Perceptual & Motor Skills: Physical Development & Measurement
2015, 121, 3, 873-888. © Perceptual & Motor Skills 2015

EFFECT OF SEX, AGE, AND BMI ON THE DEVELOPMENT OF LOCOMOTOR SKILLS AND OBJECT CONTROL SKILLS AMONG PRESCHOOL CHILDREN[1]

SHU-CHU YANG

Department of Early Childhood Education, National Chiayi University, Taiwan

SHU-JUNG LIN

Department of Early Childhood Educare, Chung Chou University of Science and Technology, Taiwan

CHIA-YEN TSAI

Department of Early Childhood Education, National Dong Hwa University, Taiwan

Summary.—Purposive sampling was used to recruit 1,200 preschoolers between the ages of three and seven from 12 preschools throughout Taiwan in order to examine locomotor skills, object control skills, and fundamental motor skills with respect to sex, age, and body mass index (BMI). Fundamental motor skills were measured using the TGMD–2. Only age had a significant influence on locomotor skills, object control skills, and fundamental motor skills; sex had a small influence on object control skills, and BMI had a very limited influence on all three categories. The difference from previous studies related to BMI may be due to the different items included in the various tests, the number of trials conducted, and ways in which BMI was categorized.

Lifestyles in technologically advanced societies are becoming increasingly sedentary. Outdoor physical play is increasingly being replaced by less physical indoor activities such as Internet browsing, playing video games, and watching television (Tsai & Yang, 2012). At the same time, children are increasingly being driven to school by car or bus instead of cycling or walking. The resulting decrease in physical activity (PA) is associated with decreased physical and mental health (Fjortoft, Pedersen, Sigmundsson, & Vereijken, 2011). Research indicates that preschool children with poorer movement skills tend to be less active than children with better-developed movement skills (Williams, Pfeiffer, O'Neill, Dowda, McIver, Brown, *et al*., 2008), suggesting that increasing children's PA should result in enhanced movement skills.

Fundamental movement skills (FMSs), movement patterns that involve various body parts and provide the basis of physical literacy, are considered important for developing neuromuscular coordination, learn-

[1]Address correspondence to Shu-Jung Lin, Department of Early Childhood Educare, Chung Chou University of Science and Technology, Taiwan or e-mail (s0970815@gmail.com).

DOI 10.2466/10.PMS.121c29x0 ISSN 0031-5125

ing complex and advanced sport skills, and enhancing interpersonal, cognitive, and emotional development (Pang & Fong, 2009). Moreover, preschool and early elementary years are the critical period for a child's development and mastery of FMSs (Ulrich & Sanford, 2000; Hardy, King, Farrell, Macniven, & Howlett, 2009). Research also indicates that FMSs and perceived physical competence are primary mechanisms associated with fitness and participation in PAs (Robinson, 2010) because they provide a foundation for advanced movement and sports-specific skills (Clark & Metalfe, 2002; Robinson & Goodway, 2009). FMSs (e.g., run, gallop, hop, leap, horizontal jump, slide, striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll) can be categorized into locomotor skills and object control skills (Hardy, *et al*., 2009). Shields (2006) stressed the importance of developing FMSs during preschool through PE classes and everyday activities. Although studies have found a positive correlation between FMSs and PA in children and adolescents, the existence of a causal relationship between the two has yet to be demonstrated (e.g., Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Barnett, Ridgers, & Salmon, 2015). Nonetheless, it is clear that the acquisition of FMSs is essential for developing neuromuscular coordination, learning complex and advanced sport skills, and enhancing interpersonal, cognitive, and emotional development (Pang & Fong, 2009).

Most recent research on FMSs focuses on differences related to sex (Hardy, *et al*., 2009; Li, 2009; Giagazoglou, Kabitsis, Kokaridas, Zaragas, Katartzi, & Kabitsis, 2011; Vandaele, Cools, Decker, & Martelaer, 2011; LeGear, Greyling, Sloan, Bell, Williams, Naylor, *et al*., 2012; Yang, Lin, & Tsai, 2014), body mass index (BMI; D'Hondt, Deforche, Bourdeaudhuij, & Lenoir, 2009; Morano, Colella, & Caroli, 2011; Gentier, D'Hondt, Shultz, Deforche, Augustijn, Hoorne, *et al*., 2013; Vameghi, Shams, & Dehkordi, 2013), age (Li, 2009; Gentier, *et al*., 2013; Vameghi, *et al*., 2013; Yang, *et al*., 2014), or socioeconomic position and family and environmental correlates (Dollman & Lewis, 2009; Venetsanou & Kambas, 2010; Barnett, Hinkley, Okely, & Salmon, 2013). Among these studies, Gentier, *et al*. (2013) and Vameghi, *et al*. (2013) investigated the interrelationship between three factors (sex, age, and BMI) and D'Hondt, *et al*. (2013) investigated the interrelationship between two factors (sex and BMI), while Yang, *et al*. (2014) investigated the interrelationship between sex and age, sex and BMI, and age and BMI. Four of these studies conducted multivariate analyses of variance (MANOVA), but each used different sets of measures and different ages and BMI groupings. Because one of the purposes of the present study was to gain increased understanding of FMS development among preschoolers, the participants were divided into four age groups: 3–4, 4–5, 5–6, and 6–7 years. As for BMI, in addition to the three groupings defined by Taiwan's Ministry of Health and Welfare (nor-

mal, overweight, and obese), a fourth grouping was added, underweight. While most of the studies cited above included less than 400 participants, in this study there was a total of 1,029 participants. The Test of Gross Motor Development–2 (TGMD–2) was used so that the results could be compared with those of studies using different testing tools so as to determine how the results are influenced by the measures employed.

