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Effect of skeletal muscle of adolescents on physical strength, physique, and motor coordination*

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Abstract

This study aims to analyze the relative importance of bone age and chronological age in physique according to gender and to identify the relative importance of bone age, chronological age, and physique in physical fitness and motor coordination according to gender in order to alleviate the imbalance between physique and physical fitness in children. A total of 666 children(346 males, 320 females) between the ages of 11-14 were enrolled as subjects, and the skeletal maturation The skeletal maturation were measured by taking hand-wrist. Physical fitness were measured through a total of 4 components: muscular strength. The results of this study. First, physique variables for both males and females aged 11-14 were found to be more significant predictors of bone age than chronological age. Second, for physical fitness in males, in the order of %fat, body water, waist-hip ratio, weight, fat-free mass, and chronological age were more significant predictor variables; and in females, in the order of %fat, fat-free mass, height, chronological age, weight, bone age, fat mass, and body water were more significant predictor variables. For bone age and chronological age in physical fitness, bone age in males and chronological age in females found to be the more representative variables respectively.

Keywords: Bone Age, Chronological Age, Physique, Physical Fitness, Motor Coordination

Major classifications: Health Science.

1. Introduction

Childhood, one of the developmental processes of human beings, is a very important period of physical growth and mental maturity at the same time (Lee, 2012). In addition, childhood is a period of puberty changes, and chronic diseases or malnutrition during this period cause growth retardation (Schoeters et al., 2008). And the rapid physical change that occurs

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during this period has a great impact on identity development, emotional and cognitive development, and also affects the physical and physiological development of childhood (Han, 2004; Kum, 2015). However, in 2010, in Korea, children's nutritional status improved due to improved dietary standards, and their physique increased compared to the previous generation, but physical activity decreased as the amount of physical activity decreased (Ministry of Education, 2010). On the other hand, in 2016, the growth trend of children's physique decreased and their weight increased slightly (Ministry of Education, 2016). In 2018, there was no significant change in the children's physique, only the weight increased (Ministry of Education, 2018). As the physique increases and physical strength decreases, symptoms such as obesity, diabetes, and low back pain, which are the causes of cardiovascular disease that occur naturally in adults, are appearing in children (Maffeis et al., 2003). In addition, the decrease in the amount of physical activity and the increase in mental stress caused by various factors such as grades resulted in a decrease in physical function, which resulted in an extreme decrease in physical strength and physical activity of children. Accordingly, the need to improve the physical fitness level by accurately evaluating the factors affecting the physical fitness of children is suggested (Yoon, 2002). In order to properly evaluate children's physical factors, it is important to understand the patterns and rates of children's growth and development. However, since each child has individual differences (Malina et al., 2004; Cumming et al., 2008; Vidal-Linhares et al., 2010). It is important to study physique and physical strength using bone age that can represent accurate biological maturity indicators instead of chronological age.

In addition, using bone age as a measure to evaluate the physical development or skeletal maturity of growing children is more accurate than the chronological age, which naturally increases from the moment of birth. Although bone age has differences between sexes, races, and regions, it is suggested as the best indicator of biological maturity (Cunha et al., 2014).

In addition, the physical fitness of growing children can be evaluated through the evaluation of bone age (Byun et al., 2014), and it is used as important clinical data for diagnosing growth disorders and endocrine disorders. Also, it is applied to estimating a child's adult height. In addition, in previous studies, it has been reported that the difference in bone age in children has an important effect on body composition and physical strength. Bone age before puberty is closely related to static strength, reflexes and agility, and moreover, the bone age of adolescent girls is positively related to static muscle strength (Song & Yoo, 2000). However, bones go hand in hand with muscle development, which can improve performance in many ways (Malina et al., 2005; Vidal-Linhares et al., 2010), but in the case of early maturation, the child has a higher body mass index (BMI) than children of the same age, and can negatively affect physical performance by causing an increase in body fat in the long term (Freitas et al., 2014).

In previous studies on children's physique and physical strength, it was reported that children's growth rate is faster than that of adults and continuous length growth occurs (Kim et al., 2018), so that degree of change in physical strength due to physical conditions can also be changed (Jones et al., 2000). Beunen et al. (1997) conducted a study on the relationship between physique factors and physical fitness for boys and girls aged 6-19 years old and adolescents. Through this study, it reported that physical fitness can be affected by physique conditions even in young children. Like this, many previous studies have reported that there is a significant relationship between the physique and physical strength of children and adolescents. In this period of continuous growth in length, it is important to evaluate the height in terms of physique, and height is an indicator of development, physique, and nutrition (Byun et al., 2014; Ko, 2016). In addition, in the recent growth of children, the physique hardly changes and the weight tends to increase (Ministry of Education, 2018), and since weight is a representative factor in measuring the degree of physical health ((Byun et al., 2014), it is important to study the body composition of children. In addition, in order to improve physical strength, it is necessary to participate in appropriate play, sports, and physical activity, which is related to motor coordination. Lopes (2011) predicted the physical activity ability of a 10-year-old child through the motor coordination ability of a 6-year-old child using a longitudinal study. As such, motor coordination is a fairly stable factor in the measurement of physical activity capacity (Magill et al., 1993).

