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Fundamental movement skill proficiency and body composition measured by DXA in eight-year-old children

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Abstract

Objective: The main aim was to examine the association between fundamental movement skills (FMS) and objectively measured body composition using dual energy X-ray absorptiometry (DXA).

Methods: Study of 304 eight-year-old children in Finland. FMS were assessed with the Test of Gross Motor Development, 2nd ed. (TGMD-2). Total body fat percentage (BF%), abdominal region fat percentage (AF%), and fat-free mass (FFM) were assessed by DXA. Waist circumference, height and weight were measured and International Obesity Task Force (IOTF) cut-off values for BMI were used for the definition of healthy weight and overweight/obesity.

Results: Better FMS proficiency (object-control, locomotor, total FMS) was significantly and strongly associated with lower BF% and lower AF% measured with DXA.

Conclusions: The inverse association between FMS and body composition measured with DXA (BF% and AF%) is an important finding, as body fatness and specifically abdominal fatness are associated with less favourable cardiovascular risk factor status in children.

Keywords: Body composition, fundamental movement skills, DXA, motor skills, obesity, overweight

Introduction

With the increasing prevalence of overweight and obesity and inadequate levels of physical activity (PA) even in young children (Lobstein, Baur, & Uauy, 2004; Ness et al., 2007; de Onis, Blossner, & Borghi, 2010) there has recently been increased interest on potential links between motor development, PA behavior and obesity (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). It has been hypothesized that children with better fundamental movement skills (FMS) have higher levels of health-related fitness and perceived motor competence, which in turn predict greater participation in PA and, consequently, healthier weight status (Stodden et al., 2008).

FMS are an important part of human life and are interrelated with a child's physical, cognitive and social development (Payne & Isaacs, 2002). In addition, PA experiences support the learning and development of FMS, which ideally should occur in early childhood, during the preschool and elementary school years (Gabbard, 2000; Gallahue, Ozmun, & Goodway, 2011). FMS are classified as locomotor, object-control and stability skills, and are a prerequisite for the more advanced and specific skills used in PA and sport. Moreover, failure to master FMS may hinder the development of specialised movement skills and create a barrier to participation in PA.

The results of studies on the association between FMS and weight status in children are still inconsistent even if the recent review (Lubans et al., 2010), which examined the relationship between FMS competency and potential psychological, physiological and behavioural health benefits in children and adolescents, concluded that there was an inverse association between FMS competency and weight status. The authors reported an inverse association in six studies and no association in three of the nine studies found. However, in one study inverse association was found only in boys but not in girls (McKenzie et al., 2002), in another study inverse association was found in total and locomotor FMS but not in object control skills between overweight and healthy weight children (Southall, Okely, & Steele, 2004) and in one study (Erwin & Castelli 2008) authors did not report association between weight status and FMS competency, even if that study was included in the list of studies which reported an inverse association. In most of the studies examining weight status and FMS, weight status was estimated using BMI only, and in one study waist circumference

(WC) was used (Okely, Booth, & Chey, 2004). BMI and WC are proxy measures of adiposity and should not be considered accurate measures of body fat (Freedman & Perry, 2000) comparable with the measurement of body composition by more sophisticated methods such as dual energy x-ray absorptiometry (DXA). DXA can be used to evaluate childhood obesity and determine fat mass (Helba & Binkowitz, 2009), and has increasingly being used as a criterion or reference for comparison with other measurements of body composition (Shypailo, Butte, & Ellis, 2008). Due to the relatively small number of studies and the inconsistency of the results there is need for studies of the association between FMS and weight status in children that rely on accurate measures of body composition. To our knowledge, no previous studies have analyzed the association between FMS and body composition measured with DXA.

The purpose of this study was to examine the association between FMS and body composition measured with DXA in eight-year-old children. A further aim was to investigate whether children differ in their FMS by weight status estimated using WC and BMI.

Methods

A random sample (n=750) of children born in 1997 and living in Tampere, Finland was drawn from the Population Register. Children and their parents were mailed an invitation to participate to the study. The participants were recruited and participated between October 2005 and July 2006 when the children were approximately eight years old (mean 8.6 y, range 8.2-9.2 y). All children and their parents were informed about the purpose and nature of the study and the measurements. All the children were accompanied by their mothers and both gave their written informed consent upon arrival at the research site. The current sample consisted of 304 children (151 girls, 153 boys) for whom complete data on FMS performance, DXA, BMI and WC were available. The study was approved by the Ethics Committee of Pirkanmaa Hospital District.