Studies of preschool children have found that total locomotor score tends to be higher among girls than boys (Hardy, *et al*., 2009; LeGear, *et al*., 2012). However, Li (2009) found no significant differences in the locomotor skills of preschool and primary school boys and girls. As for object control skills, most studies have found preschool boys to be more advanced than girls (Goodway, Crowe, & Ward, 2003; Giagazoglou, *et al*., 2011; LeGear, *et al*., 2012; Yang, *et al*., 2014), and Li (2009) found both preschool and primary school boys' object control skills to be more advanced than those of girls. Yang, *et al*. (2014), Vandaele, *et al*. (2011), and Hardy, *et al*. (2009) each conducted a detailed comparison of locomotor skills and object control skills. Yang, *et al*. (2014) found that in the 3–5 yr. age group, the boys were better at stationary dribbling than the girls. In Hardy, *et al*. (2009), among the participants 2–6 years of age, the boys had higher total and individual object control skills scores for every skill except catching, in which the difference was not significant. In Vandaele, *et al*. (2011), among 6-yr.-olds, the boys were better than the girls in throwing and catching. While all of these studies indicate that boys have more highly developed object control skills, it needs to be kept in mind that every skill score may have been influenced by the specific measures used.

Yang, *et al*. (2014) found that except for throwing and jumping, locomotor skills and object control skills steadily improve between the ages of 3 and 5 years. Li (2009) also found that FMSs tend to improve with age, but she failed to compare the different skills among different age groups.

In recent years, an increasing number of empirical studies have investigated the relationship between BMI and the development of FMSs among children. Two of these studies (Morano, *et al*., 2011; Vameghi, *et al*., 2013) found that a normal weight group had better object control skills than an obese group. Similarly, D'Hondt, *et al*. (2009) found scores for balance and ball skills to be significantly better in normal weight and overweight groups as compared with an obese group. While Yang, *et al*. (2014) found no significant difference between BMI groups in locomotor skills, they did find a normal weight group to score better on galloping and jumping than their overweight and obese groups; they also found an underweight group to be better at jumping than the overweight and obese groups. As for object control skills, they found a normal weight group to have higher overall scores than an underweight group, and that the nor-

mal-weight group was better at striking a stationary ball and throwing than the overweight and obese groups.

None of these previous studies conducted outside Taiwan included underweight as a separate BMI category, possibly due to the relatively small number of underweight children. In Taiwan, however, in addition to overweight and obese children, there are also a significant number of underweight children, as indicated in a number of related studies. In this connection, in a study conducted in southern Taiwan with 267 children between the ages of 3 and 5 years, Yang, *et al*. (2014) found that 27.7% of the participants were underweight and 13.8% were either overweight or obese. Similarly, in a study on BMI conducted in northern Taiwan with 2,638 children between the ages of 3 and 6 years, Huang (2011) found that 8.8% of the participants were underweight and 19.94% were either overweight or obese. Also, in a study on BMI conducted by Quan and Qian in Japan with 3,912 children aged 3–5 years, the percentage of underweight participants was 13.0%, 19.7%, and 27.3%, respectively, and the percentage of obese participants was 3.3%, 3.5%, and 4.9%, respectively (as cited in Huang, 2011). Thus, it was deemed necessary to include underweight as a separate category in the present study.

In sum, most studies done in this area have either separately examined the influence of age, sex, and obesity on FMSs, or else only compared the development of FMSs with respect to sex and BMI, without making a detailed comparison of age differences. In addition, few of the previous studies have included underweight children as a separate BMI category. Furthermore, very few studies have used the TGMD–2 to investigate all three variables of age, sex, and BMI. Also, few studies have been carried out on the 3–7 year age group. In light of the fact that in Taiwan many children between 6 and 7 years old are still enrolled in preschool, in this study it was deemed necessary to adjust the age groupings accordingly.

The purpose of the present study was to make a detailed comparison of the locomotor skills and object control skills of preschoolers in terms of sex, age, and BMI. It is expected that the extensive empirical data provided by this study will augment existing knowledge of this topic and be useful reference material for other researchers.

Hypothesis 1. There will be a significant three-way interaction between sex, age, and BMI on locomotor skills, object control skills, and FMSs.

Hypothesis 2. There will be significant two-way interactions of sex, age, and BMI with locomotor skills, object control skills, and FMSs.

Hypothesis 3. There will be a main effect of sex in locomotor skills, object control skills, and FMSs.

Hypothesis 4. There will be a main effect of age in locomotor skills, object control skills, and FMSs.

Hypothesis 5. There will be a main effect of BMI in locomotor skills, object control skills, and FMSs.