Also, motor coordination is the ability to integrate the motor system and various sensory modalities into an efficient motor pattern, and There are two types of motor coordination: a form that integrates visual and bodily movements and a form of accurately matching or performing a moving object (Gallahue et al., 2005). In most sports activities, motor coordination is required to perform accurate movements, and motor coordination is a very necessary function in daily life, such as using tools for eating. These movements play an important role not only in sports activities, but also in exquisitely performed movements such as playing the piano and stitching needles (Gallahue et al., 2005). Children who lack motor coordination have difficulty performing daily tasks, including play (Cairney et al., 2015). In addition, these children have difficulty in participating in physical activity because they lack motor coordination to participate in play or sports and they tend to avoid physical activity (Hill, 2001). Therefore, it is said that children with good motor coordination have higher levels of physical activity and physical fitness than children with poor motor coordination, and children with poor motor coordination are more likely to be obese (Duarte et al., 2016). And recently, there is a study result (Lopes et al., 2013; Haapala et al., 2014)

that motor coordination is related to not only physical strength but also emotional function and academic achievement, so motor coordination is an important factor for adolescent children. For balanced growth in childhood, it is important to evaluate the relationship between physique, physical strength, and motor coordination in terms of bone age and chronological age. However, most of the previous studies evaluated physique or physical strength as bone age(Song &Yoo, 2000; Hong et al, 2009; Kang et al., 2010; Lee, 2012), and studies that evaluated motor coordination, a factor necessary for improving physical strength, are insufficient.

Therefore, the purpose of this study is to analyze the importance of the influence of bone age and chronological age on the physique according to gender in order to alleviate the imbalance between the physique and physical strength of children and investigate the importance of the relative influence of bone age, chronological age, and physique on physical fitness and motor coordination according to gender.

2. Research Method

2.1. Subject of Study

According to Duarte et al. (2016) study that 11 to 14 years old is a period of transition to puberty and suitable for research on body composition and motor coordination, children aged 11 to 14 years old were selected as the population in this study. The multi-layered house radio sampling methodwas used for the sampling method of the research subjects, and the extraction procedure of the research subjects was carried out by creating a sampling frame and then selecting one sports-related facility in the metropolitan area, one elementary school, and one middle school. In the first stage of sampling, considering regional characteristics, the metropolitan area was classified into north and south, and then a total of three sports-related private institutions, one for each elementary school, and one for middle school, were randomly assigned. In the second stage of sampling, 700 children were selected from among the children using the three institutions selected from the north and south regions and cluster sampling was performed. Measurements were made on 700 people who were sampled, and data from a total of 666 people, 320 girls, were used for the actual analysis, excluding data that were insincere or part of the content was omitted. Measurement and analysis were performed based on these data.

2.2. Research Method

2.2.1. Bone Age and Chronological Age

In this study, skeletal maturity was measured through the most used and verified biological maturation index(Geithner et al., 1998) to calculate bone age. Skeletal maturity was measured by X-ray imaging of the child's left hand and wrist bones, and skeletal maturity was calculated using the skeletal maturity TW3 method devised by (Oh et al., 2009), Tanner et al.(2001) to reflect the bone maturity of each region. The bone age was calculated by applying the RUS score of 13 bones measured by the TW3 method to the skeletal maturity conversion table, and the bone age was recorded to two decimal places. Similarly, the chronological age was calculated to two decimal places of the child's age. The chronological age was calculated by dividing 12 months by 10 and assigning scores from the child's birth month to 0 in December and 0.91 in January.

2.2.2. Physical Frame and Strength

The height of children was measured using a height gauge (Samhwa Gauge, Korea), and body weight, body fat mass, abdominal fat percentage, body water, lean body mass, BMI, and body fat percentage were measured using InBody270 (Biospace, Korea) to which bioelectrical impedance method was applied. In addition, in order to measure physical strength and exercise coordination, physical strength (grip strength), flexibility (left flexion), muscular endurance (sit-up), and cardiorespiratory endurance (shuttle run) were measured for a total of four physical fitness elements. Motor coordination was measured by balance (one-legged standing), agility (flat-tapping), and quickness (long jump in place). Measurements were performed twice, and shuttle runs and sit-ups, which are difficult to measure repeatedly, were measured once.

