Body Composition Index Predict Children's Motor Skills Proficiency

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***Abstract*—**Failure in mastery of motor skills proficiency during childhood has been seen as a detrimental factor for children to be physically active. Lack of motor skills proficiency tends to reduce children's competency and confidence level to participate in physical activity. As a consequence of less participation in physical activity, children will turn to be overweight and obese. It has been suggested that children who master motor skill proficiency will be more involved in physical activity thus preventing them from being overweight. Obesity has become a serious childhood health issues worldwide. Previous studies have found that children who were overweight and obese were generally less active however these studies focused on one gender. This study aims to compare motor skill proficiency of underweight, normal-weight, overweight and obese young boys as well as to determine the relationship between motor skills proficiency and body composition. 112 boys aged between 8 to 10 years old participated in this study. Participants were assigned to four groups; underweight, normal-weight, overweight and obese using BMI-age percentile chart for children. Bruininks-Oseretsky Test Second Edition-Short Form was administered to assess their motor skill proficiency. Meanwhile, body composition was determined by the skinfold thickness measurement. Result indicated that underweight and normal children were superior in motor skills proficiency compared to overweight and obese children ($p < 0.05$). A significant strong inverse correlation between motor skills proficiency and body composition ($r = -0.849$) is noted. The findings of this study could be explained by non-contributory mass that carried by overweight and obese children leads to biomechanical movement inefficiency which will become detrimental to motor skills proficiency. It can be concluded that motor skills proficiency is inversely correlated with body composition.

***Keywords*—**Motor skills proficiency, body composition, obesity.

I. Introduction

THE development of motor skill proficiency during childhood is very important as it leads to better quality of daily life and sports activities [1]. Given that motor skills proficiency serves as a foundation of more complex and specific motor skills [2], [3]. Previous research [4] proposed that motor skills proficiency influence the amount of children's physical activity engagement. Mastery of motor skills leads to improved proficiencies in complex skills, which in turn enhances participation of children in physical activities. Motor skills proficiency acts as a potential central of self-esteem for children to be physically active [5] as it allows interaction and exploration of the environment [6]. This view was supported by previous studies [5], [7] where children with a high level of motor skill proficiency tend to be more physically active as compared to children with less well-developed motor skills. This is because mastery in motor skills enhances self-esteem to actively engage in physical activities. In addition, failure in developing and refining motor skill during childhood often results in frustration [8] and may prove to be a barrier to receive adequate amount of physical activities [1], have lower level of health –related fitness and higher level of adiposity. Due to that mastery of motor skills at early ages has been seen as a potential important contributor towards successful and satisfying participation in future physical activities [6].

Sedentary lifestyle around the world has resulted in the increment of the incidence of obesity among children [9], [10]. Centers for Disease Control and Prevention of United States [CDC], [11] reported that this globally health problem has increased since several years before in the United States, Europe, Latin America and Southeast Asia. In Malaysia, a study conducted on children from four Peninsular Malaysia regions, reported a prevalence of 6% obesity among 6 to 12 year-old children [12]. Alarmed with the dramatically spread of obesity cases among children, researchers feel the need to understand the actual causes of becoming overweight and obese in order to prevent children from experiencing the detrimental impact in the future. Apart from a genetic predisposition and poor diet, a positive energy balance is the primary cause leading to childhood obesity [13]. Traditionally, previous researchers [14], [15] viewed physical activities as the main variable which affects body composition. Based on previous evidence, low energy expenditure is a consequence of less participation in physical activities and is a major contributor to obesity [2].

