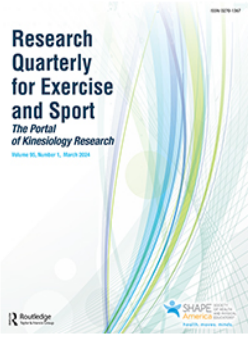

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Effect of Motor Competence and Health-Related Fitness in the Prevention of Metabolic Syndrome Risk Factors

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ABSTRACT

Purpose: In the last decades we have seen an increase in sedentary behaviors and a decrease in physical activity in children when compared to past generations. This lifestyle is commonly associated with the development of clustering risk factors that define metabolic syndrome (MetS). Knowing that motor competence (MC) development can influence lifelong physical activity habits, it is reasonable to assume that children's MC will directly link to clustered cardiometabolic health outcomes. The aim of this study was to analyze the role of MC in MetS risk factors. **Methods**: Seventy children with a mean age of 7.49 (SD = 1.28) years were evaluated on motor competence (MCA—Motor Competence Assessment instrument), cardiovascular fitness (PACER test), upper body strength (UBS; handgrip), and the components of MetS, hypertriglyceridemia, hypertension, abdominal obesity, low concentration of high-density lipoprotein cholesterol, and high fasting blood glucose. The composite value of MetS was calculated according to Burns et al. (2017). Multiple standard regressions were performed to explore the effect of different variables on MetS. Motor competence and health-related fitness (cardiovascular fitness and relative upper body strength) were used as independent variables (predictors) and MetS as dependent variable. **Results**: Overall, the results showed that motor competence ($\beta = -.072$; $p < .05$) is a significant predictor and this model explained 7,1% of the variance in MetS. **Conclusion:** Although more studies are needed, our results indicate that MC seems to have a positive role in children's health markers.

HIGHLIGHTS

- This study aimed to analyze the role of MC, cardiorespiratory fitness, and upper body strength in MetS risk factors.
- The results suggest that upper body strength is the strongest predictor for MetS (negative association), followed by MC (positive association).
- When the different MC components were entered independently instead of total MC, the upper body strength and locomotor MC were found to be significant predictors of the MetS behavior.
- Considering our results and the fact that MC levels during childhood positively influence PA levels along lifespan, this study suggests a pathway to follow in future research.

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Cardiovascular fitness; children; health; motor competence assessment; motor development; upper body strength

Chronic, non-communicable diseases are an increasing worldwide problem. A recent report by the World Health Organization stated that these conditions, including cardiovascular disease (CVD), diabetes, and obesity, now account for roughly two-thirds of deaths worldwide (Myers et al., 2019).

Metabolic syndrome (MetS) is regarded as the clustering of at least three risk factors that fit the following criteria: hypertriglyceridemia, hypertension, abdominal obesity, low concentration of high-density lipoprotein-cholesterol (HDL-C), and high fasting blood glucose (Guinhouya & Hubert, 2011). Since this term was initially suggested (Haller, 1977), MetS prevalence has grown worldwide. Average rates of adult obesity in Organization for Economic Co-operation and Development countries (OECD) have increased from 21% in 2010 to 24% in 2016 and, if this trend persists, it is expected that, from 2020 to 2050, overweight and related diseases will reduce life expectancy by about 3 years across the OECD, EU28, and G20 countries (*The Heavy Burden of Obesity: The Economics of Prevention | OECD ILibrary*, n.d.).

In addition, over the last 4 decades, western societies have been significantly less physically active than past generations (Chau et al., 2017; Hallal et al., 2012; Huotari et al., 2010; Myers et al., 2015; Pucci et al., 2017). Due to the high cost of chronic diseases linked to overweight, OECD countries will spend about 8.4% of their health budget to provide treatment for overweight-related diseases, which will represent about 425 billion USD a year and more than 200 USD per person per year. On average, overweight will be responsible for 70% of all treatment costs for diabetes, 23% of treatment costs for cardiovascular diseases and 9% for cancers. (*The Heavy*

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Burden of Obesity: The Economics of Prevention | OECD ILibrary, n.d.).