2.3. Data processing method

The data in this study were analyzed through the SPSS.WIN 25.0 statistical package program. The detailed analysis method is as follows. First, descriptive statistics were performed to analyze the characteristics of the subject's physique and physical

strength according to age and gender. Second, step-wise multiple regression was performed to investigate the relative importance of bone age and chronological age on physique (height, weight, body fat mass, abdominal fat percentage, body water, lean body mass, BMI, body fat percentage)according to age (11-14 years old) and gender (male and female).

In the analysis, bone age and chronological age were used as predictive variables, and the order of predictive variables entered into the regression equation was determined by the F-value and importance. In addition, the relative importance of age group, male and female bone age, chronological age, and physique on physical fitness (Strength, Flexibility, Muscular Endurance, Cardiorespiratory Endurance) and motor coordination (equilibrium, agility, agility) was also measured through step-wise multiple regression. In the analysis, bone age, chronological age, and physique were used as predictive variables, and the order of predictive variables in the regression equation was determined by the F-value and importance. In addition, the statistical significance level was set to $P<0.05$.

3. Result

In this study, physique, physical strength, and motor coordination were analyzed including bone age and chronological age. Table 1. shows the mean and standard deviation of physique including bone age and chronological age. According to the results, in the case of men and women by age of children, the difference between the chronological age and bone age was 0.14 to 1.34 years, and there was no significant difference between each age group.In addition, height, weight, body fat mass, abdominal fat percentage, body moisture, fat control, and BMI all tended to be higher with age, but body fat percentage remained constant at the remaining 11 and 12 years old and low at the age of 13 and 14. For girls, the age of 11, 12, and 14 years was kept constant, but showed a tendency to appear lower at the age of 13. Figure 1. presents the results of physical fitness and exercise coordination according to age between 11 and 14 years old. In the case of boys, the results of grip strength test, flat tapping, long jump in place, and sit-ups were higher as the age increased. The left vertebrae increased from 11 to 12 years of age, maintained at 13 years of age, and decreased at 14 years of age. Sit-ups increased from 11 to 13 years of age and then decreased at 14 years of age. Shuttle run increased from 11 to 12 years old, decreased at 13 years old, and increased again at 14 years old. On the other hand, unilateral standing showed a tendency to decrease from 11 to 13 years of age and to increase at 14 years of age. On the other hand, in the case of females, the results of unilateral standing and left flexion increased with increasing age, but the grip strength test increased from 11 to 13 years of age, maintained at 14 years of age, and decreased somewhat. Flat tapping, standing long jump, and sit-ups increased from 11 to 13 years of age and then decreased at 14 years of age. The left vertebrae increased from 11 to 12 years of age, maintained at 13 years of age, and decreased at 14 years of age. Shuttle run increased from 11 to 12 years of age and then decreased at 13 years of age.

Table 1: Mean Values (Standard Deviation) of Physique in Children by Sex and Age

Sex		Male(n=346)				Female(n=320)			
Age		11	12	13	14	11	12	13	14
n		91	99	110	46	92	104	80	44
BoneAge (yrs)	Mean	10.28	11.68	12.54	14.36	10.35	11.97	13.14	14.18
	SD	1.10	1.21	1.43	1.27	1.01	1.00	1.33	1.07
Chronological Age (yrs)	Mean	11.46	12.44	13.45	14.50	11.44	12.45	13.44	14.45
	SD	0.30	0.29	0.28	0.28	0.28	0.28	0.26	0.32
BA-CA (yrs)	Mean	1.18	0.75	0.91	0.14	1.09	0.48	0.29	0.27
	SD	1.01	1.31	1.34	1.17	0.97	0.95	1.26	1.07
Height (cm)	Mean	141.96	148.10	156.73	165.15	142.10	149.20	154.12	157.40
	SD	6.00	7.30	7.42	6.22	7.06	6.14	5.78	4.80
Weight (kg)	Mean	40.32	49.18	50.77	59.23	37.01	42.25	45.92	48.68
	SD	8.54	10.70	11.05	12.19	8.68	7.83	9.09	7.39
Fat Mass (kg)	Mean	11.74	12.72	12.61	13.26	10.09	11.57	12.39	13.37
	SD	5.59	5.99	7.35	7.29	4.63	4.76	5.64	4.75
Waist-Hip Ratio (%)	Mean	0.76	0.78	0.78	0.80	0.76	0.78	0.79	0.80
	SD	0.03	0.04	0.04	0.05	0.02	0.04	0.04	0.03

Body Water (L)	Mean SD	20.92 2.86	23.76 4.45	28.01 4.64	33.63 5.18	19.84 3.76	22.48 3.23	24.47 3.35	25.79 2.90
Fat—Free Mass (kg)	Mean SD	28.57 3.92	32.56 6.16	38.23 6.35	45.96 7.12	26.95 4.66	30.72 4.38	33.48 4.56	35.31 3.99
BMI (kg/m^2)	Mean SD	19.88 3.08	20.42 3.35	20.56 3.65	21.64 3.92	18.19 3.04	18.92 2.71	19.22 3.08	19.63 2.84
Percent Fat (%)	Mean SD	27.75 8.43	27.08 7.28	23.34 9.32	21.33 8.32	26.24 6.66	26.55 7.07	25.95 7.12	26.82 6.22

