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Original article

Manipulative skill competency and health-related physical fitness in elementary school students

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Abstract

Background: Improving motor skill competency and enhancing health-related physical fitness are desired learning outcomes for school-aged children. Achieving motor skill competency and a healthy level of physical fitness lay a foundation for being a physically active person across a lifetime. The purpose of this study was to investigate relationships between levels of manipulative skill competency and physical fitness for elementary school boys and girls.

Methods: In this study, 565 fourth-grade students and their 9 physical education teachers were voluntary participants. The students were assessed in 4 basic specialized manipulative skills and 4 fitness components during regular physical education lessons. Data were analyzed with descriptive statistics, univariate analyses, and multiple R^2 liner regression methods.

Results: Boys were more proficient at the manipulative skills than girls, while girls had significant higher percentages for meeting the healthy fitness zone for the fitness tests than boys. Four manipulative skills significantly predicted progressive aerobic cardiovascular endurance run (PACER), push-up, and trunk lifts tests at $p < 0.05$ level, but not curl-up test for both boys and girls. Boys and girls in the skill-competent group significantly outperformed their counterparts in the skill-incompetent group on PACER, push-up, and trunk lifts tests at $p < 0.05$ level, with an exception of curl-up test.

Conclusion: The more competent in manipulative skills, the higher healthy level in cardiovascular endurance, upper-body muscular strength and endurance, and flexibility the students demonstrated. Demonstrating manipulative skill competence and maintaining a healthy level of physical fitness are 2 major desired learning outcomes for elementary school students to be able to achieve.

Keywords: Fitness assessment; Healthy fitness zone; Manipulative skill competency; Physical fitness; Skill assessment

1. Introduction

Improving motor skill competency and enhancing health-related physical fitness are desired learning outcomes for school-aged children to achieve.[1] Children who are skillfully competent and physically fit are more likely to be active persons compared to their counterparts who are less skillful and unfit.[2–8] Demonstrating motor skill competency and achieving a health-enhancing level of physical fitness are cornerstones for developing a physically active lifestyle throughout childhood and adolescence, and into adulthood.[2–17]

National Standard 1 for K-12 Physical Education (PE) defines that students should "demonstrate competency in motor skills and movement patterns".[1] According to the outcome expectation for grades 3–5, students' achieving the Standard 1 implies to demonstrate mature forms of fundamental motor skills, to combine one skill with another, and to apply the skills in dynamic situations.[1] The fundamental motor skills, consisting of locomotor skills, manipulative skills, and non-manipulative skills, are building blocks for successful participation in many sports and various physical activities (PAs).[1–8] Empirical studies showed that children with adequate motor skill competency spent significantly more time in moderate-to-vigorous PA than children with insufficient motor skill competency.[15–18] Especially, childhood manipulative skill proficiency was associated with adolescents' participation in a variety of PA and organized

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sports and also significantly predicted their cardiovascular fitness in adolescence.[7,8] However, given a lack of performance-based motor skill assessment tools in previous studies,[2–8,15–18] motor skill competency was evaluated either using product-oriented criteria with a combined product score or merely process-oriented criteria with "yes" or "no" rating scale. To fill the gaps in motor skill assessments, the National Association for Sport and Physical Education (NASPE) published *PE Metrics*: *Assessing the National Standard 1: Elementary*,[19] as a result of conducting 4 years of extensive testing with 4000 students at 90 schools in the US. The PE metrics assessment rubrics are specifically designed to assess levels of students' competency in fundamental motor skills using both process- and product-oriented criteria.[19]

Likewise, maintaining and enhancing health-related physical fitness, including cardiovascular endurance, muscular strength and endurance, flexibility, and body composition, lays a foundation for participating in a variety of sports and PA.[1–14] A healthy level of physical fitness is a key indicator of health status.[9–14] Students who demonstrated healthy cardiovascular endurance level had a lower level of overall adiposity and abdominal adiposity[9] and low metabolic risk.[11] It is shown that muscular strength/endurance was associated with established and emerging cardiovascular disease risk factors.[9–11] Improvements in muscular fitness seem to have a positive effect on skeletal health.[9] Healthy physical fitness in children and adolescents tend to track healthy fitness in adulthood.[9–13] Given the essential role of physical fitness in maintaining health, schools should conduct physical fitness testing to determine how well students meet the National Standard 4: Achieves and Maintains a Health-enhancing Level of Physical Fitness.[1] Recently, the FITNESSGRAM® test has been used to assess students' levels of physical fitness.[2–8] It is a nationally recognized, valid, and reliable fitness assessment toolkit specifically designed for assessing cardiovascular endurance, muscular strength and endurance, flexibility, and body composition through a variety of test items.[20] The FITNESSGRAM®[7] test compares the testing scores to the healthy fitness zone (HFZ) standards based on specific age and gender guidelines to evaluate boys' and girls' physical fitness levels on each test and suggest areas for improvement.[20]

