advantages, left-handed individuals may also possess certain characteristics in spatial perception. Research has shown that the right hemisphere is more efficient in integrating spatial information and forming holistic movement representations (Yin et al., 2012). For tasks such as one-handed striking of a self-bounced ball, which demand high levels of spatial and temporal judgment and are rarely practiced in kindergarten settings, the right-hemisphere-dominant processing style may offer left-handed children an initial adaptive advantage.

However, for most routine object manipulation tasks (e. g., throwing, catching, and kicking), right-handed children tend to perform better. This is largely because these activities occur frequently in daily life, providing children with ample practice opportunities. In addition, social environments and tool designs are predominantly tailored to right-handed users, affording right-handed children systematic

and extensive practice advantages in conventional manipulative tasks. As a result, right-handed children demonstrate superior overall performance in routine object control skills compared to their left-handed peers (Table 5).

Table 5. Analysis of differences in operational motor skills scores by handedness/footedness.

Test Item	Handedness/Footedness		T	*p*
	Left	Right		
Two-handed striking of a stationary ball	3.08	3.19	−0.455	0.649
One-handed striking of a self-bounced ball	2.12	2.10	0.075	0.941
Stationary dribbling	1.96	2.01	−0.242	0.809
Two-handed catching	2.08	2.12	−0.236	0.813
Kicking	2.31	2.47	−0.899	0.369
Overhand throwing	2.31	2.49	−1.194	0.242
Underhand throwing	2.19	2.56	−1.844	0.066
Total operational motor skills score	16.08	16.89	−0.875	0.382

3.2.4. Differences in Operational Motor Skills by Kindergarten Type

As shown in Table 6, children from public kindergartens scored significantly higher than their counterparts from private kindergartens on three tasks: two-handed striking of a stationary ball, two-handed catching, and kicking. In terms of both individual task means and the overall mean score, children from public kindergartens performed slightly better than those from private kindergartens, but the difference was not statistically significant. Of note, on the underhand throwing task, private kindergarten children scored slightly higher, though the difference was not statistically significant.

Table 6. Analysis of differences in operational motor skills scores by kindergarten type.

Test Item	Kindergarten Type		T	*p*
	Public	Private		
Two-handed striking of a stationary ball	3.27	3.02	2.572	0.009**
One-handed striking of a self-bounced ball	2.10	2.10	−0.054	0.957
Stationary dribbling	2.05	1.92	1.709	0.088
Two-handed catching	2.14	1.99	2.351	0.019*
Kicking	2.56	2.31	3.306	0.001**
Overhand throwing	2.55	2.41	1.701	0.090
Underhand throwing	2.54	2.55	−0.209	0.834
Total operational motor skills score	17.02	16.59	1.111	0.267

3.2.5. Cluster Analysis of Operational Motor Skills across Different Ability Levels

A K-Means cluster analysis was performed on the scores of 620 senior kindergarten children across the seven operational motor skill tasks. The results revealed that children's operational motor skill performance could be clearly classified into three significantly distinct clusters, corresponding to three proficiency levels: the advantaged development group (*n* = 217, 35.0%), the average development group (*n* = 257, 41.5%), and the delayed development group (*n* = 146, 23.6%). One-way ANOVA results showed that the three groups differed significantly across all seven tasks (*p* < 0.01). Specifically, the advantaged development group outperformed the other two groups on all tasks, with particularly strong performance in "one-handed striking of a self-bounced ball," "kicking," and "overhand throwing." In contrast, the delayed development group scored the lowest on all tasks, with notably weaker performance in "two-handed striking of a stationary ball," "one-handed striking of a self-bounced ball," and "two-handed catching." (Table 7)

Table 7. Comparison of operational motor skills scores across ability groups (M ± SD).