The clustering of risk factors that define MetS is commonly associated with sedentary lifestyles (Myers et al., 2019). It is known that obese children are five times more likely to become obese adults (Simmonds et al., 2015) and that in the last decade there has been a disproportional increase in the use of technology, which led to an increase in sedentary behaviors and a decrease in children's physical activity (PA; Keane et al., 2017; Schwarzfischer et al., 2019) when compared to past generations (Nelson et al., 2006). This and the fact that these factors were exacerbated in the last 2 years due to the COVID-19 lockdown, by a decrease in PA behaviors (de Sá et al., 2020; Moore et al., 2020; Pietrobelli et al., 2020; Pombo, Luz, Rodrigues, et al., 2021), increase in screen time (Carroll et al., 2020; de Sá et al., 2020; Pombo, Luz, Rodrigues, et al., 2021), change in eating habits, in most cases for worse (Campagnaro et al., 2020; Geral da Saúde, 2020; Pietrobelli et al., 2020) and a decrease in children's motor competence (MC; Pombo, Luz, de Sá, et al., 2021), should concern us about the future health of younger generations.

Although the definition of MetS in childhood remains a matter of debate, compelling data have revealed that the prevalence of pediatric MetS is high and increases with worsening obesity in obese children (Guinhouya & Hubert, 2011). Also, when diagnosed, it is indicative of an increased risk of morbidity-mortality from type 2 diabetes, CVDs, and loss of functional capacities throughout life (Guinhouya & Hubert, 2011).

Practicing PA regularly can have a major impact on health outcomes related to MetS (Myers et al., 2019). There is strong evidence that increased total PA is related to low levels of adiposity, has a positive impact on several cardiometabolic biomarkers (e.g., cholesterol, blood pressure, triglycerides, fasting insulin, insulin resistance, and fasting blood glucose), and better bone health (Bunc, 2018). Also, increasing levels of PA will increase levels of physical fitness (cardiorespiratory fitness and muscle strength), which is fundamental in children's health. Cardiorespiratory fitness levels are associated with total/abdominal adiposity and with cardiovascular disease risk factors (Ortega et al., 2008).

There is also evidence that absolute handgrip strength is positively associated with metabolic profile and metabolic disease (Sayer et al., 2007; Silventoinen et al., 2009) even during childhood and adolescence (Smith et al., 2014), although some studies show contradictory results (de Lima et al., 2021; Fowles et al., 2014; Liu et al., 2014). A recent study found that absolute handgrip strength was associated with poorer metabolic profiles and preclinical/established stages of metabolic disease, in contrast to relative handgrip strength (Li et al., 2018). This association could be attributed to the influence of body weight since the increase in body weight may have a positive association with isometric muscle strength measured by grip strength (He et al., 2019).

It seems that handgrip strength, as an absolute value, is an unsuitable predictor for cardiometabolic risk factors in children (Fredriksen et al., 2018) but instead, some studies (Lawman et al., 2016; Lee et al., 2016; Li et al., 2018) have determined that relative handgrip strength is negatively associated with cardiometabolic risk, including the metabolic profile of fasting glucose, HDL cholesterol, and triglyceride.

It is well established that MC development can influence lifelong PA habits (Hulteen et al., 2015; Robinson et al., 2015; Stodden et al., 2008); indeed, the ability to be proficient in a broad range of locomotor, stability, and manipulative skills, defined as MC (Rodrigues et al., 2019), has a key role in adopting healthy lifestyles (Stodden et al., 2008). Also, low levels of MC in childhood can lead to adults being less physically active and consequently having poorer cardiorespiratory fitness (Hardy et al., 2012). However, the link between MC and PA is still underrated, especially by policymakers and practitioners (Brian et al., 2020). This can be due to a lack of a holistic developmental perspective since the only focus is still on promoting more time in moderate-to-vigorous physical activity (MVPA), without regard to how or why children move (Brian et al., 2020; Myer et al., 2015; Stodden et al., 2008).