It can be related here that motor skills proficiency is associated with obesity, which is mediated by physical activity engagement. Excessive body weight is believed to affect the outcome of physical performance [16], [17]. Due to above reason, it has been suggested that excessive body weight may impair motor skills proficiency, which in turn may nurture inactivity, thus increases the risk of obesity and poor health later in life. Research findings to date relating to motor skill proficiency and body composition are, however, mixed and inconsistent [3], [8], [16]. As physical activity is recognized for its benefits in the maintenance and promotion of physical health [4], documentation of the existence of association between motor skills proficiency and body composition could be significant to counteract the trends toward increasing obesity in children. Extend knowledge in this area could lead towards a more precise intervention and development of

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effective programs. Therefore, this study was aimed to discover the impact of body composition on motor skill proficiency through different weight category of children (underweight, normal-weight, overweight and obese). As the relationship between motor skills proficiency and body composition still remains unclear and limited, this study was conducted to produce a clearer picture regarding motor skills proficiency and body composition in an attempt to expand the knowledge towards combating the prevalence of obesity.

II. Methodology

A. Participants

In response to children's parents or guardians' permission, 112 boys aged between 8 to 10 years old from Shah Alam, Malaysia participated in this study. Participants recruited were in healthy condition with BMI for age value ≤ 97^{th} percentile. Children with chronic disease (asthma, diabetes, any type of heart disease and cancer), musculoskeletal disease or injury, physical disabilities (visual impairment, mobility impairment), learning disabilities (attention deficit hyperactive disorder, dyspraxia) and taking any type of medication were excluded as it could lead to motor skill proficiency impairments. Baseline inclusion and exclusion criteria information were obtained from school records, teachers and parents. Prior to data collection, informed consent was signed by parents. Prior to acceptance into the testing and measurements protocols, participants were assigned into four groups (underweight = 28, normal = 28, overweight = 28 and obese = 28) based on their BMI-age-percentile. However, participants were free to withdraw at any time during this study without any prejudice. The study was approved by the Research and Ethic Committee of Universiti Teknologi MARA (UiTM), Malaysia and Ministry of Education, Malaysia.

B. Anthropometric Assessment

Participants' height were measured in centimeter (cm) using a portable stadiometer (Seca 206, Wall Mounted Tape Measure; Seca Corporation Weighing and Measuring System, Hamburg, Germany). Participants were required to remove their shoes and stand up straight under the portable stadiometer. Reading was recorded to the nearest 0.1cm. Weight was measured in kilogram (kg) using a digital floor scale (Seca 803, Digital Flat Floor Scale; Seca Corporation Weighing and Measuring System, Hamburg, Germany). During the measurement, participants wore light clothing. Upon completion of height and weight measurement, body mass index (BMI) was calculated manually using the kg/m^2 formula. Body mass index score were then translated into BMI-age-percentiles by gender based on the growth charts provided by Centers for Disease Control and Prevention (CDC). In this study, BMI-age-percentiles were only used as the categorical variables to assign the children into underweight, normal, overweight and obese group. Children with a BMI < 5^{th} percentile were classified as underweight, ≥ 5^{th} to < 85^{th} percentile as normal, ≥ 85^{th} to < 95^{th} percentile as overweight, and ≥ 95^{th} to 97^{th} percentile as obese.

C. Body Composition

The context of body composition of this study was represented by body fat percentage. Body fat percentages of each participant were measured by taking triceps and calf skinfold thickness as it is a standard index of body fat in youth. The measurement was taken on the right side of the body through used of Harpenden calipers. The same investigator, trained in skinfold measurement, measured each site twice and recorded it to the nearest 0.1mm. The final value was derived from average from two trials. Body fat percentage of each participant was calculated using the following specific gender equation [18];

$$\text{Boys fat \%} = 0.735\ (\text{triceps} + \text{calf}) + 1.0$$

D. Motor Skills Proficiency

The short form section of Bruininks-Oseretsky Test Second Edition (BOT-2) was administered to each participant individually to evaluate the participant's motor skills proficiency. The BOT-2 is an individually administered test that uses engaging, goal directed activities to measure a wide array of motor skills in individuals aged 4 through 21. It was designed to provide a reliable and efficient measure of fine and gross motor control skills. The BOT-2 short form includes 14 individual assessment protocol items that discover four motor-area composites; fine manual control, manual coordination, body coordination and strength and agility.