Method

Participants

In this study, purposive sampling was used to recruit 1,200 Taiwanese preschoolers between the ages of 3 and 7 years attending a preschool in one of the four regions into which Taiwan is customarily divided (north, center, south, and east). The 12 preschools included were recommended by professors of early childhood education in each of these four regions. Each participating preschool was visited to discuss the project with the principal and teachers. A total of 22 teachers participated in this study to maintain order among the children during testing. Prior to testing, the participants' teachers and parents signed a consent form. Of the initial 1,200 participants, 171 did not participate in all the tests and were thus excluded from the results, leaving 1,029 (85.75%) participants: 516 boys and 513 girls. Of these, 104 were between the ages of 3 and 4 years, 331 were ages 4–5 years, 357 were ages 5–6 years, and 237 were ages 6–7 years (Table 1). To enroll in

TABLE 1
Distribution of Sex, Age, and BMI

BMI Category	Sex	Age				Total
		3~4 yr.	4~5 yr.	5~6 yr.	6~7 yr.	
Underweight	Boys	4	13	12	7	36
	Girls	4	13	12	5	34
	Total	8	26	24	12	70
Normal	Boys	49	129	120	83	381
	Girls	28	111	131	86	356
	Total	77	240	251	169	737
Overweight	Boys	4	17	23	19	63
	Girls	6	26	27	22	81
	Total	10	43	50	41	144
Obese	Boys	5	10	14	7	36
	Girls	4	12	18	8	42
	Total	9	22	32	15	78
Total	Boys	62	169	169	116	516
	Girls	42	162	188	121	513
	Total	104	331	357	237	1,029

an elementary school in Taiwan, the student must have reached the age of 6 years by September 1 of the school year. Thus, preschools in Taiwan have a large number of students between the ages of 6 and 7 years.

The average age of the participants was 5.1 yr. (SD = 10 mo). In the BMI categories, 70 participants were underweight, 737 were of normal weight, 144 were overweight, and 78 were obese, as defined by Taiwan's Ministry of Health and Welfare (Table 2). The participants' average height was 109.4 cm (SD = 7.1) and their average weight was 19.9 kg (SD = 4.2). Using height and weight to calculate BMI, their average BMI was 16.5 kg/m^2 (SD = 2.2). The height and weight data was measured and recorded by the teachers one day before the FMS tests were conducted or else on the same day. The research team collected this data and used Excel software to calculate the BMI (kg/m^2). This research was given formal approval by Taiwan's Human Research Ethics Committee.

TABLE 2
BMI (KG/M^2) DEFINED BY TAIWAN'S MINISTRY OF HEALTH AND WELFARE

Age (yr.)	Normal Weight		Overweight		Obese	
	BMI		BMI ≥		BMI ≥	
	Boy	Girl	Boy	Girl	Boy	Girl
3–4	14.8 ~ 17.7	14.5 ~ 17.2	17.7	17.2	19.1	18.5
4–5	14.4 ~ 17.7	14.2 ~ 17.1	17.7	17.1	19.3	18.6
5–6	14.0 ~ 17.7	13.9 ~ 17.1	17.7	17.1	19.4	18.9
6–7	13.9 ~ 17.9	13.6 ~ 17.2	17.9	17.2	19.7	19.1

Measures

FMSs were measured using TGMD–2, a widely used test developed in the United States by Ulrich and Sanford (2000). The TGMD–2 is designed for testing children between the ages of 3 and 10 years in a period of between 15 and 20 min., and includes six locomotor skills (run, gallop, hop, leap, horizontal jump, slide) and six object control skills (striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll). The TGMD–2 was selected for this study because it provides a valid and reliable measure of the FMSs of preschool-aged children. The mean test-retest reliability coefficients were .88 for locomotor skills and .93 for object control skills. The interrater reliability coefficient was .98. Content validity for the scale was established via assessment by three experts, and construct validity was established via factor analysis (Ulrich & Sanford, 2000).

Each skill included between three and five performance criteria which were scored as either 1: Present or 0: Absent in two trials. Scores for each child were calculated by totaling the number of correct performances for each skill (e.g., striking a stationary ball consists of five performance cri-

teria, so the score range was 0–10). The maximum subtest score is 48 for both locomotor skills and object control skills, with a minimum of zero. The sum of these subtests yields the total score (total FMS).

Procedure

Individual testing was conducted at the participating preschools. In addition to the three lead researchers, the testing personnel included nine research assistants: six university seniors studying physical education and early childhood education, two graduate students of early childhood education, and one doctoral student of early childhood education. All of the research assistants had a strong interest in the topic of study and adequate time to participate and had already completed a university or graduate school course in sports and physical skills. Each of the research assistants attended three training sessions (3–4 hours each) in which they learned how to use the testing equipment and the testing methods to be used. The training sessions also included watching a demonstration video produced by the researchers, practice drills, and a discussion of the problems most commonly encountered during testing. From among the research assistants, four who had a reliability of .80 or higher were selected to rate the performances. The inter-rater reliability was .84 for locomotor skills and .83 for object control skills.

The testing was carried out at each participating preschool over the course of two days, entirely in accordance with the procedures prescribed for TGMD–2. Using each preschool's outdoor playground, the tester set up a video camera and prepared the testing equipment: a 8–10-in. plastic playground or soccer ball, a 4-in. plastic ball, a tennis ball, a 4–5-in. square bean bag, two traffic cones, colored tape, a plastic baseball bat, a nerf ball, and a batting tee. The testing was conducted on a level and uncluttered surface in good weather during daylight hours, at a time when there was little noise or other distractions.