Despite that manipulative skills are central to a variety of sports and PA and manipulative skill competency contributed significantly more to children' participation in sports and PA than locomotor skill competency,[2–7] few studies had ever assessed elementary school students' both process and product of performance in manipulative skills using the PE metrics assessments rubrics.[19] Therefore, the impact of manipulative skill competency assessed with both process- and product-oriented criteria on healthy levels of physical fitness in elementary school students remains largely unknown. Thus, this study aimed at examining relationships between levels of manipulative skill competency and levels of health-related physical fitness in elementary school boys and girls. This study will provide empirical insight about what specific manipulative skills contribute to what specific health-related fitness components for boys and girls.

2. Methods

2.1. Participants

Five hundred and sixty-five fourth-grade students and their 9 PE teachers from 9 elementary schools located in a suburban area in the US were recruited as subjects from the third year of the *Healthy Kids and Smart Kids* project. The project was designed to help elementary school students become physically active, mentally healthy, and socially cooperative children through implementing the Coordinated Approach to Child Health (CATCH) PE curriculum and Mileage Club (MC) Recess Program as well as family/community events.[21–23] The project was awarded Carol White Physical Education Program (PEP) grant by U.S. Department of Education.

In this study, the fourth-grade students consisted of 318 of boys and 247 of girls aged 9–10 years old who completed all tests. The social-economic status of the students' family ranged from lower-middle, middle, to upper-middle classes. The fourth-grade students had one 60-min co-ed PE class each week, a total of 72 weeks during an academic year. The regular PE class size ranged from 18 to 28 students. Students with learning disabilities participated in a special education class which was not included in this study. Four male and 5 female PE teachers' ages ranged from 33 to 55 years old and their teaching experience varied from 6 to 26 years. The University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS) and the school district granted the permission for conducting this study. The student's parent/guardian signed the consent form to grant the permission for their child to participate in this study. All 9 PE teachers signed the consent form to indicate their willingness to participate in this study.

2.2. Data collection

2.2.1. Motor skill measurements

Students' performance in 4 manipulative skills was assessed with validated PE metrics assessment rubrics[19] by their PE teachers who underwent 3 days of training in PE Metrics. Each assessment rubric has its specific essential dimensions, performance indicators (assessment criteria for each level of the rating scale) on 0–4 rating scales, and the number of trial for testing.[19] Table 1 presents the criteria for competence (Level 3) on each essential dimension and the total competent score on each skill assessment described in the PE metrics. To learn more detailed information about each skill assessment, please refer to the PE metrics.[19]

Four manipulative skills selected from the PE metrics[19] and assessed in this study were soccer dribbling, passing, and receiving skills, overhand throwing skill, striking skill with a paddle, and basketball dribbling, passing, and receiving skills. The rationales for assessing the 4 manipulative skills are that they are the core PE content taught to upper-elementary school students and they are basic manipulative skills used playing a variety of team- and individual-sports by upper-elementary school students.[1]

Throughout the academic year of 2011–2012, the soccer skills were assessed in the first week of October, the throwing

Table 1
Criteria for competence (Level 3) on each essential dimension of the PE metrics assessment rubrics.

	Essential dimensions	Total competence score	Criteria for competence (Level 3)
Soccer: dribbling, passing, and receiving (1 trial)	Dribbling, passing, and receiving	9 out of 12	1. Dribbling: dribbles with control while moving at a slow, consistent jog. 2. Passing: sends a receivable lead pass to a partner so it can be received outside the passing lane without a break in the receiver's stride on at least 3 passes. 3. Receiving: moves forward and outside the passing lane to meet the ball while receiving at least 3 receivable passes.
Overhand throwing (3 trials)	Form and accuracy to target	18 out of 24	1. Form: throws with selected essential elements: a) Throwing elbow shoulder-high, hand back and side orientation in preparation for the throw. b) Trunk rotation, with elbow lagging behind hip. c) Weight transfer to non-throwing forward foot. 2. Accuracy to target: hits target area on wall.
Striking with a paddle (1 trial)	Form and continuous strikes	6 out of 8	1. Form: usually uses a side orientation. 2. Continuous strikes: strikes the ball continuously against the wall 5 times from 10 feet with added strokes that may be in front of the 10-foot striking line.
Basketball: dribbling, passing, and receiving (1 trial)	Dribbling, passing, and receiving	9 out of 12	1. Dribbling: dribbles with control while moving at a slow, consistent jog. 2. Passing: sends a catchable lead pass to a partner so it can be caught outside the passing lane without a break in the receiver's stride on at least 3 passes. 3. Receiving: moves forward and outside the passing lane to meet the ball and catches 3 catchable passes.

skill was assessed in the second week of November, the striking skill with a paddle was assessed in the second week of January, and the basketball skills were assessed in the second week of March. Each PE teacher was required to strictly use the PE metrics assessment testing protocols, directions, assessment criteria, assessment rubrics, and assessment tasks[19] to conduct each skill assessment with 1 student at a time in the school gymnasium during a regular PE class at his/her school.

