Research Paper : Growth and Development

Relationships between Gender Difference in Motor Performance and Age, Movement Skills and Physical Fitness among 3- to 6-year-old Japanese Children based on Effect Size Calculated by Meta-analysis

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[Received September 4, 2008 ; Accepted June 8, 2009]

Gender differences in movement skills and physical fitness are explained by overt motor performance, which can be measured. Generally, motor performance develops in parallel with movement skill and physical fitness; however, the actual correlations have yet to be evaluated. The first purpose of the present study was to elucidate the relationships between gender differences in motor performance and age, movement skills and physical fitness among preschool-aged Japanese children by considering the relative influence of movement skills and physical fitness. The second purpose was to elucidate the relationship between gender differences and a combination of physical fitness and movement patterns. Gender differences were determined based on effect sizes calculated in a meta-analysis. In order to consider the interaction between movement skills and physical fitness, analyses were conducted using Quantification Method I. According to both the category weights calculated using this method and the means of the effect sizes, boys were more skilled at "throwing" and "muscular strength and explosive power". Although there were gender differences in the mean effect size observed for "walking" (boys > girls) and "ball control" (girls > boys), no differences were observed for category weights. Furthermore, although girls were more skilled in "running" and "kicking", no differences were observed for the means of the effect sizes. Different results were observed in gender differences for movement skills and physical fitness when comparing overt values of measurement and category weights in consideration of their relative influence. Movement skills showed a larger relation to effect sizes than age or physical fitness. Thus, the clearly observed gender differences in motor performance are not the result of physical maturity or physical fitness, but movement skills. The present results indicated that the combination of "manipulation and energy system", "manipulation and cybernetics" (boys > girls) and "stability and energy system" have an interactive effect on gender differences. Furthermore, these findings suggest that the combination of physical fitness and movement patterns should be considered when investigating the motor performance of preschool children.

Keywords: Physical Fitness, Gender difference, Motor Ability, Preschool-aged Children, Quantification Method I

[School Health Vol.5, 9-23, 2009]

1. Introduction

The motor ability of preschool-aged children has been investigated by a number of researchers. In some studies, gender differences in motor ability have been demonstrated (Murase & Demura, 2005).

While some researchers have reported that boys are superior to girls with regard to ball control (Matsuura, 2005), however, some other researchers have reported that there are no gender differences in ball control within a certain distance (Takeuchi & Tateishi, 1993). In this way, not all reports on gender differences of children correspond. In order to resolve such issues, Ikeda & Aoyagi (2008) have attempted to integrate the outcomes of various studies on the motor performance of preschool-aged children utilizing the meta-analysis method.

Since movement skills, such as running, jumping, and throwing, and characteristics of physical fitness, such as muscular strength and balance, are latent by nature, there are few direct methods by which measurement can be obtained. Hence, values are estimated from the results of physical exertion phenomenon; that is, motor performance (Matsuura, 1983). In general, gender differences in potential physical fitness and movement skills are also examined through motor performance. This method, however, requires consideration. When trying to examine gender differences in physical fitness for certain fields from the results of tests containing multiple test items, it should be noted that physical fitness relating to such test items may consist of more than one element. In other words, not only physical fitness for the target field but other elements may also be reflected in the test results. For instance, there are no gender differences in grip strength, an index of muscle strength (Matsuura, 1982). Boys are superior to girls, however, in terms of ball throw, which is related to muscle strength and dexterity (Demura, 1993). In order to examine gender differences in muscle strength from these 2 test results, it is necessary to consider the effect of gender differences in dexterity. When examining gender differences in movement skills, it should also be noted that physical fitness for multiple exercise fields may associate with movement skills in a certain field. For example, while both the standing long jump and side step are test items for jumping skills, boys are superior in the former (Yoshizawa, 2002) and girls are superior in the latter (Kobayashi, et al., 1990). Since the standing long jump is related to explosive power and the side step is related to agility (Aoyama, 2004), it is essential to remove the effect of physical fitness related to motor performance for the respective items in order to examine gender differences in jumping. It is also noteworthy that gender differences in movement skills or physical fitness as examined individually are not always consistent with gender differences in motor performance demonstrated in specific combinations of movement skills and physical fitness. For example, boys are superior in running (Matsuda & Kondo, 1965; Miyaji, et al., 1971). It has been reported that there are no gender differences in agility (Kondo, et al., 1998). However, girls are superior in the zigzag run, which is related to agility and running skills (Kobayashi, 1987). Thus, gender differences in motor performance may emerge as the result of specific combinations of movement skills and physical fitness. It is, therefore, necessary to investigate such interactions. In previous studies on gender differences in the motor ability of preschool-aged children, the major focus has been on gender differences in movement skills and physical fitness based on the results of motor performance which was overt and measurable. Meanwhile, few researchers have investigated the interaction of age, movement skills, and physical fitness and their combinations.

This study, therefore, aimed to clarify the relationships between gender differences in motor performance of preschool-aged Japanese children and physical fitness and movement skills in various fields in consideration of their interaction as well as the effect of age. Clarification of their relationships in specific combinations of movement skills and physical fitness was also a goal of this study.