Working in groups of two (one tester for locomotor skills and one for object control skills), the testers arrived at the preschool 30 min. prior to conducting the testing and prepared the test equipment. After assigning numbers to each participant and having them line up in order, each tester explained the testing procedures, twice demonstrated each skill to be tested, and then had each participant practice the skill twice. Any participants who were reluctant to participate in the activity were not pressured to continue. After concluding the testing, the testers put away the equipment and presented crackers to the teacher and students as a token of appreciation.

Analysis

The Statistical Package for the Social Sciences (SPSS) for Windows, Version 22.0, was used to compile and analyze the data. In addition to calculating the means and standard deviations of the participants' back-

ground data, a two-tailed *t* test was used to compare sex differences in the 12 FMS. A MANOVA was used to assess the effects of age and sex, age and BMI, and sex and BMI on motor skills measures (Hypotheses 1 and 2). A one-way analysis of variance (ANOVA) was used to compare the four age groups and four BMI groups for all 12 FMSs (Hypotheses 3 to 5). Where significant differences were found, the Scheffé test was applied as a follow-up; $p < .01$ was accepted as significant.

Results

Interaction Effects

The 2 × 4 × 4 MANOVA indicated that there was no significant three-way interaction effect between sex, BMI, and age group on locomotor skills, object control skills, and FMSs, so Hypothesis 1 was not supported. Additionally, the MANOVA indicated no significant interaction effects between sex and age group ($F_{3, 1021} = 0.82$, $p > .01$; $F_{3, 1021} = 1.30$, $p > .01$; $F_{3, 1021} = 0.40$, $p > .01$), sex and BMI group ($F_{3, 1021} = 0.48$, $p > .01$; $F_{3, 1021} = 0.73$, $p > .01$; $F_{3, 1021} = 0.78$, $p > .01$), or age and BMI group ($F_{9, 1013} = 0.35$, $p > .01$; $F_{9, 1013} = 0.82$, $p > .01$; $F_{9, 1013} = 0.59$, $p > .01$) on locomotor skills, object control skills, and FMSs, so Hypothesis 2 was not supported.

Main Effects

There were main effects for sex, age, and BMI on locomotor skills, object control skills, and FMSs in the *t* tests and one-way ANOVAs, supporting Hypotheses 3, 4, and 5.

Children's sex.—Table 3 shows that the boys had significantly higher FMS scores than the girls ($t = 3.02$, $p < .01$, $d = -0.19$). However, the trivial effect size indicated that sex was in fact not an important factor in the FMS scores. In the locomotor skills scores, there were no significant sex differences ($t = -1.02$, $p > .01$) except for galloping ($t = -2.88$, $p < .005$) and hopping ($t = -2.67$, $p < .01$). However, the effect size for sex was small. In object control skills, the boys performed significantly better than the girls ($t = 6.10$, $p < .001$, $d = 0.38$), a small effect. Boys had higher scores in striking a stationary ball ($t = 4.45$, $p < .001$), kicking ($t = 4.80$, $p < .001$), and overhand throwing ($t = 4.53$, $p < .001$).

Children's age.—From Table 4, it can be seen that the different age groups had significantly different FMS scores ($F_{3, 1025} = 74.38$, $p < .001$, $\eta^2 = 0.18$). The scores of the 5–7 year age group were higher than those of the 3–5 year age group, and the scores of the 4–5 year age group were higher than those of the 3–4 year age group. Moreover, the strength of large association ($\omega^2 = 0.18$) indicated that age had a strong effect on FMSs. For locomotor skills as a whole, there were significant differences between the various age groups ($F_{3, 1025} = 45.43$, $p < .001$, $\eta^2 = 0.12$). The scores of the 5–7 year age group were higher than those of the 3–5 year age group, and the scores of the 4–5 year

TABLE 3
MEANS, STANDARD DEVIATIONS, AND COMPARISONS BY SEX OF LOCOMOTOR SKILLS, OBJECT CONTROL SKILLS, AND FMSS

Item	Boys		Girls		t	p	d
	M	SD	M	SD			
Locomotor skills	22.08	5.99	22.45	5.77	−1.02	.31	−0.06
Running	6.61	1.49	6.50	1.23	1.28	.20	0.08
Galloping	2.36	1.20	2.59	1.35	−2.88†	.004	−0.18
Hopping	3.96	2.14	4.32	2.20	−2.67*	.01	−0.17
Leaping	4.53	1.47	4.32	1.65	2.15	.03	0.13
Horizontal jumping	2.94	1.86	3.00	1.97	−0.50	.62	−0.03
Sliding	1.68	2.22	1.72	2.21	−0.28	.78	~
Object control skills	22.60	6.36	20.29	5.74	6.10‡	.00	0.38
Striking a stationary ball	4.40	2.10	3.84	1.96	4.45‡	.00	0.28
Stationary dribble	2.41	2.06	2.19	1.98	1.74	.08	0.11
Catching	2.87	1.31	2.66	1.23	2.59	.01	0.16
Kicking	6.28	1.72	5.77	1.65	4.80‡	.00	0.30
Overhand throwing	3.50	1.98	2.97	1.74	4.53‡	.00	0.28
Underhand rolling	3.13	1.92	2.85	1.80	2.43	.02	0.15
Total FMS score	42.68	10.68	42.75	9.79	3.02†	.003	0.19

Note.—516 boys, 513 girls. *$p<.01$. †$p<.005$. ‡$p<.001$.

age group were higher than those of the 3–4 year age group. The medium effect size ($0.06<\eta^2<0.14$) indicated that age has a moderate effect on locomotor skills. Except for running and sliding, there were significant differences for all the other locomotor skills.