In this study, the Cronbach α reliability coefficients of soccer skills, throwing skill, striking skill with a paddle, and basketball skills assessments were 0.90, 0.89, 0.88, and 0.92. The results showed that 4 manipulative skill assessments had satisfactory internal consistency reliability.[24]

2.2.2. *FITNESSGRAM® tests*

Students' physical fitness was assessed using 4 FITNESSGRAM® test items[20] by their PE teachers who attended 1-day training. The physical fitness tests included: (a) 15 m version of progressive aerobic cardiovascular endurance run (PACER) for cardiovascular endurance, (b) curl-up test for abdominal muscular strength and endurance, (c) push-up test for upper body strength and endurance, and (d) trunk lift for trunk extensor strength and flexibility. During the first 2 weeks of May, each PE teacher administered 1 physical fitness test at a time to their students in the school gymnasium during a regular PE lesson in accordance with the testing protocols such as test objective, equipment and facilities, test instructions, when to stop the test, and scoring described in FITNESSGRAM® Test Administration Manual.[20] For PACER test, a group of students were tested at a time while the other group of students counted and recorded their partner's number of successful running laps on the PACER testing sheet. After the completion of the test, each group switched its role. For the other 3 fitness tests, the PE teacher tested 1 student at a time and recorded the student's score on each testing scoring sheet. Then, each PE teacher used the FITNESSGRAM® software (Version 8.4; the Cooper Institute, Dallas, TX, USA) to record the testing results.

The FITNESSGRAM® test uses criterion-referenced standards to classify fitness levels into the HFZ and the Needs Improvement (NI) Zone.[20] If a child's score on a fitness test is in the HFZ he/she is considered to have a healthy level of that specific fitness. In contrast, the NI indicates that if the student continues to track at this level there is the potential for future health risks. The HFZ is defined specifically for each test type, age, and gender.[20] The "FITNESSGRAM® standards for HFZ for boys" and the "FITNESSGRAM® standards for HFZ for girls" were used to determine whether a student's score on each test was placed into the HFZ or not.[20]

2.3. *Data analysis*

SPSS statistics software (Version 21.0; IBM Cooperation, Armonk, NY, USA) was used to conduct all statistical analysis of the data assessed in this study. A significant level of $p < 0.05$ was set for all statistical analysis. To determine levels and proportions of boys' and girls' demonstration of competency in each manipulative skill assessment and meeting the HFZ in each physical fitness test, descriptive statistics and percentages

were computed. To examine the mean score difference in each manipulative skill assessment between boys and girls, the independent sample *t* test was utilized. To examine if there was a significant difference of observed frequency for meeting HFZ between boys and girls on each physical fitness test, the Fisher exact χ^2 method was conducted. Regardless of the gender-specific guidelines for HFZ, to determine the mean score difference in each physical fitness test between boys and girls, the independent sample *t* test was utilized.

Given gender differences in the manipulative skill assessments and physical fitness tests by means of the univariate analysis, the rest of statistical analysis were conducted for boys and girls separately. A composite score of the skill competent level in the 4 skill tests were computed to classify an overall skill competence into 2 groups (skill-competent level = 42–56 scores, skill-incompetent level = 14–41 scores) based on the PE metrics criteria for defining the competent level. To examine whether the manipulative skills predicted the HFZ in each physical fitness test for boys and girls, the multiple R^2 linear regression analyses were then performed using the total score of each manipulative skill assessment as predictors. Subsequently, to assess the relative importance of each manipulative skill in predicting each physical fitness test for boys and girls, the standardized multiple regression coefficients were analyzed. Furthermore, to examine mean score difference of each physical fitness test between the 2 levels of overall skill competency, the independent sample *t* test was conducted by gender.

