Original Article

Sex differences in motor performance and anaerobic peak power of Japanese primary school children aged 11 to 12 years

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ABSTRACT

The purpose of this study was to investigate sex differences in motor performance and anaerobic peak power in children. Furthermore, the relationship between power-associated variables and motor performance was also examined. Ninety-four Japanese primary school children aged 11 to 12 years volunteered. Grip strength, repeated lateral jumps, 50-m sprint, and standing broad jump were assessed following the guidelines published by the Japanese Ministry of Education and Science. Anaerobic peak power was assessed based on 6 sec sprint cycling with 4% of body mass as the braking load. The absolute peak power and peak power normalised by body mass were calculated as power-associated variables. The correlation analysis revealed that normalised peak power was moderately and strongly correlated with 50-m sprint time in both sexes, indicating the possibility that the sex difference in sprint performance could be derived from the discrepancy in anaerobic peak power. Sex differences were found in normalised peak power, lateral jumps, and 50-m sprint time. However, absolute peak power and standing broad jump did not differ significantly, and the results were not consistent with those of previous studies that examined participants in a different age range. The non-significant results in terms of absolute peak power and standing broad jump distance suggested the notion that sex differences in some variables fluctuate depending on the participants' age. Therefore, future studies are required to investigate the sex differences in motor performance and anaerobic peak power in children of different age groups.
Keywords: Sprint; Maturation; Physical fitness; Strength; Physical education.

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INTRODUCTION

Maturity-associated variables in the physical fitness of children and adolescents has been well demonstrated. According to Malina et al. (2004), performance in standing broad jump (SBJ) increases linearly with age until 14 years for girls and 18 years for boys. In addition, the mean sprinting velocity over 30 yards improves with age in both sexes. These developments in motor performance are substantially influenced by maturation in height and body mass (BM), which are fundamental factors for motor performance and strength. In fact, Yoshimoto et al. (2014) found that maturity-associated variables in body composition, such as height, BM, and lean BM, significantly correlated with sprint velocity ($0.44 < r < 0.68$) as well as vertical jump height ($0.17 < r < 0.51$).

Besides, some additional studies have assessed sex differences in motor performance in children and adolescents. Kanehisa et al. (1994) demonstrated that boys had significantly better knee extension torque than girls. In addition, sex differences were found in vertical jump height, SBJ distance, and sprint time (Malina et al., 2005 and 2010; Eisenmann and Malina, 2003). Previous studies have also examined anaerobic peak power (PP) assessed via the Wingate anaerobic test. Chia (2003) found sex differences in both absolute PP and PP normalised by BM (PP/BM) among 13 to 14-year-old adolescents. Furthermore, in healthy adults, previous studies have consistently shown that males are superior to females in both absolute PP and PP/BM (Nikolaidis, 2009; Weber et al., 2006), in agreement with the results presented in the study by Chia (2003). However, according to Malina et al. (2004), there was no difference between sexes in absolute PP until 14 years, even though PP/BM of boys was higher than that of girls. Therefore, it is considered the possibility that the sex difference in absolute PP might fluctuate depending on age.

It is well known that there is a discrepancy between the sexes in the timing of the growth spurt (peak height velocity, PHV). Suwa et al. (1992) showed that PHV in Japanese children and adolescents appears at 13.05 ± 0.94 years in boys and 11.05 ± 1.05 years in girls. The difference in PHV timing is a unique factor that influences the sex differences in motor performance and anaerobic PP in children and adolescents. Based on the result reported by Suwa et al. (1992), most of the participants in the study by Chia (2003) would have already reached PHV, which might have influenced the sex differences noted in absolute PP and PP/BM. Therefore, further study should be conducted at different ages to develop a comprehensive understanding of sex differences in anaerobic PP and motor performance.

