



Association Between Motor Skills and Musculoskeletal Physical Fitness Among Preschoolers

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Published online: 18 June 2019

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Abstract

Objective Previous work is conflicted regarding the relationship between motor skill development and physical activity. One potential explanation for this equivocality is the difficulty and lack of precision in physical activity measurement, particularly within preschool populations. Our exploration of plank performance as a proxy measure for fitness addresses a void in the literature, as few studies have investigated the role of motor skill development on fitness. The purpose of this study was to evaluate the potential relationship between motor skill level and musculoskeletal endurance (via the plank test).

Methods Data from the 2012 National Youth Fitness Survey were used, which included 224 preschool-aged children (3–5 years). Motor skill level was assessed from the Test of Gross Motor Development-Second Edition (TGMD2). Motor skill parameters included general motor skills, locomotor skills, and object control skills.

Results Within this nationally representative sample of preschoolers, increased motor skills were positively associated with plank performance [General Motor Skills ($\beta = 0.45$; 95% CI 0.31–0.59), locomotor skills ($\beta = 1.88$; 95% CI 1.15–2.61), and object control skills ($\beta = 2.05$; 95% CI 1.11–2.98)].

Conclusion Motor skill level in this national preschool sample was associated with musculoskeletal endurance. Thus, future interventions should aim to develop and refine motor skills among preschoolers.

Keywords Epidemiology · Exercise · Physical fitness · Youth

Significance

This is the first manuscript to evaluate the relationship between musculoskeletal fitness and motor skill level among a national sample of preschoolers. These findings demonstrate a favorable association between these parameters, underscoring the importance of improvement musculoskeletal fitness and motor skill levels among young children, as both of these parameters are associated with better health

outcomes later in life (Cattuzzo et al. 2016; Robinson et al. 2015).

Introduction

Healthy growth and development during the preschool years involves learning to execute skilled movement patterns (Okely et al. 2004), which may help to facilitate exercise initiation and maintenance throughout childhood. A plank is an isometric exercise measuring muscular endurance of abdominal, back, and pelvic musculature. Successful maintenance of a plank involves holding an upright push-up position, without compromising safe form by dropping the hips, or arching the back. The development of adequate plank strength is important, as this measure provides not only an indication of skeletal muscle endurance, but also upper extremity strength, balance, and coordination among this population.

There is an emergent need for modification of existing test batteries, and for convergence regarding measurement

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selection of validated instruments that may be employed to reliably evaluate fundamental and functional movement abilities of young children (Barnett et al. 2016; Plowman 2014). A construction of convenient, and applicable examination measures is warranted, especially concerning balance and strength in preschoolers (Frey and Chow 2006). Studies have examined the association between motor skill level and physical activity (Loprinzi and Frith 2017). According to Corbin et al. (2000), physical activity is defined as “bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure (Corbin et al. 2000; Bouchard et al. 1990; Services, U.S.D.O.H.A.H. 1996).” As an example, in the data set used for this paper (National Youth Fitness Survey), we observed no relationship between preschool motor skill performance and free-living physical activity (Loprinzi and Frith 2017). Although the relationship between motor skill level and physical activity has been evaluated, the relationship between motor skills and musculoskeletal fitness has been less investigated. Musculoskeletal fitness is the combination of muscular strength, which comprises the ability for a muscle or group of muscles to produce maximal force, as well as muscular endurance, which is defined as the ability to sustain voluntary, loaded muscular contractions over time (whether maximal or repeated, submaximal contractions), and, lastly, dynamic and static flexibility of joints, including movement opposition and range of motion, respectively (Artero et al. 2011; Kell et al. 2001). The specific aim of this brief report was to examine the association between motor skill level and plank-performance in a national sample of preschool children. Therefore, we hypothesized that preschoolers with greater motor skills would perform better on the plank test than those with insufficient motor skills.