3. Results

3.1. Descriptive statistics and univariate analysis in manipulative skill assessments

Table 2 presents the descriptive statistics of manipulative skill assessments by gender and the total sample. The mean score of the total sample was slightly higher than the competent level on soccer skills, throwing skill, and basketball skills, while the mean score of the total sample was at the competent level on striking skill assessment. Boys' mean scores of 4 manipulative skill assessments and girls' mean scores of 3 skill assessments were slightly higher than the competent level, but girls' mean score of striking skill assessment was lower than the competent level. Independent sample *t* tests indicated that boys scored significantly higher than girls on soccer skills ($t = 3.55$, $df = 563$), overhand throwing skill ($t = 4.59$, $df = 563$), basketball skills ($t = 5.23$, $df = 563$), and striking skill ($t = 4.01$, $df = 563$) at $p < 0.01$ significant level.

Among 318 boys, 92% of them demonstrated the competent level or above in basketball skills, 84% in throwing skill, 81% in soccer skills, and 70% in striking skill. Of 247 girls, 83% of the girls demonstrated the competent level or above in basketball skills, 76% in throwing skill, 68% in soccer skills, and 56% in striking skill. Results of χ^2 tests revealed a significant difference of percentages between boys and girls on soccer skills ($\chi^2 = 26.29$, $df = 9$), throwing skill ($\chi^2 = 45.47$, $df = 16$), basketball skills ($\chi^2 = 35.67$, $df = 8$), and striking skills ($\chi^2 = 24.30$, $df = 6$) at the significant level of $p < 0.01$.

Table 2
Descriptive statistics for manipulative skills by gender and total sample.

Skill	M	SD	SE	Min.	Max.	% of competence
Soccer (competence score: 9)						
Boy	9.79	1.74	0.098	4	12	81
Girl	9.29	1.73	0.110	3	12	68
Total	9.55	1.75	0.074	3	12	75
Throwing (competence score: 18)						
Boy	20.82	3.24	0.182	4	24	84
Girl	19.55	3.36	0.214	6	24	76
Total	20.25	3.35	0.141	4	24	81
Basketball (competence score: 9)						
Boy	10.43	1.65	0.092	3	12	92
Girl	9.72	1.59	0.101	5	12	83
Total	10.11	1.66	0.070	3	12	88
Striking (competence score: 6)						
Boy	6.22	1.50	0.084	2	8	70
Girl	5.72	1.43	0.091	2	8	56
Total	6.00	1.49	0.063	2	8	64
Total skill (competence score: 42)						
Boy	47.26	6.30	0.353	25	56	82
Girl	44.27	6.08	0.387	19	56	70
Total	45.91	6.37	0.268	19	56	77

Note: $n = 565$ (boy 318, girl 247).
Abbreviations: M = mean; Max. = maximum score; Min. = minimum score; SD = standard deviation; SE = standard error.

3.2. Descriptive statistics and univariate analysis in physical fitness tests

Table 3 presents descriptive statistics of physical fitness tests by gender and the total sample. To meet the HFZ standards for 15 m PACER test, a 10-year-old boy should run between 30 and 80 laps, while a 10-year-old girl run between 9 and 54 laps.[20] For PACER test, boys' mean score was on the low end of HFZ and 47% of the boys ran 30 laps or more, meeting the HFZ. In contrast, the girls' mean score was in the middle of HFZ and 98% of the girls ran 9 laps or more, reaching HFZ. χ^2 test

Table 3
Descriptive statistics of physical fitness tests by gender and total sample.

	HFZ	M	SD	SE	Min.	Max.	% of persons meeting HFZ
PACER							
Boy	30–80	30.00	17.15	0.962	4	72	47
Girl	9–54	25.00	13.21	0.834	5	72	98
Total		28.00	15.68	0.660	4	12	70
Curl-up							
Boy	12–24	27.00	20.35	1.141	1	80	77
Girl	12–26	27.00	18.30	1.164	1	80	83
Total		27.00	19.46	0.819	1	80	72
Push-up							
Boy	7–20	13.00	9.38	0.526	1	54	75
Girl	7–15	12.00	7.63	0.486	1	46	73
Total		13.00	8.69	0.366	1	54	74
Trunk lift							
Boy	9–12	10.98	1.90	0.101	5	12	87
Girl	9–12	11.43	1.33	0.085	5	12	92
Total		11.00	1.62	0.068	2	12	80

Note: $n = 565$ (boy 318, girl 247).
Abbreviations: HFZ = healthy fitness zone; M = mean; Max. = maximum score; Min. = minimum score; PACER = progressive aerobic cardiovascular endurance run; SD = standard deviation; SE = standard error.

indicated that the percentage of girls who met the HFZ was significantly higher than that of boys based on the gender-specific guidelines ($\chi^2 = 113.89$, $df = 63$, $p < 0.01$). However, regardless of the age- and gender-specific guidelines for the healthy zone, an independent t test was used to examine the mean lap differences between the boys and the girls. The results of the t test indicated that boys statistically outperformed girls on the PACER test ($mean_{boys} = 30$ *vs*. $mean_{girls} = 25$, $t = 3.578$, $df = 563$, $p < 0.01$).