BA-CA:BoneAge-ChronologicalAge

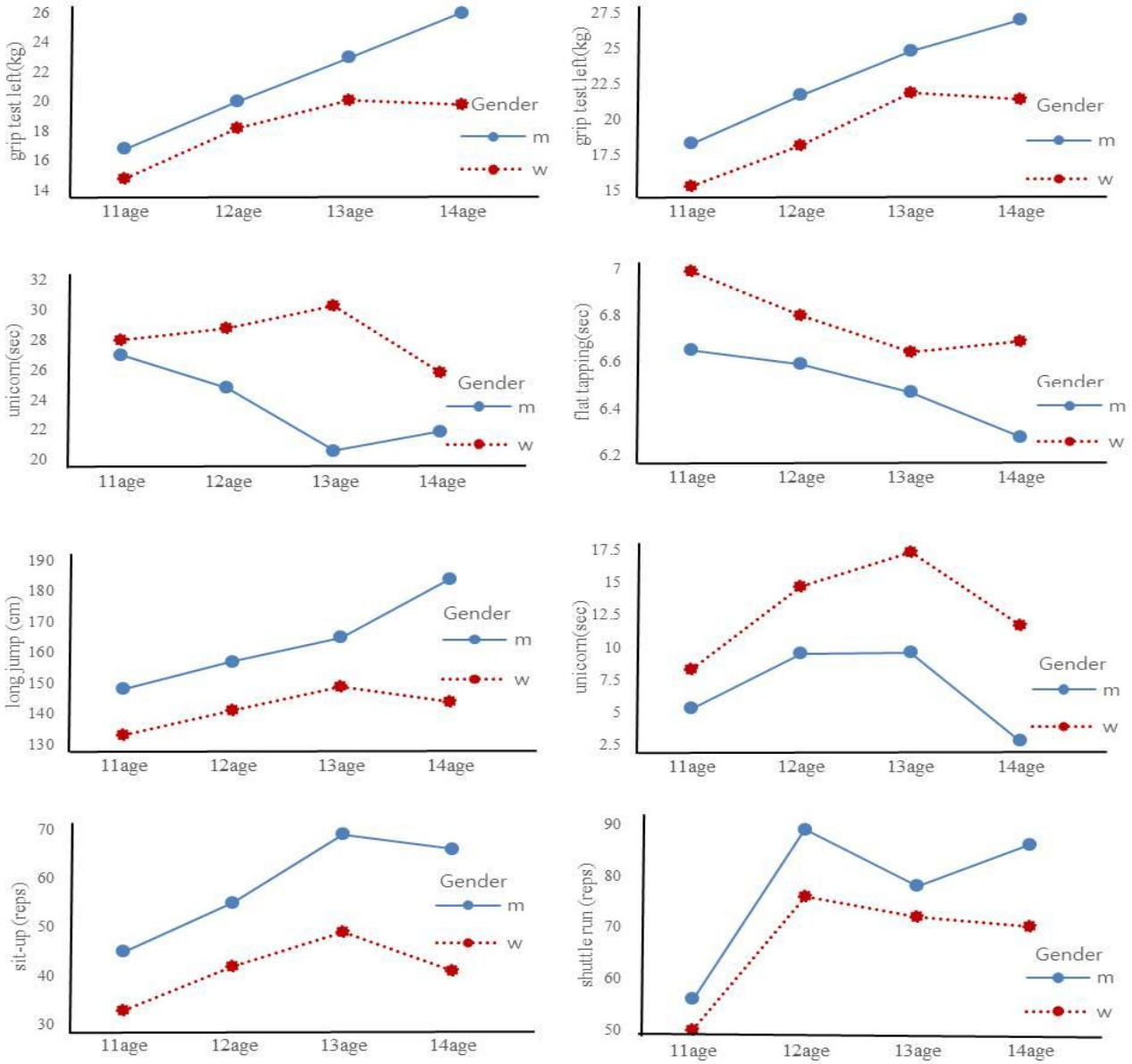

Figure.1: Appearance Pattern of Physical Fitness and Motor Coordination by Age

3.1. Bone age of men and women by age, and the relationship between age and physique

Stepwise regression analysis was performed to investigate the effect of bone age and chronological age on the physique, and the results are shown in Table 2. and Table 3.