For object control skills, the older group performed significantly better than the younger group ($F_{3,1025}=58.79$, $p<.001$, $\eta^2=0.15$); the strength of association was large ($\omega^2=0.14$). The group aged 5 years old and above was significantly better than the group under the age of 5 years on three locomotor skills (galloping, leaping, and hopping) and five object control skills (striking a stationary ball, stationary dribbling, catching, overhand throwing, and underhand rolling). Moreover, in hopping the 4–5 yr. age group had higher scores than the 3–4 yr. age group; in horizontal jumping the 6–7 yr. age group had higher scores than the 3–4 yr. age group; and in stationary dribbling the 6–7 yr. age group had higher scores than the 5–6 yr. age group.

BMI.—BMI had a significant main effect on FMSs ($F_{3,1025}=10.83$, $p<.001$, $\eta^2=0.03$), locomotor skills ($F_{3,1025}=9.02$, $p<.001$, $\eta^2=0.03$), and object control skills ($F_{3,1025}=7.44$, $p<.001$, $\eta^2=0.02$; Table 5). The normal weight and overweight groups had higher scores than the obese group. However, the strength of association was low between BMI and FMS, locomotor skills,

TABLE 4
DESCRIPTIVE STATISTICS AND ONE-WAY ANOVA OF LOCOMOTOR SKILLS, OBJECT CONTROL SKILLS, AND FMSs BY AGE GROUPS, CHILDREN 3–7 YEARS OLD

Item		A	B	C	D	$F_{3,1025}$	η^2	Scheffé *post hoc* Test
Running	*M*	6.17	6.52	6.66	6.62	3.63	0.01	
	SD	1.82	1.38	1.19	1.33			
Galloping	*M*	1.87	2.29	2.67	2.73	16.54‡	0.05	C, D>A, B
	SD	0.71	1.15	1.37	1.39			
Hopping	*M*	2.66	3.48	4.55	5.08	51.96‡	0.13	C, D>B>A
	SD	2.46	2.09	2.02	1.72			
Leaping	*M*	3.63	4.03	4.78	4.79	28.90‡	0.08	C, D>A, B
	SD	1.96	1.72	1.33	1.16			
Horizontal jumping	*M*	2.44	2.87	3.05	3.21	4.43†	0.01	D>A
	SD	1.65	1.85	1.99	1.95			
Sliding	*M*	1.23	1.57	1.93	1.74	3.26	0.01	
	SD	1.77	2.15	2.29	2.31			
Total locomotor skills	*M*	18.00	20.76	23.64	24.17	45.43‡	0.12	C, D>B>A
	SD	5.98	5.70	5.45	5.23			
Striking a stationary ball	*M*	3.26	3.66	4.48	4.61	21.08‡	0.06	C, D>A, B
	SD	1.56	1.91	2.03	2.22			
Stationary dribble	*M*	1.07	1.69	2.56	3.33	51.99‡	0.13	D>C>A, B
	SD	1.26	1.66	2.02	2.19			
Catching	*M*	2.18	2.55	2.91	3.11	18.94‡	0.05	C, D>A, B
	SD	1.12	1.19	1.24	1.37			
Kicking	*M*	5.75	6.07	5.97	6.16	1.60	0.01	
	SD	1.76	1.56	1.74	1.82			
Overhand throwing	*M*	2.82	2.77	3.51	3.66	15.66‡	0.04	C, D>A, B
	SD	1.46	1.64	1.87	2.18			
Underhand rolling	*M*	2.14	2.70	3.15	3.53	18.14‡	0.05	C, D>A, B
	SD	1.65	1.77	1.85	1.93			
Total object control skills	*M*	17.22	19.44	22.58	24.41	58.79‡	0.15	D>C>B>A
	SD	4.50	5.25	5.56	6.87			
Total FMS score	*M*	35.22	40.20	46.23	48.57	74.38‡	0.18	C, D>B>A
	SD	8.54	9.23	9.22	9.97			

Note.—A. 3–4 yr.: $n=104$; B. 4–5 yr.: $n=331$; C. 5–6 yr.: $n=357$; D. 6–7 yr.: $n=237$. †$p<.005$. ‡$p<.001$.

and object control skills. As for locomotor skills, in hopping and catching the scores of the normal weight and overweight groups were higher than those of the obese group. However, in horizontal jumping the overweight group had a higher score than the normal weight group. In object control