Height was measured to the nearest 0.1 cm and weight was determined using a high-precision electronic scale (F 150S-D2, Sartorius AG, Goettingen, Germany) to the nearest 0.1 kg, and the results of the measurements were used to calculate BMI (kg/m2). Participants were then classified as healthy weight, overweight or obese, according to the International Obesity Task Force (IOTF) cut-off points for age and sex (Cole, Bellizzi, Flegal, & Dietz, 2000) recommended by the European Childhood Obesity Group (ECOG) (Rolland-Cachera, 2011). Height and weight were measured in light clothing and without shoes. WC was measured in triplicate by a measuring tape, midway between the lowest rib and the superior border of the iliac crest. The average of the three WC measurements was used in all analyses. The total body fat percentage (BF%), abdominal region fat percentage (AF%) and fat free mass (FFM) of the participants were assessed with DXA (GE Lunar Prodigy Advance, GE Lunar Radiation Corp., Madison, WI). In addition, abdominal region fat, which includes intra-abdominal fat plus subcutaneous fat, was evaluated from a manually delineated region of interest that included the soft tissue area of the body between the lowest ribs and superior border of the iliac crest.

The test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000) was used to assess fundamental movement skills. The TGMD-2 is a valid, reliable and process-oriented assessment of gross motor development and is used in FMS research on young children between 3 and 10 years. The TGMD-2 assesses two dimensions of gross motor performance: locomotor and object-control skills. In the present study, three locomotor skills (gallop, leap, horizontal jump) and two object-control skills (stationary dribble, overhand throw) were evaluated. The test was administered in pairs or individually following standardized procedures, instructions and demonstrations (Ulrich, 2000).

The children were given a standardized visual demonstration of the correct technique for performing the skill before each test, but were not told what components were being assessed. All the children were videotaped performing two trials of each task, and the presence or absence of the designated criteria of form were evaluated by the assessor who has experience in FMS assessment as a PE teacher (researcher SS). 25% of randomly selected children and all the unclear cases were later double-checked on the videotape by the same assessor. In this study, intra-observer reliability tests were conducted with 24 children and Intraclass Correlation (ICC) for locomotor skill was 0.978 and for object-control skill 0.995. A correct performance was scored 1 and incorrect performance was scored 0. Each of the two trials was scored independently. The sum of the scores for the two performances represents the final score for each item. The correctly performed criteria for two trials each of the three locomotor and the two object-control skills were summed to provide subtest raw scores for locomotor skills (range 0 – 24 / 12 skill criteria) and object control skills (range 0 – 16 / 8 skill criteria). The raw scores (locomotor, object-control) were used in the data analysis as this is recommended for research purposes (Ulrich, 2000). In order to transform the sub-test raw scores into comparable final scores both sub-test raw scores were standardized to a maximum score of 16. The sum of both sub-tests yielded the total fundamental movement skill score (total FMS, range 0-32).

Means and standard deviations were calculated for all variables. Prior to analysis, normality and equality of variances of the groups were assessed using Kolmogorov–Smirnov test (with Lilliefors' correction) and Levene test, respectively. A one-way ANOVA was used to examine the differences in participant characteristics across the FMS groups. When the ANOVA result was significant ($p < 0.05$), a Tukey’s post hoc comparison test was used to identify specific between-groups differences. When the variables were normally distributed, t-test and F-test were used. When the variables were shown to be non-normal, the Mann-Whitney U-test was used to test the difference between two groups, the Kruskal-Wallis test for differences between several groups and Spearman's rank-order correlation when assessing the associations between the variables. Exact p-values are reported for non-parametric statistics. Cohen's d was used as an indicator of the effect size (the values of Cohen's f were transformed to values of Cohen's d). The absolute value of the effect size is reported within the text; in the Tables, a negative value indicates that the higher value is subtracted from the lower value in the calculation procedure. Tukey's test was used in the post hoc analysis. Based on the test-performance, the children were assigned to three groups: low FMS (lowest third), moderate FMS (middle third) and high FMS (highest third). According to the IOTF cut-off points (Cole et al., 2000), children were classified as healthy weight, overweight or obese and then assigned to two categories, healthy weight or overweight/obese, for statistical analysis. All statistical analyses were undertaken using SPSS version 20.0 and the level of significance was set at $p = 0.05$.

