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Review Article

Motor Fitness in Children: A Brief Update

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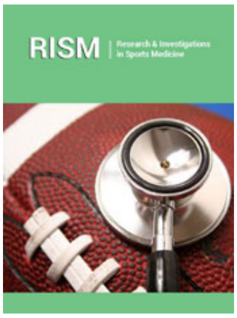

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Abstract

Motor fitness is considered as an integral component of skill related fitness that includes aspects of neuromuscular fitness such as agility, coordination, balance, power, speed and reaction time that enables a person to perform a specific skill, activity or game successfully. This brief review focuses on studies concerning motor fitness in children. In case of children, attainment of motor competency is dictated by various factors that are crucial in both sustaining as well as honing their motor skills. Biological maturity, physical fitness and body composition in children are some of the factors that are vital in attainment of motor proficiency. Advancement of age and healthy weight gain status in children, both have been identified as crucial aspects conducive to motor skill development which in children has been found to have dual benefits as it also facilitates performance of higher order cognitive tasks. Therefore, changes in policy level interventions should emphasize on holistic development of children with special attention given to regular participation in physical activities apart from educational excellence through age specific training design. Optimal levels of motor proficiency may be attained if interventions are given early before the attainment of puberty and continued till adulthood.

Keywords: Motor fitness; Children; Physical activity; Biological maturity; Body composition; Health

Abbreviations: VJT: Vertical Jump Test; BMI: Body Mass Index; W/H: Waist, Hip Ratio; PA: Physical Activity; MABC 2: Movement Assessment Battery for Children 2nd edition; MPA: Moderate Physical Activity; MVPA: Moderate-to-Vigorous Physical Activity; UK: United Kingdom; CSPAP: Comprehensive School Physical Activity Programme; US: United States; SES: Socio Economic Status

Introduction

According to the definition motor ability refers to "the acquired and innate ability to perform motor skills of generalized and fundamental nature exclusive of highly specialized sports or gymnastic techniques" [1].It is a vital aspect as far as physical fitness and motor fitness parameters encompassing speed, strength, power, balance, coordination, endurance and flexibility are concerned. It aids in optimizing the performance of a skill at the rate of success, precision and reducing the energy consumption desirable for that performance [2]. Agility, flexibility and Vertical Jump Test (VJT) score are some of the parameters that are important contributors to the measurement of motor fitness in the studied population of both athletes and non-athletes [3-9]. An individual's level of performance in a wide range of activities is determined through both general and specific motor skills. Success in sports for an athlete requires involvement of both motor fitness as well as reaction time [10].

This present review article has been aimed to focus on the studies that have been conducted in the recent past on motor fitness in children, in relation with various compounding factors, such as physical fitness, maturity, body composition and certain social factors that are vital to attain desired levels of motor fitness.

Children and motor fitness

According to the 1989 United Nations Convention on the Rights of the Child, a child is defined as an individual who has not attained the age of 18 years [11]. As per convention, motor fitness also termed as skill-related fitness encompasses the neuromuscular components of fitness, that enable an individual to perform successfully at a specific motor skill, game, or activity. Specific motor fitness components comprise of agility, balance, coordination, power, reaction time, and speed [12].

Physical fitness Vs motor fitness

In case of children, physical fitness refers to the child's continually enhancing ability to function and operate within the ambit of the environment in accordance with his or her level of physical and motor fitness. Physical abilities in children are influenced by a plethora of health as well as performance related factors that in turn renders an impact on the child's ability to move. Therefore, physical development is segregated into physical fitness and motor fitness, although these terms are elusive and often used interchangeably. On one hand, physical fitness is generally considered to be the ability to perform an individual's daily tasks without undue fatigue and the components of physical fitness encompass muscular strength, muscular endurance, muscular flexibility in addition to cardiorespiratory endurance [13]. However, on the other hand, motor fitness is often considered as part of physical fitness and the factors necessary to skilfully perform any activity is termed as the motor ability of that individual that are influenced by factors concerning agility, balance, power, speed and coordination [14].

Maturity and motor competence

A study examined the interrelationship between skeletal maturity, strength, body size and motor fitness among American children between 7-12 years of age [15]. The results of their study lead to the observation that there exists a complex relationship with respect to biological maturation, body size, motor fitness and strength. Further, the study highlighted that the differences in case of skeletal age independent of chronological age may be considered as a significant predictor as far as motor fitness in children is concerned. The individual effects affect the performance in children as confounding factors owing to the interrelationship among skeletal age, chronological age and body size. Effects due to skeletal age are evident through body size although skeletal age as a discrete component is found to impact the motor fitness in 7-12 years old children rather than muscular strength.

