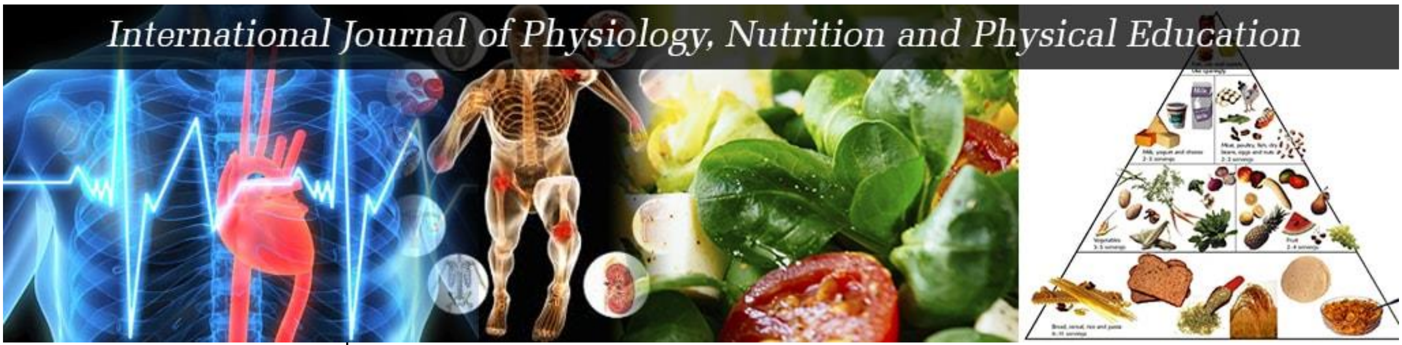

ISSN: 2456-0057
IJPNPE 2025; 10(2): 182-188
Impact Factor (RJIF): 5.91

www.journalofsports.com
Received: 07-07-2025
Accepted: 09-08-2025

Maria Sofia Amarra
[1] Department of Food Science and Nutrition, University of the Philippines Diliman, Quezon City, Metro Manila 1101, Philippines
[2] Nutrition Foundation of the Philippines Inc., Quezon City, Metro Manila 1113, Philippines

Francisco De Los Reyes
School of Statistics, University of the Philippines Diliman, Quezon City, Metro Manila 1101, Philippines

Christian Wisdom Valleser
College of Human Kinetics, University of the Philippines Diliman, Quezon City, Metro Manila 1101, Philippines

Wilson Sumpio
Department of Food Science and Nutrition, University of the Philippines Diliman, Quezon City, Metro Manila 1101, Philippines

Corresponding Author:
Maria Sofia Amarra
[1] Department of Food Science and Nutrition, University of the Philippines Diliman, Quezon City, Metro Manila 1101, Philippines
[2] Nutrition Foundation of the Philippines Inc., Quezon City, Metro Manila 1113, Philippines

Stunting, High BMI, and High Serum Vitamin C Adversely Affect Physical Fitness of Filipino Schoolchildren

Maria Sofia Amarra, Francisco De Los Reyes, Christian Wisdom Valleser and Wilson Sumpio

DOI: https://doi.org/10.22271/journalofsport.2025.v10.i2c.3094

Abstract
The study examined the association of nutritional status and inflammation with physical fitness in kindergarten and first grade schoolchildren attending public schools in Metro Manila. Physical fitness was measured using the following tests: a) jumping 7 m on two feet, b) medicine ball push, c) grip strength, d) 4x10 meter shuttle, e) 10x5 meter shuttle. Fitness scores were compared by child age, sex, micronutrient status (vitamins D, C, riboflavin, iron), anthropometric measurements (height-for-age, BMI-for-age), and presence or absence of inflammation (qualitative C-reactive protein). An overall physical fitness index (PFI) was computed. Children with significantly better scores in both strength and speed tests were males, older children, not stunted, and had low vitamin C status. Significant predictors of PFI were lower serum vitamin C (p=0.037), taller height (p=0.000), and lower BMI (p=0.000). Excess vitamin C, stunting, overweight and obesity should be avoided for improved physical fitness of Filipino schoolchildren.