Test Item	Average Development Group (n = 257)	Delayed Development Group (n = 146)	Advantaged Development Group (n = 217)	F	p
Two-handed striking of a stationary ball	3.311 ± 0.855	1.801 ± 0.980	3.954 ± 0.786	276.310	0.000**
One-handed striking of a self-bounced ball	2.105 ± 0.662	0.979 ± 0.679	2.853 ± 0.636	354.630	0.000**
Stationary dribbling	1.887 ± 0.744	1.096 ± 0.799	2.756 ± 0.509	261.875	0.000**
Two-handed catching	2.043 ± 0.568	1.322 ± 0.684	2.636 ± 0.528	221.636	0.000**
Kicking	2.296 ± 0.711	1.699 ± 0.764	3.189 ± 0.718	196.023	0.000**
Overhand throwing	2.366 ± 0.799	1.610 ± 0.800	3.198 ± 0.695	193.116	0.000**
Underhand throwing	2.482 ± 0.919	1.918 ± 0.986	3.032 ± 0.802	68.392	0.000**

3.3. Effects of Age, Gender, and Kindergarten Type on Operational Motor Skills Development

Hierarchical regression analysis was employed to examine the factors influencing the total operational motor skills score in senior kindergarten children (see Table 8). In the first step, control variables (kindergarten type, handedness, and footedness) were entered into the model. The overall model was not significant (R^2 = 0.003, p = 0.377), and none of the control variables significantly predicted the total score. In the second step, age and gender were added to the model, resulting in a significant increase in explanatory power (ΔR^2 = 0.716, p < 0.001), with the final model accounting for 71.8% of the total variance. Age emerged as the strongest positive predictor (β = 0.851, p < 0.01), indicating that increasing age is the primary driver of operational motor skill development. Gender also showed a significant predictive effect (β = −0.095, p < 0.01), suggesting differences between boys

and girls in motor skill performance. Furthermore, after controlling for age and gender, kindergarten type exhibited a significant negative predictive effect (β = −0.173, $p < 0.01$), indicating that kindergarten type may influence motor development through differences in instructional resources or activity arrangements.

To further examine whether gender moderates the relationship between age and total score, the interaction term (age × gender) was entered into the model (see Table 9). The results showed that the interaction term was not significant (B = −0.008, $p = 0.979$), and the model did not gain additional explanatory power ($\Delta R^2 = 0.000$, $p = 0.979$). This suggests that although gender independently predicts motor development, it does not moderate the relationship between age and operational motor skills—that is, the facilitative effect of age on motor skill development does not differ significantly between boys and girls.

Table 8. Hierarchical regression analysis of factors influencing operational motor skills.

Variable	Step 1					Step 2				
	B	SE	t	*p*	β	B	SE	t	*p*	β
Intercept	15.885**	1.917	8.287	<0.001	-	9.602**	1.079	8.897	<0.001	-
Kindergarten type	−0.421	0.386	−1.091	0.276	−0.044	−1.659**	0.207	−8.000	<0.001	−0.173
Handedness	0.395	0.465	0.850	0.396	0.017	−0.075	0.247	−0.304	0.761	−0.003
Footedness	0.395	0.465	0.850	0.396	0.017	−0.075	0.247	−0.304	0.761	−0.003
Age						5.472**	0.139	39.332	<0.001	0.851
Gender						−0.884**	0.198	−4.462	<0.001	−0.095
R^2	0.003					0.720				
Adjusted R^2	−0.000					0.718				
F-value	F (2.0,617.0) = 0.978, $p = 0.377$					F (4.0,615.0) = 394.441, $p < 0.001$				
ΔR^2	0.003					0.716				
ΔF	F (2.0,617.0) = 0.978, $p = 0.377$					F (2,615.0) = 0.059, $p = 0.943$				

Table 9. Moderation effect of gender on the relationship between age and total score.