2. Methods

2.1. Relationship between Test Items and Movement Patterns/ Movement Skills/ Physical Fitness

Table 1 shows motor ability test items used in the examination of the relationship between gender differences in motor performance and movement patterns/ movement skills/ physical fitness in an integrated manner.

Movement patterns and movement skills were categorized based on the "Fundamental Movement Skills" established by Gallahue & Donnelly (2003). Gallahue & Donnelly (2003) have classified basic movements into 3 movement patterns; namely, locomotion, manipulation, and stability. They have also made the respective movement patterns correspond to specific movement skills. Based on their method, movement skills in this study were

Table 1 Classification by movement patterns, movement skills and physical fitness.

Test items	Movement patterns	Movement skills	Physical fitness
[1]Crawling	Locomotion	Walking	Muscular strength & Explosive power/ Dexterity
[2]Balance beam walk			Balance
[3]10-m shuttle run /[4]20-m, [5]25-m, [6]50-m or [7]100-m run		Running	Muscular strength & Explosive power/ Dexterity
[8]Shuttle run / [9]Zigzag run			Muscular strength & Explosive power/ Agility
[10]Jump elastics / [11]Vertical jump / [12]Standing long jump		Jumping	Muscular strength & Explosive power
[13]Running long jump			Muscular strength & Explosive power/ Dexterity
Popping [14][m] / [15][times] / [16][sec.]			Muscular endurance/ Balance
[17]Side step			Agility
[18]Jump ropes			Muscular endurance/ Dexterity
[19]Continuous jump over			Muscular endurance/ Agility/ Dexterity
[20]Kick for target	Manipulation	Kicking	Muscular strength & Explosive power/ Dexterity
[21]Grip strength		Gripping	Muscular strength & Explosive power
[22]Bar gripping reaction time			Agility
Ball throwing ([23]Tennis ball / [24]Soft ball / [25]Ball) / [26]Throw with both hands		Throwing	Muscular strength & Explosive power/ Dexterity
[27]Ball bouncing / [28]Ball catching		Manipulation with ball without throwing	Dexterity
[29]Stepping	Stability	Walking	Balance
[30]Arm hang / [31]Body supporting duration		Static & dynamic postures	Muscular endurance
Trunk extension [32][cm] / [33][degree]		Axial movement	Flexibility
[34]Back strength			Muscular strength & Explosive power
[35]Foot balance / [36]With eyes closed / [37]On the bar		Static & dynamic postures	Muscular endurance/ Balance
[39]Side rolling			Dexterity
Trunk flexion; [40]sitting / Standing [41][degree] / [42][cm]		Axial movement	Flexibility
[38]Getting up		Getting up	Agility

classified into 10 categories: walking, running, and jumping as "locomotion"; kicking, throwing, gripping, and manipulation of ball as "manipulation"; and static & dynamic postures and axial movement as "stability."

Based on the corresponding relationships to test items shown in some of the previous studies (Asano, 1977; Matsui, et al., 1955; Matsuura, 1983; Research Group on Standards of Physical Fitness, Tokyo Metropolitan University, 2000; and Takeuchi, et al., 1968), physical fitness was classified into 6 elements; namely, muscular strength and explosive power, muscular endurance, balance, flexibility, agility, and dexterity.

2.2. Effect Size as an Index of Gender Differences in Motor Performance

As an index of gender differences in motor performance, effect size (Ikeda & Aoyagi, 2008) was calculated for 42 items and 135 samples as shown in **Table 2**. This was calculated following the procedure established by Cohen (1969), Hedge (1981), and Thomas & French (1985). In this procedure, effect size is calculated using the respective data resources[1)] and the respective items[2)] were integrated by means of test of homogeneity (Shiba & Haebara, 1990)[3)].

Documents used for meta-analysis as data resources were selected based on reviews of studies on the

1) Effect size (ES) is calculated for each document using formula (1).

$$ES = \frac{M_m - M_f}{SD}$$

However, M_m : Mean value for boys
M_f : Mean value for girls

$$SD = \sqrt{\frac{(N_m - 1)\,SD_m^2 + (N_f - 1)\,SD_f^2}{N_m + N_f - 2}}$$

N_m : Number of boys
N_f : Number of girls
SD_m : Standard deviation for boys
SD_f : Standard deviation for girls

Table 2 Effect sizes and chi-square value for each test item by age.