A total of 14 items were used to asses both fine and gross motor skills. Six out of the 14 items were for fine motor skills: drawing line through path-crooked, folding paper, copying a square, copying a star, transferring pennies and tapping feet and fingers-same side synchronized while the remaining items were gross motor skills (jumping in a place-same sides synchronized, walking forward in a line, standing one leg on a balance beam-eyes open, one-legged stationary hop, dropping and catching a ball-both hands, dribbling a ball-alternating hands, knee push-ups and sit-ups.). The BOT-2 quantifies motor skills on the basis of the results of goal-directed activities. The result may be drawing, a number of objects or events, or a length of time. Raw score for each data was converted into point score based on the scale provided by manual of BOT-2 ranging from 0 to 9. Maximum total point score of short form is 88. The assessment was conducted in the same order for all the participants. In order to ensure consistency in results, the tests were conducted by the same examiner. All the 14 examiners were trained to administer the motor skill tests.

Prior to the data collection, participants were familiarized with the testing procedures and allowed practice trials. Demonstration was also performed by the examiner during the assessment and verbal cues were implemented to reinforce correct technique throughout the test. Motor skills items were arranged into stations, to enable participants to cycle through each station in a specified order. The assessment was conducted outdoors within the school compound during schooling time.

E. Statistical Analysis

Descriptive and inferential statistics were utilized and values are presented as mean and standard deviation (M ± SD). Prior to the analyses normality of the data were determined by Kolmogrov-Smirnov test. Significant value was set at $p < 0.05$. One – way analysis of variance (One-way ANOVA) was used to compare the differences in overall motor skill proficiency between all four groups. This statistical tool was also performed to determine differences in each of the motor skills involved. Pearson Product Moment Coefficient of Correlation was used to examine the association between motor skills proficiency and body composition. All the data were analysed using the Statistical Package for Social Science version 17.0. The criterion for significance of all analyses was set at an alpha level of $p < 0.05$.

III. Results

A. Overall Motor Skills Proficiency

Overall motor skills proficiency for all the samples is illustrated in Fig. 1. The result of One-way ANOVA revealed that there was a significant difference in overall motor skills proficiency between underweight, normal-weight, overweight and obese children. This shows that the most superior group in overall motor skills proficiency was the normal-weight children, followed by underweight and overweight group. The worst performance in motor skills proficiency was recorded by the obese group. It can be seen that the worst performance was accompanied by higher fat percentage.

B. Fine Motor Skills Proficiency

Further analysis on fine motor skills items showed that there were no significant differences between underweight, normal-weight, overweight and obese groups as $p > 0.05$. However, results showed that one out of six fine motor skills items, the transferring of pennies did showed a significant difference between the 4 groups ($p < 0.05$). Based on the analysis the differences occurred between underweight ($M = 7 \pm 1.05$) and normal ($M = 7.64 \pm 1.12$) with overweight ($M = 4.85 \pm 0.75$) and obese ($M = 4.57 \pm 1.10$) group as presented in Fig. 2.