In a study where motor fitness tests were conducted among 5-7 years old children, motor fitness was found to be largely dependent on age and to a lesser extent on sex. Anthropometric measures such as body height and body weight did not influence the test variables for this age group, which appeared to be the case in studies carried out in older children [14].

In course of a review work, researchers aimed to provide an overview of studies that in turn rendered evidence for association between motor and cognitive skills in case of 4-16 years old typically developing children [16]. The results obtained from the studies showed that in typically developing children, the relationships between categories of cognitive and motor skills varied between weak to strong. The strongest relationship was found between higher order cognitive skills and complex motor skills. Contrarily, it was noted that this strength of the relationships between cognitive and motor skills declined in pubertal children, older than 13 years of age.

Detailed analysis revealed that bilateral body coordination, timed performance in movements and fine motor skills had the strongest relationships with cognitive skills, although less relationship was found between balance and strength/agility with respect to cognitive skills. These observations have been attributed to the fact that the first group of motor skills comprising of fine motor skills, timed performance in movements coupled with bilateral body coordination that may be further classified as complex motor skills demanded higher cognitive skills. The motor tasks that showed lower associations with cognitive skills demanded lesser cognitive engagement in those tasks [17]. These were in corroboration with the neuropsychological perception that the co-activation of the cerebellum (responsible for complex and coordinated movements) and the pre-frontal cortex (crucial for higher order cognitive skills) mediates the relationship between motor and cognitive skills [18]. Moreover, the weak to moderate correlation between various motor skills as well as visual processing and fluid intelligence that was noted were designated as higher order cognitive skills that were further required to execute motor tasks. Furthermore, the findings supported the fact that both motor skills and cognitive skills develop simultaneously in young children while an accelerated development is attained between 5- and 10-years ages [19]. Thus, an insight was provided regarding relationship between motor and cognitive skills.

Body composition and motor competence

Researchers evaluated and compared the motor fitness with respect to Body Mass Index (BMI) in one hundred school going male children of 9th and 10th grade associated with physical activities [20]. The entire sample of 100 children were divided into three groups according to their BMI, Low BMI (n=25), Middle BMI (n=50) and High BMI (n=25) and were compared with each other. The authors referred to motor fitness as the efficiency in performing basic movements in conjunction with physical fitness whereby the components of motor performance included balance, power, agility, speed and reaction time. The participants were tested for various parameters related to Vertical Jump, Sit and Reach, Chin Up, Shuttle Run and BMI. Results depicted some crucial findings. Middle BMI group and High BMI group were equal on flexibility and vertical jump (explosive leg strength). Middle BMI group represented more muscular strength, more agility and speed in contrast to High BMI group.

No significant differences were observed in terms of flexibility, vertical jump and chin up between Low BMI group and High BMI group. However, both High and Low BMI group were equal in terms of flexibility component. High BMI group showed lower muscular strength when compared to their Low BMI counterparts. Greater speed and agility were noted in Low BMI group compared to High BMI group, while there was no difference in chin up in these two groups when compared. It was found that both Low and Middle BMI group were equal on vertical jump. Further when compared to Middle BMI group. Low BMI group were superior in terms of speed and agility [20].

In another study motor abilities and anthropometric parameters were evaluated along with their inter-relationships in case of 152 children belonging to the age group of 6-12 years [21]. The key findings of this study suggested that the waist circumference and amount of subcutaneous fat positively correlated with Body Mass Index (BMI), while the Waist: Hip (W/H) ratio did not. In case of males, motor fitness tests were significantly correlated with age and performances were also higher. However, BMI did not correlate with motor fitness tests, while the amount of subcutaneous fat was inversely correlated with such tests. Moreover, in females, motor fitness tests were positively correlated with each other. Furthermore, both velocity and explosive strength that are generally considered as power events involving horizontal movements of the centre of mass were found to be related in children within 6-12 years age bracket [21]. All the observed differences may be attributed to the changing patterns of physical development in children measurable through body size and/or composition coupled with the physical profile [22].