In the case of boys, a total of 12 regression equations were found in which bone age and chronological age had a significant effect on physique from 11 to 14 years old. The explanatory power was 4.3% to 36.5% for height, 15.9% for body weight, 5.6% for abdominal fat, 22% to 35.4% for body water, 4.5% to 35.1% for lean mass, and 3.8% to 10.2% for body fat. Also, in the results of the step-by-step regression analysis, as the variable that best represents the physique, 10 out of 12 regression equations is the most significant predictor variable (first), bone age. On the other hand, chronological age was found to be the most significant predictor variable twice out of the 12 regression equations, and as the second predictor variable once.

In the case of girls, a total of 24 regression equations were found in which bone age and chronological age had a significant effect on physique from 11 to 14 years old. In the case of height, 18.5%~43.5%, weight 45.1%~57.3%, body fat 7.1%~57.3%, abdominal fat rate 6.8%~27.5%, body water 24.6%~39.7%, body fat 25.1%~29.5%, BMI 8.3%~17, and body fat rate
8.3%~8.6%. Also, in the step-by-step regression analysis, the variable that best represents the physique (the first) is bone age, in which 23 out of 24 regression equations were shown as the most significant predictor variable. On the other hand, chronological age was found to be the most significant predictor variable once out of 24 regression equations and as the second predictor variable three times.

3.2. Effect of bone age, chronological age, and physique on physical fitness and exercise coordination in men and women by age

Stepwise regression analysis was conducted to find out the influence of bone age, chronological age, and physique on physical strength and exercise cooperation, and the results are shown in Table 4-1, Table 4-2, and Table 5.

According to<Table 4-1>,there were a total of 26 regression equations in which bone age, chronological age, and physique significantly influence physical strength and exercise cooperation from 11 to 14 years old in boys. In terms of physical strength, the grip test (left) showed 36.7% to 61.8%, the grip test (right) 30.3% to 59.4%, the left front cave 19.5% to 26.2%, the shuttle run 18.9% to 48%, and the single-legged stand 3.9% to 4.4% in sports cooperation and the long jump 26.5% to 60.5% in place.In addition, in the stepwise regression analysis of <Table 5>, the order of variables representing physical strength and exercise cooperation was in the order of 11 body fat percentage, 7 body water minutes, 6 weight, 5 bone age, 4 body fat percentage, 4 abdominal fat percentage, 4 BMI, 3 height, and 2 chronological age. The variables that best represent physical strength and exercise coordination were body fat percentage, body moisture, abdominal fat percentage, weight and fat percentage, and age, which were included 11 times, 6 times, 3 times, 2 times, and 1 time, respectively. In boys, the variables that best represent physical fitness and exercise coordination are body fat percentage and body water, which were performed 11 times and 7 times, respectively

Looking at <Table 4-2>,a total of 23 regression equations were found for girls from 11 to 14 years old, in which bone age, chronological age, and physique had a significant effect on physical fitness and exercise coordination. In terms of physical strength, the grip test (left) showed 31.2% to 44.3%, the grip test (right) showed 8.1% to 9.4%, the sit-up 17.8% to 32.6%, the shuttle run showed 5% to 25.6%, and the single-legged jump 11.9% to 23.9%.In addition, in the stepwise regression analysis, the order of variables representing physical strength and exercise cooperation was 10 times in body fat, 6 times in body fat, 4 times in height, 4 times in BMI, 3 times in chronological age, 2 times in weight, 2 times in abdominal fat, 1 time in bone age, and 1 time in body water. The variables that best represent physical strength and exercise cooperation were body fat percentage, lean, height, chronological age, weight, bone age, body fat mass, and body water, which were the most significant predictive variables (first) among a total of 23 regression equations, and were included 10 times, 5 times, 2 times, 1 time, 1 time, 1 time, and 1 time, respectively. In girls, the variables that best represent physical fitness and exercise coordination are body fat percentage and lean body mass, which were performed 10 times and 6 times, respectively

Table 2: Results of Multiple Regression Analysis (Stepwise Regression Analysis)in Physique

Group (Age)	Height	Weight	Fat Mass	Waist-Hip Ratio	Body Water	Fat-Free Mass	BMI	%fat
	R- Variables	R- Variables	R- Variables	R- Variables	R- Variables	R- Variables	R- Variables	R- Variables
Male								

11																
12	0.043	CA (0.208)									0.045	BA (-0.213)				
13	0.365	BA (0.512) CA (0.192)	0.159	BA (0.398)			0.056	BA (0.238)	0.354	BA (0.595)	0.351	BA (0.593)			0.038	CA (-0.194)
14	0.295	BA (0.544)							0.220	BA (0.469)	0.219	BA (0.468)			0.102	BA (-0.319)
Female																
11	0.435	BA (0.573) CA (0.307)	0.328	BA (0.573)	0.221	BA (0.470)	0.275	BA (0.525)	0.397	BA (0.568) CA (0.221)	0.395	BA (0.568) CA (0.216)	0.171	BA (0.413)	0.083	BA (0.287)
12	0.265	BA (0.515)	0.203	BA (0.451)	0.071	BA (0.267)	0.068	BA (0.262)	0.246	BA (0.496)	0.251	BA (0.501)	0.081	BA (0.285)		
13	0.185	BA (0.431)	0.228	BA (0.478)	0.140	BA (0.374)	0.187	BA (0.432)	0.252	BA (0.502)	0.252	BA (0.502)	0.158	BA (0.398)	0.086	BA (0.294)
								CA (0.312)								