Since Seefeldt (1980) first proposed the idea of a "proficiency barrier" for motor skills, MC significance has come to be regarded as an essential component of PA. It is suggested that there may be a level of MC above which a child would be more likely to engage in various physical activities (Malina, 2014; Seefeldt, 1980). A study published in 2018 found that children with more advanced skills were 2.5 times more likely to meet the MVPA guidelines than lower-skilled children, offering a compelling insight and a novel strategy to investigate the impact of motor skill development on various health-related variables across childhood (De Meester et al., 2018).

Poor levels of MC are often associated with childhood obesity (Castetbon & Andreyeva, 2012; Eva D'Hondt et al., 2008). Previous studies showed negative relationships between MC and waist circumference (WC; D'Hondt et al., 2011; Libardoni dos Santos et al., 2016; Wahi et al., 2011), and children with lower levels of MC tend to have higher low-density lipoprotein (LDL; Wahi et al., 2011), lower high-density lipoprotein (HDL), and higher levels of triglycerides (Cantell et al., 2008). However, there is still little knowledge about the relationship between MC and clustered cardiometabolic biomarkers in children and adolescents.

Given the proficiency barrier of Seefeldt and the developmental model proposed by Stodden et al. (Stodden et al., 2008), which emphasizes the role of MC in promoting positive or negative trajectories of health, it is reasonable to assume that increases in children's MC will directly link to clustered cardiometabolic health outcomes. Considering this, the aim of this study is to analyze the role of MC, cardiorespiratory fitness, and upper body strength in MetS risk factors.

Methods

Participants

Participants were 70 children (31 boys and 39 girls; mean age of 7.49 years old, SD = 1.28), from a public school in the Lisbon district, who had no motor, cognitive, or health impairments (parent-reported) that could affect their performance on the motor tests. Written informed consent was obtained from the school director and the parents of all participants. Verbal assent was obtained from the children before data collection.

Measures

MC

MC was evaluated with a valid quantitative instrument, the Motor Competence Assessment (MCA) developed by Luz and colleagues (Luz et al., 2016; Rodrigues et al., 2019, 2021). The MCA is composed of two tests for each MC component, namely, Stability: lateral jumps (LJ), shifting platforms (SP); Locomotor: standing long jump (SLJ), 10 m shuttle run (SHR), and Manipulative: ball kicking velocity (BKV), ball throwing velocity (BTV). All tests are quantitative (product-oriented) motor tests without a marked developmental (age) ceiling effect, and of feasible execution. Normative values based on age and sex can be assigned to each test, component, and MCA total score (for full description see Rodrigues et al., 2019).

One testing session was used for this study. For all MCA tests, three experienced researchers followed the respective test protocols. All participants completed a 10 min general and standardized warm up before the beginning of the tests. After a proficient demonstration of each test technique with verbal explanation, participants were allowed to try each test once before being assessed. The children performed all the tests in small groups (usually about five children for each task). Motivational feedback was provided by the researchers, but verbal feedback on skill performance was not. The same procedures were used for all tests.

The raw results of all tests were transformed to percentile values, according to the Portuguese MCA norms (Rodrigues et al., 2019). The MCA subscale scores were calculated as the average of the percentile values of the corresponding two motor tests, and the total MCA scores were calculated as the average of the three subscales.

Cardiorespiratory and upper body strength

Cardiorespiratory fitness was assessed by the "20 m shuttle run test," which consists of running a maximum number of 20 m laps at a progressive pace. The running speed starts at 8.5 km/h and increases by 0.5 km/h every minute. Time at the end of each 20 m lap is marked by a beep sound. The test is considered completed when the participant is unable to reach the final lines by the time the beep sounds on two consecutive occasions. The number of laps completed successfully within the beeps by each participant is recorded.