Children's growth in terms of the lean body mass for boys and girls over the first decades is almost linear and changes occur at similar rates, although females tend to show a heightened percentage of body fat [22-25]. It has been found that by the age of 5 or 6 years, the fundamental pattern of movement is mastered and thereafter majority of the markers for motor performance are linked to age thereby exhibiting similar performance curves in case of both sexes before puberty [26]. During early childhood, improvement in motor fitness in children is noted with age [27]. Moreover, it has also been highlighted that in early childhood minimum gender differences exist in terms of motor development and hence motor tests [28]. However, from age 10 years onwards, these gender differences become more prominent as the sexual maturation commences [29]. Therefore, the observations as obtained from another study indicated that motor fitness remain unaffected with individual variability of BMI within normal range, while is significantly impacted in case of very lean and obese/ overweight children [21]. Strength is built up in a developing child owing to the contribution of weight, linear growth and muscle size. Until puberty, increment of strength is fairly linear and henceforth heightens at variable rates for males and females [30]. Thus, muscle strength has been attributed as a major component of running speed [31].

A research work evaluated the relationship between Body Mass Index (BMI) and motor competence among a total of 816 Santal children of 5-12 years old [32]. Results of their study indicated that healthy weight children outperformed the overweight and underweight children in motor competence. Further, it highlighted that in contrast to the heathy weight children, both the underweight or overweight children performed poorly in gross motor skills and not fine motor skills. Gross motor skills comprise mobilization of large group of muscles that generate leg, arm and chest strength. Activities of daily living such as kicking, jumping and running are derived from these skills and aid in acquiring more elaborate skills that the overweight children might face difficulty in performing. In overweight children, they face difficulty in moving their larger body size against gravity.

As per regression analyses, BMI acted as a major factor for motor competence among the surveyed population. For several test components such as balance, running speed and agility, bilateral competence, manual dexterity, upper limb competence and strength, a negative relationship was found between overweight and motor competence in case of both boys and girls. Learning a series of complex movements together producing smooth efficient action constitutes motor development. Negative association between motor competence and overweight has been attributed to excess adiposity triggering hindrance in biomechanical movement that in turn proves to be detrimental for motor competence. Additionally, a declining trend in motor competence was noted among children with lower BMI in contrast with their healthy weight counterparts. An impaired motor competence due to significant positive differences in certain motor skills such as upper limb competence (only in girls) and strength was possibly due to poor nutritional status that might negatively impact motor development leading to deficits in strength, perception and power [32].

Relationship between health and motor skills

In a study the relationship between the components of motor competence and health related fitness were investigated in a large sample belonging to the age bracket of 7 and 14 years [33]. Findings of the study represented that the association between motor competence and health related fitness is both stable and strong across childhood and early adolescence. Further, while taking into consideration various components of motor competence, both girls and boys revealed diverse relationship patterns with regards to varying age. Positive moderate to high associations between motor competence and health related fitness were noted irrespective of age or sex attributed to participation in physical activity that in turn impacts the development and maintenance of motor competence as well as health related fitness. In case of both boys and girls, it was found that locomotor motor competence depicted most significant relationship to health-related fitness.

The reason may be due to cardiorespiratory fitness, a vital component of health-related fitness that is majorly dependent on locomotor running skills for the development in childhood and adolescence. In comparison to girls, the boys demonstrated a higher correlation of manipulative component of motor competence with health-related fitness. The reason has been attributed to gender variations in sports participation in Portuguese society where boys are more likely to take part in team sports compared to their girl counterparts. It has been suggested in course of the study that in case of boys, both manipulative motor competence and locomotor competence played major role in initial development of motor activities whereby participation in ball games offers these dual benefits. Moreover, dynamic body balance renders more advantage in motor activities. For girls, it is of vital significance quality of jumping, running, jumping and others as part of locomotor motor competence in order to kindle their participation in physical activities. In the transition phase from childhood to adolescence, biological maturation impacts all motor competence variables. With increase in age for both sexes, stability skills act as major predictors of health-related fitness [33].

Changes in paediatric physical fitness has been a topic of investigation since decades and some studies have focused on various aspects of such fitness to report their findings. A study was carried out in which they compared the neuromotor fitness test scores of Dutch youths belonging to the age range of 9-12 years in the year 2006 in contrast to the scores of their same aged counterparts in the year 1980 [34]. Neuromotor fitness comprising of flexibility, muscle strength, speed of movement and coordination and often classified as a vital component of physical fitness apart from another component of aerobic fitness, was taken into consideration. Parameters such as body height, body weight and indices in performing neuromotor fitness tests were examined in 2050, 9-12 years old Dutch children in the year 2006 and were compared with data obtained from same aged 2603 Dutch children in the year 1980 where same battery of neuromotor fitness tests were performed.