Table 3:.Predictor sand The Order of Entered Predictors of Stepwise Regressions in Physique

Predictors§	The Order of Entered Predictors		Effectiveness		Total Number of Times
	1st	2nd	Positive	Negative	
Male					
Bone Age(BA)	10	0	8	2	10
Chronological Age(CA)	2	1	2	1	3
Female					
Bone Age(BA)	23	0	23	0	23
Chronological Age(CA)	1	3	4	0	4

Criterion of entered variable is probability of F to enter p< .05. There are 12 and 24 significant regression for the physique items in males and females, respectively.

Table 4-1: Results of Multiple Regression Analysis (Stepwise Regression Analysis) in Physical Fitness and Motor Coordination§

Group (Age)	Muscular Stength				Flexibility		Muscular Endurance		Cardiovascular Endurance		Motor Coordmation					
	Left Hand Grip Stength(kg)		Right Hand Grip Stength(kg)		Sit&Reach (cm)		Set-up (Reps)		Shuttle Run (Reps)		Plate Tapping (Sec)		Bass Stick Test (Sec)		Standing Long Jump (cm)	
	R	Variables	R	Variables	R	Variables	R	Variables	R	Variables	R	Variables	R	Variables	R	Variables
Male																
11	0.367	BW (0.536) W (-0.387) BMI (0.315) BA	0.303	BW (0.433) FM (-0.315 BMI (0.251)	0.195	WHR (-0.442)	0.103	WHR (-0.321)	0.480	%fat (-0.420) WHR (-0.259)	0.044	%fat (0.209)	0.109	W (-0.330)	0.265	%fat (-0.508) BW (0.032)

		(-0.249)												
12	0.618	BW (0.625) BW (0.625) H (-0.358) W (-0.238)	0.668	BW (0.317) H (-0.441) W (-0.258) FM (0.247)	0.113	%fat (-0.337) BMI (0.266)	0.189	%fat (-0.434)	0.039	CA (-0.199)	0.077	%fat (-0.278)	0.284	%fat (0.068) FFM (0.286) FM (-0.220)
13	0.446	BW (0.500) BA (0.204)	0.514	BW (0.443) BA (0.309) W (-0.255) H (-0.194)	0.125	%fat (-0.353)	0.296	FM (-0.544)					0.402	%fat (-0.590) BMI (0.385) CA (-0.192)
14	0.544	FFM (0.557) BA (0.408)	0.596	FFM (0.600) BA (0.443)	0.262	%fat (-0.512)	0.235	%fat (-0.485)			0.195	W (-0.442)	0.608	%fat (-0.772) FFM (0.399)

R2: Coefficient of Multiple Determination, BA: Bone Age, CA: Chronological Age, H: Height, W: Weight, FM: Fat Mass, WHR: Waist-Hip Ratio, BW: Body Water, FFM: Fat-Free Mass, ( ): Partial Correlation of the Independent Variables, §: Criterion of entered variable is probability of F to enter p< .05. There are significant regression for the physical fitness and motor coordination items in males, respectively

Table 4-2: Results of Multiple Regression Analysis (Stepwise Regression Analysis) in Physical Fitness and Motor Coordination

Group (Age)	Muscular Strength				Flexibility		Muscular Endurance		Cardiovascular Endurance		Motor Coordination					
	LeftHandGrip Strength(kg)		RightHandGrip Strength(kg)		Sit&Reach (cm)		Sit-Up (Reps)		ShuttleRun (Reps)		PlateTapping (Sec)		BassStickTest (Sec)		StandingLong Jump (cm)	
	R^2	Variables	R^2	Variables	R^2	Variables	R^2	Variables	R^2	Variables	R^2	Variables	R^2	Variables	R^2	Variables
Female																
11	0.361	FFM (0.601)	0.433	FFM (0.644) WHR (-0.288)			0.178	%fat (-0.385) BMI (0.233)	0.256	%fat (-0.506)			0.106	H (-0.325)	0.137	%fat (-0.370)
12	0.440	FFM (0.601)	0.389	BW (0.624)	0.081	BA 0.284			0.050	%fat (-0.223)					0.239	%fat (-0.446) FFM (0.284)
		FFM (0.656)		FFM (0.512)				%fat (-0.546)		FM (-0.481)				H (-0.322)		%fat (-0.459)