To assess upper body strength, a handgrip dynamometer (T. K.K. 5001; Grip-A, Takei, Japan) was used, adjusted by hand size for each child. Participants are instructed to keep their arms fully extended, gradually, and continuously squeezing the wrist to the maximum of their strength, for at least 2 s, performing the test twice with each hand. The best score for each hand was recorded in kilograms, and an average value from both hands was computed. This absolute value was divided by BMI to determine the relative handgrip strength (Lawman et al., 2016).

Waist circumference assessment

Waist circumference was directly measured on the skin to the nearest 0.1 cm according to the World Health Organization method with a non-extensible and flexible tape (SECA 201®, SECA Deutschland, Hamburg, Germany; Riley et al., 2016).

Blood pressure

Blood pressure was measured on the left upper arm using a standardized digital blood pressure measuring machine (Omron Digital M6, Tokyo, Japan), in a seated position using age-appropriate child blood pressure cuffs. Two blood pressure readings were taken following at least 5 min of rest, and the average of the readings was used for analysis. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) percentiles were calculated according to age, gender, and height in accordance with the fourth report on the diagnosis, evaluation, and treatment of hypertension in children and adolescents (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). Blood pressure status was classified according to SBP and/or DBP percentiles as follows: normal blood pressure (average SBP and/or average DBP classified as normal if ≤90th percentile); prehypertension (between 90th to <95th percentile or if BP exceeds 120/80 mmHg even if below 90th percentile up to <95th percentile); and hypertension (≥95th percentile).

Biochemical markers

Capillary blood was collected by pricking at the fingertips with a lancing device after 4-hours of fasting.

Blood glucose measurements were performed using portable devices, On Call® Extra (ACON Laboratories, San Diego, USA), and correspondent reagent strips.

Measurements of total cholesterol, triglycerides, HDL-Cholesterol (high-density cholesterol), and calculation of LDL-Cholesterol (low-density cholesterol) were performed with Mission® Cholesterol Meter (ACON Laboratories, San Diego, USA) and reagent strips 3-in-1 Lipid test.

Statistics

MetS was calculated through the sum of the z-scores of fasting triglycerides, blood glucose, HDL cholesterol, waist circumference, and estimated mean arterial pressure ($MAP = ((2 \times DBP) + SBP)/3$; Burns et al., 2017). Because HDL cholesterol is inversely related to cardiometabolic risk, the HDL residual z-score was multiplied by −1. The higher MetS score represented a worse cardiometabolic profile (Eisenmann et al., 2010). Pearson's bivariate correlations were used to assess the relationship between the MetS and all other variables. Multiple regression analysis was performed to measure the predicted effect of MC, cardiovascular fitness, and relative grip strength (independent variables) on MetS (dependent variable). All statistical analyses were conducted in the SPSS version 26 and

Table 1. Mean and standard deviation of boys and girls for MC, AF, UBS, RUBS, and MetS.

	Boys n = 31	Girls n = 39	Total
Var.	Mean±SD	Mean±SD	Mean±SD
MCA (Points)	55.102±21.003	57.504±15.896	56.440±18.232
AF (Laps)	19.935±12.609	12.051±5.955	15.542±10.208
UBS (kg)	10.637±3.111	9.888±2.746	10.224±2.918
RUBS (kg)	.632±.165	.608±.147	.619±.155
MetS (z-score)	.536±3.793	−.134±3.030	.1630±3.380

MCA – Motor Competence Assessment; AF - Aerobic Fitness; UBS -Upper Body Strength; RUBS - Relative Upper Body Strength; MetS – Metabolic Syndrome.

at a 0.05 level of significance. An a priori power analysis was conducted using G*Power3 (Faul et al., 2007) to test the difference between three independent groups means using a two-tailed test, a medium effect size (d = .50), and an alpha of .05. The results showed that a sample of 42 participants was required to achieve a power of .80.

Results

The descriptive data of our participants indicated that the average values of MCA were in percentile 60 (Rodrigues et al., 2019). The values for aerobic fitness (AF) indicate that both sexes were above the healthy zone but, below the athletic zone (Welk, Laurson et al., 2011) and that upper body strength values were in percentile 50 (Oliveira et al., 2014). Regarding MetS values, although there were no statistically significant differences between boys and girls, boys seemed to have a tendency for an unfavorable cardiometabolic profile compared to girls (see Table 1).

