Journal of Education and Learning; Vol. 12, No. 5; 2023
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

Comparing Muscular Fitness Among School Children Based on Sport Participation and Gender

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Received: June 25, 2023 Accepted: September 19, 2023 Online Published: September 28, 2023

doi:10.5539/jel.v12n5p233 URL: https://doi.org/10.5539/jel.v12n5p233

Abstract

The objective of this study was to examine muscular fitness using measurements of the right hand grip (RHG) and left hand grip (LHG), as well as the counter movement jump (CMJ) performance of both athlete and non-athlete school children. Additionally, the study aimed to compare these variables between genders. A total of 221 school children aged 11–13 participated in this study. The participants were categorized into four groups based on their characteristics: female athletes (n = 57), female non-athletes (n = 60), male athletes (n = 59), and male non-athletes (n = 45). The primary exclusion criteria included any musculoskeletal limitations that could potentially affect test performance. The strength of the RHG and LHG (kg) was assessed using the Takei-TKK-5101 device. CMJ heights (cm) were measured using the Smart-Speed device. For all variables, a mixed-design two-way univariate analysis of variance (ANOVA) was employed to identify differences between and within groups. The findings of the present study indicated that the RHG, LHG, and CMJ values of athletes were significantly greater than those of non-athletes for both genders ($p < 0.001$). Moreover, the analyzed performance values exhibited significant differences between male athletes and male as well as female non-athletes, and also between female athletes and female as well as male non-athletes ($p < 0.001$). Engaging in sports is highly important for school children aged 11–13 to enhance their muscular fitness. It can be stated that the development of muscular fitness for both genders would be higher in children who participate in sports compared to those who do not engage in sports.

Keywords: counter movement jump, hand grip, children, physical fitness, sports

1. Introduction

Muscular fitness plays a significant role in the development of children, serving as a fundamental component for locomotive movements and facilitating social interaction and play with peers. Throughout childhood, sufficient muscular fitness functions as a cornerstone for social development. Inadequate muscular fitness levels and muscular strength, in the worst-case scenario, can hinder a child's engagement in play, lead to social isolation, and pose challenges in forming friendships (Fredriksen et al., 2018). In recent years, various studies have documented a noticeable increase in obesity prevalence, reduced levels of physical activity, heightened cardiometabolic risk factors, and an overall decline in physical fitness among child populations (Dobbins et al., 2009; GBD, 2017; Ekelund et al., 2007; WHO, 2016). This underscores the imperative of prioritizing physical activity engagement and cultivating muscle strength among children in the contemporary context (Ekelund et al., 2016). Consistent, vigorous, and high-quality physical activity is indispensable for effectively carrying out bodily tasks throughout one's life and building appropriate muscle mass (Silverman, 2011). Comparing present-day situations with studies conducted a few decades ago allows us to ascertain that modern children possess lower levels of the requisite muscle mass (Steene-Johannessen et al., 2009).

During growth, children often engage in daily tasks, play, or sports activities involving short-duration, high-intensity exercises. However, the relationships between performance and age, especially in girls, still need comprehensive documentation (Martin et al., 2004; Van Praag & Dore, 2002). This necessity is partly due to the need for valid and appropriate testing protocols. Measuring anaerobic metabolism through a biopsy is not feasible in exercising children for ethical reasons. Hence, research has mainly focused on assessing maximal short-term power output (Martin et al., 2003; Martin et al., 2004; Van Praagh & Dore, 2002). Numerous studies have investigated changes in anthropometric characteristics among boys and girls during growth (Wikland et al., 2002; Deheeger et al., 2004; Martin et al., 2003; Martin et al., 2004).

Since the 1980s, the vertical jump test battery, which encompasses a series of vertical jump tests, has been employed across diverse populations of varying ages, encompassing both athletes and non-athletes, for the evaluation of explosive lower limb power (Bosco, 2002). Squat jumps (SJ) and countermovement jumps (CMJ) tests have been utilized to investigate the neuromuscular capabilities and developmental processes of young children (Acero et al., 2011). While numerous experimental studies on jumping performance development primarily center on comparing differences among distinct age groups, the literature offers few investigations that juxtapose boys and girls engaged in sports with those who are not, within the same age cohort. Considering the substantial variability in growth rates within any given age group, it is plausible that performance differences at any age may arise not only from anatomical size discrepancies but also from functional disparities (Floría & Harrison, 2013). Thus, evaluating factors about to jumping performance in boys and girls, encompassing both athletes and non-athletes, is essential to recognizing significant anthropometry variations during childhood (Floría & Harrison, 2013).