13	0.430		0.4	W				WHR						BMI
			01				0.326		0.231		0.103	0.212		
				(-0.235)				(0.466)						(0.384)
								H						
								(-0.365)						
		CA		W		CA		%fat		%fat				%fat
		(0.416)		0.418		(0.307)		(-0.515)		(-0.410)				(-0.345)
14	0.312	BMI	0.327	CA	0.094		0.305	BMI	0.168				0.1	
		(0.385)		0.366				(0.375)						
								H						
								(-0.361)						

R^2: Coefficient of Multiple Determination, BA: Bone Age, CA: Chronological Age, H: Height, W: Weight, FM: Fat Mass, WHR: Waist-Hip Ratio, BW: Body Water, FFM: Fat-Free Mass, ( ): Partial Correlation of the Independent Variables, §: Criterion of entered variable is probability of F to enter p< .05. There are significant regression for the physical fitness and motor coordination items in females, respectively.

Table 5: Predictors and The Order of Entered Predictors of Stepwise Regressions in Physical Fitness and Motor Coordination§

Predictors	The Order of Entered Predictors					Effectiveness		Total Number of Times
	1st	2nd	3rd	4th	5th	Positive	Negative	
Male								
Bone Age (BA)	0	4	0	1	0	4	1	5
Chronological (CA)	1	0	1	0	0	0	2	2
Height (H)	0	2	0	1	0	0	3	3
Weight (W)	2	1	3	0	0	0	6	6
Fat Mass (FM)	1	1	1	1	0	1	3	4
Waist-Hip Ratio (WHR)	3	1	0	0	0	0	4	4
Body Water (BW)	6	1	0	0	0	7	0	7
Fat-Free Mass (FFM)	2	2	0	0	0	4	0	4
BMI	0	2	2	0	0	4	0	4
%fat	11	0	0	0	0	2	9	11
Female								
Bone Age (BA)	1	0	0	0	0	1	0	1
Chronological (CA)	2	1	0	0	0	3	0	3
Height (H)	2	0	2	0	0	0	4	4
Weight (W)	1	1	0	0	0	1	1	2
Fat Mass (FM)	1	0	0	0	0	0	1	1
Waist-Hip Ratio (WHR)	0	2	0	0	0	1	1	2
Body Water (BW)	1	0	0	0	0	1	0	1
Fat-Free Mass (FFM)	5	1	0	0	0	6	0	6
BMI	0	4	0	0	0	4	0	4
%fat	10	0	0	0	0	0	10	10

Criterion of entered variable is probability of F to enter p< .05. §: There are 26 and 23 significant regression for the physical fitness and motor coordination items in males and females, respectively.

4. Discussion

4.1. Bone age and chronological age of men and women by age, and the relationship between age and physique

According to the results of multiple regression analysis in this study, bone age had a greater effect on physique variables than chronological age. Specifically, among the predictive variables included in the step-by-step regression analysis, bone age best represents the physique variables.Of a total of 12 and 24 regression equations, respectively, 10 and 23 were included as the most significant predictive variables (first), but out of a total of 12 and 24 regression equations, only 2 and 1 were included as the first and 3 were included as the second predictive variables. In other words, bone age is a factor that represents physical strength better than chronological age, and overall, girls showed higher explanatory power than boys. These results are similar to those reported collectively in previous studies Byun et al.(2014), Vieira F. et al.(2013), Freitas A. S. et al.(2014), Ko(2016), Koo et al.(2018), Kim et al.(2018), and support the results of this study. In particular, it suggests that bone age can reflect physique variables such as height, body water, and body fat well. On the other hand, in the case of body weight, body fat mass, abdominal fat percentage, BMI, and body fat percentage, bone age was found to be the main predictive variable only for boys at a specific age. For girls, bone age was found to be the main predictor of body fat percentage only at a specific age, and the explanatory power (R2) was also low.

These results are considered as follows when considering the results of this study and the results of previous studies. In the study of Byun et al.(2014), according to the level of bone maturity, there was a significant positive correlation in height and weight in the immature group, the normal group, and the precocious group. In a study by Kim et al. (2018), it is said that changes in bone age had a direct effect on changes in physique factors for both males and females in upper grades. In a study byKo et al.(2016), it was found that bone age and chronological age had an effect on the children's physique and physical performance in children who applied to the sports gifted program in grades 2-6 of elementary school. In this study, bone age was found to be a major predictor of body fat percentage only in certain grades for both males and females, and the explanatory power was around 20%. In the study of Ahn& Kim (2015), the effect of skeletal maturation in children on body composition and physical strength differs between men and women, which partially coincides with the results of this study. In the case of male physique factors in this study, bone age was not included as a major predictor of each physique factor. According to the results of Ahn and Kim (2015), the reason is that female students grow faster than male students due to the increase in bone age, so there may be differences in physique.