TABLE 5
DESCRIPTIVE STATISTICS AND ONE-WAY ANOVA OF LOCOMOTOR SKILLS, OBJECT CONTROL SKILLS, AND FMSS BY BMI GROUP

Item		A	B	C	D	$F_{3,1025}$	η^2	Scheffé *post hoc* Test
Running	*M*	6.21	6.55	6.74	6.63	2.40	0.01	
	SD	1.87	1.34	1.22	1.24			
Galloping	*M*	2.70	2.46	2.65	2.15	3.32	0.01	
	SD	1.58	1.25	1.32	1.13			
Hopping	*M*	4.31	4.15	4.49	3.21	6.26‡	0.02	B, C>D
	SD	2.06	2.16	2.14	2.33			
Leaping	*M*	4.47	4.47	4.35	4.15	1.06	0.003	
	SD	1.67	1.51	1.73	1.62			
Horizontal jumping	*M*	2.79	2.93	3.56	2.42	7.17‡	0.02	C>B
	SD	2.11	1.87	2.15	1.43			
Sliding	*M*	1.80	1.69	2.05	1.03	3.69	0.01	
	SD	2.21	2.25	2.25	1.60			
Total locomotor skills	*M*	22.29	22.24	23.84	19.59	9.02‡	0.03	B, C>D
	SD	6.74	5.89	5.69	4.31			
Striking a stationary ball	*M*	4.24	4.12	4.31	3.67	1.75	0.01	
	SD	2.10	2.07	2.07	1.76			
Stationary dribble	*M*	1.46	2.37	2.58	1.95	6.14‡	0.02	B, C>A
	SD	1.75	2.02	2.12	1.93			
Catching	*M*	2.69	2.80	2.89	2.27	4.77‡	0.01	B, C>D
	SD	1.15	1.29	1.28	1.15			
Kicking	*M*	6.03	6.05	6.03	5.77	.64	0.002	
	SD	1.79	1.67	1.77	1.83			
Overhand throwing	*M*	2.97	3.22	3.59	2.94	2.86	0.01	
	SD	1.88	1.91	1.89	1.47			
Underhand rolling	*M*	2.76	3.00	3.37	2.45	4.56†	0.01	C>D
	SD	1.89	1.88	1.85	1.61			
Total object control skills	*M*	20.14	21.57	22.76	19.04	7.44‡	0.02	B, C>D
	SD	6.10	6.18	6.19	5.18			
Total FMS Score	*M*	42.43	43.81	46.60	38.63	10.83‡	0.03	B, C>D
	SD	10.77	10.29	10.42	7.18			

Note.—A: Underweight ($n=70$); B: Normal weight ($n=737$); C: Overweight ($n=144$); D: Obese ($n=78$). †$p<.005$. ‡$p<.001$.

skills, in underhand rolling the scores of the overweight group were higher than those of the obese group; and in stationary dribbling the scores of the normal weight and overweight group were higher than those of the underweight group.

Discussion

Although two-factor testing indicated no significant differences in terms of sex, age, and BMI, the results of the ANOVA confirmed Hypotheses 3, 4, and 5. However, in terms of effect size, only age had a significant influence on locomotor skills, object control skills, and FMSs. As for the other variables, sex had a small influence on object control skills, but the influence of BMI on all three categories was limited.

There was no significant three-way interaction effect between sex, BMI, and age group, as reported by Gentier, *et al*. (2013) and Vameghi, *et al*. (2013). Additionally, there were no significant interaction effects between sex and age, sex and BMI, and age and BMI in locomotor skills, object control skills, and FMSs, similar to Yang, *et al*. (2014) and D'Hondt, *et al*. (2009). D'Hondt, *et al*. (2009) focused on the relationship between motor skills and BMI in children aged 5–10 yr. (60 girls, 57 boys), and their measure was the Movement Assessment Battery for Children (MABC). Their results indicated that sex did not significantly interact with the BMI group. However, the current results differed from those of Gentier, *et al*. (2013) and Vameghi, *et al*. (2013) in one important respect. Gentier, *et al*. (2013) focused on the differences in fine and gross motor skills between healthy-weight and obese children. Their sample consisted of 68 children (24 girls, 44 boys; ages 7–13 years), and their measure was the Bruininks–Oseretsky Test of Motor Proficiency, 2nd Edition (BOT–2). Their analysis revealed a significant interaction effect between the two BMI groups and the two age groups. In Vameghi, *et al*. (2013), the focus was the effect of age, sex, and obesity on the FMSs of children aged 4–6 years (200 boys, 200 girls). They measured FMSs using the OSU–SIGMA scale. Their results showed significant interactions for the two age groups (4–5 and 5–6 yr.) and the two sexes. These results indicate that differences in measures affect the observed interaction. For example, Gentier, *et al*. (2013) found an interaction between BMI and age group, and Vameghi, *et al*. found an interaction between age and sex. However, in D'Hondt, *et al*. (sex and BMI), Yang, *et al*., and the current study (age, sex, and BMI), no such interaction was found. This suggests that it is necessary to conduct further research to determine the influence the measures used have on the results, by using all four of the measures mentioned above in the same sample. The results of such an experiment will help future researchers to choose the test best suited to their studies.