Item no.	2 yr			3 yr			4 yr			5 yr			6 yr		
	*ES**	χ^2	*df*	*ES**	χ^2	*df*	*ES**	χ^2	*df*	*ES**	χ^2	*df*	*ES**	χ^2	*df*
1				0.042	2.159	3	0.478	4.934	3	0.955	5.857	3	0.753	0.001	1
2				-0.019	18.008	7	-0.063	7.936	5	-0.099	11.046	4			
3				0.005	17.908	10	0.146	22.462	14	0.026	23.571	13	0.018	18.130	8
4				0.019	26.345	17	0.039	57.923	41	0.051	62.533	49	0.028	35.406	23
5													0.085	0.233	2
6													-0.139	5.424	1
7							0.084	1.276	2	0.295	5.058	3	0.152	5.755	3
8				0.062	0.155	3	0.278	2.047	3	0.006	5.318	4	0.559	9.315	5
9				0.001	2.717	3	0.221	11.961	8	0.447	13.987	9	0.040	14.310	6
10							0.067	0.067	1	0.281	1.078	1			
11							0.072	12.726	7	0.019	12.026	7	0.045	1.454	5
12	-0.226	0.351	1	-0.008	43.345	29	0.134	70.304	55	0.147	81.264	65	0.391	44.108	31
13										0.211	1.864	1			
14				-0.012	1.616	1	0.004	20.157	11	-0.011	17.126	17	-0.046	1.698	5
15				-0.004	13.227	4	-0.106	2.541	4	-0.117	5.681	4	0.002	7.086	3
16							0.372	0.039	1	0.010	2.723	1			
17				-0.005	12.438	13	0.004	31.772	22	0.002	33.128	23	-0.005	18.468	8
18				-0.270	7.443	3	-0.420	2.007	2	-0.556	2.646	2	-0.574	11.745	4
19				-0.054	2.507	4	-0.016	22.335	16	0.002	38.932	21	-0.020	14.463	11
20							0.002	1.100	1	-0.074	3.483	1	-0.068	3.438	1
21				0.251	5.386	7	0.044	38.551	21	0.110	25.856	24	-0.007	6.569	7
22							0.016	3.930	1	0.002	0.180	1			
23				0.259	24.206	16	0.628	34.322	24	1.080	38.288	22	1.003	22.043	13
24				0.136	15.391	6	0.775	33.332	20	1.021	44.134	27	1.547	26.897	15
25				0.026	0.649	2	0.548	10.983	4	1.089	9.750	4	0.843	3.554	1
26				0.097	7.306	1	0.057	2.746	1	0.417	0.689	1	0.279	16.609	1
27				-0.243	8.901	3	-0.681	12.692	6	-0.770	17.988	8	-0.147	10.961	3
28							0.003	8.643	6	0.008	5.433	7	-0.023	12.829	6
29							-0.155	4.306	1	0.003	3.424	2			
30				-0.277	13.575	10	0.015	34.300	18	-0.031	28.896	18	-0.014	8.558	10
31				-0.004	11.579	12	-0.007	35.787	35	-0.007	70.607	49	0.005	40.627	27
32				-0.001	1.561	1	-0.085	15.674	11	-0.216	22.140	11	-0.012	8.352	5
33										-0.043	0.008	1			
34				0.093	2.644	3	0.511	10.229	5	0.605	7.355	6	0.320	0.985	2
35				-0.033	16.294	10	-0.003	27.521	17	-0.092	27.366	20	0.110	14.135	9
36				0.090	5.406	1	-0.346	0.063	1	-0.154	0.034	1			
37				-0.049	3.610	4	-0.017	23.476	12	0.027	34.839	20	-0.112	22.675	11
38							-0.002	4.440	3	-0.097	8.513	3	0.136	0.748	1
39				-0.061	1.751	1	0.179	5.241	1	-0.133	9.145	2			
40				-0.017	13.290	8	-0.228	25.805	12	-0.006	32.425	19	-0.020	23.074	13
41										-0.017	3.207	1			
42							-0.021	9.449	3	-0.206	9.543	3			

Note 1: Item numbers correspond to **Table 1**. (small number)
Note 2: No chi-square values were significant at the 0.01 level.

motor ability of preschool-aged children (Aoyagi, 1987; Ikeda & Aoyagi, 2006; Murase & Demura, 2005; Nakamura, et al., 1980; and Nishijima, 2005) and the National Institute of Informatics Scholarly and Academic Information Navigator (CiNii) with the use of preschool-aged children, physical fitness, motor ability, test, and measurement as keywords.

The selected documents were further screened in consideration of the following 3 points: (1) data was based on field tests; (2) data included age-/gender-based mean values and standard deviation needed for meta-analysis; and (3) data was readily available. Data of ordinary preschool-aged (3-6 years of age) Japanese children were used. In case of intervention studies, data of control groups was adopted. Data resource-based variation in sample size was adjusted by calculating unbiased estimators[4)].

Ultimately, 100 documents published during the period from 1957 to 2006 were selected as data resources for this study. Sugihara, et al. (2006) conducted a comparison study on the motor ability of preschool-aged children during the period from the 1960s to the 2000s and reported that changes over time had occurred equally in boys and in girls. Ikeda & Aoyagi (2008) have reported that there are no time-based differences among documents on gender differences in motor performance.