Keywords: Nutritional status, Philippines, micronutrient, overweight, obesity

Introduction

Physical fitness refers to a set of attributes that enable individuals to perform physical activity [1] with vitality and sharpness, without undue fatigue while being able to appreciate recreation time interests and to meet the unpredicted emergencies [1,2]. Categories of physical fitness are skill-related and health-related fitness [1]. Skill-related fitness refers to motor skill performance or sport performance while health-related fitness is an important aspect of overall health [1]. Components of health-related fitness include body composition, cardiorespiratory endurance, and muscular strength and endurance [1]. Physical fitness in childhood is associated with health in later life. Health risks among children who are unfit include cardiovascular and metabolic disease, poor bone health, depression, anxiety, and reduced academic performance [1,3].

In 2021, the proportion of overweight and obese children aged 5 to 10 years exceeded that of thin children (13.9 % vs. 14.1%, respectively) [4]. One behavior that influences the rise in obesity is the lack of physical activity. The 2022 Philippines' report card on physical activity for children and adolescents concluded that only less than 20% of Filipino youth aged 5 to 17 years had sufficient physical activity, while the rest do not meet the recommended amount of physical activity for health [5] indicating that this population is likely to have low fitness levels.

Micronutrient deficiencies (e.g., vitamins D, C, iron) and health status (e.g., presence of inflammation) may also influence physical fitness. One study among athletes showed a positive association between serum vitamin D level and the following fitness tests: grip strength, vertical jump, and total work for both the right and left lower extremities during extension [6]. Iron deficiency anemia can limit endurance capacity leading to reduced physical performance [7]. Inflammation is the body's response to infection or other damaging stimuli. An inverse association between fitness status and inflammation has been shown, wherein individuals practicing more frequent and intense physical activity have reduced concentrations of inflammatory biomarkers [8].

The present study examined the association of nutritional status and inflammation with physical fitness in kindergarten and first grade schoolchildren attending public schools in Metro Manila.

The objectives were to

1. Measure the following indicators of physical fitness using specific tests: a) lower body power - jumping 7 m on two feet, b) upper body power - medicine ball push, c) upper body strength - grip strength, d) speed and agility - 4x10 m shuttle, e) cardiorespiratory fitness - 10x5 m shuttle;
2. Compare scores for each test by child age, sex, micronutrient status (vitamins D, B2, C, iron), anthropometric measurements (height-for-age, BMI-for-age) and presence or absence of inflammation (measured by C-reactive protein);
3. Summarize physical fitness scores into an overall physical fitness index (PFI) and compare PFI by child nutritional status (anthropometric status, micronutrient status) and inflammation;
4. Identify factors that contribute to the variance in children's PFI scores after controlling for age and sex.

Materials and methods

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Region II Trauma and Medical Center Philippines (protocol code R2TMC-IRB Protocol No. 2022:102 dated July 28, 2022). The methods below have been described in an earlier study [9].

2.1 Sampling method.

Two public elementary schools in low-income communities within Metro Manila were selected based on geographic location (i.e., one in the north and another in the south). In both schools, parents of the entire population of kindergarten and first grade children were invited to a meeting wherein researchers explained the study objectives and methods. Parents were given consent forms to take home after the meeting. They were asked to decide if they would allow their children to participate in the study, and if so, return the signed consent form to the child's teacher. Out of a total of approximately 800 children, 166 parents whose children were apparently healthy (i.e., with no known or current co-morbidities e.g. fever, cough etc. and actively attending class) gave signed consent forms. These children comprised the study sample.

Anthropometric measurements

Weight and height were measured using a standard Detecto weighing scale with height rod by two trained public health nutritionists. Weighing scales were calibrated with known weights prior to use during each weighing session. Two readings were obtained and the average was taken. BMI-for-age z-score was determined using WHO AnthroPlus software [10] which used the 2007 WHO Growth Reference (BMI-for-age) for classification. Cut-offs were: low BMI <-2 z-score, normal BMI ≥ -2 to ≤ -1 z-score, high BMI > +1 z-score.

Micronutrient status and inflammation

An accredited diagnostic laboratory in Metro Manila collected [11] and analyzed [11,12] the blood samples. Approximately 12 mL venous blood was extracted. Hemoglobin (iron) was obtained from a complete blood count (CBC) using fully automated hematology analyzers (Sysmex, Alinity). Serum vitamin D was determined using LC-MS/MS (liquid chromatography tandem mass spectrometry) technique. Briefly, the sample was subjected to protein precipitation followed by solid phase extraction. The resulting sample solution was then placed in the LC-MS/MS system. The generated calibration curves of both 25(OH)D2 and 25(OH)D3 were used to compute for the vitamin D concentration.