In the present study, the FMS scores of the boys were significantly higher than those of the girls. However, this finding may have been the result of the large sample size, since $\eta^2 = -.003$, indicating no difference. Interestingly, a number of other studies using the TGMD–2 found no significant difference between boys and girls in FMSs. These include Goodway, *et*

al. (2003; $N=63$, 29 boys, 34 girls; ages 4–6 years); Li's study (2009) in Shandong, China ($N=511$, 260 boys, 251 girls; ages 3–10 years); Hardy, *et al*.'s (2009) study in Australia ($N=425$, 171 boys, 159 girls; ages 2–6 years); Morano, *et al*.'s (2011) study in South Italy ($N=80$, 38 boys, 42 girls; ages 4–5 years); and LeGear, *et al*.'s (2012) study in Canada ($N=260$, 136 boys, 134 girls; M age = 5.9 yr.). However, Vameghi, *et al*. (2013) used the OSU–SIGMA scale and found that boys outperformed girls in FMSs ($N=400$, 200 boys, 200 girls; ages 4–6 years). This suggests that the test used has a significant bearing on the results (D'Hondt, *et al*., 2009; Morano, *et al*., 2011). Selecting a suitable sample size with respect to the effect size is important.

In the current study, boys performed better than the girls on object control skills, as was found in a number of other studies (Goodway, *et al*., 2003; Li, 2009; Hardy, *et al*., 2010; Giagazoglou, *et al*., 2011; LeGear, *et al*., 2012; Yang, *et al*., 2014). Among these, in Giagazoglou, *et al*. (2011) the MABC was used, while the others all used the TGMD–2. This demonstrates that even when using different tests boys tend to have higher object control skills scores. This difference may be due to the influence of the role expectations of parents, many of whom consider ball games to be too rough for girls and therefore tend to discourage their daughters from participating in them. In fact, a number of related studies have found that parents, especially fathers, have a major influence on the sports their children participate in and that fathers tend to encourage their sons, but not their daughters, to participate in ball games (Fagot & Leinbach, 1989; Payne & Isaacs, 2008). Moreover, girls often lack opportunities for instruction and practice in ball games (Haywood & Getchell, 2005). The teachers who participated in this study (most of whom were women) indicated that outdoor play mainly consists of playing, running, and jumping on the playground, supplemented by rhythmic movement activities. They also indicated that those who request to play ball games are mainly boys. Tsai and Yang (2012) found that girls in Taiwan prefer to play hopscotch, walk on balance beams, and play house, while boys prefer ball games and rough-and-tumble play. Thus, as Hardy, *et al*. (2009) pointed out, information on the relationship between sex and FMSs can help preschools and parents identify which skills should be targeted, so that both boys and girls are given the opportunity to learn and practice basic skills before starting primary school.

The results of this study indicate that children's object control skills improved with age, as was found by Yang, *et al*. (2014) and Li (2009), both of whom also found the same for FMSs and locomotor skills. However, in the current study no difference was found between the 5–6 year age group and the 6–7 year age group in terms of FMSs and locomotor skills. This may be because children in Taiwan must reach 6 years of age by Septem-

ber 1 to be allowed to begin elementary school; as a result, many children ages 5–7 years are grouped in preschool and thus engage in the same activities. The importance of age was also indicated in the present study by the effect size, which was at least medium for FMSs, locomotor skills, and object control skills.

The results also indicated that the obese group had poorer performance on FMSs, locomotor skills, and object control skills than the normal and overweight groups. Similarly, D'Hondt, *et al*. (2009) found that for ball skills and total MABC normal and overweight groups always had higher scores than obese groups. Furthermore, Gentier, *et al*. (2013) found that a healthy-weight group performed better in all gross motor subtests than a group of obese peers, which partially agrees with the findings of the current study. However, in Morano, *et al*. (2011) the overweight group had lower scores in locomotor skills and object control skills than a group of their non-overweight peers. The differences relating to BMI between previous studies and the current study may be due to the different items included in the various tests used, the number of trials conducted, and the different ways in which BMI was categorized. Moreover, the small effect size of BMI in relation to FMSs, locomotor skills, and object control skills indicates that BMI as a factor requires further investigation. Also, there were no significant differences between the underweight group and the normal and overweight groups. This may be due to the lack of control over the number of underweight participants included in the sample. This limitation can be made up for in future research by including underweight as one of the BMI categories and recruiting a roughly equal number of participants in each category.

REFERENCES

Barnett, L. M., Hinkley, T., Okely, A. D., & Salmon, J. (2013) Child, family and environmental correlates of children's motor skill proficiency. *Journal of Science and Medicine in Sport*, 16(4), 332-336.

Barnett, L. M., Morgan, P. J., Van Beurden, E., Ball, K., & Lubans, D. R. (2011) A reverse pathway? Actual and perceived skill proficiency and physical activity. *Medicine & Science in Sports & Exercise*, 43(5), 898-904.

Barnett, L. M., Ridgers, N. D., & Salmon, J. (2015) Associations between young children's perceived and actual ball skill competence and physical activity. *Journal of Science and Medicine in Sport*, 18(2), 167-171.

Clark, J. E., & Metalfe, J. S. (2002) The mountain of motor development: a metaphor. In J. E. Clark & J. H. Humphrey (Eds.), *Motor development: research and reviews*. Vol. 2. Reston, VA: National Association for Sport and Physical Education. Pp. 163-190.