Correlations between motor variables (MCA total and subscales) and physical fitness (cardiovascular and relative upper body strength) with MetS are presented in Table 2. Results showed that the Mets displayed a moderate to weak relationship with stability and locomotor MCA. No other associations were found.

Results for hierarchical multiple regressions are presented in Table 3. In the first model 1, only MCA ($p < .05$) was found to be a significant predictor explaining 7.1% of the MetS variance. For example, if all predictors are held constant, for each rise of one value in MC a fall of −.072 in the value of MetS occurs.

In the second model, the different MCA subscales were entered independently instead of the total MCA. The model kept a similar power of the explained variance (10.8%) and locomotor MCA (p =.016) was found to be a significant predictor of the MetS behavior.

Discussion

The main goal of this study was to analyze the role of MC and health-related fitness (cardiovascular fitness and upper body strength) in MetS risk factors. As mentioned above, the cardiometabolic profile in this study (MetS variable) incorporated blood markers, blood pressure, and waist circumference measurements into a clustered metabolic syndrome composite. Our results show that in the first model of the multiple regression analysis only MC was a significant predictor of MetS. Additionally, in the second model, when the different MCA subscales were entered, only the locomotor component was a significant predictor. The two models present a similar variance explanation of MetS (7.1% and 10.8%, respectively).

In the early childhood years, learning to move is a necessary skill underlying PA. Children begin to learn a group of motor skills, known as fundamental motor skills, such as running, galloping, skipping, hopping, sliding, leaping, throwing, catching, bouncing, kicking, striking, and rolling (Haywood & Getchell, 2005). These skills form the foundation for future movement and PA, which will be fundamental to build a sufficiently diverse motor repertoire that allows the child to learn adaptive skilled actions and that can be flexibly tailored to different movement contexts.

If a proficiency barrier exists, children will continue to show lower developmental levels in multiple skills over a long period of time, which in turn will hamper their ability to effectively maximize their movement. If we extrapolate this to locomotor skills, children might not have the capacity to reach the intensity needed to have positive results in their cardiorespiratory fitness, especially because cardiorespiratory fitness heavily

Table 2. Correlations between motor competence and physical fitness with MetS.

	MCA Total	MCA Stability	MCA Locomotor	MCA Manipulative	Relative Upper Body Strength	Aerobic Fitness
Metabolic Syndrome	−.227	−.243*	−.291*	−.023	.096	.033

*p < .05.

Table 3. Multiple linear regression analysis of the effect of motor competence, muscular strength, and cardiorespiratory fitness in the Metabolic Syndrome.

Model	Predictors	β	Beta	p	F	R^2	p
1					2.817	.071	.046
	Aerobic Fitness	−.005	−.014	.917			
	MCA Total	−.072	−.393	.006			
	Relative Upper Body Strength	5.783	.277	.073			
2					2.724	.108	.027
	Aerobic Fitness	.008	.024	.862			
	MCA Stability	−.025	−.157	.287			
	MCA Locomotor	−.058	−.388	.016			
	MCA Manipulative	.007	.052	.685			
	Relative Upper Body Strength	6.001	.288	.063			

depends on the development of locomotor running skills (Luz et al., 2017). This and the fact that locomotor MC has been recognized as a precursor of aerobic fitness (Luz et al., 2017; Okely et al., 2001), may be the reason why aerobic fitness was not a predictor of MetS alongside locomotor MC in our study.

The fact that the manipulative MC is not a predictor of MetS is not a surprising factor, especially in this age span. Manipulative skills generally develop later than locomotor skills and do not show a strong association with PA (Barnett et al., 2009, 2011) or even with fitness (Stodden et al., 2014) until late childhood/adolescence.