To reach the HFZ for the curl-up test, 10-year-old boys and girls need to complete 12–24 and 12–26 curl-ups.[20] For curl-up test, both boys' and girls' mean scores were higher than the high end of HFZ. Seventy-seven percent of boys and 83% of girls met HFZ and above. A χ^2 test revealed that the percentage of girls' meeting the HFZ was statistically and significantly higher than that of boys' ($\chi^2 = 84.6$, $df = 60$, $p < 0.05$). However, t test revealed no statistically significant difference in the mean score of curl-up test between boys and girls ($mean_{boys} = 27$ *vs*. $mean_{girls} = 27$, $t = 0.138$, $df = 563$, $p > 0.05$).

To meet the HFZ for push-up test, 10-year-old boys and girls need to perform 7–20 and 7–15 completed push-ups.[20] Regarding push-up test, boys' and girls' mean scores were moderately higher than the low end of HFZ. Seventy-five percent of boys and 73% of girls reached HFZ. A χ^2 test yielded no significant difference of percentages for meeting the HFZ between boys and girls. In contrast, the results of the t test indicated that boys' mean score in push-up test was significantly higher than girls' ($mean_{boys} = 13$ *vs*. $mean_{girls} = 12$, $t = 2.285$, $df = 563$, $p < 0.05$).

To meet the HFZ for the trunk lift test, both boys and girls need to lift the upper body 9–12 inches off the floor from the prone position.[20] For trunk lift test, boys' and girls' mean scores were close to the high end of HFZ. Eighty-seven percent of boys and 92% of girls met HFZ. A χ^2 test indicated that the percentage of girls reaching HFZ was statistically and significantly higher than that of boys ($\chi^2 = 22.59$, $df = 12$, $p < 0.05$). Similarly, the t test yielded a significant mean score difference in the trunk lift test between boys and girls ($mean_{boys} = 10.98$ *vs*. $mean_{girls} = 11.43$, $t = -3.349$, $df = 563$, $p < 0.01$).

3.3. Predictors of manipulative skills to physical fitness tests

Table 4 presents the results of the multiple R^2 linear regression analysis with manipulative skills predicting each physical fitness test for boys and girls. The regression model with the 4 manipulative skills as independent variables and PACER test as a dependent variable indicated that these skills significantly predicted PACER test for boys ($F(4, 313) = 10.98$, $p < 0.01$) and girls ($F(4, 242) = 2.93$, $p < 0.05$). These manipulative skills explained 12% of the variance in PACER test for boys and 5% for girls. The results of standardized regression coefficients (β) for boys indicated that basketball and throwing skills were significant contributors to predicting the number of laps run for PACER test, while soccer and striking skills did not display significant β weights. In contrast, none of the skills for girls displayed significant β weights at $p < 0.05$ level.

The regression model containing 4 manipulative skills predictors of push-up test revealed that the 4 skills significantly predicted the number of push-up performed by boys ($F(4, 313) = 6.54$, $p < 0.01$) and girls ($F(4, 242) = 6.49$, $p < 0.01$). The 4 skills accounted for 8% of the variance in the number of push-up completed by boys and 10% for girls. For boys, basketball skills demonstrated significant β weight. In contrast, throwing and striking skills displayed significant β weights for girls.

Table 4
Results of multiple R^2 regression model using manipulative skills predicting physical fitness tests.