Results

Of 304 children in the study, 80.9% were healthy weight (girls 81.4% and boys 80.4%) and 19.1% overweight/obese (girls 18.6% and boys 19.6%).

Descriptive statistics of the children by gender are shown in Table 1. In body composition, girls had a significantly bigger AF % ($p < 0.001$) and BF % ($p < 0.001$) than boys, although mean BMI was exactly the same. The effect sizes were medium or high (Cohen's d equals 0.59 and 0.66 respectively). When the FMS raw sub-test scores were examined by gender, boys were more proficient at object-control skills ($p < 0.001$, $d = 1.19$) and girls more proficient at locomotor skills ($p = 0.002$, $d = 0.36$). For total FMS, however, boys scored significantly higher ($p < 0.001$, $d = 0.70$).

--------------- Insert Table 1 about here ----------------

Descriptive statistics of the children by BMI group are shown in Table 2. In body composition, the overweight/obese children had significantly bigger AF % ($p < 0.001$, $d = 2.04$), BF % ($p < 0.001$, $d = 2.02$) and WC ($p < 0.001$, $d = 2.39$) than the healthy weight children. FMS proficiency was significantly lower among the overweight/obese children than healthy weight children in all the FMS categories: object-control skills ($p = 0.001$, $d = 0.49$), locomotor skills ($p < 0.001$, $d = 0.95$) and total FMS ($p < 0.001$, $d = 0.84$).

--------------- Insert Table 2 about here ----------------

The descriptive characteristics of boys and girls by low, moderate and high FMS groups are shown in Table 3. Among boys, BF % and AF % were statistically significantly higher in the low FMS group compared with the moderate and the high FMS groups. Also, the moderate FMS group differed significantly from the high FMS group. Among girls, BF % and AF % were statistically significantly higher in the low FMS group compared with the high FMS group. Among both genders, BMI, WC and weight were also higher in the low FMS group compared with high FMS group. There were no statistically significant differences in FFM or height between the FMS groups.

--------------- Insert Table 3 about here ----------------

The correlations between FMS and the different obesity variables in boys and girls are shown in Table 4. All the obesity variables (BF%, AF%, WC and BMI) were statistically significantly inversely correlated with FMS proficiency (object-control, locomotor and total FMS) among both genders. All the variables showed stronger correlations in boys than in girls. BF % was the strongest predictor of each of the FMS proficiency variables in boys. Among girls, object-control skills showed the strongest correlation with AF% and locomotor skills the strongest correlation with WC.

--------------- Insert Table 4 about here ----------------

Discussion

To our knowledge, this is the first study to examine the association between FMS proficiency and objectively measured body composition using DXA. The primary finding of the present study was that higher FMS proficiency was significantly and strongly associated with lower total body fatness and lower abdominal fatness measured with DXA in eight-year-old boys and girls. The inverse association between FMS and body composition measured with DXA (BF% and AF%) is an important finding, as body fatness and specifically abdominal fatness are associated with less favourable cardiovascular risk factor status in children (Daniels, Morrison, Sprecher, Khoury, & Kimball, 1999).

In addition, there were significant inverse correlations between all the FMS categories (object control, locomotor and total FMS) and the different weight status variables (BF%, AF%, WC and BMI) measured. These results are consistent and build on those of previous studies that have used only BMI or WC alone to estimate weight status (Lubans et al., 2010; Morano, Colella, & Caroli, 2011) indicating an inverse relationship between obesity and FMS proficiency. All the variables correlated more strongly in boys than in girls. BF % was the strongest predictor of each of the FMS proficiency variables in boys. Among girls, object-control skills showed the strongest correlation with AF% and locomotor skills the strongest correlation with WC.