Variable	Model 1			Model 2			Model 3		
	B	t	*p*	B	t	*p*	B	t	*p*
Intercept	16.856**	160.088	0.000**	16.856**	162.285	0.000**	16.856**	162.144	0.000**
Age	5.309**	36.345	0.000**	5.302**	36.795	0.000**	5.302**	36.703	0.000**
Gender				−0.883**	−4.252	0.000**	−0.883**	−4.249	0.000**
Age × Gender							−0.008	−0.026	0.979
R^2	0.681			0.690			0.690		

Continued

Adjusted R^2	0.681	0.689	0.689
F-value	F (1.0,618.0) = 1320.946, $p < 0.001$	F (2.0,617.0) = 687.769, $p < 0.001$	F (3.0,616.0) = 457.770, $p < 0.001$
ΔR^2	0.681	0.009	0.000
ΔF	F (1.0,618.0) = 1320.946, $p < 0.001$	F (1,617.0) = 18.081, $p < 0.001$	F (1,616.0) = 0.001, $p = 0.979$

Note: *$p < 0.01$. The interaction term (Age × Gender) was not significant ($p = 0.979$), indicating no moderation effect.

To further verify the robustness of the above regression model and identify the most parsimonious combination of predictor variables, a stepwise regression analysis was conducted using five candidate variables: age, gender, kindergarten type, handedness, and footedness, to screen for predictors with significant explanatory power for the total operational motor skills score. As shown in Table 10, the variables ultimately retained in the regression equation were age, kindergarten type, and gender, with the model explaining 71.9% of the total variance (adjusted $R^2 = 0.719$, F (3,616) = 526.666, $p < 0.001$). Handedness and footedness were excluded due to non-significant predictive effects. This result is highly consistent with the hierarchical regression model, further confirming the stable and core roles of age, kindergarten type, and gender in predicting operational motor skills. Multicollinearity diagnostics indicated no collinearity issues among the variables (VIF ≈ 1), and the Durbin-Watson statistic (1.632) suggested acceptable residual independence.

Table 10. Stepwise regression analysis: Final predictive model after variable selection.

Variable	Unstandardized Coefficients		Standardized Coefficients	t	p	Collinearity Statistics	
	B	SE				VIF	Tolerance
Intercept	9.309**	0.486	-	19.169	0.000	-	-
Age	5.469**	0.139	0.850	39.392	0.000	1.023	0.977
Kindergarten type	−1.657**	0.207	−0.173	−8.000	0.000	1.023	0.977
Gender	−0.884**	0.198	−0.095	−4.465	0.000	1.000	1.000
R^2	0.719						
Adjusted R^2	0.718						
F-value	F (3.0,616.0) = 526.666, $p < 0.001$						
Durbin-Watson	1.632						

Specifically, among the three variables retained in the model, age demonstrated the strongest predictive effect ($\beta = 0.850$, $p < 0.01$), reinforcing its role as the core influencing factor in the development of operational motor skills. Kindergarten type showed a significant negative predictive effect ($\beta = -0.173$, $p < 0.01$), indicat-

ing that, after controlling for age and gender, differences in kindergarten type still exert an independent influence on motor performance, possibly through variations in instructional resources or activity arrangements. Gender also maintained a significant negative predictive effect ($\beta = -0.095$, $p < 0.01$), suggesting stable differences between boys and girls in total motor skill scores. In line with the results of the difference analysis, boys scored significantly higher than girls in operational motor skills, and this difference persisted even after controlling for age and kindergarten type.

4. Discussion

4.1. Age as the Core Driver of Operational Motor Skill Development, Independent of Gender Moderation

The results indicated that age had a highly significant positive predictive effect on children's total operational motor skills score ($\beta = 0.85$), with skill levels improving markedly as age increased. Comparisons across age groups revealed that children aged 5 years 11 months to 6 years 4 months performed significantly better than those aged 5 years 5 months to 5 years 10 months, who in turn outperformed those aged 4 years 11 months to 5 years 4 months. This finding is consistent with the theory of neuromaturational development, reflecting the gradual maturation of motor skills with increasing age. Although gender independently predicted operational motor skills (with boys scoring higher than girls overall), the moderation analysis showed that gender did not moderate the relationship between age and total skill scores. This suggests that the facilitative effect of age on motor development follows a similar pattern for both boys and girls, and that the mechanisms underlying age-related changes—namely physiological maturation and accumulated motor experience—operate equally across genders.