The ability to exert anaerobic power over a short duration is also a key factor for motor performance because some studies demonstrated that the absolute PP and PP/BM were significantly correlated with motor performance in adult participants (Alemdaroğlu, 2012; Nikolaidis, 2009). The cross-sectional area, especially for first twitch, strongly influences the power-associated variables (Linossier et al., 1997); this means that the absolute PP and PP/BM associated with the amount of first twitch would be important even in children and adolescents. However, the relationship between anaerobic PP and motor performance in children and adolescents has not been investigated well enough. Aziz and Chuan (2004) showed a significant correlation of PP/BM with 40 m sprint time; however, in this study, senior and junior athletes were included as participants. Thus, the results may not indicate the accurate relationship between these factors in children.

Therefore, based on the context of these studies, we conducted an investigation of the sex differences in anaerobic PP and motor performance in children aged 11 to 12 years. We hypothesized that boys would be significantly superior to girls in all variables such as absolute PP, PP/BM, and motor performance. We also examined whether absolute PP and PP/BM were significantly correlated with motor performance in children.

MATERIAL AND METHODS

Participants

Ninety-four children (age, 11.7 ± 0.4 years; height, 1.42 ± 0.07 m; mass, 36.60 ± 7.32 kg), who were 11 to 12 aged Japanese public primary school children, volunteered for this study. Since all measurements were implemented as a physical education class, the school principal were informed about the study purpose, procedure of measurement and potential risk in experiment via an information sheet prior to testing. In addition, before each test, participants were informed about the protocol verbally by teachers and practitioners. Moreover, teachers cooperated with all tests to ensure safety. All procedures of this study were approved by the Human Ethics Committee in Osaka University of Economics (approval number: 2019-H02).

Measures

Motor performance

Motor performance tests in this study included grip strength assessment, repeated lateral jumps (RLJ), 50-m sprint, and SBJ. In the present study, all test procedures followed the implementation guideline published by The Japanese Ministry of Education and Science (https://www.mext.go.jp/a_menu/sports/stamina/05030101/001.pdf). All Japanese primary, middle, and high schools are required to conduct these tests once a year as part of a physical fitness test. Grip strength was measured using a hand dynamometer (EVERNEW, Tokyo, Japan) in the standing upright posture. It was attempted two times in each hand with instructions to grip as hard as possible without swinging the dynamometer. The best trial for each hand was chosen and the two measurements were averaged for further analysis. RLJ was counted as the number that a participant exceeded three lines separated by 1.0-m intervals in 20 seconds. The 50-m sprint time was measured using a stopwatch (SEIKO, Tokyo, Japan). Participants were instructed to sprint as fast as possible, and the signal "*on your marks, set, GO*" was provided. SBJ distance was measured as the horizontal distance jumped from a static standing position. Using a tape measure, the distance was measured from the point of heel contact with the ground at touch-down to the point of toe contact at the initial position.

Sprint cycle ergometer

Anaerobic PP was measured via the Wingate power test using a cycling ergometer (OC LABO, Tokyo, Japan). The braking load was determined based on 4% of body mass. Double-toe stirrups and straps were used to tightly fix the participants' feet on the pedals. The height of the saddle was adjusted for the most comfortable posture for cycling. Participants were instructed to start cycling at the signal "*3, 2, 1, GO*" and continue for 6 sec with maximum effort under verbal encouragement. The power-associated variables, absolute PP and PP/BM, were calculated for further analysis. The power output was recorded at 10 Hz by the cycling ergometer, and a power-time curve was obtained. The absolute PP was determined as the PP in the power-time curve for each participant. Furthermore, the PP/BM was calculated by dividing the absolute PP by the participants' BM.

Statistical analysis

The descriptive statistics are represented by mean and standard deviation (SD). Un-paired t-tests were performed to compare variables between the sexes. Cohen's d values were calculated as effect size to demonstrate the magnitude of the sex difference in each variable, while Pearson's product-moment correlation was used to analyse the relationship between anaerobic PP and motor performance. The correlation analysis was implemented in three groups: boys, girls, and pooled group of boys and girls (Pooled). The scale modified by Hopkins et al. (2009) was used to interpret the correlation coefficient as: trivial = .1 to .29, moderate = .30 to .49, strong = .50 to .69, very strong = .70 to .89, nearly perfect = .90 to

.99, and perfect = 1. All statistical analyses were performed using SPSS v25 software (IBM, New York, USA). The statistical significance was set at $p < .05$.