For plasma riboflavin, the sample was subjected to protein precipitation and the resulting supernatant subjected to the LC-MS/MS system. The resulting peak areas of samples were processed against peak areas of calibration solutions.

Vitamin C in serum sample was determined using a plate-based colorimetric assay. Using a microplate reader, a dose-response curve correlating absorbance units to concentration of ascorbic acid in the sample was generated. The vitamin C concentration of sample was computed by subtracting sample absorbance from blank and comparing against that of the calibrator. All solutions were protected from light during the sample preparation to prevent degradation of biomarkers. Reference values for the different micronutrients are shown in Table 1: Qualitative serum C-reactive protein (CRP) was determined by immunoturbidimetric method on an Alinity system.

Table 1: Reference values for micronutrients examined

Micronutrient	Reference values	
	Normal	Insufficient/Deficient
Vitamin D (serum 25OHD$_3$)	>20 ng/mL (>50 nmol/L)	<20 ng/mL (<50 nmol/L)
Vitamin C (serum ascorbic acid)	6.00-20.00 mg/L	Below 6.00 mg/L
Riboflavin (plasma riboflavin)	1.00-19.00 mcg/L	Below 1.00 mcg/L
Iron (hemoglobin)	100-140 g/L	Below 100 g/L

Physical fitness tests

Following is a description of each test

1. Jumping 7m on 2 feet: This test evaluates the child's lower body explosive power, strength, and coordination. The child performs repeated two-footed jumps over a 7-meter marked course as quickly as possible. Two trials are given, with the fastest time being recorded as the final score. Proper form requires the child to maintain balance and control throughout each jump.
2. Medicine ball push: Designed to measure the child's upper body strength and power, this test uses a 2-kg medicine ball. The child stands stationary and pushes the ball forward from chest level with both hands. Distance is then measured from the starting line to where the ball first contacts the ground. After two attempts, the longest throw is recorded as the official result.
3. Grip strength: This test specifically measures the child's hand and forearm strength using a grip dynamometer. The child stands with elbows bent at 90 degrees and squeezes the device with maximum effort for 2 to 3 seconds. The test is performed on both hands, with the highest reading from either hand being recorded. Proper

instruction is needed to ensure that the child understands how to exert full force during each attempt.

4. 4x10 meter shuttle run: This test assesses the child's speed, quickness, and change-of-direction ability. The child runs back and forth over a 10-meter course, completing four total lengths (40m). Only one official trial is performed unless the child makes an error in procedure. The total time is recorded in seconds from start to finish. This test is particularly useful for evaluating the child's athletic potential and movement efficiency.
5. 10x5 meter shuttle run: Designed to measure the child's cardiovascular endurance and anaerobic capacity, this test involves repeated sprints. The child completes ten lengths of a 5-meter course (50m total), turning quickly at each end. Unlike the 4x10m test, this longer version places greater emphasis on stamina. The total completion time provides insight into the child's fitness level, recovery ability, and overall physical conditioning.

Statistical Analysis.

An overall physical fitness index (PFI) score was calculated for each child following the method of Lu et.al. [13]. Z-scores for each fitness test were calculated according to sex and age as follows:

Z-score = (measured value of each physical fitness test - average value of each test in each age/sex group) / standard deviation of each test in each age/sex group

Age groups were 5 to 5.9 years, 6 to 6.9 y, 7 to 7.9 y, 8 y and above. The PFI is obtained by adding up the z-scores of each individual physical fitness indicator and taking the opposite number for the z-scores of 7m jump, 40m run, 50 m run because the higher the z-score, the lower the subject's performance. The formula for PFI computation follows:

PFI = Z gripstrength + Z medball push - Z jump 7m on two feet - Z shuttle 4x10 - Z shuttle 10x5

Independent samples t-test and one-way ANOVA were used to determine differences in fitness scores in individual tests and in overall PFI scores. Multiple linear regression (backward elimination) was used to identify factors that contributed to the variance in overall PFI (SPSS v.26).