The 100 documents used for meta-analysis consisted of academic conference presentation abstracts and articles from academic journals, Bulletin of university and textbooks related to

2) Integrated effect size ($\overline{ES}$) is calculated using formula (2).

$$\overline{ES} = \frac{\sum_{i=1}^{k} d_i / Sest_i^2}{\sum_{i=1}^{k} 1 / Sest_i^2}$$

However, k: Size of data used
d_i: Effect size (ES_i or ES_i^*)

$$Sest^2(ES) = \frac{N_m + N_f}{N_m N_f} + \frac{d_i^2}{N_m + N_f}$$

3) For integration, test of homogeneity is conducted using formula (3). The testing hypothesis is "$H_0 : ES_1 = ES_2 = \cdots = ES_k$." When sample size in a document is large, statistics (χ^2_o) follows distribution (χ^2) under hypothesis (H_0). When study results (ES_i) include a value that is significantly deviated from total estimated value ($\overline{ES}$), χ^2_o becomes large. When the value exceeds the probability (α) on the distribution (χ^2) with degree of freedom ($k - 1$), the hypothesis is rejected. In this study, effect size is integrated on the condition that the hypothesis is not rejected at 1% of standard value.

$$\chi_o^2 = \sum_{i\text{-}1}^{k} \frac{(ES_i - \overline{ES})^2}{Sest^2}$$

4) When sample size for the effect size (ES_i) calculated with use of formula (1) is small, unbiased estimator (ES^*) is calculated according to the formula (4).

$$ES_i^* = \left(1 - \frac{3}{4m - 1}\right) ES_i \qquad \text{(However, } m = N_m + N_f - 2\text{)}$$

Table 3 Relationship between resource and effect size when excluded and not excluded

Resource	Number of literatures		χ^2	*df*	*p*
	Not including excluded ESs	Including excluded ESs			
Journal	9	18			
Bulletin	19	38	0.10	2	ns
Annual report or text book	6	10			
Total	34	66			

preschool education. In regard to these documents, the proportion of documents including effect sizes which were rejected through the test of homogeneity was examined by chi-squared test. As a result, no significant difference was observed (χ^2_o=0.104 < χ^2[0.05, df=2]=5.991, ns).

For this reason, therefore, it is thought that there are no significant problems in the selection of the 100 documents used for meta-analysis.

For the effect sizes calculated in this study, the positive sign, +, indicates the superiority of boys, and the negative sign, -, indicates the superiority of girls. Absolute values which are 0.2 or larger but smaller than 0.5 represent a small difference; absolute values which are 0.5 or larger but smaller than 0.8 represent a moderate difference; and absolute values which are 0.8 or larger represent a large difference (Thomas & French, 1985).

2.3. Statistical Processing

Relationships between the various factors and effect size, an index of gender difference in the motor performance of preschool-aged children, were examined by Quantification Method I (Kobayashi,1981). This method enables the estimation of relationships between integrated effect size (dependent variable) in continuous quantity and age, movement skills, and physical fitness (independent variables), which were discrete data. Due to the fact that the category weights to be obtained corresponded to partial regression coefficients in the multiple regression formula, it was also possible to examine relationships with effect size under a constant level of effect of the other independent variables. Furthermore, relationships between items and dependent variables, which are not explored in traditional multiple regression analysis, could also be examined from partial correlation coefficients. Age was classified into 4 categories representing ages 3 to 6, respectively, while movement skills were classified into 10 categories. In regard to physical fitness, 1 test item can correspond to 2 elements in some cases. For example, crawling corresponds to muscular strength & explosive power and dexterity. Considering this, 6 elements of physical fitness (muscular strength & explosive power, muscular endurance, balance, flexibility, agility, and dexterity) were used as analysis items, regarding each of which, applicability or non-applicability was determined and was used as a category. For the analysis based on Quantification Method I, the SPSS quantification theory program GUI 2.2.3 was used. For verification of multicollinearity, the variance inflation factor (VIF) was calculated (benchmark: ≤10).

3. Results

3.1. Integrated Effect Size

Mean values and standard deviations of the integrated effect sizes calculated by test item are shown in **Table 4** and those calculated by category are shown in **Table 5**.

Boys were superior in the following 8 motor performance items: soft-ball throw (0.870), tennis ball throw (0.743), ball throw (0.627), crawling (0.557), back strength (0.382), shuttle run (0.226), and throw with both hands (0.213). Meanwhile, girls were superior in jump rope (-0.455) and ball bouncing (-0.460). Regarding other items, there were no effect sizes that exceeded an absolute value of 0.2. Effect size increased with the increase of age. However, no age groups had effect sizes that were larger than an absolute value of 0.2. Boys were superior in muscular strength & explosive power (0.284) in physical fitness, manipulation (0.257) in movement patterns, throwing (0.613) and walking (0.211) in movement skills, while girls were superior in manipulation of ball (-0.265). In terms of other items relating to physical fitness, movement patterns, and movement skills, none of the effect sizes exceeded an absolute value of 0.2.

Table 4 Sample size, means and standard deviations of effect size for each test item