Hands are the most effective means of communication and are utilized to perform intricate tasks in daily life activities, such as eating and bathing (Exner, 2001; Bohannon et al., 2006; Marr et al., 2003). Developing adequate grip strength from early childhood becomes essential to managing tasks like eating and playing independently. Grip strength holds significance as a comprehensive health measure and is frequently estimated during routine motor function assessments (Häger-Ross & Rösblad, 2002). Occupational tasks and recreational activities, and play and leisure activities, necessitate a combination of grip strength and manual dexterity (Exner, 2001; Bohannon et al., 2006; Marr et al., 2003). Moreover, approximately 60% of school activities demand fine motor skills and manual dexterity (McHale & Cermak, 1992).

The prediction of grip strength is conducted as part of the physical and occupational therapy assessment for children with various conditions, such as traumas or congenital neurological disorders, to ascertain developmental levels and the extent of disability. This process contributes to treatment planning and evaluation (Häger-Ross & Rösblad, 2002). Additionally, grip strength is considered one of the most reliable clinical methods for assessing strength and is widely employed among adults as well (Häger-Ross & Rösblad 2002). For children, the assessment of hand function has become a standard practice as part of clinical evaluation, as diminished grip strength is observed in many children with diverse illnesses or lesions. The assessment of grip strength is essential for gauging developmental stages and the functionality of upper extremities, as well as for comparing scores of typical and atypical children based on variables such as age, gender, race/ethnicity, and body measurements (Exner et al., 2001; Bohannon et al., 2006; Marr et al., 2003; Fess, 2002; American Society of Hand Therapists, 1992).

The objective of this study was to examine muscular fitness using measurements of the right hand grip (RHG) and left hand grip (LHG), as well as counter movement jump (CMJ) performance of both athletes and non-athletes school children. Additionally, the study aimed to compare these variables between sports participants and non-participants and between genders.

2. Method

2.1 Participants

A total of 221 children aged 11 to 13 participated in this study. The participants were divided into four groups based on their characteristics: female athletes (n = 57), female non-athletes (n = 60), male athletes (n = 59), and male non-athletes (n = 45). The primary exclusion criteria included the presence of musculoskeletal limitations that could potentially hinder test performance. Moreover, participants with medical conditions, physical limitations, or undergoing treatment were excluded. At the commencement of the study, all participants were informed about the potential risks of the experiment and their right to withdraw from the study at any point without facing adverse consequences. The study protocol adheres to the ethical principles outlined in the 1975 Declaration of Helsinki, and written consent forms were obtained from all participants. The study was approved by the local ethics committee, and the required permissions were obtained from the City Provincial Directorate of National Education. Written consent was obtained from parents or legal guardians. The study was approved by the Ethics Committee of Relevant University (IRB protocol: 120851).

2.2 Procedures

The heights (cm) and weights (kg) of the participants were measured using a portable stadiometer and a scale (Tartı and Seca, respectively). Muscular fitness using measurements of the right hand grip (RHG) and left hand grip (LHG), counter movement jump (CMJ) performance of both athletes and non-athlete school children. RHG and LHG (kg) were measured using the Takei TKK 5101 hand grip dynamometer (Takei Scientific Instruments Co. Ltd) while the participants were standing. Additionally, the counter movement jump (CMJ) (cm) was measured using the Smart Speed device (Fusion Sport). The body mass index (BMI) (kg/m²) was calculated.

2.3 Measurement of Hand-Grip Strength

The strength of the right hand grip and left hand grip (kg) was measured using the Takei TKK 5101 hand grip dynamometer (TKK 5101, Grip-D Takei, Tokyo, Japan), which was adjusted to accommodate the hand size of each participant. Before the measurements, the hand dynamometer was individually adjusted for each hand according to the dynamometer usage instructions, taking into account the hand size and structure of the person. This adjustment involved positioning the grip handle to allow the fingers to flex at approximately a 90° angle at both the proximal and distal interphalangeal joints. Participants received preliminary instructions and a demonstration of correctly gripping the dynamometer. Before data collection, participants were given the opportunity to perform up to three practice repetitions, closely observed by researchers to correct any incorrect movement patterns. They were then instructed to exert maximum force while squeezing the hand grip dynamometer separately with their right and left hands. The test was repeated three times for each hand, with a 30-second interval between repetitions. The highest recorded value from the trials was selected for data analysis. This test was conducted using a methodology and device that have been found to possess high validity and reliability (Bellace et al., 2000; Reis et al., 2011).