Methods

Study Design and Participants

The National Youth Fitness Survey (NYFS) was the data base used for the present study. The National Center for Health Statistics’ ethics committee approved this study. The authors’ institution provided institutional review board exemption. The NYFS was conducted in 2012 by the Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, as part of the Centers for Disease Control and Prevention. The NYFS used the sampling design of the National Health and Nutrition Examination Survey, employing a multistage probability sample of the non-institutionalized civilian population of the United States. The NYFS consisted of a household interview followed by a subsequent assessment in a mobile examination center (MEC). The 2012 NYFS interviewed a total of 1640 children

and adolescents aged 3–15 in their home and additionally examined 1576 of these children in the MEC. Within the total sample of 1640, 368 were pre-school aged children (3–5 years), from which motor skill and plank assessment data available for covariates in this study (noted below) were available for 224.

Measurement of Motor Skills

As described elsewhere (Loprinzi and Frith 2017), the Test of Gross Motor Development-Second Edition (TGMD2) was used within the MEC examinations to test the motor skills of all children aged 3–5 years. The TGMD-2 demonstrates appropriate reliability, in excess of 0.80, with respect to demographics and stability measuring the performance of children over time, and has a test scorer reliability correlation coefficient of 0.98. Adequate test–retest reliability has additionally been established for locomotion ($r=0.88$; $\alpha=0.85$). An object control subtest confirmed an appropriate correlation and average alpha coefficient ($r=0.93$; $\alpha=0.88$). This instrument is also appropriately valid across five constructs including age differentiation, group differentiation, item validity, subtest correlations, and factor analysis (Ulrich 2000).

The TGMD-2 is composed of two subtests for gross motor development—locomotor and object control. Both of these subtests are comprised of six different gross motor skills. For each of these six skills, there are between 3 and 5 assessment criteria. The locomotor subset measures run (4 criteria), gallop (4 criteria), hop (5 criteria), leap (3 criteria), horizontal jump (4 criteria) and slide (4 criteria). The object control subset measures striking a stationary ball (5 criteria), stationary dribble (4 criteria), kick (4 criteria), catch (3 criteria), overhand throw (4 criteria) and underhand roll (4 criteria). Standardized procedures were followed in order to obtain and compare a child’s score to those made by peers in the normative sample (<http://www.cdc.gov/nchs/data/nyfs/TGMD.pdf>). Three outcomes measures (standard scores) from the TGMD-2 were evaluated, including Locomotor, Object Control, and an overall Gross Motor Quotient (GMO) based on Dale A. Ulrich’s Test of Gross Motor Development, Second Edition (Houwen et al. 2010; Sun et al. 2011).

Plank Assessment

Previous research has demonstrated that the plank is both a reliable and valid index of muscular endurance among childhood samples (Boyer et al. 2013). Testing procedures were followed in accordance with a standardized assessment manual (National Youth Fitness Survey (NYFS) 2012). Participants were instructed to lie face down on the mat resting on their elbows with their hands on the floor and their toes curled under their feet so that some of their weight was on

the balls of their feet. Then they were told to tighten their stomach muscles and the muscles along the front of their thighs. Next, they were told to push off the floor and rise up onto their toes, keeping their elbows on the floor and their back straight. Participants were instructed to hold this position for as long as they could without letting their hips drop towards the floor or their knees bend. They were given one practice plank test before beginning the measured test. Participants were instructed to correct their position if they wobbled or moved out of position during the measured test. If it happened a second time the test was stopped. The test ended either when participants could no longer maintain the correct position, or when they requested the test be stopped. The number of seconds the plank position was held was recorded.