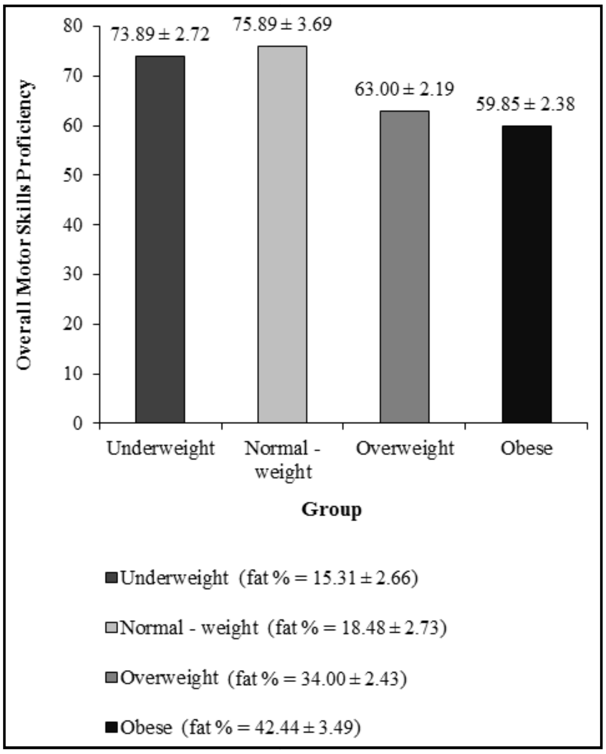

Fig. 1 Comparison of overall motor skills proficiency between groups Values are presented as mean ± SD

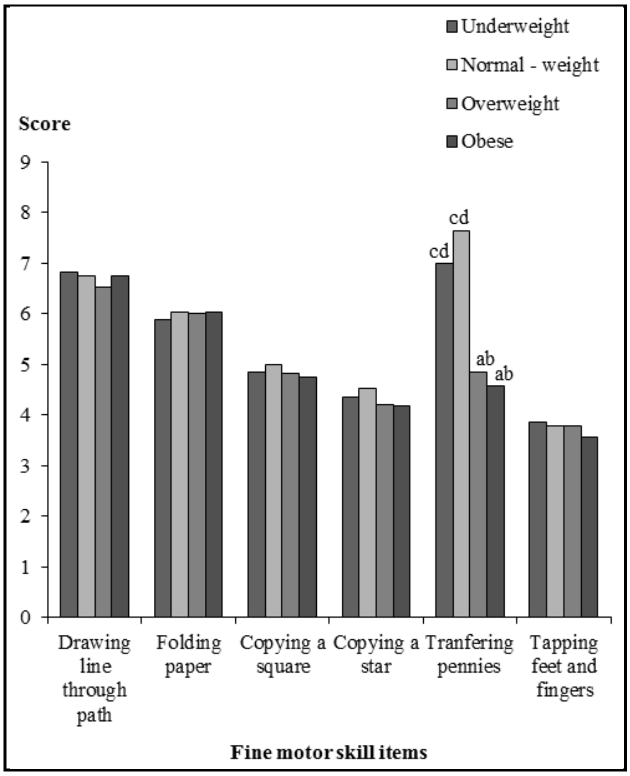

Fig. 2 Comparison of fine motor skills proficiency between groups [a] = significantly different with underweight [b] = significantly different with normal [c] = significantly different with overweight [d] = significantly different with obese

C. Gross Motor Skills Proficiency

In contrast, significant differences ($p < 0.05$) were noticed in all gross motor skill items across the groups; jumping in place-same sides synchronized $F(3, 108) = 16.53$, $p > 0.05$, tapping feet and fingers-same side synchronized walking forward on line ($F(3, 108) = 10.20$, $p > 0.05$), standing on one leg on a balance beam-eyes open ($F(3, 108) = 30.95$, $p > 0.05$), one-legged stationary hop ($F(3, 108) = 35.68$, $p > 0.05$), dropping and catching a ball-both hands ($F(3, 108) = 35.33$, $p > 0.05$), dribbling a ball-alternating hands, ($F(3, 108) = 15.32$, $p > 0.05$) knee push-ups ($F(3, 108) = 49.15$, $p > 0.05$) and sit-ups ($F(3, 108) = 41.84$, $p > 0.05$). The trend of the result demonstrated that major differences existed between the obese group to the other three groups (underweight, normal and overweight). As illustrated in Table I, obese children showed the worst score in each gross motor skill items as compared to the normal peers. Sharing a similar trend, the overweight groups is also behind the normal peers in most of the gross motor skills items except for jumping in place same side synchronized. No significant difference obtained between underweight and normal-weight group in all the items. Summary of the result is presented in Table I.