2.4 Measurement of Counter Movement Jump

The CMJ (cm) was measured using the Smart Speed device (Fusion Sport, Qld, Australia). Before data collection, participants were given the opportunity to perform up to three practice repetitions, closely observed by researchers to correct any incorrect movement patterns. Participants were directed to perform a squat until their knees were flexed at approximately 90 degrees, followed by explosive vertical propulsion without delay. They were instructed to keep their hands securely on their hips to minimize the impact of arm movement on the jumping outcome. Each participant completed two trials with a 120-second rest interval between attempts, and the highest jump height (in centimeters) achieved was recorded (Thomas et al., 2009). This test was conducted using a methodology and device that have been found to possess high validity and reliability (Markovic et al., 2004; Mizuguchi et al., 2015).

2.5 Statistical Analyses

The results are presented as mean ± standard deviation (SD). The normal distribution of the data was assessed using the Shapiro-Wilk test. The BMI was calculated. Univariate analyses of variance with a mixed design were performed for all variables to detect differences both between and within groups. The analysis was conducted using SPSS version 23 (Statistical Package for the Social Sciences, SPSS Inc.). Statistical significance was determined at a significance level of $p < 0.05$.

3. Results

The current study's findings indicate that male and female athletes exhibited significantly higher RHG, LHG, and CMJ values compared to non-athlete males and non-athlete females ($p < 0.001$). Additionally, the examined performance values were significantly higher in male athletes compared to non-athlete males and non-athlete females, and significantly higher in female athletes compared to non-athlete males and non-athlete females ($p < 0.001$). Additionally, no statistically significant difference was found between non-athlete males and non-athlete females for RHG and LHG data, as well as between male athletes and female athletes. Right hand grip strength (kg), left hand grip strength (kg), values are presented in Table 2 and Table 3. In contrast, regarding CMJ, there is no statistically significant difference between non-athlete males and non-athlete females, while the data of female athletes is statistically higher than those of non-athlete males and non-athlete females. Furthermore, the CMJ data of male athletes were statistically significantly higher than those of non-athlete males, non-athlete females, and female athletes. Counter movement jump height (cm) values are presented in Table 4.

Table 1. The mean ± SD values of demographic variables of participants

	Females		Males		F	p	1-β	η_p^2
	Non-athletes	Athletes	Non-athletes	Athletes				
Age (years)	12.25±0.89^{b}	12.54±0.89^{b}	11.44±0.59^{acd}	12.25±0.99^{b}	14.339	0.000	1.000	0.165
Height (cm)	149.13±8.06^{bc}	154.37±8.34^{abd}	143.95±6.59^{acd}	149.31±10.43^{bc}	12.460	0.000	1.000	0.147
Weight (kg)	46.02±12.25	48.87±10.35^{b}	41.00±10.06^{c}	43.90±11.99	4.455	0.005	0.874	0.058
BMI	20.43±4.02	20.32±3.01	19.57±3.50	19.39±3.11	1.324	0.267	0.350	0.018

Note. $^{a}p < 0.05$ Significantly different from male athletes; $^{b}p < 0.05$ Significantly different from male non-athletes; $^{c}p < 0.05$ Significantly different from female athletes; $^{d}p < 0.05$ Significantly different from female non-athletes.

Table 2. The mean ± SD values of right hand grip strength

Gender	Groups	Right Hand Grip (kg)	F	p	1-β	η_p^2
Males	Athletes	21.80 ± 6.04^{bd}	13.994	0.000	1.000	0.162
	Non-athletes	17.69 ± 3.63^{ac}				
Females	Athletes	22.92 ± 4.29^{bd}				
	Non-athletes	19.05 ± 4.12^{ac}				

Note. $^{a}p < 0.001$ Significantly different from male athletes; $^{b}p < 0.001$ Significantly different from male non-athletes; $^{c}p < 0.001$ Significantly different from female athletes; $^{d}p < 0.001$ Significantly different from female non-athletes

Table 3. The mean ± SD values of left hand grip strength

Gender	Groups	Left Hand Grip (kg)	F	p	1-β	η_p^2
Males	Athletes	20.86 ± 5.77^{bd}	15.359	0.000	1.000	0.175
	Non-athletes	16.63 ± 3.57^{ac}				
Females	Athletes	21.71 ± 4.36^{bd}				
	Non-athletes	17.64 ± 4.04^{ac}				

Note. $^{a}p < 0.001$ Significantly different from male athletes; $^{b}p < 0.001$ Significantly different from male non-athletes; $^{c}p < 0.001$ Significantly different from female athletes; $^{d}p < 0.001$ Significantly different from female non-athletes