Test items	Effect size N	M	SD
Crawling	4	0.557	0.395
Balance beam walk	3	-0.060	0.040
20-m run	3	0.177	0.108
25-m run	4	0.049	0.065
50-m run	4	0.034	0.014
100-m run	1	0.085	
10-m shuttle run	1	-0.139	
Shuttle run	4	0.226	0.251
Zigzag run	4	0.177	0.204
Jump elastics	2	0.174	0.151
Vertical jump	3	0.045	0.027
Standing long jump	4	0.166	0.166
Running long jump	1	0.211	
Popping [m]	4	-0.016	0.021
Popping [times]	4	-0.056	0.064
Popping [sec.]	2	0.191	0.256
Side step	4	-0.001	0.005
Jump ropes	4	-0.455	0.141
Continuous jump over	4	-0.022	0.023
Kick for target	3	-0.047	0.042
Grip strength	4	0.100	0.112
Bar gripping reaction time	2	0.009	0.010
Tennis ball throw	4	0.743	0.378
Soft ball throw	4	0.870	0.586
Ball throw	4	0.627	0.457
Throw with both hands	4	0.213	0.167
Ball bouncing	4	-0.460	0.311
Ball catching	3	-0.004	0.017
Stepping	2	-0.076	0.112
Arm hang	4	-0.077	0.135
Body supporting duration	4	-0.003	0.006
Trunk extension [cm]	4	-0.079	0.099
Standing trunk extension [degree]	1	-0.043	
Back strength	4	0.382	0.226
Foot balance	4	-0.005	0.085
Foot balance with eyes closed	3	-0.137	0.219
Foot balance on the bar	4	-0.038	0.058
Getting up	3	0.012	0.117
Side rolling	3	-0.005	0.163
Sitting trunk flexion	4	-0.068	0.107
Standing trunk flexion [degree]	1	-0.017	
Standing trunk flexion [cm]	2	-0.114	0.131

Table 5 Sample size, means and standard deviations of effect size for each classification

Classification		Effect size N	M	SD
Age	3 yr	27	0.001	0.124
	4 yr	37	0.068	0.280
	5 yr	40	0.105	0.390
	6 yr	31	0.165	0.405
Physical fitness	Muscular strength & Explosive power	62	0.284	0.358
	Muscular endurance	37	-0.073	0.177
	Balance	26	-0.032	0.121
	Flexibility	12	-0.073	0.090
	Agility	21	0.075	0.167
	Dexterity	55	0.166	0.464
Movement patterns	Locomotion	60	0.067	0.249
	Manipulation	32	0.257	0.516
	Stability	43	-0.009	0.173
Movement skills	Walking	9	0.211	0.411
	Running	21	0.115	0.164
	Jumping	32	-0.014	0.211
	Kicking	3	-0.047	0.042
	Gripping	6	0.069	0.098
	Throwing	16	0.613	0.458
	Manipulation with ball without throwing	7	-0.265	0.328
	Axial movement	16	0.041	0.240
	Static & dynamic postures	22	-0.042	0.116
	Getting up	3	0.012	0.117

Table 6 Relationship between gender difference in motor performance and age and movement skills

Item	Category	Sample size of ES	Category weight	Range	Partial correlation coefficient
Age	3 yr	27	-0.110	0.186	0.256
	4 yr	37	-0.013		
	5 yr	40	0.028		
	6 yr	31	0.076		
Movement Skills	Walking	9	0.134	0.893	0.672
	Running	21	0.020		
	Jumping	32	-0.103		
	Kicking	3	-0.165		
	Gripping	6	-0.018		
	Throwing	16	0.530		
	Manipulation with Ball	7	-0.363		
	Axial movement	16	-0.047		
	Static & dynamic Postures	22	-0.117		
	Getting up	3	-0.106		
Constant term			0.088		
Multiple correlation coefficient					0.683

3.2. Relationships between Gender Differences in Motor Performance and Age/ Movement Skills

Using 2 items and 14 categories of age and movement skills as independent variables, multiple correlation coefficients, constant terms, and the partial correlation coefficients, ranges, and category weights for the respective items were calculated. The results are shown in **Table 6**. The VIF was 3.488, indicating the absence of multicollinearity. The multiple correlation coefficient of regression formula was 0.683, showing a moderate level of correlation. The partial correlation coefficient for relations between gender differences in motor performance and movement skills under the constant level of effect of age was 0.672, which was larger than that for age (0.256). In movement skills, the category which had the strongest relation to gender differences in motor performance was throwing (0.530), in which the superiority of boys was demonstrated. The category which had the second strongest relation was manipulation of ball (-0.363), in which the superiority of girls was demonstrated. In terms of the other 8 categories of movement skills, none of the category weights reached an absolute value of

Table 7 Relationship between gender difference in motor performance and age and physical fitness

Item	Category	Sample size of ES	Category weight	Range	Partial correlation coefficient
Age	3 yr	27	-0.083	0.131	0.172
	4 yr	37	-0.010		
	5 yr	40	0.028		
	6 yr	31	0.048		
Muscular strength & Explosive power	Applied	62	0.223	0.412	0.454
	Not applied	73	-0.189		
Muscular endurance	Applied	37	0.000	0.001	0.001
	Not applied	98	0.000		
Balance	Applied	26	0.119	0.147	0.144
	Not applied	109	-0.028		
Flexibility	Applied	12	0.089	0.097	0.076
	Not applied	123	-0.009		
Agility	Applied	21	0.068	0.080	0.091
	Not applied	114	-0.012		
Dexterity	Applied	55	0.032	0.055	0.079
	Not applied	80	-0.022		
Constant term			0.088		
Multiple correlation coefficient					0.581

Table 8 Relationship between gender difference in motor performance and age, movement skills and physical fitness