4.2. Differentiated Stratification Characteristics of Children's Operational Motor Skills

Using K-Means cluster analysis based on children's performance in operational motor tasks, this study identified three distinct developmental subgroups: the advantaged development group (35.0%), the average development group (41.5%), and the delayed development group (23.6%). The advantaged development group outperformed the other two groups across all tasks, with particularly strong performance in overhand throwing and kicking—tasks that demand higher levels of coordination. In contrast, the delayed development group scored lowest on all tasks. These findings indicate that children's operational motor skills exhibit significant group-based stratification, and that performance across different motor tasks is highly correlated: children who perform well on one task tend to perform well on others, and vice versa. This consistency suggests that children's overall motor competence can serve as a valid basis for tiered instruction and targeted intervention.

Previous research has established that gross motor skills are closely associated

with age-related growth and physiological maturation (Wang, 2022). However, according to Dynamic Systems Theory, physiological maturation alone does not guarantee the natural progression of motor competence. In the absence of adequate external stimulation or clear behavioral goals, motor development may be substantially hindered. Conversely, when children are placed in supportive environments, the development of object manipulation skills tends to accelerate (Fan, 2013). This theoretical perspective provides a robust rationale for the implementation of differentiated, module-based interventions tailored to children's diverse developmental profiles, as identified in the present study.

4.3. Independent Predictive Effects of Gender and Kindergarten Type on Operational Motor Skills

Multivariate analysis revealed that both gender and kindergarten type served as significant independent predictors of operational motor skills. Specifically, boys scored significantly higher than girls in one-handed striking of a self-bounced ball, two-handed catching, and kicking. Although univariate analysis showed no significant difference in total scores between children from public and private kindergartens, kindergarten type still exerted a significant negative predictive effect ($\beta = -0.173$) on operational motor skills after controlling for age and gender. This suggests that kindergarten type may exert independent influences through variations in educational philosophy, curriculum design, and instructional resources. Notably, children from public kindergartens performed better in two-handed striking of a stationary ball, two-handed catching, and kicking compared to their private kindergarten counterparts.

This disparity may be attributed to the distinct institutional mechanisms underlying the two types of kindergartens. Public kindergartens are primarily funded by government allocations and are subject to systematic internal and external quality supervision. In contrast, private kindergartens rely mainly on market-based funding, and local government oversight tends to focus on licensing and fee regulation, with relatively weak ongoing monitoring of educational processes and substantive quality (Cai & Deng, 2023). Under pressures such as enrollment competition and parental expectations, some private kindergartens may prioritize surface-level service quality over developmentally oriented programming, including systematic support for foundational motor skills such as gross motor development.

5. Recommendations

5.1. Implementing Age-Staged Physical Activity Programs Aligned with Developmental Milestones

The present study confirms that age serves as the core driver of operational motor skill development, with significant differences observed across monthly age subgroups. Accordingly, educational practices should be designed to align with this developmental trajectory by offering age-staged physical activities. For younger

children within the senior kindergarten cohort (lower-monthly-age subgroup), instructional efforts should prioritize the consolidation of fundamental motor patterns, with an emphasis on tasks that are relatively well-mastered, such as two-handed catching and stationary dribbling, to build motor confidence and body awareness. For children in the middle-monthly-age subgroup, instruction should progressively introduce simple coordination tasks—for example, kicking with the non-dominant foot and low-difficulty striking activities—to promote motor coordination and integration. For older children within the senior kindergarten cohort (higher-monthly-age subgroup), programming should emphasize more complex movements and coordination challenges, such as one-handed striking of a self-bounced ball and throwing combined with stepping patterns, with focused attention on improving movement speed and accuracy.