Results

Characteristics of the sample

Table 2 shows the characteristics of the sample. The mean age of children was 6.25 ± 0.8 years. The prevalence of stunting was 6.0%. There were more overweight and obese than thin children (19.4% vs. 15.1%, respectively). More than 28% of children were deficient in vitamin D, while 20% were deficient in vitamin C. None were deficient in iron and riboflavin. Inflammation was present in 11.2% of children.

Table 2: Characteristics of the study sample (n=166)

Mean age ±S.D. = 6.25 ± 0.8 years	No.	%
Age range (years)		
5 to 5.9	29	17.5
6 to 6.9	80	48.2
7 to 7.9	45	27.1
8 and above	12	7.2
Sex		
Males	94	56.6
Females	72	43.4
Grade level		
Kindergarten	109	65.7
Grade one	57	34.3
Height-for-age		
Severe stunting	2	1.2
Moderate stunting	8	4.8
Normal	154	93.3
Tall	1	0.6
BMI-for-age		
Severe thinness	8	4.8
Moderate thinness	17	10.3
Normal	108	65.5
Overweight	18	10.9
Obese	14	8.5
Iron (hemoglobin) (g/L)		
Normal	146	92.4
High	12	7.6
Vitamin D (mcg/L)		
Deficient	46	28.7
Sufficient	114	71.3
Vitamin C (mg/L)		
Deficient	26	20.0
Sufficient	104	80.0
Riboflavin (mcg/L)		
Normal	120	76.9
High	36	23.1
Inflammation (C-reactive protein)		
- Negative	143	88.8
Positive	18	11.2

Physical fitness scores by child age and sex

Older children performed significantly better than younger children in all fitness tests (Table 3). Male children performed significantly better than females in all tests except jumping 7 m on two feet.

Table 3: Physical fitness by child age and sex

Child characteristic	Physical fitness test									
	Jump 7 m on 2 feet (seconds)		Medicine ball push (meters)		Grip strength (lbs)		4x10 m shuttle (seconds)		10x5 m shuttle (seconds)	
	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.
Age (y)										
5 to 5.9	5.7 ± 1.6 [a,b,c]	.000*	1.4 ± 0.3 [a,b]	.000*	8.7 ± 2.2 [a]	.000*	17.7 ± 3.4 [a,b]	.001*	28.7± 4.4	.037*
6 to 6.9	4.9 ± 1.1 [a]		1.6 ± 0.4 [c,d]		9.6 ± 2.5 [b]		16.6 ± 2.9		26.3 ± 4.2	
7 to 7.9	4.5 ± 0.9 [b]		2.0 ± 0.4 [a,c]		12.2 ± 2.2 [a,b]		15.3 ± 2.2 [a]		25.5 ± 8.0	
8 and above	4.1 ± 0.9 [c]		2.0 ± 0.5 [b,d]		12.5 ± 4.9 [a,b]		14.7 ± 1.7 [b]		23.8 ± 2.1 †	
Sex										
Male	4.9 ± 1.4	.533	1.8 ± 0.5	.000*	10.8 ± 3.2	.020*	15.7 ± 2.9	.001*	25.4 ± 4.4	.015*
Female	4.8 ± 0.9		1.6 ± 0.4		9.7 ± 2.5		17.1 ± 2.7		27.5 ± 6.7	

*Significant at 0.05 level

[a,b,c,d] Values with the same letter are significantly different from each other using Tukey post hoc test

†Significantly different from all other groups using Tamhane post hoc test

Physical fitness scores by nutritional status and inflammation

Table 4 shows children's physical fitness scores by nutritional status (micronutrient status, anthropometric measurements) and inflammation status.

Micronutrient status. There was no difference in fitness scores between children with sufficient and deficient serum vitamin D levels. Ironically, children with deficient serum vitamin C levels performed significantly better than vitamin C-sufficient children in all tests except the 10x5 m shuttle run. None of the children were deficient in iron and riboflavin, hence no comparisons were made.

Anthropometric measurements. Non-stunted children (i.e., normal height and taller) performed significantly better than stunted children in most tests (medicine ball push, grip strength, 4x10 m shuttle). Obese children had significantly stronger grip strength than those who were non-obese but were the worst performers in the 10x5 m shuttle.

Inflammation status. Fitness scores did not differ between children with and without inflammation.