	R^2	F	df	p	β	t	p
PACER							
Boy							
Model	0.12	10.98	4, 313	<0.01			
Soccer skill					0.10	1.68	>0.05
Throwing skill					0.14	2.09	<0.05
Basketball skill					0.16	2.43	<0.05
Striking skill					0.05	0.84	>0.05
Girl							
Model	0.05	2.93	4, 242	<0.05			
Soccer skill					0.04	0.58	>0.05
Throwing skill					0.12	1.70	>0.05
Basketball skill					0.12	1.69	>0.05
Striking skill					−0.02	−0.02	>0.05
Push-up							
Boy							
Model	0.08	6.54	4, 313	<0.01			
Soccer skill					0.06	0.98	>0.05
Throwing skill					0.01	0.18	>0.05
Basketball skill					0.18	2.75	<0.01
Striking skill					0.10	1.50	>0.05
Girl							
Model	0.10	6.49	4, 242	<0.01			
Soccer skill					0.01	0.13	>0.05
Throwing skill					0.18	2.47	0.05
Basketball skill					0.02	0.22	>0.05
Striking skill					0.18	2.40	<0.05
Trunk lift							
Boy							
Model	0.11	9.21	4, 313	<0.01			
Soccer skill					0.12	1.93	0.05
Throwing skill					−0.04	−0.59	>0.05
Basketball skill					−0.08	−1.26	>0.05
Striking skill					0.31	4.87	<0.01
Girl							
Model	0.15	10.69	4, 242	<0.01			
Soccer skill					0.03	0.40	>0.05
Throwing skill					0.31	4.34	<0.01
Basketball skill					−0.14	−2.03	<0.05
Striking skill					0.15	2.12	<0.05
Curl-up							
Boy							
Model	0.02	1.45	4, 313	>0.05			
Soccer skill					0.04	0.53	>0.05
Throwing skill					−0.07	−0.98	>0.05
Basketball skill					0.08	1.16	>0.05
Striking skill					−0.12	−1.80	>0.05
Girl							
Model	0.01	0.82	4, 242	>0.05			
Soccer skill					0.02	0.26	>0.05
Throwing skill					−0.13	−1.81	>0.05
Basketball skill					0.01	0.15	>0.05
Striking skill					0.06	0.74	>0.05

Abbreviation: PACER = progressive aerobic cardiovascular endurance run.

The regression model with the 4 manipulative skills as predictors of trunk lift test indicated that the 4 skills significantly predicted trunk lift for boys ($F(4, 313) = 9.21$, $p < 0.01$) and girls ($F(4, 242) = 10.69$, $p < 0.01$). The 4 skills explained 11% of the variance in trunk lift for boys and 15% for girls. Striking and soccer skills for boys and throwing, basketball and striking skills for girls displayed significant β weights. The regression model with the 4 manipulative skills as predictors of curl-up test revealed no significant associations for boys and girls.

3.4. Differences in physical fitness tests between skill competent and skill incompetent groups

The composite skill competent score of 42 in the 4 manipulative skill assessments was used to classify 261 boys into the skill-competent group and 57 boys into the skill-incompetent group. Table 5 shows boys' mean scores of physical fitness tests between the skill-competent and the skill-incompetent groups. The results of *t* tests indicated that boys in the skill-competent group significantly outperformed their counterparts in the skill-incompetent group on PACER ($t = 4.54$, $df = 85.39$, $p < 0.01$), push-up ($t = 2.96$, $df = 81.76$, $p < 0.01$), and trunk lift test ($t = 2.30$, $df = 74.04$, $p < 0.05$), but not on curl-up test.

Similarly, the composite skill competent score of 42 in the 4 manipulative skill assessments was used to classify 173 girls into the skill-competent group and 74 girls into the skill-incompetent group. Table 5 shows girls' mean scores of fitness tests between the skill-competent and skill-incompetent groups. Results of *t* tests revealed a significance difference of mean scores between the 2 groups for PACER ($t = 4.45$, $df = 206.25$), push-up ($t = 4.39$, $df = 169.17$), and trunk lift test ($t = 2.86$, $df = 96.93$) at $p < 0.01$ significant level, not for curl-up test.

4. Discussion

This study was central to examining the relationship between levels of manipulative skill competency and levels of health-related physical fitness. The discussion of the results was organized into 4 parts: (a) gender differences in manipulative skills, (b) gender differences in physical fitness tests, (c) relationship between manipulative skills and physical fitness by gender, and (d) physical fitness differences between skill-competent and skill-incompetent groups.

4.1. Gender differences in manipulative skills

Consistent with the previous studies,[5–8,25–27] this study found gender differences in manipulative skill competence. Previous studies[5–8,25–27] showed that boys were more proficient than girls in manipulative skill performance. Similarly, this study confirmed that boys were more skillfully competent in performing all 4 manipulative skills than girls. The gender differences in the 4 manipulative skills might be related to environmental influences.[15–17] Due to the fact that 3 of the 4 skills including soccer dribbling, passing, and receiving skills, overhand throwing skill, and basketball dribbling, passing, and receiving skills are all basic specialized skills used for playing team sports. These team sports are more popular among boys than girls. Boys are more likely to play these team sports during recesses in school and outside of school, compared to girls. Therefore, participation in these team sports may be considered more socially acceptable for boys, compared to girls. Given the social environment influences, boys may have more opportunities to participate in these sports. Therefore, they may have more opportunities to practice and refine the manipulative skills widely used in playing these sports.[15–18]

However, it is important to note that despite the gender differences in the manipulative skill competence, the promising results of this study indicated that both boys and girls, on average, demonstrated slightly higher than the competent level on the manipulative skills, except for girls' performance on striking skill assessment, which was slightly lower than the competent level. The results of this study were much better than the findings reported by Zhu et al.[28] who examined levels of fifth-grade students' manipulative skill competency while testing the validity of the PE metrics assessment rubrics. They reported that fifth-grade students, on average, scored 1 level lower than the competent level in soccer dribbling, passing, and receiving skills, scored slightly lower than the competent level in overhand throwing skill, and demonstrated 2 levels lower than the competent level in striking skill with a paddle.