Statistical Analyses

All statistical analyses for the complex survey data within the NYFS were computed in Stata (v. 12). Multivariable linear regression was used to examine the association between motor skill levels on plank performance (outcome variable). Covariates included age, gender, race-ethnicity, physician-diagnosed asthma (yes/no), child physical activity (# of past 7 days the child engaged in at least 60 min/day of physical activity; proxy-reported by parent; range 0–7 days), and child weight status (underweight, normal weight, overweight and obese) based on measured body mass index (BMI) percentiles from the sex-specific 2000 BMI-for-age CDC growth curves. Statistical significance was established as $P < 0.05$.

Results

As shown in Table 1, the mean (SE) age of the sample was 4.25 years (0.03), with the mean GMO, locomotor and object control standard scores, respectively of 98.6 (0.8), 10.6 (0.2), and 8.97 (0.2). In the sample, 51.3% were boys, 56.1% were non-Hispanic white, 15.6% were non-Hispanic black, 14.2% were Mexican–American, 10.3% had asthma, 67.2% were normal weight, 15.6% were overweight and 15% were obese.

As shown in Table 2, and after adjustments, we observed a positive association between motor skill level and plank performance, with this association occurring for each motor skill evaluated. Specifically, for every 1 unit increase in the GMO, participants lasted 0.45 s longer on the plank ($\beta = 0.45$; 95% CI 0.31–0.59; $P < 0.01$). For every 1 unit increase in the locomotor skill, participants lasted 1.88 s longer on the plank ($\beta = 1.88$; 95% CI 1.15–2.61; $P < 0.01$). For every 1 unit increase in the object control motor skill,

Table 1 Weighted characteristics of the study variables (N = 224)

Variable	Point estimate (SE)
N	224
Asthma (%)	10.27
Age (mean years)	4.25 (0.3)
Gender (% male)	51.3 (0.03)
Body weight category (%)	
Underweight	1.8 (0.08)
Normal	67.2 (0.3)
Overweight	15.6 (0.2)
Obese	15.0 (0.3)
Race–ethnicity (%)	
Non-Hispanic white	56.1 (0.8)
Non-Hispanic black	15.6 (0.6)
Mexican–American	14.2 (0.4)
Other Hispanic	10.2 (0.4)
Other multi-racial	3.91 (0.1)
Mean plank time (s)	21.02 (1.15)
Mean # days (out of 7) child engaged in at least 60 min/day of physical activity	6.28 (0.96)
Mean general motor skills score (1 unit)	98.6 (0.8)
Mean locomotor skills score (1 unit)	10.6 (0.2)
Mean object control skills score (1 unit)	8.97 (0.2)

SE linearized standard error

Table 2 Multivariable linear regression analyses examining the association between motor skills and plank performance among preschool children, 2012 NYFS (N = 224)

Variable	β	95% CI	P value
General motor skills	0.45	0.31–0.59	<0.01*
Locomotor skills	1.88	1.15–2.61	<0.01*
Object control motor skills	2.05	1.11–2.98	<0.01*

Three multivariable linear regression models were computed; one for general motor skills, one for locomotor standard score and one for object control standard score. In each model, covariates included: physical activity, age, gender, race-ethnicity, asthma status and weight status

CI confidence interval

*Statistical significance ($P < 0.01$)

participants lasted 2.05 s longer on the plank ($\beta = 2.05$; 95% CI 1.11–2.98; $P < 0.01$).

Discussion

Motor skill acquisition in early childhood may be an important antecedent to the development of physical fitness across youth and adolescence. While studies have evaluated the influence of motor skill level on physical activity, the link

between motor skills and muscular fitness has been less examined. We hypothesized preschoolers with greater motor skills would perform better on the plank test than those with insufficient motor skills. We observed extended plank times in accordance with level of motor skill competency. Specifically, superior general motor skills, locomotor skills and object control skills were positively associated with plank performance in preschoolers.