Data retrieved from 9-12 years old Dutch in the year 2006 were found to be significantly taller and heavier in contrast to their age-matched peers in the year 1980. Significantly poor outcomes were obtained for both age and sex specific almost all test items for neuromotor fitness in the year 2006. Hence, this study brought to the forefront that over the past 26 years there has been a significant decline in neuromotor fitness among the Dutch youth [34]. Thus, poor physical fitness in children has been accrued to various impaired health indicators such as increased body fatness, many cardiovascular risk factors alongside hypertension thereby necessitating the importance of promoting high levels of fitness amongst the youth.

In another study by virtue of multiple regression analyses, researchers examined both independent and combined relationships between children's Physical Activity (PA), weight status and motor skills [35]. The study was conducted amongst children belonging to the age group of 3-10 years and motor skills were measured using Movement Assessment Battery for Children 2nd edition (MABC-2) while physical activity status was evaluated through accelerometry. Higher total motor skill scores were depicted in terms of MABC-2 for children devoting more time in moderate and moderate-to-vigorous PA. Moreover, higher balance scores were represented in children performing higher moderate physical activity (MPA) levels while those performing moderate-to-vigorous (MVPA) depicted greater Aiming and Catching scores. Interestingly, children engaged having healthier BMIs and spending sufficient time in PA irrespective of the intensity was associated with greater Aiming and Catching scores. Children who were overweight/obese represented higher Balance scores in relation to more time devoted in MPA or MVPA thereby suggesting that PA influences children variedly across weight status spectrum [35]. These findings further validate the fact that physiological, psychological and cognitive growth and development in children are influenced by motor skills.

In a study the motor proficiency of children aged 4-7 years were assessed while taking into consideration their gender as well as socio-economic status [36]. A sample size of 369 children were evaluated for balance, agility and speed, strength, bilateral coordination, upper limb coordination, fine motor integration, fine motor precision and manual dexterity. For fine motor skills, females were found to outperform males, while for catch and dribble gross motor skills boys outperformed the girls. Overall, for total, fine and gross motor proficiency, high socio-economic status significantly outperformed middle and/or low socio-economic status. Thus, the motor proficiency in primary children between age 4-7 years were found to be below average in United Kingdom (UK) alongside evident variations in both gender as well as socio-economic status. The decline in motor proficiency of the UK children as propounded in this study has been attributed to certain changes in government policy whereby School Sport Partnerships were dismantled and funding for the Physical Education and Sport Strategy were withdrawn. Another plausible reason for such low motor proficiency was linked to inadequate preparedness of the primary school teachers to teach Physical Education thereby lacking in providing an environment where nurturing and improvement of developing movement patterns and sequences for the children can be done.

The gender-based differences in motor proficiency has been accrued to certain stereotyped practices both in the school and home environments that in turn facilitate the development of specific motor skills [37]. Furthermore, in this context, gender influence while selecting toys for children also played a crucial role, as traditionally toys for boys include sport equipment, while conventionally toys for girls comprise of dolls, furniture, and other fictional characters to name a few [38]. The gender influence has been further corroborated with previous findings that suggested that with the passage of time in children, the gender effect tends to be more pronounced and biological diversity more prominent [39]. A positive association between socio-economic status and fine motor skill mastery has been established in empirical research [40]. Researchers also established a correlation between motor deficiency and reading attainment thereby indicating the far-reaching consequences of motor deficiency apart from attenuating the full participation of children in physical activity [36]. Moreover, this evidence suggest that as gross motor skill proficiency is a likely determinant of children's subsequent patterns of physical activity, the prevalence of motor deficiency might have repercussions causing a life of exclusion from physical activity for the children who are in a socially disadvantaged position.

Social factors and motor proficiency

In their review work, the researchers studied extensively the correlates of gross motor competence in both children as well as adolescents [41]. It was revealed that both biological and demographic factors were the most studied correlates of gross motor competency in the studied populations. While age was identified as a positive correlate, on the contrary it was noted that adiposity was a negative correlate for motor coordination, skill composite and stability. Meta-analysis in course of the study depicted that age was associated positively with object control, locomotor and stability skills. Further, sex was also identified as a correlate whereby it was found that boys were better skilled than girls in terms of motor coordination and object control. As far as age is concerned, it was narrated that with advancement of age there occur improvement in skills provided that there are enough opportunities for participation in activities that are conducive for building competence.

In the very early years of development, motor development in case of young children is heavily impacted by biological maturation while post this phase, both practice and opportunity influence the motor development. Hence it may be said that across developmental ages of an individual encompassing early childhood, preschool, childhood and adolescence, the relationship between age and gross motor competence undergoes alterations. The authors cited an interesting observation, where in the adolescent group, age was found to be a negative correlate.