Interestingly, the stability component showed a correlation with MetS but was not a significant predictor when all components were entered into the model. We believe that this lack of predictive power for MetS might be due to the amount of shared variance with the other predictors tested. To our knowledge, this is the first study to analyze the stability component with MetS, which leads us only to speculate on our results. A review by Cattuzzo et al. (2016) found that there is a negative association between the pathway from weight status to locomotor/coordination and balance/stability skills and some support for the reverse (e.g., excess weight negatively influences stabilization and vice-versa). This tells us that MC (also stability component) can be compromised if children are overweight, increasing the possibility of presenting higher MetS.

Although it was previously suggested that relative handgrip strength was associated with better metabolic profiles and preclinical/established stages of metabolic disease (Li et al., 2018), we did not find associations between relative upper body strength and MetS in our study. Again, we can only speculate, but we believe that, since strength is associated with size and maturation (Beunen & Thomis, 2000), our results are due to the mean age of our sample. Between 3 and 6 years of age, the levels of isometric strength increase gradually. Strength in boys increases linearly from 6 to 12/13 years of age, with an acceleration in the late teens. As for girls, it improves linearly with age until about 15 years, with no clear evidence for an adolescent spurt (Malina et al., 2004). Since the children in our sample are about 7 years old (mean age), it is possible that they still do not have the maturity, and consequently, strength levels needed to show significant results. We would need a larger and more heterogenous sample to confirm these results.

We would like to emphasize the fact that our results point to an important role of MC in health markers. Although this relationship is logical since more MC fosters more PA and vice-versa (Stodden et al., 2008), and overweight and obesity usually tend to negatively affect MC in children (Eva D'Hondt et al., 2011; Libardoni dos Santos et al., 2016; Slotte et al., 2015), we still have scarce evidence supporting the positive role of MC in health markers.

Limitations and future directions

It is recommended that future research further explores the relationship between MC and variables related to metabolic risk factors, especially in larger samples. Longitudinal observations and MC interventions should be performed to better understand this relationship and help to provide policies that minimize the negative impact of low MC in children's health.

The fact that we use a small convenience sample makes our results hard to generalize because of the potential bias. Also, the cross-sectional design of this study can be a limitation since longitudinal and experimental research designs are preferable to make valid causal inferences. However, our results provide a first insight into how the development of MC is related to MetS risk factors, highlighting the importance of this line of investigation.

Conclusion

To our knowledge, this is the first study to examine the role of MC on children's MetS risk factors. The results of this study can help provide insights on how the development of MC, especially locomotor MC, may affect metabolic markers in children. Given our results and the established link between specific components of health-related fitness and health outcomes (Lubans et al., 2010; Ortega et al., 2008), the development of MC should be reinforced in physical education and in other PA settings, alongside improving the levels of health-related fitness in children, especially at these ages.

What does this article add?

This study provides a first insight into the role of MC in clustered cardiometabolic markers in children. The key role of MC in children's health was expected because: (a) there is a known bidirectional relationship between MC and PA, depending on the child's developmental stage (De Meester et al., 2016; D'Hondt et al., 2013; Stodden et al., 2008); (b) PA plays an important role in the prevention of overweight and obesity in childhood and adolescence, reducing the health risks of the condition (Strong et al., 2005); and (c) studies have shown negative relationships between MC and isolated health markers (Cantell et al., 2008; D'Hondt et al., 2011; Libardoni dos Santos et al., 2016; Wahi et al., 2011). However, until now we could only speculate about the relationship between MC and clustered cardiometabolic markers in children. In the last decades, there has been an emphasis on improving health outcomes by improving the levels of health-related fitness in children (Welk, Going et al., 2011) but, if we take into account our results, we probably need to take a step back and reinforce the development of MC in physical education and in other physical activity settings. Our results show the importance of promoting the development of MC from an early age, to decrease the possibility of developing negative trajectories of healthy habits over life span.

Disclosure statement

No potential conflict of interest was reported by the authors.

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IRB approval

The ethical committee of the Lisbon School of Health Technology ensured the conformity procedures regarding scientific research involving human beings and approved the study (CE-ESTeSL—Nº.47–2019).

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