RESULTS

Descriptive statistics are shown in Table 1 as well as the t-test results and Cohen's d values. In terms of height, girls were significantly taller than boys ($t = -3.64$, $p < .05$, $d = 0.77$), while boys were superior to girls in PP/BM ($t = 3.02$, $p < .05$, $d = 0.63$). In addition, there were significant differences in RLJ and 50-m sprint time according to the sex (RLJ: $t = 2.08$, $p < .05$, $d = 0.43$, 50-m sprint time: $t = -2.49$, $p < .05$, $d = 0.51$).

Table 1. Sex difference in body composition and physical fitness test.

	Boys (n = 46)			Girls (n = 48)			t-test	
	Mean	±	SD	Mean	±	SD	t value	Cohen's d
Body Composition								
Height (m)	1.39	±	0.06	1.44	±	0.07	-3.64 †	0.77
BM (kg)	35.24	±	8.41	37.90	±	5.88	-1.78	0.37
Anaerobic Peak Power								
Absolute PP (w)	203.22	±	59.79	198.71	±	50.90	0.39	0.08
PP/BM (W/kg)	5.75	±	0.93	5.20	±	0.82	3.02 †	0.63
Motor performance								
Grip Strength (kg)	17.22	±	4.46	17.52	±	3.78	0.34	0.07
RLJ (times)	44.65	±	6.12	41.88	±	6.77	2.08 †	0.43
SBJ (cm)	169.11	±	24.81	159.63	±	21.97	1.96	0.41
50-m sprint (sec)	9.23	±	0.99	9.72	±	0.93	-2.49 †	0.51

Body Mass; BM, Peak Power; PP, Peak Power normalised by Body Mass; PP/BM, Repeated Lateral Jump; RLJ, Standing Broad Jump; SBJ. †; Significant difference between boys and girls (p < .05).

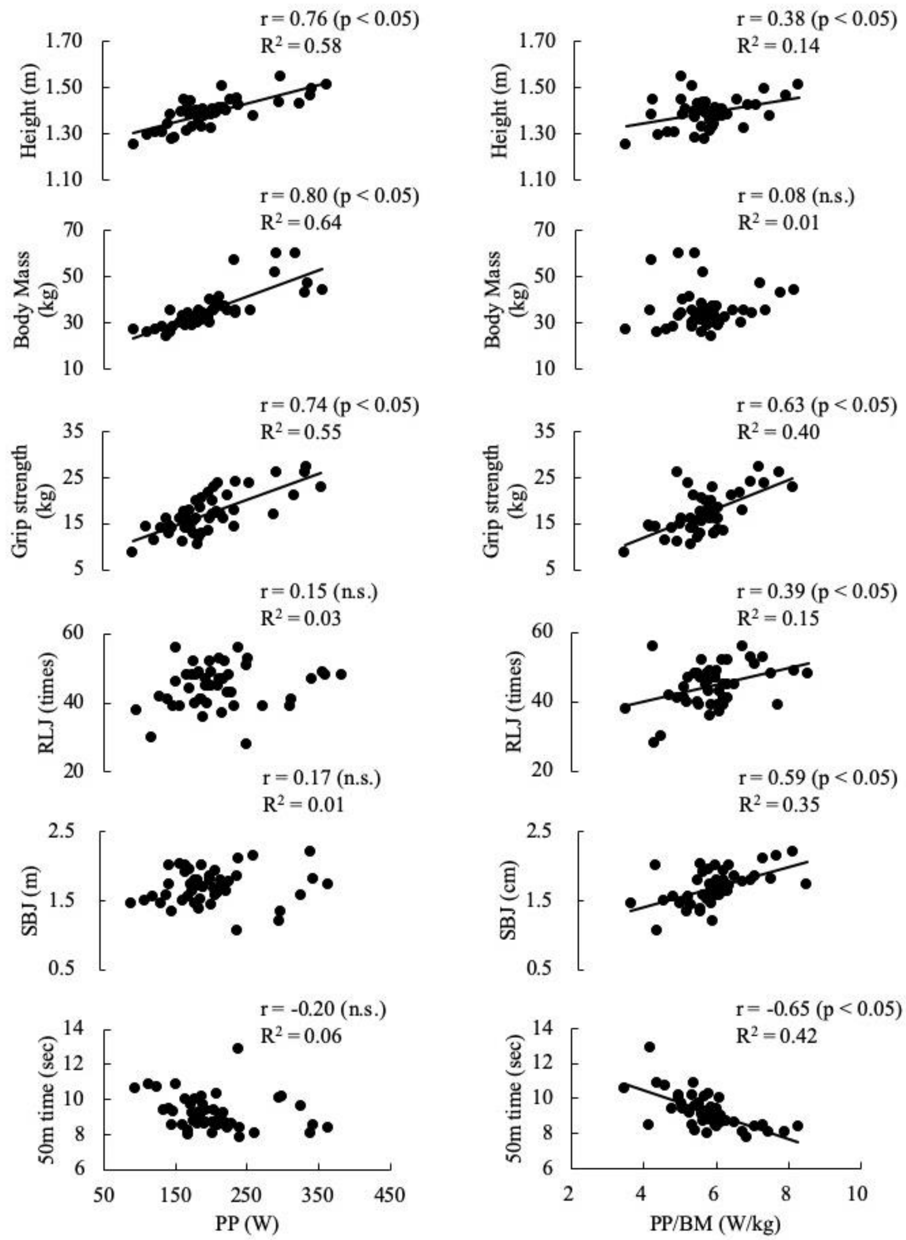
Table 2 shows the correlation coefficients for the relation between power associated variables and body composition and motor performance in the pooled group. PP was significantly correlated with height ($r = 0.65$), BM ($r = 0.78$), and grip strength ($r = 0.62$), whereas PP/BM was significantly correlated with height ($r = 0.25$), RLJ ($r = 0.43$), 50-m sprint time ($r = -0.57$), and SBJ ($r = 0.54$).