4.2. Effect of bone age, chronological age, and physique on physical fitness and exercise coordination of men and women by age

In this study, the effect of bone age, chronological age, and physique on physical fitness and exercise coordination of men and women by age was investigated. As a result, in the case of boys, a total of 26 regression equations were found in which bone age, chronological age, and physique from 11 to 14 years of age had a significant effect on physical fitness and exercise coordination. Body fat percentage and body water were measured 11 times and 6 times, respectively, as the first predictive variables, indicating that they represent the best. In addition, in the case of bone age and chronological age, bone age was measured as a predictor variable 5 times, and chronological age was measured 2 times. Through this, it can be seen that bone age better represents physical strength than chronological age in the same way as physique. In the case of girls, from 11 to 14 years old, a total of 23 regression equations were found in which bone age, chronological age, and physique had a significant effect on physical fitness and exercise coordination. As the first predictor variables, body fat percentage and fat-free were shown 10 times and 6 times, respectively. Also, in the case of bone age and chronological age, bone age was included as the first predictor once, whereas chronological age was measured twice in the first and once in the second. Through this, it can be seen that the chronological age represents the physical strength better than the bone age for girls. These results are partially consistent with previous studies. In the study of Lee(2012), there was no significant correlation between the rate of change of bone age and the rate of change of physical factors. However, the results of measurement of favorable physical factors according to the physical condition were reflected in the study. Song(2018) also found that among elementary school baseball players of the same age, players with earlier birth dates had an advantage in exercise performance. In the study of Ahn& Kim (2015), the premature male student group tended to have high muscle strength according to the increase in muscle strength factors due to high body weight, high lean body mass, and high BMI. Lee (2012) study on the correlation between physique and physical strength factors, height and weight showed a significant

correlation with the agility measures of male and female students. This study reported that height and weight had a significant correlation with exercise performance. In a study by Ko (2016), it was found that the lower the body fat percentage, the more advantageous it is to exercise coordination. Also, on the premise that they possess the same motor function, this study explains that children with low body fat percentage are more advantageous in exerting motor coordination than children with high body fat percentage. In addition, on the premise that they possess the same motor function, this study showed that children with low body fat percentage were more advantageous in exerting motor coordination compared to children with high body fat percentage. Lopes et al. (2012) suggested that motor coordination had an effect on BMI, which partially coincided with the results of this study. Conversely, Jones et al. (2000) reported that chronological age had an effect on motor performance. In addition, Freitas et al. (2015) and Luz et al. (2016) reported that bone age and motor coordination showed a negative correlation and had an effect on height and weight gain. The reason for these different results among previous studies is that bone age differs according to race, gender, and environment (Beunen et al., 1997; Cunha et al., 2014). As shown in Table 1, this result must have appeared because the average chronological age of the subjects of this study was higher than the bone age.

5. Conclusion

In this study, one sports-related private institution, one elementary school, and one middle school were selected in the metropolitan area, and based on the data of a total of 666 people, bone age, chronological age, and physique according to age (11-14 years old) and gender (male and female), The relationship between physical fitness and exercise coordination was investigated through stepwise regression analysis. The following conclusions were reached through this study. First, in the case of males and females between 11 and 14 years of age, bone age was found to be a more significant predictor than chronological age as a variable of physique. This means that bone age can better reflect physique variables than chronological age.

Second, in the case of male physical fitness, when the predictors were listed in order of significance, they were listed as body fat percentage, body water, abdominal fat percentage, weight and lean body mass, and age. Bone age did not appear as the most significant predictor, but bone age was measured 4 times as the second predictor and once as the third predictor. It was analyzed that bone age explained physical fitness better than chronological age, which was measured once as the most significant predictor and once as the third predictor. In the case of girls, when the significant predictors were listed in order, body fat percentage, lean body mass, height, chronological age, weight, bone age, body fat mass, and body water were found in the following order. This indicates that, in the case of the same age group, boys with a higher bone age may have better physical strength. In addition, in the case of girls, it can be seen that children with an earlier birth month have better physical strength than children with a large bone age. It can also be seen that the lower the body fat percentage, the better the physical strength for both men and women. In the case of physique, bone age was found to be a more significant predictor than chronological age in the results of this study. In the case of children of the same age, it can be said that the more biologically mature children, the more developed their physique. In the case of physical fitness and exercise coordination, body fat percentage was found to be a more significant predictor than chronological age or bone age. Through this, it can be said that it is advantageous to reduce the bodyfat percentage in order to alleviate the imbalance of the child's physique and physical strength.

A limitation of this study is that although the study subjects were 666 children, the number of samples for each age and gender was sampled disproportionately. In particular, it is somewhat difficult to generalize the results of this study because the 14-year-old group has a smaller number of people compared to other age groups. In addition, since the sampling area was limited to the metropolitan area, it is thought that there may be differences in reality depending on the area. Therefore, it is suggested that follow-up research needs to be conducted by evenly sampling a lot of data by age and gender by region.

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