4.2. Gender differences in physical fitness tests

Largely in line with the previous studies,[2–8] this study found gender differences in physical fitness tests. According to the gender-specific standards for the HFZ, almost all girls (98%) in this study met HFZ in PACER test, while less than half of the boys (47%) reaching the HFZ for cardiovascular endurance. However, comparing the mean laps, boys ran significant more laps than girls. Likewise, Erwin and Castelli[6] reported that boys statistically outperformed girls on PACER tests. Similarly, Barnett et al.[7] found that boys ran more laps than girls on cardiovascular endurance test.

Despite the higher percentage of girls' meeting the curl-up HFZ than that of boys, both girls and boys had same mean score

Table 5
Physical fitness tests between skill-competent and skill-incompetent groups by gender (mean ± SD).

Group	Gender	*n*	PACER	Curl-up	Push-up	Trunk lift
Skill-competent	Boy	261	31.91 ± 16.83*	26.82 ± 18.75	14.13 ± 9.25*	11.10 ± 1.72*
	Girl	173	27.27 ± 14.04*	25.67 ± 17.41	12.95 ± 7.82*	11.62 ± 1.06*
Skill-incompetent	Boy	57	21.19 ± 15.97	27.72 ± 26.67	10.12 ± 9.34	10.43 ± 2.05
	Girl	74	20.57 ± 9.11	28.65 ± 20.19	8.80 ± 6.32	10.99 ± 1.75

* $p < 0.01$, compared with counterparts in skill-incompetent group.
Abbreviation: PACER = progressive aerobic cardiovascular endurance run.

of the curl-up test. Erwin and Castelli[6] also reported no statistically significant difference on the curl-ups by gender. Regarding the push-up test, the boys had slightly higher percentages for meeting the HFZ than the girls. Also, boys performed significantly higher number of push-ups than girls. Inconsistent with this finding, the studies[5,6] found no significant difference in the mean score of the push-up test between boys and girls. For the trunk lift test, consistent with previous studies[5–8] that the girls had better flexibility than the boys, this study found that more girls met the HFZ compared to boys and girls were more flexible than boys.

It is worthy to note that the proportions of the students' meeting the HFZ for the 4 fitness tests were higher, compare to previous studies.[5,6] Both boys and girls of this study, on average, met the HFZ for cardiovascular endurance, upper-body strength and endurance, back extension strength and flexibility, and reached a higher level than the HFZ for abdominal muscular strength and endurance. The promising results of the manipulative skills assessments and physical fitness tests might be attributed to the third year of implementation of the project including teaching CATCH PE curriculum and conducting mileage club recess program. The CATCH PE curriculum provides students with developmentally appropriate PE content which maps most of the essential content addressed by the national standards.[29] The instructional practices of the CATCH PE are associated with maximizing time on task and learning opportunities, increasing levels of physical activity in PE class, and providing students with congruent and specific feedback about their motor performance.[29]

4.3. Relationship between manipulative skills and physical fitness

In accordance with previous studies that manipulative skill proficiency was significantly associated with health-related physical fitness,[2–8] this study found that all 4 manipulative skills were significant predictors of cardiovascular endurance, upper-body muscular strength and endurance, and back extensor flexibility in upper-elementary school students.

Supporting the previous studies[2–8] that strength of the associations between the manipulative skills and physical fitness tests was gender-specific, one unique finding of this study was that the manipulative skill competency contributed to cardiovascular endurance more for boys than for girls. Furthermore, basketball skills and throwing skill were more significant predictors of the total variance in PACER test for boys. Partially inconsistent with this study, Okely et al.[8] found that a model containing fundamental locomotor and manipulative skills explained more variances in cardiovascular endurance test for adolescent girls than for boys. Given the significant role of manipulative skills in contributing to the healthy level of cardiovascular endurance for boys, this study suggests that to better enhance boys' cardiovascular endurance, school PE should provide quality instructions and developmentally appropriate learning opportunities for students to improve manipulative skills.