Table 2. The relationship between power and the other variables when boys and girls pooled in a group.

	Height	BM	Grip Strength	RJL	50-m sprint	SBJ
PP	0.65 †	0.78 †	0.62 †	0.15	-0.20	0.17
PP/BM	0.25 †	0.11	0.50 †	0.43 †	-0.57 †	0.54 †

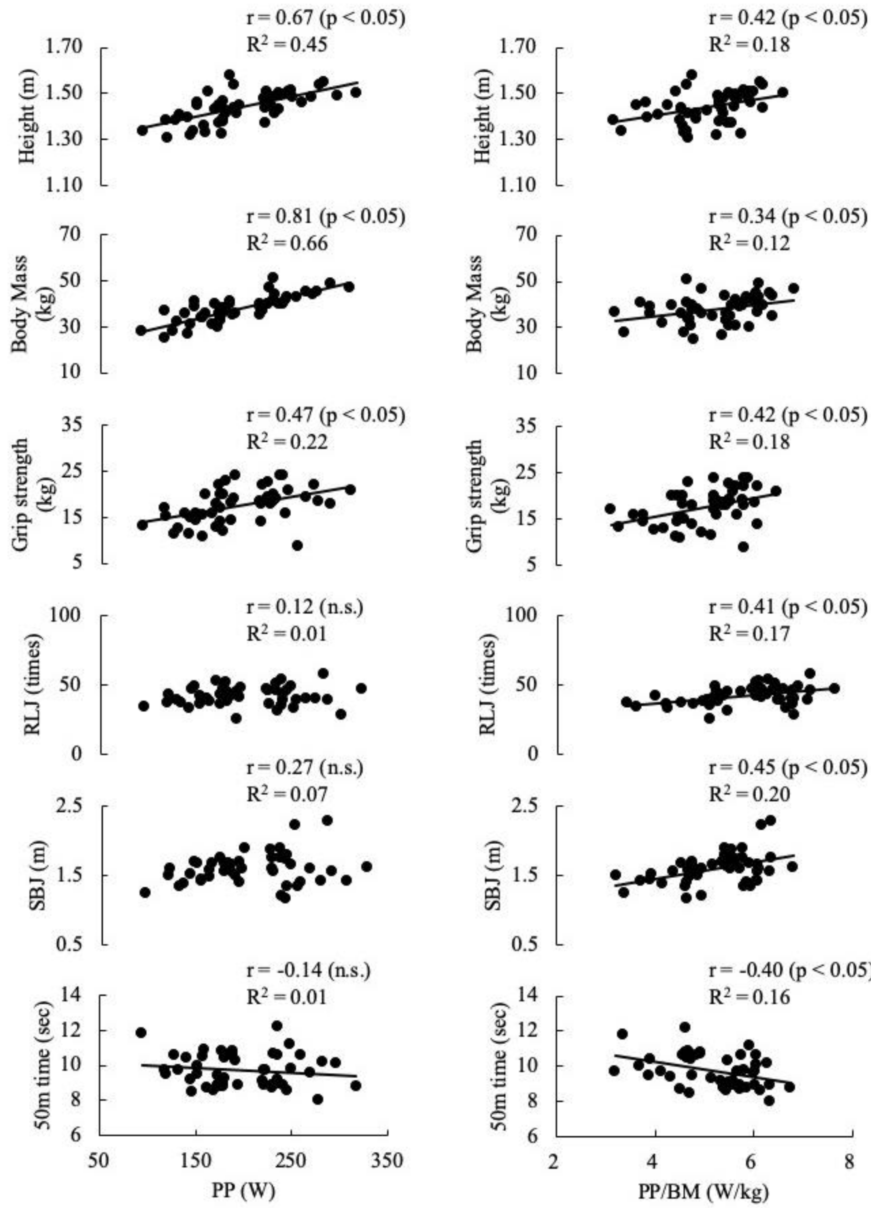
Body Mass; BM, Peak Power; PP, Peak Power normalised by Body Mass; PP/BM, Repeated Lateral Jump; RLJ, Standing Broad Jump; SBJ. †; Significant relationship (p < .05).

Figures 1 and 2 show the scatter plots for power-associated variables, body composition, and motor performance in boys and girls, respectively. In both boys and girls, the absolute PP was significantly correlated with height, BM, and grip strength ($0.47 < r < 0.81$), and the PP/BM was significantly correlated with height, grip strength, RLJ, 50-m sprint time, and SBJ ($0.38 < r < 0.65$).



Body Mass, BM; Peak Power, PP; Peak Power normalised by Body Mass, PP/BM; Repeated Lateral Jump, RLJ; Standing Broad Jump, SBJ. †, significant relationship (p < .05).

Figure 1. The relationships between anaerobic power and motor performance in male participants.



Body Mass, BM; Peak Power, PP; Peak Power normalised by Body Mass, PP/BM; Repeated Lateral Jump, RLJ; Standing Broad Jump, SBJ. †, significant relationship (p < .05).

Figure 2. The relationships between anaerobic power and motor performance in female participants.

DISCUSSION