Item	Category	Sample size of ES	Category weight	Range	Partial correlation coefficient
Age	3 yr	27	-0.113	0.183	0.288
	4 yr	37	-0.010		
	5 yr	40	0.031		
	6 yr	31	0.070		
Movement Skills	Walking	9	0.132	0.696	0.623
	Running	21	-0.246		
	Jumping	32	-0.080		
	Kicking	3	-0.357		
	Gripping	6	-0.110		
	Throwing	16	0.338		
	Manipulation with ball	7	-0.123		
	Axial movement	16	0.140		
	Static & dynamic postures	22	0.075		
	Getting up	3	-0.061		
Muscular strength & Explosive power	Applied	62	0.234	0.432	0.564
	Not applied	73	-0.199		
Muscular endurance	Applied	37	0.013	0.018	0.025
	Not applied	98	-0.005		
Balance	Applied	26	0.098	0.121	0.152
	Not applied	109	-0.023		
Flexibility	Applied	12	-0.029	0.031	0.031
	Not applied	123	0.003		
Agility	Applied	21	0.192	0.228	0.305
	Not applied	114	-0.035		
Dexterity	Applied	55	0.020	0.033	0.060
	Not applied	80	-0.013		
Constant term			0.088		
Multiple correlation coefficient					0.771

0.2. Concerning category weights for age, that for age 3 was the smallest (-0.110) and values increased with the increase of age. Up to age 4, corresponding category weights were with negative signs while category weights for age 5 and age 6 had positive signs. All these values were below an absolute value of 0.2.

3.3. Relationship between Gender Differences in Motor Performance and Age/ Physical Fitness

Using the 7 items and 16 categories of age and physical fitness as independent variables, multiple correlation coefficients, constant terms, and the partial correlation coefficients, ranges, and category weights for the respective items were calculated. The VIF was 2.297, indicating the absence of multicollinearity. As shown in **Table 7**, the multiple correlation coefficient of regression formula was 0.518, being smaller than that for age/ movement skills. Partial correlation coefficient for any of the items was less than 0.5, showing little relation to gender differences in motor performance. The item which had the largest partial correlation coefficient was muscular strength & explosive power (0.454). The category weight for the applicable cases was 0.223, showing the superiority of boys. The category weights for the respective ages showed a similar tendency to the results of the regression formula for movement skills.

3.4. Relationships between Gender Differences in Motor Performance and Age/ Movement Skills/ Physical Fitness

Using age, movement skills, and physical fitness as independent variables, regression formula was calculated in order to explore the relationships with integrated effect size. Multiple correlation coefficients, constant terms, and the ranges, partial correlation coefficients, and category weights for the respective items are shown in **Table 8**. The VIF was 7.178, indicating the absence of multicollinearity. The multiple correlation coefficient was 0.771, showing the moderate power of explanation of the regression formula. In terms of the partial correlation coefficients for items, the highest was for movement skills, which was 0.623, and the second highest was for muscular strength & explosive power, which was 0.564. None of the partial correlation coefficients of the other items reached 0.5. Concerning category weights for movement skills, absolute values were high in throwing (0.338) with a positive sign, and in kicking (-0.357) and running (-0.246) with negative signs. None of the category weights for the other categories in movement skills reached an absolute value of 0.2. No category weights for physical fitness exceeded an absolute value of 0.2 except for the applicable case of muscular strength & explosive power, which was 0.234. Signs and values of category weights for age showed a similar tendency to those in the earlier-mentioned two regression formulas.

3.5. Effects of Interactions of Various Factors Relating to Gender Differences in Motor Performance

Three multiple regression analyses were conducted in order to examine the relationships between gender differences in motor performance and age/ physical fitness/ movement skills. The results of all these analyses showed that "throwing" in movement skills and "muscular strength & explosive power" in physical fitness were related to motor performance with the boys exhibiting superiority. Usually, only the main effects are analyzed in Quantification Method I. In this study, however, analysis was conducted regarding items of interactions based on the assumption that specific combinations of movement skills and physical fitness were related to gender differences in motor performance. In theory, 60 different combinations exist for the interactions of 10 items of movement skills and 6 elements of physical fitness. If an analysis were conducted for all 60 combinations, it would cause not only complexity of data processing but also a limitation of test items, which could result in the emergence of multicollinearity. Furthermore, it has been reported that the physical fitness/ movement skills of preschool-aged children are in a undifferentiated state (Inoue, 1968; Ichimura, et al., 1969). Considering these factors, an analysis was conducted after reclassifying items of movement skills into "movement patterns" consisting of 3 categories (locomotion, manipulation, and stability); muscular strength & explosive power and muscular endurance into "energy system;" balance, flexibility, agility, and dexterity into "cybernetics;" and age into "age groups" consisting of the 3-4 year-old age group, for which category weights had negative signs and the 5-6 year-old age group, for which category weights had positive signs.

Using these revised independent variables, relationships to gender differences in motor performance without any interactions were examined. The VIF of this regression formula was 1.183, indicating absence of multicollinearity. The multiple correlation coefficient was 0.455, while the partial correlation coefficient for "energy system" was 0.346 and that for "movement patterns" was 0.309. The highest category weight was 0.170, which was for "manipulation." All the category weights were less than 0.2.