TABLE I
COMPARISON OF GROSS MOTOR SKILLS PROFICIENCY

Gross Motor Skill Items	Under-weight	Normal-weight	Over-weight	Obese
Jumping in place-same sides synchronized	2.85 $\pm$ 0.35^{d}	2.89 $\pm$ 0.31^{d}	2.82 $\pm$ 0.50^{d}	2.035 $\pm$ 0.79^{abc}
Walking forward on a line	3.57 $\pm$ 0.63^{cd}	3.64 $\pm$ 0.48^{cd}	2.89 $\pm$ 0.73^{ab}	2.89 $\pm$ 0.83^{ab}
Standing on one leg on a balance beam-eyes open	3.82 $\pm$ 0.39^{cd}	3.78 $\pm$ 0.41^{cd}	2.89 $\pm$ 0.73^{abd}	2.35 $\pm$ 0.98^{abc}
One-legged stationary hop	7.42 $\pm$ 1.06^{cd}	7.57 $\pm$ 0.92^{cd}	6.21 $\pm$ 0.87^{abd}	5.39 $\pm$ 0.78^{abc}
Dropping and catching a ball-both hands	4.67 $\pm$ 0.61^{cd}	4.64 $\pm$ 0.48^{cd}	3.25 $\pm$ 0.36^{ab}	3.60 $\pm$ 0.83^{ab}
Dribbling a ball-alternating hand	5.96 $\pm$ 0.83^{cd}	6.07 $\pm$ 0.81^{cd}	5.14 $\pm$ 0.89^{ab}	4.82 $\pm$ 0.77^{ab}
Knee push-ups	6.26 $\pm$ 0.79^{cd}	6.67 $\pm$ 0.81^{cd}	4.89$\pm$ 0.83^{ab}	4.28 $\pm$ 0.93^{ab}
Sit-ups	6.53 $\pm$ 0.79^{cd}	6.85 $\pm$ 0.89^{cd}	5.07 $\pm$ 0.76^{abd}	4.60 $\pm$ 1.10^{abc}

^{a} = significantly different with underweight
^{b} = significantly different with normal
^{c} = significantly different with overweight
^{d} = significantly different with obese

D. Association between Motor Skills Proficiency and B. C.

In order to determine the relationship between motor skill proficiency and body composition among children aged 8 to 10 years old, Pearson Product Moment Correlation was conducted and the result is presented in Table II. Results indicated a significant inverse correlation between motor skill proficiency and body composition with $r = -0.849$ at $p < 0.05$. Based on the result, increase in body composition leads to decrease of motor skill proficiency.

TABLE II
RELATIONSHIP BETWEEN MOTOR SKILLS PROFICIENCY AND .C.

Variables	N	Correlation	Sig. (2-tailed)
Motor Skills Proficiency and Body Composition	112	- 0.849	0.00

IV. DISCUSSION

This study supports the small but growing body of evidence that points to an important relationship between motor skill proficiency and body composition. The purpose of this study was to compare motor skills proficiency between groups (underweight, normal, overweight and obese) and to examine the possible relationship between motor skill proficiency and body composition. As postulated, the present study found there exists differences in the motor skills proficiency between underweight, normal-weight, overweight and obese children. The present study clearly showed that the worst result for motor skill proficiency was recorded amongst overweight and obese children compare to the others peers. Normal weight children demonstrated the most superior in overall motor skill proficiency followed by underweight, overweight and obese. The results of the current study is in line with other previous studies [19] which reported that preschool children classified as overweight or obese may have lower motor skills proficiency than their normal weight and underweight peers. Rationally, this study suggests that differences in motor skills scores among the children may be due to the anatomic and physiological differences that already existed in that particular group. Clark [20] previously stated that if we change any one of the factor that influence motor skill proficiency the emergent movement may change. As mentioned by Magill [21], one of the factors that influence the performance of motor skills was physical characteristics, thus, changes in physical characteristics influence the motor skills proficiency.