Table 4: Physical fitness indicators by nutritional and health status (micronutrient status, anthropometry, inflammation)

Child health status	Physical fitness test									
	Jump 7 m on 2 feet (seconds)		Medicine ball push (meters)		Grip strength (lbs)		4x10 m shuttle (seconds)		10x5 m shuttle (seconds)	
	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.	Mean ± S.D.	Sig.
Vitamin D status										
Sufficient	4.9 ± 1.3	.220	1.7 ± 2.4	.106	10.1 ± 2.7	.058	16.4 ± 2.9	.220	26.4 ± 4.6	.670
Deficient	4.6 ± 1.0		1.8 ± 0.4		10.9 ± 2.8		15.8 ± 2.3		26.0 ± 7.7	
Vitamin C status										
Sufficient	5.0 ± 1.4	.000*	1.7 ± 0.4	.002*	9.9 ± 2.6	.003*	16.5 ± 2.9	.016*	26.7 ± 4.3	.406
Deficient	4.1 ± 0.6		2.0 ± 0.5		11.8 ± 3.5		15.0 ± 2.5		25.6 ± 10.1	
Height-for-age										
Non-stunted	4.8 ± 1.3	.214	1.8 ± 0.5	.004*	10.8 ± 3.0	.007*	15.9 ± 2.4	.046*	26.1 ± 5.8	.372
Stunted	5.0 ± 1.1		1.6 ± 0.4		9.4 ± 2.5		17.1 ± 3.6		26.9 ± 5.1	
BMI-for-age										
Thin	4.6 ± 0.9	.397	1.7 ± 0.5	.142	9.7 ± 3.3 †	.048*	16.2 ± 2.3	.433	25.3 ± 1.9	.031*
Normal	4.9 ± 1.2		1.7 ± 0.4		10.2 ± 2.6 ‡		16.2 ± 3.1		25.9 ± 4.5 [a]	
Overweight/obese	5.0 ± 1.5		1.9 ± 0.4		11.5 ± 3.6 †‡		16.9 ± 2.5		28.6 ± 9.3 [a]	
C-reactive protein										
Negative	4.9 ± 1.3	.462	1.7 ± 0.5	.450	10.4 ± 2.8	.715	16.2 ± 2.8	.766	26.4 ± 5.8	.713
Positive	4.6 ± 1.0		1.8 ± 0.4		10.7 ± 4.1		16.0 ± 2.3		25.9 ± 3.4	

*Significant at 0.05 level

[a] Values are significantly different from each other using Tukey posthoc test

†‡ Values are significantly different at 0.10 level using Tukey posthoc test

Physical Fitness Index by nutritional status and inflammation

Significantly higher PFI levels were seen among children with deficient vitamin C status and normal height-for-age (i.e., not stunted) (Table 5). The rest of the variables showed no associations.

Table 5: Physical Fitness Index (PFI) z-scores by nutritional status and inflammation

		Physical Fitness Index (PFI) z-score	
Nutritional status	N	Mean ± S.E.	Sig.
1. Vitamin C status			
Sufficient	99	-0.28 ± 0.34	.012*
Deficient	26	1.55 ± 0.57	
2. Vitamin D status			
Sufficient	110	0.04 ± 0.32	.423
Deficient	45	0.51 ± 0.50	
3. Height-for-age			
Non-stunted	111	0.79 ± 0.29	.000*
Stunted	48	-1.42 ± 0.49	
4. BMI-for-age			
Thin	25	0.65 ± 0.58	.569
Normal	103	0.12 ± 0.34	
- Overweight/obese	31	-0.30 ± 0.58	
Inflammation status			
CRP (-)	137	0.16 ± 0.30	.821
CRP (+)	18	0.35 ± 0.55	

*Significant at 0.05 level

Variables that contribute to the variance in physical fitness index (PFI) levels of Filipino schoolchildren

Using PFI as the dependent variable, linear regression (backward elimination) analysis showed that taller height-for-age, lower BMI-for-age, and lower serum vitamin C level significantly predicted higher PFI score (Table 6) after controlling for age and sex. No significant interactions among predictors were found. The beta-coefficient shows that with a one-unit increase in serum vitamin C concentration, there is a 0.066 unit decrease in overall fitness z-score. While a one-unit increase in BMI is accompanied by a 0.552 unit decrease in overall fitness score. In contrast, a one-unit increase in height results in a 0.557 unit increase in overall fitness score.