This study was conducted to investigate sex differences in anaerobic PP and motor performance in children aged 11 to 12 years. As shown in Table 1, we noted significant differences between the sexes in the PP/BM (d = 0.63) but not in the absolute PP (d = 0.08). In addition, the SBJ did not differ between the sexes (d = 0.41). Thus, our hypothesis that boys are superior to girls in terms of anaerobic PP and motor performance was partially unsupported. The significant difference observed in PP/BM is in agreement with the results from a study by Chia (2003); however, the absolute PP in boys was also significantly superior to that in girls in the previous study. A possible explanation for the lack of difference between the sexes in absolute PP in our study is the difference in the BM. The results of this study showed a very strong correlation between BM and the absolute PP in both sexes (Pooled: r = 0.78; boys: r = 0.80; girls; r = 0.81). Previous studies examining healthy adults showed that males were much superior to females in terms of absolute PP and were also heavier (Nikolaidis, 2009; Weber et al., 2006), while the BM of girls was non-significantly higher than that of boys in the current study. With regard to growth spurt in Japanese children, Suwa et al. (1992) demonstrated that PHV occurred at 13.05 ± 0.94 years in boys and 11.05 ± 1.05 years in girls. Thus, we speculate that most of the male participants in this study had not reached the PHV phase yet, whereas most of the female participants were either in the PHV phase or had already crossed it.