Previous studies have suggested that differences in FMS proficiency between overweight/obese and healthy weight children are mostly due to differences in locomotor skills rather than object-control skills (Okely, Booth, & Chey, 2004; Southall, Okely, & Steele, 2004). For example, Southall et al., (2004) reported that while overweight children had significantly lower FMS proficiency, when FMS was partitioned into locomotor and object-control skills, the differences only existed for locomotor skills. Compared to these studies, FMS proficiency in our study was significantly lower among the overweight/obese children than healthy weight children in all the FMS categories: object-control skills, locomotor skills and total FMS, although the difference was more marked in locomotor skills and total FMS than in object control skills. These results agree with those of another European study (Morano et al., 2011) with younger children.

When FMS proficiency between the genders was examined, our findings are consistent with those of previous studies showing better locomotor skills among girls (Barnett, van Beurden, Morgan, Brooks, & Beard, 2008; Beurden, Zask, Barnett, & Dietrich, 2002; Hardy, King, Farrell, Macniven, & Howlett, 2010) and better object-control skills among boys (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Hardy et al., 2010). In our study, the high effect size found for object-control skills is noteworthy, boys were markedly better than girls. Biology does not fully explain gender differences in the FMS proficiency of eight-year-old children. Gender differences are more likely socially and environmentally induced (Garcia, 1994; Hardy et al., 2010; Thomas & French 1985) and it would be important to encourage girls to practise object-control skills like kicking, throwing and catching. In fact, previous longitudinal studies have shown that children who had better object-control skill proficiency were more likely to become active and fit adolescents (Barnett et al., 2008; Barnett, van Beurden, Morgan, Brooks, & Beard, 2009).

When boys and girls were divided into tertiles - low FMS (lowest third), moderate FMS (middle third) and high FMS (highest third) - according to their test performance, increased BF%, AF%, WC and BMI were all correlated with poorer FMS results. Among both boys and girls the trend was very clear: the higher the children's FMS proficiency, the lower their body composition values. In fact, the boys in the Low FMS group had 8.6 % points more BF and 11.3 % points more AF than the boys in the High FMS group. In both cases, the differences are notable; the effect sizes were high (d = 1.11 and d = 0.99). The corresponding differences in girls' groups were 4.1 % and 7.1 % points. The differences are moderate; effect sizes were of medium size (d = 0.58 and d = 0.64).

The main strengths of this study were that DXA was used to measure body composition, all the children were within a narrow age range and mastery of FMS was double-checked afterwards on the videotape by the assessor. A limitation of this cross-sectional research is that the direction of the relationship between body composition and FMS proficiency cannot be determined. No conclusion can be drawn whether obesity in early childhood leads to poorer FMS development or whether children will become obese because of their lower FMS level, both of which possibilities may act as a barrier to PA participation. As both causal hypotheses are possible, longitudinal research would be needed to gain a better understanding the nature of the relationships between FMS, PA and body composition.

Because FMS are prerequisites of PA, it is important to support FMS development in young children. The recent meta-analyses provide evidence for the effectiveness of motor skill interventions to improve FMS in children (Logan, Robinson, Wilson, & Lucas, 2011; Morgan et al., 2013), however there is limited knowledge of effective strategies to promote long-term PA participation among overweight and obese children (Cliff, Okely, Morgan, Jones, & Steele, 2010). In addition, one longitudinal study (D'Hondt et al., 2014) found that children's weight status negatively influenced future level of gross motor coordination, and vice versa but total PA at baseline was not significantly related to motor skill performance nor BMI. It has been suggested that the first eight years of life would be the best time to learn FMS (Gallahue et al., 2011).

However, the development of FMS does not happen by chance or maturation alone; children also need opportunity and guidance within a supportive learning atmosphere. Although children should be provided with opportunities to practise FMS during free play, evidence indicates that teacher-directed activities lead to greater improvements in children's FMS proficiency (Deli, Bakle, & Zachopoulou, 2006). Moreover children require quality instruction, not just exposure to equipment and practice opportunities to develop appropriate FMS proficiency (Wall, Rudisill, Parish, & Goodway, 2004). Especially overweight and obese children should be given the opportunity to practice the entire range of motor skills in a motivational and supportive atmosphere with quality teaching (Morgan, Okely, Cliff, Jones, & Baur, 2008).