Next, items for interactions of 3 movement patterns and 2 elements of physical fitness were determined. As the combinations of interactions, the following 6 were selected: (1) locomotion and energy system, (2) manipulation and energy system, (3) stability and energy system, (4) locomotion and cybernetics, (5) manipulation and cybernetics, and (6) stability and cybernetics. An analysis was conducted by adding each of these 6 interaction items to the previously used regression formulas. As a result, the absolute values of category weights exceeded 0.2 in (3) manipulation and energy system (0.461), (4) stability and energy system (-0.242), and (6) manipulation and cybernetics (0.214). The VIFs in these regression formulas were 4.304, 7.711, and 3.763, respectively, indicating the absence of multicollinearity in any of the categories. Category weights in these 3 regression formulas and the one with no consideration of interactions are shown in **Figure 1**.

When compared, the results of the regression analysis with no consideration of interactions and those for the interaction of "manipulation and energy system" (combination 3), category weight for manipulation in the former was 0.170 and that in the latter was -0.135, showing a significant decrease in value by 0.305. Concerning energy system, category weight for the former was 0.068 and that for the latter was 0.024, showing a slight decrease in value. In the regression formulas including interaction of "manipulation and cybernetics" (combination 6) relating to motor performance with boys showing superiority, category weights for "manipulation" and

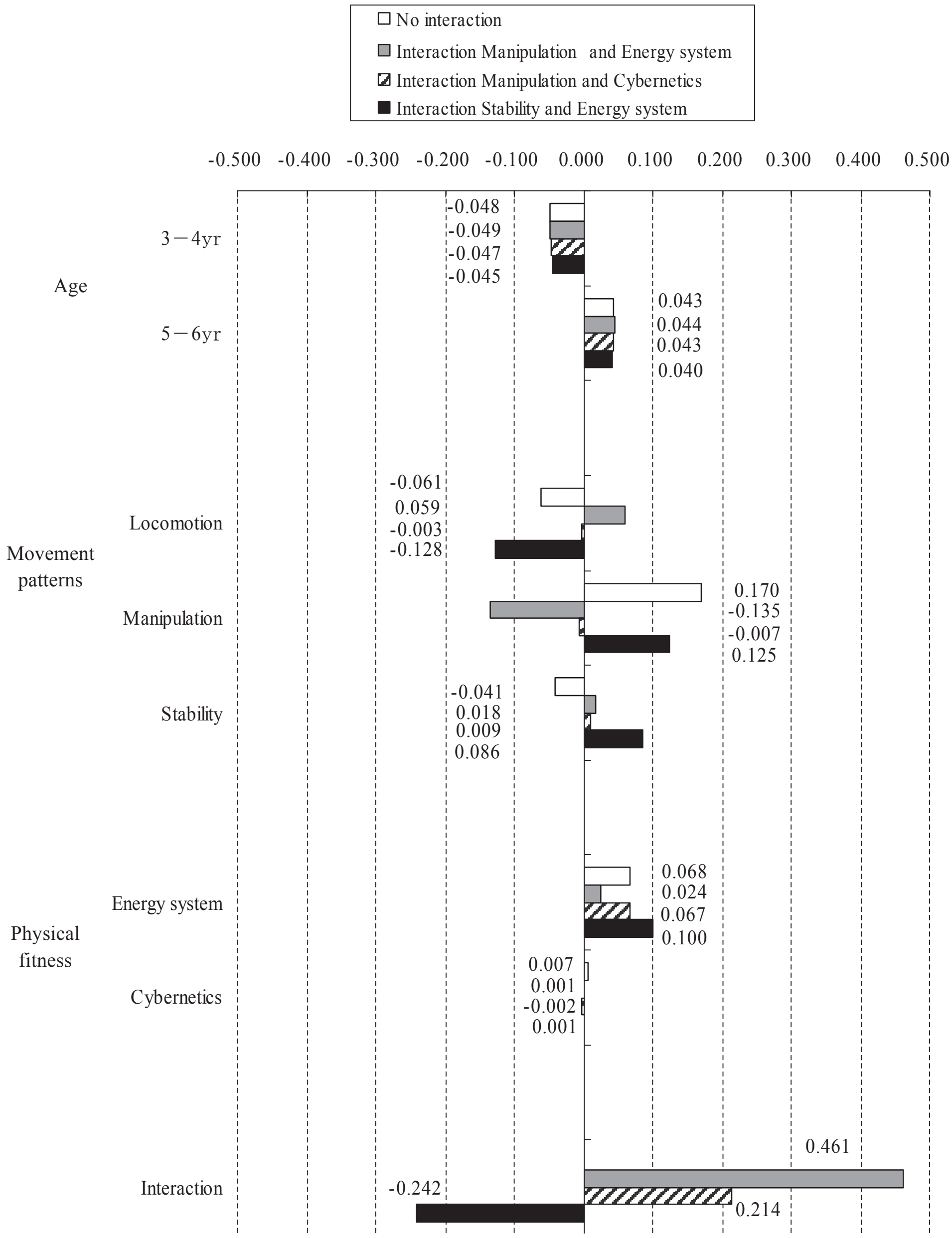

Figure 1 Comparison to category of four formulas

"cybernetics" decreased. In the regression formulas including the interaction of "stability and energy system" (combination 4), which was related to motor performance with girls showing superiority, category weights for "stability" and "energy system" increased.