Table 6: Factors that contribute to the variance in physical fitness index (PFI)

Factors that contribute to the variance in physical fitness index (PFI)	**Unstandardized coefficients**		**Standardized coefficients**		
	B	**Std. Error**	**Beta**	**t**	**Sig.**
Constant	1.059	.522		2.030	.045
Serum vitamin C mg/L	-.066	.031	-.186	-2.115	.037*
Height-for-age z-score	.557	.143	16.034	3.881	.000*
BMI-for-age z-score	-.552	.143	-15.911	-3.851	.000*

*Significant at 0.05 level

Variables entered/removed: C-reactive protein, serum vitamin C, serum vitamin D, hemoglobin, plasma riboflavin, height-for-age, BMI-for-age, age in years, sex

Discussion

Differences in individual fitness indicator tests

Results of the present study showed that characteristics of children with significantly higher scores in both strength and speed tests (shown in Tables 2 and 3) were: male sex, older age, normal height-for-age, and deficient vitamin C status. The findings on the association of male sex and older age with physical fitness are consistent with existing literature showing that age and gender are the two strongest predictors of physical fitness in children [14,15]. Overweight and obese children had the strongest grip strength (p=.048) but the slowest 10x5 m shuttle speed (p=.031), indicating greater arm strength but reduced cardiorespiratory fitness compared with those who were non-overweight or obese (Table 3). These results are consistent with studies showing greater muscle arm strength but low aerobic fitness among overweight/obese children [16,17,18]. Obese children tend to perform better in exercise using strength and power due to their higher muscle mass compared with normal weight children [18]. However, Alaniz-Arcos et.al.[17] found that absolute muscle strength was significantly lower among the overweight and obese when they carried their body weight (e.g., Bent arm hang test) compared with normal weight subjects.

Factors that contribute to the variance in Physical Fitness Index (PFI).

Lower serum vitamin C, taller height, and lower BMI significantly predicted better PFI scores in this sample (Table 5). Low vitamin C appeared to enhance physical fitness level in this sample. Children with deficient vitamin C status had significantly better scores in most of the fitness tests (jumping 7 m, medicine ball push, grip strength, and 4x10 m shuttle) compared to those with sufficient vitamin C (Table 3). Vitamin C functions as an antioxidant, is involved in wound healing, collagen formation, and immune function and is therefore necessary for good physical performance [19]. On the other hand, it has been shown that exercise is accompanied by the excess formation of free radicals, considered a physiologic adaptation to physical activity [20]. Oxidative stress during exercise initiates cellular signaling processes that lead to adaptations to training [20,21]. These processes include mitochondrial biogenesis, induction of endogenous antioxidant defense systems, and muscle hypertrophy needed for improved performance [20]. Vitamin C supplementation in athletes has been shown to blunt the effects of training by inhibiting mitochondrial biogenesis in skeletal muscle [20,22,23]. Studies showed that vitamin C supplementation reduced the exercise-induced expression of key transcription factors involved in training adaptation such as PGC-1α (peroxisome proliferator-activated receptor gamma coactivator-1 alpha), nuclear respiratory factor 1, and mitochondrial transcription factor A [20,22,23]. A recent review [21] cited the importance of reactive oxygen species (ROS) in signaling pathways for muscular adaptation during training and that high doses of antioxidants may interrupt this pathway. The authors recommended the consumption of vitamin C-rich foods rather than using supplements to enhance physical performance [21]. In the present sample, many children were taking vitamin C supplements to protect against COVID virus, which might have affected their fitness test results. An earlier study on the same sample revealed these children's negligible intake of fresh fruits and vegetables (approximately 44 grams per day compared with the WHO recommendation of 400 grams per day) [24]. Studies are needed to determine the optimal levels of vitamin C supplementation for Filipino children that will protect against viral infection without adversely affecting physical performance.