Conclusion

Our findings suggest that FMS proficiency (object-control, locomotor, total FMS) is inversely associated with body composition measured with DXA (BF% and AF%) and weight status estimated using WC or BMI in eight-year-old boys and girls. Increased BF%, AF%, WC and BMI were all correlated with poorer FMS results. The inverse association between FMS and body composition measured with DXA (BF% and AF%) is an important finding, as body fatness and specifically abdominal fatness are associated with less favourable cardiovascular risk factor status in children. Lower FMS level may obstruct a child's participation in physical activities and, as a consequence, lead to greater risk for weight gain and future health risks. The findings of this study are important for kindergarten and primary school teachers, parents and health care personnel working with overweight and obese children and when planning obesity intervention programs.

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Jari Metsämuuronen (PhD, Adjunct Professor) is one of the leading methodological experts in Finland. He has popularized research methodology in 13 volumes of the Methodology series. The Handbook of Practical Qualitative Research (in Finnish) was published in 2006. His largest book, Basics of Research Methods in Human Sciences, will be published in English by SAGE Publication Inc. in 2015. He has served as an international consultant in Sri Lanka, Kenya, Ethiopia, Palestine and Nepal. From 1998 onwards he has been a senior methodologist in the student assessment unit on the Finnish National Board of Education.

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Table 1. Descriptive characteristics of the participants

Variable	All (n=304) Mean (SD)	Boys (n=153) Mean (SD)	Girls (n=151) Mean (SD)	*P*	Cohen's d
Age	8.6 (0.2)	8.6 (0.2)	8.6 (0.2)	0.634	0.05
BMI	17.1 (2.1)	17.1 (2.2)	17.1 (2.1)	0.971	0.00
AF (%)	23.3 (11.2)	20.2 (10.9)	26.5 (10.5)	<0.001	-0.59
BF (%)	21.6 (7.7)	19.2 (7.7)	24.0 (6.9)	<0.001	-0.66
WC (cm)	59.7 (6.2)	60.1 (6.2)	59.3 (6.1)	0.286	0.12
OC (range 0-16)	11.4 (3.8)	13.3 (3.3)	9.4 (3.3)	<0.001	1.19
LM (range 0-24)	15.8 (3.3)	15.2 (3.2)	16.4 (3.3)	0.002	-0.36
Total FMS (range 0-32)	21.9 (4.8)	23.5 (4.5)	20.3 (4.5)	<0.001	0.70

Abbreviations: AF: abdominal fat, BF: total body fat, BMI: body mass index, LM: locomotor skills raw score, OC: object control skills raw score, Total FMS: total fundamental movement skills score, WC: waist circumference

Table 2. Descriptive characteristics of the participants divided into BMI groups

Variables	Healthy weight (n=246) Mean (SD)	Overweight/Obese (n=58) Mean (SD)	*P*	Cohen's d
Age	8.6 (0.2)	8.6 (0.2)	0.26	-0.17
BMI	16.3 (1.2)	20.4 (2.0)	<0.001	-2.90
AF (%)	19.9 (8.8)	37.7 (8.7)	<0.001	-2.04
BF (%)	19.3 (6.2)	31.4 (5.4)	<0.001	-2.02
WC (cm)	57.6 (3.9)	68.3 (6.4)	<0.001	-2.39
OC	11.7 (3.7)	9.9 (3.9)	0.001	0.49
LM	16.3 (3.1)	13.4 (3.2)	<0.001	0.95
Total FMS	22.6 (4.5)	18.8 (4.8)	<0.001	0.84

Abbreviations: AF: abdominal fat, BF: total body fat, BMI: body mass index, LM: locomotor skills raw score (range 0-24), OC: object control skills raw score (range 0-16), Total FMS: total fundamental movement skills score (range 0-32), WC: waist circumference

Table 3. Descriptive characteristics of boys and girls divided into low, moderate and high FMS groups