Table 4. The mean ± SD values of counter movement jump height

Gender	Groups	Counter Movement Jump (cm)	F	p	1-β	η_p^2
Males	Athletes	25.42 ± 4.32^{bcd}	38.395	0.000	1.000	0.347
	Non-athletes	19.80 ± 3.54^{ac}				
Females	Athletes	22.84 ± 3.43^{abd}				
	Non-athletes	18.81 ± 3.25^{ac}				

Note.$^{a}p < 0.001$ Significantly different from male athletes; $^{b}p < 0.001$ Significantly different from male non-athletes; $^{c}p < 0.001$ Significantly different from female athletes; $^{d}p < 0.001$ Significantly different from female non-athletes

4. Discussion

This research aimed to investigate the counter movement jump (CMJ) performance, right hand grip (RHG) strength, and left hand grip (LHG) strength of both athlete and non-athlete children. Additionally, the study aimed to compare these variables sports participants and non-participants and between genders. The main findings of the current study show that sports participation and being an athlete, regardless of gender, can enhance muscular fitness levels and strength parameters. Furthermore, female athletes have higher RHG, LHG, and CMJ values compared to non-athlete males, and male athletes have higher RHG, LHG, and CMJ values compared to non-athlete females.

Counter movement jump height is a commonly used method for measuring leg strength and explosiveness (Frick et al., 1991). Counter movement jumps are employed in various areas, including measuring strength, assessing and enhancing capabilities, evaluating the athlete levels, gauging training effects, developing training strategies, analyzing age and gender differences, and establishing normative data (Bencke et al., 2002; Bissas & Havenetidis, 2008; Harrison & Gaffney, 2001; Oliver et al., 2007; Thomas et al., 2009). Consequently, counter movement jumps have been evaluated across different ages, genders, or groups based on jumping experience, serving as a valid and reliable method for diagnosing strength performance in these groups. As known, jump performance is influenced by various factors such as age (Gerodimos et al., 2008; Harrison & Gaffney, 2001; Temfemo et al., 2009), gender (Harrison & Gaffney, 2001; McKay et al., 2005; Temfemo et al., 2009; Walsh et al., 2007), and physical activity level (Laffaye et al., 2006). Most of the previously reported studies have typically included adult male participants (Harman et al., 1990; Markovic et al., 2004). Only a few studies have focused on the effects of age and gender on jumping performance (Temfemo et al., 2009). Research investigating gender differences has often been conducted on limited numbers of individuals and within predetermined age groups, such as children, adults (Arteaga et al., 2000), adolescents (Temfemo et al., 2009), or pre-pubertal period (Temfemo et al., 2009). Studies examining gender-related differences in jumping performance during childhood and adolescence are limited in the literature. Along with age and gender, the level of physical activity could significantly influence variations in jumping performance. Some previously published studies have included only participants experienced in jumping (Markovic et al., 2004, Vanezis & Lees, 2005). Data from non-athlete participants are also scarce, yet comparisons with athlete groups could provide crucial insights into the assessment of jumping performance in non-athlete participants. Considering parameters that define the variability of jumping performance could help analyze differences related to age, gender, or physical activity level (Richter et al., 2010). Despite considerable research focusing on CMJ, most studies have compared children of different ages (Gerodimos et al., 2008; Harrison & Gaffney, 2001; O'Brien et al., 2009; Wang et al., 2004). Limited information about biomechanical differences among children within the same growth period. To better understand child development, it is essential to assess the ability of certain children of similar age and size to jump higher than others. In the assessment of muscular strength, it is reported that jump performance, especially under the age of 10–13, does not exhibit a significant difference between girls and boys. However, in later ages, it is noted that boys have better muscular strength compared to girls (Harrison & Gaffney, 2001; McKay et al., 2005; Temfemo et al., 2009; Walsh, et al., 2007). In terms of CMJ performance, Klausen et al. (1989) reported no gender difference between girls and boys aged 10 to 13 in their study. However, they noted an increase in vertical jump height for boys between 13 and 15 years of age, while reporting consistent performance in girls during the same 3-year period. Malina et al. (2004) found that vertical jump heights doubled between ages 5 and 14 and were similar for boys and girls. These researchers reported that gender differences were greater for boys, the difference in increased height during childhood being greater than that for girls (Temfemo et al., 2009).