Previous research conducted on children ages 8–12, shows plank performance is improved among older participants, with no gender difference influencing plank time (Ervin et al. 2014). It is unlikely for gender polarizations to manifest during prepubescent years (Lundgren et al. 2011). Thus, males and females within the preschool population are expected to exhibit similar anthropometric characteristics with respect to height, weight, and muscle mass (Backman et al. 1989). Similar plank scores between males and females simplify administration and scoring of plank time results. Therefore, this measure of isometric muscular endurance could be easily implemented in large cohorts for feasibility of mass physical fitness assessment in physical education or research settings. Additionally, previous research has demonstrated that the plank test is a robust measure of muscular endurance among 8–12-year-old children (Boyer et al. 2013). However, to our knowledge, additional experimental work is needed to reinforce the putative utility of including the plank test to assess physical fitness in validated test batteries for preschool populations. One potential limitation exists for the generalizability of plank tests to accurately assess physical fitness. Despite this challenge, the plank test remains a critical component of fitness testing batteries (Boyer et al. 2013). As an index of torso muscular endurance, which has been associated with spinal stability, lower body function, and injury prevention (Cowley et al. 2009; McGill et al. 2003; Parkhouse and Ball 2011). Thus, plank analysis offers a robust counterbalance against discrepancies in muscular strength and endurance and should be included in comprehensive examinations of child and youth fitness.

Other limitations to this study include our inability to establish causal impetus for plank exercises to become integrated into comprehensive fitness assessments; however, the primary goal of this paper was to highlight the potential for various motor skills to be associated with plank performance and to generate hypotheses for future research if such relationships were illuminated. Prior experience, or practice, with planking exercises may also have influenced plank performance of some children. Although the purpose of the study was not to assess plank performance in isolation, but rather to evaluate an association between general, locomotive, and object-control skills, which would likely not be driven by planking experience. The use of parent-reported physical activity is an additional limitation sensitive to biased estimates

of daily exercise. The likelihood of inaccurate estimation is increased if children engage in physical activity predominantly during preschool hours, outside of immediate parental supervision. Our findings may not fully elucidate the magnitude of the association between motor skills and physical fitness, possibly due to the measurement error associated with our physical activity covariate. Although, even those children meeting physical activity guidelines in early childhood, may become susceptible to increasingly sedentary behaviors throughout puberty and adolescence (Hills et al. 2011). The steep decline in physical activity from early childhood into adolescence may be attenuated if adequate motor skill development is promoted during preschool years (Hands 2008). In 2011, youth sport participation was reportedly on the rise (Hills et al. 2011), however recent 2018 data highlight manifold trends suggesting nuanced sport-specific, social, and economic variables may drive participation (State of Play 2018), which underscores the need for access to healthy motor skill education, and administration and improvement of fitness measurements tailored to preschool-aged individuals. Injuries, and/or lack of fitness may prevent sufficient engagement in sports, as well as potentially impede learning motor skills conducive to better physical fitness, as well as desirable sport performance. Additionally, inadequate motor skill development warrants further exploration, as risk of physical injury and lower levels of physical fitness may be exacerbated by motor skill deficiencies.

In conclusion, preschoolers with greater motor skills had increased musculoskeletal endurance (via the plank test). This may help to reinforce the rationale for successful motor skill performance to potentiate healthy development of physical fitness across childhood and adolescence. Additionally, muscular fitness is linked with health independent of physical activity behavior (Smith et al. 2014; Hass et al. 2001). We hypothesized preschoolers with greater motor skills would perform better on the plank test than those with insufficient motor skills. Our hypothesis was supported as longer plank times were associated with motor skill competency within this sample of preschoolers. There was a positive relationship between plank performance and specific areas of motor skill development measured in this investigation, which included general motor skills, locomotor skills and object control skills. Future research is needed to explore the relationships between early motor skill development on a battery of fitness outcomes in preschoolers. Longitudinal research is also warranted to track changes in physical fitness across childhood and adolescence, specifically among children who demonstrate sufficient motor skills during preschool years, in comparison to those who do not.

Compliance with Ethical Standards

Conflicts of interest The authors declare that they have no conflict of interest.

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