	Variables	Low (n=28) Mean (SD)	Moderate(n=53) Mean (SD)	High (n=72) Mean (SD)	*P*	η^2	Cohen's d	Tukey
Boys	Age	8.7 (0.2)	8.6 (0.2)	8.6 (0.2)	0.187	0.022	0.37	ns
	BMI	18.2 (2.4)	17.2 (2.4)	16.6 (1.7)	0.003	0.073	0.69	13
	Height (cm)	135.1 (5.8)	135.9 (6.3)	133.6 (5.7)	0.112	0.029	0.42	ns
	Weight (kg)	33.3 (5.9)	31.9 (6.1)	29.7 (4.7)	0.007	0.065	0.65	13
	WC (cm)	63.2 (7.1)	60.4 (6.5)	58.6 (5.2)	0.003	0.074	0.69	13
	BF (%)	25.1 (8.4)	19.8 (7.7)	16.5 (5.9)	<0.001	0.17	1.11	12 13 23
	AF (%)	28.1 (11.9)	20.6 (11.5)	16.8 (8.3)	<0.001	0.141	0.99	12 13 23
	FFM (g)	23340.5 (2240.8)	23927.7 (3025.3)	2341.1 (2752.7)	0.52	0.009	0.23	ns
	OC (range 0-16)	8 (3.4)	13.3 (1.8)	15.4 (0.8)	<0.001			12 13 23
	LM (range 0-24)	11.7 (3.1)	14.1 (2.2)	17.3 (2.1)	<0.001			12 13 23
	Total FMS (range 0-32)	15.8 (3.6)	22.7 (1.2)	27.0 (1.6)	<0.001			12 13 23

	Variables	Low (n=73) Mean (SD)	Moderate(n=49) Mean (SD)	High (n=29) Mean (SD)	*P*	η^2	Cohen's d	Tukey
Girls	Age	8.6 (0.2)	8.6 (0.2)	8.6 (0.2)	0.513	0.009	0.23	ns
	BMI	17.6 (2.6)	16.8 (1.6)	16.3 (1.1)	0.014	0.056	0.60	13
	Height (cm)	134.1 (6.4)	134.3 (4.5)	132.0 (5.3)	0.186	0.023	0.38	ns
	Weight (kg)	31.8 (6.7)	30.4 (4.1)	28.5 (3.5)	0.024	0.049	0.56	13
	WC (cm)	60.6 (7.3)	58.9 (4.6)	56.6 (3.5)	0.01	0.061	0.62	13
	BF (%)	25.4 (7.7)	23.5 (6.0)	21.3 (5.2)	0.018	0.053	0.58	13
	AF (%)	28.9 (11.4)	25.9 (9.8)	21.8 (7.6)	0.007	0.064	0.64	13
	FFM (g)	22123.9 (2940.1)	21880.0 (2044.0)	21081.3 (2090.4)	0.173	0.023	0.38	ns
	OC (range 0-16)	7.0 (2.6)	10.7 (1.6)	13.4 (1.7)	<0.001			12 13 23
	LM (range 0-24)	14.5 (2.7)	17.1 (2.2)	19.9 (2.7)	<0.001			12 13 23
	Total FMS (range 0-32)	16.6 (2.7)	22.1 (1.1)	26.7 (2.1)	<0.001			12 13 23

Abbreviations: AF: abdominal fat, BF: total body fat, BMI: body mass index, FFM: fat free mass, LM: locomotor skills raw score, OC: object-control skills raw score, 1: Low, 2: Moderate, 3: High, Total FMS: total fundamental skills score, WC: waist circumference,

Table 4. Spearman's correlations between FMS and different obesity variables in boys and girls

Boys

Variables	OC	*P*	LM	*P*	Total FMS	*P*
BMI	-.194	0.017	-.316	<0.001	-.287	<0.001
WC	-.200	0.013	-.343	<0.001	-.308	<0.001
BF %	-.304	<0.001	-.383	<0.001	-.408	<0.001
AF %	-.262	0.001	-.352	<0.001	-.362	<0.001

Girls

Variables	OC	P	LM	P	Total FMS	P
BMI	-.157	0.054	-.292	<0.001	-.259	<0.001
WC	-.158	0.054	-.332	<0.001	-.276	<0.001
BF %	-.173	0.034	-.318	<0.001	-.276	<0.001
AF %	-.176	0.031	-.312	<0.001	-.276	<0.001

Abbreviations: AF: abdominal fat, BF: total body fat, BMI: body mass index, LM: locomotor skills score, OC: object control skills score, Total FMS: total fundamental movement skills score, WC: waist circumference,