Upon reviewing the literature, a variety of studies with diverse participant numbers and distinct methodologies can be observed. Particularly concerning gender differences, when comparing boys to girls of similar age and equivalent levels of physical activity, no significant difference is observed between the ages of 4 to 6. However, from the age of 13-14 onwards, males demonstrate better performance compared to females (Temfemo et al., 2009). Gender differences in jump performances can be explained by the increase in leg length and leg muscle volume, along with the increase in the percentage of fast-twitch muscle fibers, favoring the increase in boys' performance from the age of 14 onwards. Davies and Young (1985) showed that there were no gender differences in short-term jumping power output in 11-year-old children. Doré et al. (2005) reported similar anthropometric characteristics and strength performance in boys and girls aged 8 to 14. Temfemo (2009) demonstrated that boys had higher power output values in jumping compared to girls from age 14 onwards.

Physically active participants have been reported to exhibit higher jumping performance compared to sedentary participants (Focke et al., 2013). These findings suggest that physical activity and sports experience enhance jumping performance. To provide more robust insights, sport-specific and age-related analyses are necessary. When interpreting jumping performance data in children, consideration of sports activity level is imperative, as it can influence jumping performance. Future research should concentrate on sport-specific analyses that could reinforce and augment the findings of this study. Consistent with certain findings in the existing literature, the present study's findings indicate that female athletes demonstrate statistically higher CMJ performance when compared to both non-athlete males and non-athlete females. On the other hand, male athletes' CMJ values are also found to be statistically significantly higher than those of non-athlete males and non-athlete females, as well as female athletes. These gender-related developmental changes can be explained by the differential effects of puberty on males and females during adolescence (Tanner, 1962; Focke et al., 2013).

Hand grip strength is commonly used to assess muscular fitness in physical education settings at schools and clinical environments. Grip strength can be measured using relatively affordable, portable, and user-friendly dynamometers, making it a reliable and valid method for evaluating strength. Grip strength correlates well with measures of both maximal upper and lower body strength, as well as muscle mass and bone mineral density. Similar to aerobic fitness, muscular fitness is one of the components of overall health-related fitness and also predicts both current and future health. It is becoming increasingly evident that strength is associated with metabolic health in both adults and children. Hand grip strength can be tracked from childhood to adulthood, implying that low strength in childhood might lead to adverse health outcomes in later years (Cohen et al., 2010).

It is crucial to have normative data concerning hand grip strength. These data serve various purposes, including determining developmental levels and the degree of disability, evaluating the effectiveness of rehabilitation, assessing the integrity of upper extremity functions, and comparing scores obtained from typical and atypical children based on age, gender, race/ethnicity, and body measurements. Furthermore, similar to CMJ data, there are no significant differences in hand grip strength values between male and female children at a young age. However, it is noted that, especially during adolescence and beyond, male children tend to exhibit greater muscular fitness compared to female children (Exner, 2001; Bohannon et al., 2006; Marr et al., 2003; Fess, 2002; American Society of Hand Therapists, 1992). In hand grip strength measurements, it is specifically observed that males aged 14 and above demonstrate greater performance compared to females. However, in a study that employed grip strength adjusted for body weight and height to enable a more accurate comparison of grip strength between the two populations, it was illustrated that the grip strength of both males and females is analogous (Cohen et al., 2010). The findings of this study particularly indicate that the results of both right hand grip and left hand grip are similar in male athletes and female athletes. Additionally, these results are also similar in non-athlete males and non-athlete females. Jeune et al. (2006) compared grip strength across regions and suggested that historical regional differences, genetic factors, nutritional deficiencies, and the sociocultural environment might contribute to these variations. The reluctance of families to encourage girls to participate in leisure activities, either within or outside of school, is another point of discussion in the literature. These lifestyle changes and physical inactivity could influence children's muscular strength, particularly in specific geographical areas, potentially accounting for gender-specific differences in grip strength (Omar et al., 2018). This study finds that female athletes exhibit higher grip strength compared to both male non-athletes and female non-athletes, which may further support this notion.

There are several limitations associated with the present study that need to be taken into account when interpreting the results. The age group under examination in this study specifically falls within the range of 11 to 13 years; therefore, the findings of this study cannot be generalized to all age groups. The results have not been categorized according to the sports disciplines and the level of physical activity of the participants, which represents a limitation. Furthermore, the socioeconomic statuses of the participants were not assessed, and their potential influence on the study's results remains undisclosed within the context of this research. The study also lacks an evaluation based on ethnic background and race, which represents a limitation. Consequently, these limitations underscore the need for future research to target a more representative sample.

5. Conclusion

Male children who participate in sports have higher muscular fitness and strength performance compared to both male and female children who do not participate in sports. Additionally, female children participating in sports also have higher muscular fitness and strength performance compared to both male and female children who do not participate in sports. It is crucial for children aged 11-13, irrespective of gender differences, to engage in sports to enhance their strength development and muscular fitness.

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