4. Speculation

In terms of physical fitness, the partial correlation coefficient for "muscular strength & explosive power" was large and its category weight suggested the superiority of boys in this element. These results have supported the view of Yoshizawa (2002) that boys are superior to girls from preschool-age regarding power, speed, and muscle strength. Other elements of physical fitness, however, had minor relations to gender differences in motor performance, being inconsistent with the reports that girls exhibit superiority in dexterity (Harada, 1997) and that girls are superior in balance (Matsuura, 2005).

From category weights for movement skills, the superiority of boys in throwing was indicated. Under the constant effect of age, girls showed a tendency for superiority in manipulation of ball except for throwing skills such as ball bouncing. This tendency decreased under the constant effect of age and physical fitness. Meanwhile, no relation was observed between running/ kicking and gender differences in motor performance under the constant effect of age. When the effects of age and physical fitness were taken into consideration, girls showed a tendency for superiority in running/ kicking. Malina & Bouchard (1991) have reported that boys are superior in not only throwing skills but also in running and jumping skills. The results of this study have supported their view in terms of throwing skills. In terms of jumping skills, however, no relation to gender differences in motor performance was observed in this study. Regarding running, the superiority of girls was demonstrated.

In terms of age, a similar tendency was observed in all of the 3 regression formulas in consideration of movement skills, physical fitness, and interactions of movement skills and physical fitness. That is, category weight for age 3 was the smallest and its values increased with the increase in age. Signs were negative for subjects up to age 4 and positive for age 5 and 6. Ueda (1986) has reported that, in preschool period, girls tend to develop faster than boys in the fields of language, fine motor skills, and adaptability and that there may be gender differences in the course and timetable of development. In this study, though all absolute values were smaller than 2.0, category weights gradually increased, altering from negative, indicating the superiority of girls, to positive, indicating the superiority of boys. From these results, it has been considered that though showing no significant relation to gender differences in motor performance, relations between boys and girls begin to change during the period of age between 3-6 due to differences in rhythm and course of development.

Compared to age and physical fitness, movement skills have a stronger relation to gender differences in motor performance. In other words, gender differences in motor performance become obvious due to differences in movement skills rather than differences in physical fitness or age, which represents temporal growth. The relation to "muscular strength & explosive power" in physical fitness was the second greatest. It has been considered that gender differences are likely to emerge in motor performance which depends on muscle.

In this study, relationships with gender differences in motor performance were examined by Quantification Method I while keeping interrelations of age, movement skills and physical fitness constant. When comparing the category weights shown in **Table 8** and mean values of effect sizes shown in **Table 5**, both the mean value and the category weight for "muscular strength & explosive power" in physical fitness suggested the superiority of boys by a small difference. Though boys were superior in throwing, however, the mean value of effect size for throwing showed a moderate difference while its category weight showed a small difference. The superiority of boys in walking was suggested from the mean value, while category weight for walking indicated no gender differences. Similarly in movement skills showing the superiority of girls, the mean value for manipulation of ball indicated a small difference while category weight indicated no gender differences. Furthermore, there was no difference in mean values for running and kicking; however, category weights indicated a small difference. In this way, use of Quantification Method I contributed to results that were different from the gender differences indicated by the measured values of overt motor performance.

Concerning relationships between specific combinations of movement patterns and physical fitness and gender differences in motor performance, boys tended to exhibit superiority in "manipulation/ energy system" and "manipulation/ cybernetics," while girls tended to show superiority in "stability/ energy system." In any regression formula, category weight for the main effect decreased when adding interactions with boys showing superiority, while it increased when adding interactions with girls showing superiority. This suggests that gender differences in motor performance in preschool-age children are produced in specific combinations.

Estimation of potential movement skills and physical fitness from the results of motor performance of preschool-aged children has generally been conducted by corresponding motor performance in each test item to each element of movement skills or physical fitness. The results of this study, however, have suggested the need to investigate the effects of combinations of these items and elements. If gender differences in motor performance of preschool-aged children reflect a part of their activities and social expectance they receive in this period (Malina & Bouchard, 1991) and if there are already gender differences in the ways they play in this period (Matsuura, 1982), it is necessary to consider what combinations of movement skills and physical fitness are involved in motor performance appearing in the daily play and physical activities of children. Further investigation should be conducted in consideration of these interactions.

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Main Works:

- Testing the causal relationship between children's motor ability and lifestyle; How does life rhythm influence physical activity and motor ability ?. Japan Journal of Human Growth and Development Research 42:11-23. 2009.
- Meta-analytic study of gender differences in motor performance and their annual changes among Japanese preschool-aged children. School Health 4: 24-39. 2008.
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Membership in Learned Societies:

- Japan Society of Physical Education, Health and Sport Sciences
- The Japanese Association of Health Psychology
- The Japanese Association of School Health
- Japanese Society of Test and Measurement in Health and Physical Education
- Japan Society of Human Growth and Development
- Japan Society of Research on Early Childhood Care and Education