Another unique findings were that the manipulative skills competency were significant contributor to push-up and trunk lift tests more for girls, compared to boys. For boys, basketball skills were significant predictors of the variance in push-up test; soccer and striking skills were significant predictors of the variance in trunk lift test. In contrast, for girls, throwing and striking skills were significant predictors to the variance in push-up test; throwing skill, basketball skills, and striking skill were significant contributors to the variance in trunk lift test. The results indicated that manipulative skills, especially throwing and striking skills are instrumental to improving girls' upper body strength and back extensor flexibility. To effectively enhance girls' upper body strength and endurance and flexibility, PE teachers may engage students in practicing throwing and striking skills with different types of balls and rackets and performing the skills with different ways within the context of a variety of learning tasks and game situations.

4.4. Physical fitness differences between skill-competent and skill-incompetent groups

In line with the findings of previous studies,[2–8] this study confirmed that elementary school students' manipulative skill competency played a critical role in contributing to their healthy levels of health-related fitness. This study confirmed that both boys and girls who were skillfully competent in performing all 4 manipulative skills were more physically fit, compared to their counterparts who were less competent in the manipulative skills.

Regarding the differences in cardiovascular endurance between the skill-competent and the skill-incompetent groups, this study showed that boys who demonstrated the competent level in all 4 manipulative skills exhibited a very healthy level of cardiovascular endurance. In contrast, boys who were in skill-incompetent group did not reach the HFZ in cardiovascular endurance. Consistent with the present findings, previous study[4] found that children with motor skill competence showed good cardiovascular fitness performance, while children with motor skill incompetence performed poorly on a cardiovascular fitness test. Although the girls in the skill-competent and skill-incompetent groups all reached the HFZ for cardiovascular endurance, the girls who were manipulative skill competent ran significant more laps than the girls who were manipulative skill incompetent. In other words, the girls who demonstrated manipulative skill competent level reached more toward high end of the HFZ in PACER test with the mean lap of 27.27 (HFZ of 9–54 laps), while the girls who showed manipulative skill incompetent level reached more toward low end of the HFZ in PACER test with the mean score of 20.57.

With respect to the differences in muscular strength and endurance between the skill-competent and the skill-incompetent group, this study showed that both boys and girls who were manipulative skill competent demonstrated more healthier level of upper-body muscular strength and endurance and flexibility, compared to their counterparts who were manipulative skill incompetent, although boys and girls in the 2 groups met the HFZ for upper-body muscular strength and endurance, and back extensor strength and flexibility. Both boys and girls who demonstrated manipulative skill competence reached high end of HFZ for push-up with mean score of 14.13 and 12.95 (HFZ:

7–20 for boys, 7–15 for girls), compared to their counterparts who showed manipulative skill in-competence with the mean score of 10.12 and 8.80 in push-up test. Similarly, both boys and girls who demonstrated manipulative skill competence reached toward high end of HFZ in trunk lift test with mean score of 11.10 and 11.62 (HFZ: 9–12 for boys and girls), compared to their counterparts who were manipulative skill incompetent. Interestingly, both boys and girls in skill-competent group performed lower number of curl-ups than their counterparts in the skill-incompetent group, though no statistically significant difference was found.

Due to the more competent in the manipulative skills, the more physically fit in the health-related physical fitness in upper elementary schools students, this study suggests that school PE should continually focus on teaching the essential content like manipulative skills which are used in playing a variety of sports. This is because that mastery of manipulative skills while playing the sports is a major vehicle for elementary school students to maintain and enhance health-enhancing level of physical fitness.

5. Conclusion

It was concluded that boys outperformed girls on all 4 manipulative skills, but girls outperformed boys on 3 fitness tests, except for push-up test. All 4 manipulative skills were significantly contributed to PACER, push-up, and trunk lift tests for boys and girls, but not curl-up test. However, the magnitudes of the manipulative skills predicting and contributing to healthy levels of physical fitness were gender-specific. Demonstration of competency in manipulative skills was instrumental to promoting healthy levels of physical fitness for boys and girls. This study suggests that manipulative skills used for playing a variety of team and individual sports should be essential PE content for elementary schools students to learn and improve through engaging in developmentally appropriate learning activities. Demonstrating manipulative skill competency is one of the major desired learning outcomes for elementary school students to be able to achieve. Given the purpose of this study and age-specific HFZ standards used for each physical fitness test in FITNESSGRAM®, this study was limited to use cross-sectional research design to examine the relationship between manipulative skills and physical fitness in fourth-grade students.

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Authors' contributions

WC designed the project, analyzed the data, and drafted the manuscript. SM, AHB, and SZ searched the literature on motor skills and fitness, input the data, and edited the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of the presentation of the authors.

Competing interests

There is no financial assistance with this project. There is no conflict of interests regarding financial and/or non-financial aspects. We do not have any financial interest of the subject matter discussed in the manuscript.

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