A decline in motor competence among the girls was noted in this study that was attributed to reduced opportunity to stay active as physical activity in those girls were also further reduced in this period. Moreover, it was also stated that apart from increasing age, healthy weight status, male sex and higher socio-economic status were found to be consistent correlates for certain facets of motor competence. In addition, it was also identified that 'being male' was also a correlate of motor coordination and object control skills. This was congruent to the surging evidence that object control competence is a better salient predictor of fitness behaviour and physical activity compared to locomotor competence [41]. Hence, it was inferred that a positive association exists between motor competence and various components of health such as cardiorespiratory fitness, muscular strength, muscular endurance, physical activity and a healthy weight status.

Scientists in their study examined the effects of a 12-week Comprehensive School Physical Activity Programme (CSPAP) concerning the gross motor skills in a sample of US (United States) children hailing from low-income families [42]. Their findings suggested that gross motor skills were developed over the 12 weeks intervention by approximately 10% in younger children compared to their older counterparts. Children of 7 to 9 years old showed statistically greater improvements in motor skills in contrast to those aged 10 to 12 years. The variations due to age-groups has been attributed to developmental phases rather than intervention programme. Natural maturation alone does not necessarily contribute to achievement of motor competency alone [42]. Thus, the bidirectional relationship between development of motor skills with physical activity and health-related fitness facilitated student participation in various physical activities during school hours through behavioral approach-based intervention like that of CSPAP that in turn have beneficial outcomes for the children [43].

In a pioneering work carried out on school going adolescent Indian girls from the city of Kolkata, scientists showed that the individuals belonging to high Socio-Economic Status (SES) performed better in majority of the physical fitness parameters that also included motor proficiency parameters such as agility, flexibility and explosive muscle power followed by Low and Medium SES groups [44]. High SES groups girls also revealed highest level of academic achievement. This study highlighted the necessity of introducing favorable physical education scheme on the part of the policy makers to establish the significance of physical fitness and their impact on academic achievement of the students. In another work researchers aimed to explore the features concerning proprioception, balance and gross motor development of 3-6 years old Chinese children [45]. The study results brought to the forefront that children showed significant age and gender differences in terms of proprioception, static and dynamic balance and levels of gross motor development. Furthermore, a significant positive correlation was found between proprioception and gross motor development.

Balance which is considered as the ability to maintain a specific body posture through control of the body's center of gravity on a small supporting surface and is categorized into static and dynamic balance and are essential for performing, learning, and controlling fundamental movement skills [46,47]. Empirical evidence revealed that as far as balancing act is concerned it matures with age and balancing act mechanism of a 7 years old children is similar to that in adults [48]. Furthermore, balancing is also dependent on interaction with surrounding environments and exercises of muscle during the growth process [49]. Proprioception acts a source of sensory information that aids in accurate sensing of position, movements of human body and posture that in turn facilitates learning as well as control of fundamental movement skills and these skills are developed prior to the age of 8 years [47]. Proprioception has been further found to play a crucial role in judging the starting position, providing motor parameters for starting state and finally communicating the sensory feedback after motor response. This was in compliance with maturity and development of proprioception that in turn is intimately linked with motor development in case of young children. It was stated that preschool children's not only motor skills and physical health was impacted due to good or bad motor development, but a basic impact was also felt in case of children's cognitive development, social development, emotional development, and other aspects of health [47].

Practical implications

According to the available research-based evidence, it has been found that in humans, development of motor competency is achieved before puberty and the gross motor skills may be enhanced with regular participation in physical activity and maintenance of overall health-related fitness. It may be better achieved if the training begins with the onset of the pubertal age and continued till the adulthood is attained. Thus, it is desirable that improvements in motor skills as well as higher order cognitive skills in children may be achieved through innovation of complex motor intervention programs with special emphasis on participation in physical activities and maintenance of healthy weight status.

Conclusion

Mounting evidence with regard to the motor fitness in children have revealed that for enhancing the skills with respect to motor proficiency, it is vital to focus on the holistic development rather than emphasizing on a particular component of fitness. Interventions may be administered early preferably prior to the onset of puberty in both boys and girls so that the benefits derived from them may be sustained life-long for a greater period. Achievement of motor competency is found to be positively associated with greater caliber in performing higher order cognitive tasks and maintenance of the overall fitness level in children. Therefore. keeping in view all these benefits, changes in policies in school level curriculum as well as home-based interventions may be designed for ensuring attainment of the optimal motor competency in children.

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