Further analysis conducted found that the differences in motor skill proficiency between groups were most obvious in gross motor skills. In this study, all the fine motor skills items did not showed any significant differences between groups except for in transferring pennies. The failure to obtain significant differences of the five tasks in this study is consistent with previous research investigated on fine motor skills [22] which pointed out that it was because of the nature of the tasks itself which does not directly rely on body weight. The fine motor skill task was highly demanded on the precision of accomplishing the tasks [23] and does not involve body movement against gravity [24]. Therefore, excessive body weight does not lead towards disadvantages among overweight and obese children in those tasks. Unexpectedly, transferring pennies did show a significant difference. This is consistent with previous finding [17] that reported overweight and obese children were poor in peg placing tasks as compared to normal children. This finding could be caused by the mechanical demands connected to the movement of the-heavier-arm itself to place the pennies properly into the box [17] as time and accuracy [25] play an important role in this task.

The present study revealed that normal children outperformed overweight and obese children in all gross motor skills tasks (jump in place-same sides synchronized, walking forward on a line, standing on one leg on a balance beam-eyes open, dropping and catching a ball-both hands, dribbling a ball-alternating hands, one-legged stationary hop, knee push-ups and sit-ups). The plausible explanation of the significant findings of poor performances among overweight and obese children in the remaining tasks is because of the greater overall movement requirement [26] during the action of the tasks. To simplify, the involvement of body weight directly on the tasks causes difficulties among overweight and obese children to perform successfully especially on time dependent tasks (knee push-ups and sit-ups) that required them to move excess weight quickly. A previous study state that skeletal structure is affected by adiposity in terms of structures and alignments [27], especially on lower extremities where it increases joint, bone and soft tissue stress [28], [29]. This mechanism explains the low scores by overweight and obese children in tasks that challenge the lower body extremities (jumping in place-same sides synchronized, walking forward on a line and standing on one leg on a balance beam-eyes open) because impairments in skeletal structures lead to abnormal mechanics of body segments [27], [29]. As a consequence of the inhibition on normal patterns of body mechanics, overweight and obese children motor skills performances is restricted.

Low bone mass and reduced bone strength is associated with musculoskeletal impairments that are caused by excessive body weight. Study by Goudling, Jones, Taylor, Piggot, and Taylor [30] confirms that obese children have low bone mass relative to bone size and body weight. This study points out that consequences arising from musculoskeletal impairment which occurs in overweight and obese children cause disruption of muscular strength and postural balance [27]. A reduction in muscular strength and postural balance might be reflected in the decrease of motor skill proficiency. A study [31] notes that disruptions on balance become higher when performed at different and novel situations and this might lead to impaired performances. Additionally, the requirement of joint torque to stabilize the body causes a greater postural sway.

Findings obtained from the present study regarding the worst performance of gross motor skills (such as standing on one leg on a balance beam-eyes open and one leg stationary hop tasks) on overweight and obese children is supported by previous studies. The increase in body weight results in a decrease of balance stability [32] which is caused by insufficient muscular functions [6]. Instability is a result of greater inertial properties of adipose tissue [27]. Poor performances in both ball manipulation tasks (dribbling ball-alternating hands, dropping and catching a ball-both hands) are supported by [33] who state that success in ball manipulation is accompanied by the ability to control postural balance while moving the arm. Hence, this study proves that overweight and obesity imposed constraints on balance control lead to the low proficiency of motor skills that require balance and postural stability while being performed (jumping in place-same sides synchronized, walking forward on a line, standing on one leg on a balance beam-eyes open and one-legged stationary hop).