5.2. Optimizing Resource and Activity Allocation in Response to Kindergarten Type Differences

The findings suggest that kindergarten type independently influences operational motor skills. To narrow potential gaps in resources and instructional quality between different types of kindergartens, the following three strategies are recommended. First, kindergartens should adopt a holistic educational philosophy that values the development and refinement of physical education curricula, with attention to both diversity and playfulness in activity design. In practice, educators can explore effective approaches to integrating physical training with playful engagement—for example, framing striking tasks as "defeating monsters" or designing throwing activities within a "supply transport" scenario—so that children can refine their operational motor skills in a relaxed and enjoyable context. Second, kindergartens should invest in simple yet multifunctional sports equipment, such as balls of various sizes and resilient striking implements, to support diverse training outcomes. In addition, outdoor or activity spaces should be zoned into functional areas—such as throwing zones and striking zones—to provide children with more opportunities for varied motor practice. Third, it is essential to enhance teachers' capacity for systematic observation and differentiated guidance. This includes promptly identifying children's difficulties during object manipulation, adjusting task difficulty levels or utilizing assistive tools as needed, and translating movement requirements into child-friendly language or demonstrations. Kindergartens are also encouraged to organize regular teaching and research activities and peer observation sessions to continuously improve instructional practices in operational motor skills.

5.3. Establishing a Targeted, Tiered Intervention Mechanism for Improving Operational Motor Skills

Accurate assessment of children's motor competence serves as a prerequisite for targeted instruction. The cluster analysis revealed considerable variation in children's operational motor skills, identifying three distinct subgroups: advantaged

development group, average development group, and delayed development group. Kindergartens should conduct routine motor skill assessments using validated and standardized tools to accurately determine each child's developmental level and subsequently tailor instructional strategies accordingly.

For children with weaker operational motor skills—for example, those struggling with one-handed striking of a self-bounced ball—teachers are advised to adopt a task decomposition approach, breaking down complex movements into smaller, manageable components. Providing lightweight, appropriately sized rackets and integrating skill practice into scenario-based games can facilitate children's acquisition of movement techniques. During instruction, teachers should actively guide children to attend to their body posture, sequencing of force exertion, and spatial orientation, thereby enhancing their body awareness and movement control.

In addition, it is recommended that kindergartens establish individual developmental portfolios for each child to systematically document their progress in operational motor skills. Such records can serve as an evidence base for planning and refining instructional practices.

5.4. Building a Supportive Environment for Collaborative Home-Kindergarten-Community Partnerships

The Healthy China strategy emphasizes the promotion of health from early life, with gross motor development in early childhood serving as a cornerstone for lifelong physical literacy and healthy lifestyles. To this end, kindergartens, families, and communities should work collaboratively to foster a "dynamic and healthy community". Kindergartens can actively fulfill a leadership role by organizing regular parent open days or parent-child activities, allowing parents to observe and appreciate the significance of operational motor development firsthand. Communicating assessment processes and outcomes with families can further strengthen parents' recognition of operational motor skills at both cognitive and practical levels.

The family setting offers a natural and valuable context for practicing operational motor skills. Kindergartens can design home-based physical tasks that require simple materials and are easy to implement—for example, encouraging families to engage in two-handed catching games with their children for 10 attempts per day, thereby integrating gross motor practice into daily family routines.

Community resources can effectively compensate for the limitations of kindergartens and families in terms of space and facilities. Community sports centers and parks could host family physical activity zones on weekends, equipped with child-safe apparatus and staffed by volunteer instructors. Alternatively, community fitness instructors may be invited to kindergartens to deliver professional activity guidance, enriching children's motor experiences.

Author Contributions

ZHU Jiajia (First Author): Responsible for research design and manuscript writ-

ing. YANG Mengping (Second Author): Responsible for data collection. CAI Ying (Third Author): Responsible for statistical analysis.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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