The results of the present study showed that higher BMI predicted poorer overall fitness. Studies have confirmed the association of overweight and obesity with poorer physical fitness due to low aerobic capacity [25,26] compared with normal BMI. In contrast, increasing height-for-age predicted improved fitness levels. Non-stunted children had significantly better scores for medicine ball push (p=.004), grip strength (p=.007), and 4x10 m shuttle (p=.046) compared with those who were stunted (Table 3). Studies have confirmed the association of normal height (i.e., not being stunted) with higher fitness level [27,28]. Height is an indicator of bone mass, an important determinant of bone strength [29]. Peak bone mass is the highest level of bone mass obtained during normal skeletal growth [29]. During childhood, the goal is to enhance skeletal growth, achieve peak bone mass, and maintain bone strength to prevent osteoporosis in adulthood [29].

Limitations of the study

Limitations are the study's small sample size, cross-sectional design, non-use of physical fitness biomarkers (e.g., creatine kinase), and limited use of nutrition and health biomarkers. Longitudinal studies are needed to determine the effects of dietary and non-dietary (e.g., environmental, social) components on children's physical fitness. Further studies are needed to determine optimal levels of ascorbic acid intake in Filipino children that will improve physical fitness without sacrificing immune function especially during viral pandemics such as covid-19.

Conclusions

The following characteristics were significantly positively associated with scores in speed and strength tests among Filipino schoolchildren: male sex, older age, not stunted, not overweight and obese, deficient in vitamin C. Overweight and obesity, stunting, and high serum levels of ascorbic acid significantly predicted reduced physical fitness using an overall Physical Fitness Index score. Interventions that prevent stunting, overweight and obesity, and excess intake of vitamin C are needed to increase Filipino children's physical fitness and help prevent disease in later life.

Acknowledgments

The authors wish to acknowledge the following: Mrs. Demetria Cabalona, School Head of Leodegario Victorino Elementary School, Marikina; Mrs. Veronica Francisco, School Head of San Isidro Elementary School, Parañaque; Department of Education Undersecretary Wilfredo E. Cabral.

References

1. Ganley KJ, Paterno MV, Miles C, Stout J, Brawner L, Girolami G, *et al*. Health-related fitness in children. Pediatr Phys Ther. 2011;23(3):208-20. doi:10.1097/PEP.0b013e318227b3fc.
2. Singh K, Singh R. Comparison of selected physical fitness components of badminton and basketball players. Int J Appl Res. 2017;3(4):236-40.
3. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes (Lond). 2008;32(1):1-11. doi:10.1038/sj.ijo.0803774.
4. Department of Science and Technology-Food and Nutrition Research Institute (DOST-FNRI). Philippine nutrition facts and figures: 2021 expanded national nutrition survey (ENNS). Taguig City: DOST-FNRI; 2024.
5. Cagas JY, Mallari MFT, Torre BA, Kang DPMG, Palad YY, Guisihan RM, *et al*. Results from the Philippines' 2022 report card on physical activity for children and adolescents. J Exerc Sci Fit. 2022;20(4):382-90. doi:10.1016/j.jesf.2022.10.001.
6. Ksiazek A, Dziubek W, Pietraszewska J, Słowińska-