The instability and loss of balance in obese children are caused by gait alteration. Obese children tend to tilt the upper body anteriorly while walking, have greater vertical displacement of the center of the mass and have a large degree of toe out [29]. This explanation describes the findings of poor performances by overweight and obese children in walking forward on a line tasks. Flatter foot structures of obese children play an important role in explaining current findings [34], [35]. Children's foot structures are affected by excessive body weight by which obese children have broader, higher and thicker features of calves, ankle, feet and toes [36], [37]. Foot structures that differ from normal children lead to greater strains on soft tissues [38] which decrease the ability to absorb [28] and dissipate force associated with dynamic weight support tasks [34]. Pressure magnitude and duration affect foot movements [35]. A study on 12-14 years old children from both obese and non-obese demonstrated that noncontributory mass that is supported by overweight and obese children may contribute to biomechanical inefficiency of movements as well as stability [39].

Corresponding to the previous study [26], [40], the present study also found that overweight and obese children perform poorly in tasks that involve movements against gravity (sit-ups, knee push- ups, one leg stationary hop and jumping in a place). According to [41], the lower extremities muscle is vital in supporting and moving additional fat mass. However, an additional body mass reduces muscle conditioning which in turn decreases the muscle strength [27]. In order to perform successfully in motor skills, muscular strength is required for most of the gross motor performances. Lack of muscular strength among overweight and obese children leads to worse performance when strength is an essential requirement in the task reiterates that the increase in body mass results in the decrease of arm strength which is important for knee push-ups task [42]. Additionally, a high demand of energy cost required by overweight and obese children to lift a greater body mass [43] supports the findings.

In terms of the existence of relationship between the motor skills proficiency and body composition, this study is in line with previous studies that examined the relationship between excessive adiposity in children and fundamental motor skills performances [8], [44], [45]. Results obtained from this study indicate that a significant decline occurs in motor skill scores as body fat percentage increase. As mentioned earlier, physical characteristics of performer [21] are one of the factors that influence the outcome of motor skill performances. Due to this fact, as the body composition is a part of physical characteristics, it indirectly gives an impact on the motor skill outcomes. In addition, previous studies verified that physical fitness of children is affected by growth and body composition [46].

Generally, body weight and excess fat have been demonstrated to restrict motor developments [47] and negatively affect physical performance [48]. The motor skills proficiency that has been measured in this study is highly demanded on a variety of body geometry and body segments such as balance, coordination and reaction. Apart from that, in order to succeed in most of the skills, it requires the strength of upper and lower extremities. In other words, a lack in those requirements of each skill might negatively reflect on the performances of the motor skills. The existence of correlation between the motor skills proficiency and body composition could be briefly explained through physiological and mechanical perspectives. From the view of physiological aspects, adiposity affects the ontogenic development of the musculoskeletal system [27]. It is found that children with high adiposity are associated with low bone mass and reduced bone strength. Meanwhile, the mechanical point of view found that excessive body weight affects body posture [17] and body geometry as well as increases the mass of different body segments [26]. Both perspectives might explain the findings of this study as noncontributory mass could result in the less efficient biomechanical movement involved in motor skills and consequently become detrimental for the motor skill proficiency.

In summary, this study suggests that the loss of motor skills proficiency among overweight and obese children is due to the difficulties of carrying excessive body weight. The negative impact of the excessive body weight hampers children's postural balance and muscle strength. It becomes a barrier when performing the tasks as it involves a shift of the center of gravity. Here, it can be stated that overweight and obese children are lower than their underweight and normal peers in the gross motor skills proficiency.

V. Conclusion

Overall findings showed that normal children are more superior in motor skills compared to other peers. Results indicated that normal children have better dexterity, more efficient in bilateral coordination, greater balancing, quicker reaction, more efficient upper-limb coordination and greater strength when compared to overweight and obese children. However, for skills those disregard adiposity, tend to have similar proficiencies among the children. The present cross sectional study did not lead towards determination of cause and effect. It is possible that poor motor skill proficiency is due to lack of physical activity involvement and lead towards obesity. It is equally possible that excessive body weight hamper motor skills proficiency resulting with less physical activity. Future longitudinal studies are needed to determine the nature impact of motor skills proficiency on children health status to enable children to successfully engaged in physical activities during adolescence.

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