Furthermore, the difference in growth spurt timing could also influence the results of the SBJ, wherein we found a non-significant sex difference. Although SBJ is used to assess the explosive strength of participants (Kale et al., 2009), the SBJ distance is also influenced by the height of the centre of gravity. In a previous study, Malina et al. (2010) reported a significant difference in SBJ between the sexes among track and field athletes aged 14–15 years; this result contradicts the findings of the current study. The primary discrepancy between the two studies is in terms of the age of the participants enrolled. Malina et al. (2010) examined participants of both sexes who had reached PHV; thus, the boys were much taller than the girls. However, in our study, the girls were significantly taller than the boys likely because the most of boy participants had not reached PHV yet. The non-significant results in terms of the absolute PP and SBJ support the hypothesis that that sex differences in some variables fluctuate depending on the participants' age, and that different stages of growth spurt between the sexes could be one of the potential factors that led to the non-significant difference between the sexes noted in this study.

This study also investigated the relationship between power-associated variables and motor performance. In both the sexes, we found significant correlations between these two variables as shown in Table 2 and Figures 1-2. In particular, PP/BM was moderately or strongly correlated with 50-m sprint time (boys: r = -0.65; girls: r = -0.40; pooled: r = -0.57). This result is consistent with those of previous studies that examined this relationship among athletes. For instance, Aziz and Chuan (2004) demonstrated a strong relationship between the PP/BM and 40-m sprint time among senior field hockey and junior soccer athletes (r = -0.63). Furthermore, Perez-Gomez et al. (2008) also found a similar relationship among collegiate physical education students (men: r = -0.36; women: r = -0.66). Since these previous studies had enrolled junior and senior athletes, the current findings, which were obtained in healthy children, represent additional knowledge in this research area. Moreover, this significant relationship could be a crucial factor influencing the sex difference noted in the 50-m sprint time. Therefore, practitioners should remember that the difference in sprint ability between the sexes derives from the difference in anaerobic power output.

Longitudinal training interventions to enhance anaerobic PP have not been fully investigated with regard to whether they can help enhance motor performance in both the sexes equally, although a significant correlation was found in this study. Previous studies have conducted longitudinal interventions in children and adolescents for enhancing anaerobic PP; however, most of these studies focused only on boys. For instance, Chelly et al. (2009) implemented an intervention comprising back squats twice a week for 2 months among junior soccer players aged approximately 17 years and showed a significant improvement in both anaerobic PP and sprint ability. Accordingly, development of anaerobic PP via strength training could be an effective intervention for boys to improve motor performance, especially sprint performance. If enhancement of anaerobic PP contributes to improved motor performance in boys but not in girls, teachers and coaches should take a sex-specific approach. Therefore, future research should be conducted to clarify whether training interventions to improve anaerobic PP are able to enhance motor performance, such as sprint ability, in both the sexes equally.

CONCLUSION

We aimed to investigate sex differences in anaerobic PP and motor performance among children aged 11 to 12 years. We found significant sex differences in PP/BM, RLJ, and 50-m sprint time, while the absolute PP and SBJ were not significantly different contrary to our hypothesis. The non-significant difference in these variables is likely due to the discrepancy in the growth spurt between the sexes. Therefore, these results added value to the understanding of exercise-related sex differences in children aged 11 to 12 years, and additional studies focusing on participants of different age groups are required.

AUTHOR CONTRIBUTIONS

Seita Kuki: Data collection and analysis, Writing Original draft. Yu Konishi: Writing, Reviewing and Editing. Masamichi Okudaira: Validation, Visualization. Kensuke Takezawa: Data collection and analysis. Koji Wakayoshi: Supervision.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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