D'Hondt, E., Deforche, B., Bourdeaudhuij, I. D., & Lenoir, M. (2009) Relationship between motor skill and Body Mass Index in 5- to 10-year-old children. *Adapted Physical Activity Quarterly*, 26, 21-37.

Dollman, J., & Lewis, N. R. (2009) Interactions of socioeconomic position with psychosocial and environmental correlates of children's physical activity: an observational study of South Australian families. *International Journal of Behavioral Nutrition and Physical Activity*, 6, 56.

Fagot, B. I., & Leinbach, M. D. (1989) The young child's gender schema: environmental input, internal organization. *Child Development*, 60, 663-672.

Fjortoft, I., Pedersen, A.V., Sigmundsson, H., & Vereijken, B. (2011) Measuring physical fitness in children who are 5 to 12 years old with a test battery that is functional and easy to administer. *Physical Therapy*, 91(7), 1087-1095.

Gentier, I., D'Hondt, E., Shultz, S., Deforche, B., Augustijn, M., Hoorne, S., Verlaecke, K., Bourdeaudhuij, I. D., & Lenoir, M. (2013) Fine and gross motor skills differ between healthy-weight and obese children. *Research in Developmental Disabilities*, 34(11), 4043-4051.

Giagazoglou, P., Kabitsis, N., Kokaridas, D., Zaragas, C., Katartzi, E., & Kabitsis, C. (2011) The movement assessment battery in Greek preschoolers: the impact of age, sex, birth order, and physical activity on motor outcome. *Research in Developmental Disabilities*, 32, 2577-2582.

Goodway, J. D., Crowe, H., & Ward, P. (2003) Effect of motor skill instruction on fundamental motor skill development. *Adapted Physical Activity Quarterly*, 20(3), 298-314.

Hardy, L. L., King, L., Farrell, L., Macniven, R., & Howlett, S. (2009) Fundamental movement skills among Australian preschool children. *Journal of Science and Medicine in Sport*, 13(5), 503-508.

Haywood, K. M., & Getchell, N. (2005) *Life span motor development.* (4th ed.) Champaign, IL: Human Kinetics.

Huang, D. W. (2011) The study of Body Mass Index of children: example of preschoolers in New Taipei City. Unpublished master's thesis, National Taiwan Sport Univer., Taoyuan, Taiwan.

LeGear, M., Greyling, L., Sloan, E., Bell, R. I., Williams, B. L., Naylor, P. J., & Temple, V. A. (2012) A window of opportunity? Motor skills and perceptions of competence of children in kindergarten. *International Journal of Behavior Nutrition and Physical Activity*, 9, 29.

Li, L. (2009) Children's gross motor development from ages 3 to 10 in Shandong. *Journal of Shandong Institute of Physical Education and Sports*, 25(4), 47-50.

Morano, M., Colella, D., & Caroli, M. (2011) Gross motor skill performance in a sample of overweight and non-overweight preschool children. *International Journal of Pediatric Obesity*, 6(S2), 42-46.

Pang, A. Y., & Fong, W. Y. (2009) Fundamental motor skill proficiency of Hong Kong children aged 6–9 years. *Research in Sports Medicine*, 17, 125-144.

Payne, V. G., & Isaacs, L. D. (2008) *Human motor development: a lifespan approach.* (7th ed.) New York: McGraw-Hill.

Robinson, L. E. (2010) The relationship between perceived physical competence and fundamental motor skills in preschool children. *Child: Care, Health and Development*, 37, 589-596.

Robinson, L. E., & Goodway, J. D. (2009) Instructional climates in preschool children who are at-risk. Part I: object control skill development. *Research Quarterly for Exercise and Sport*, 80, 549-551.

Shields, M. (2006) Overweight and obesity among children and youth. *Health Reports*, 17, 27-42.

Tsai, C. Y., & Yang, S. C. (2012) Study on the appearance of childhood games. *Journal of Educational Studies*, 46(1), 1-19.

Ulrich, D. A., & Sanford, C. B. (2000) *TGMD–2: Test of Gross Motor Development: examiner's manual*. (2nd ed.) Austin TX: PRO-ED.

Vameghi, R., Shams, A., & Dehkordi, P. S. (2013) The effect of age, sex and obesity on fundamental motor skills among 4 to 6 years-old children. *Pakistan Journal of Medical Sciences*, 29(2), 586-589.

Vandaele, B., Cools, W., Decker, S., & Martelaer, K. (2011) Mastery of fundamental movement skills among 6-year-old Flemish pre-school children. *European Physical Education Review*, 17(1), 3-17.

Venetsanou, F., & Kambas, A. (2010) Environmental factors affecting preschoolers' motor development. *Early Childhood Educational Journal*, 37, 319-327.

Williams, H. G., Pfeiffer, K. A., O'Neill, J. R., Dowda, M., McIver, K. L., Brown, W. H., & Pate, R. R. (2008) Motor skill performance and physical activity in preschool children. *Obesity*, 16(6), 1421-1426.

Yang, S. C., Lin, S. J., & Tsai, C. Y. (2014) Comparison of fundamental movement skills among young children with different gender, age, and BMI. *Sports & Exercise Research*, 16(3), 287-296.

Accepted November 13, 2015.