Lisowska M. Relationship between 25(OH)D levels and athletic performance in elite Polish judoists. Biol Sport. 2018;35(2):191-6. doi:10.5114/biolsport.2018.74195.
7. Solberg A, Reikvam H. Iron status and physical performance in athletes. Life (Basel). 2023;13(10):2007. doi:10.3390/life13102007.
8. Brinkley TE, Nicklas BJ. Effect of exercise training on chronic inflammation. Clin Chim Acta. 2010;411(11-12):785-93.
9. Amarra MS, de los Reyes F, Sumpio W, dela Cruz L, Cayabyab B, Angbengco JM, *et al*. Obesity and micronutrient status predict inflammation and weaker immune function in Filipino schoolchildren. Acad Nutr Diet. 2025;2(1). doi:10.20935/AcadNutr7518.
10. World Health Organization. WHO AnthroPlus software [Internet]. Geneva: WHO; 2024 [cited 2025 Feb 2]. Available from: https://www.who.int/tools/growth-reference-data-for-5to19-years/application-tools
11. Metametrics Laboratory [Internet]. 2025 [cited 2025 Feb 2]. Available from: https://metametricslab.com/
12. Singapore Diagnostics [Internet]. 2025 [cited 2025 Feb 2]. Available from: https://www.sgdlabs.ph/
13. Lu J, Sun H, Zhou J, Xiong J. Association between physical fitness index and psychological symptoms in Chinese children and adolescents. Children (Basel). 2022;9(9):1286. doi:10.3390/children9091286.
14. Matejek C, Starc G. The relationship between children's physical fitness and gender, age and environmental factors. Ann Kinesiol. 2013;4(2):17-30.
15. Karacabey K. Investigation of physical activity and physical fitness of children. J New Results Sci. 2011;8(2):921-35. Available from: http://www.insanbilimleri.com
16. Malina RM, Peña Reyes ME, Tan SK, Little BB. Physical fitness of normal, stunted and overweight children 6-13 years in Oaxaca, Mexico. Eur J Clin Nutr. 2011;65(7):826-34. doi:10.1038/ejcn.2011.44.
17. Alaniz-Arcos L, Ortiz-Cornejo ME, Larios-Tinoco JO, Klünder-Klünder M, Vidal-Mitzi K, Gutiérrez-Camacho C. Differences in the absolute muscle strength and power of children and adolescents with overweight and obesity: a systematic review. BMC Pediatr. 2023;23:474. doi:10.1186/s12887-023-04290-w.
18. Aucouturier J, Thivel D. Physical activity intervention in overweight/obese children and adolescents: endurance and/or resistance training. In: European Childhood Obesity Group, editor. The ECOG free e-book [Internet]. 2024 [cited 2025 Feb 2]. Available from: https://ebook.ecog-obesity.eu/the-ecog-free-e-book/
19. Ghazzawi HA, Hussain MA, Raziq KM, Alsendi KK, Alaamer RO, Jaradat M, *et al*. Exploring the relationship between micronutrients and athletic performance: a comprehensive systematic review. Sports (Basel). 2023;11(6):109. doi:10.3390/sports11060109.
20. Otocka-Kmiecik A, Król A. The role of vitamin C in two distinct physiological states: physical activity and sleep. Nutrients. 2020;12(12):3908. doi:10.3390/nu12123908.
21. Rogers DR, Lawlor DJ, Moeller JL. Vitamin C supplementation and athletic performance: a review. Curr Sports Med Rep. 2023;22(7):255-9.
22. Gomez-Cabrera MC, Domenech E, Romagnoli M, Arduini A, Borrás C, Pallardó FV, *et al*. Oral administration of vitamin C decreases muscle mitochondrial biogenesis and hampers training-induced adaptation in endurance performance. Am J Clin Nutr. 2008;87(1):142-9. doi:10.1093/ajcn/87.1.142.
23. Paulsen G, Cumming KT, Holden G, Hallén J, Rønnestad BR, Sveen O, *et al*. Vitamin C and E supplementation hamper cellular adaptation to endurance training in humans: a double-blind randomized controlled trial. J Physiol. 2014;592(8):1887-901. doi:10.1113/jphysiol.2013.267419.
24. Amarra MS, de los Reyes F, Sumpio W, dela Cruz L. Processed snacks and baked goods predict inflammation risk in Filipino schoolchildren. Acad Nutr Diet. 2025;2. doi:10.20935/AcadNutr7724.
25. Chen X, Cui J, Zhang Y, Peng W. The association between BMI and health-related physical fitness among Chinese college students: a cross-sectional study. BMC Public Health. 2020;20:444. doi:10.1186/s12889-020-08517-8.
26. Zhang Y, Su F, Song Y, Lu J. Associations between physical fitness index and body mass index in Tibetan children and adolescents in different high-altitude areas: based on a study in Tibet, China. Int J Environ Res Public Health. 2022;19(16):10155. doi:10.3390/ijerph191610155.
27. Malina RM, Peña Reyes ME, Tan SK, Little BB. Physical fitness of normal, stunted and overweight children 6-13 years in Oaxaca, Mexico. Eur J Clin Nutr. 2011;65(7):826-34. doi:10.1038/ejcn.2011.44.
28. Armstrong ME, Lambert MI, Lambert EV. Relationships between different nutritional anthropometric statuses and health-related fitness of South African primary school children. Ann Hum Biol. 2016;44(3):1-25. doi:10.1080/03014460.2016.1224386.
29. Klentrou P. Influence of exercise and training on critical stages of bone growth and development. Pediatr Exerc Sci. 2016;28(2):178-86. doi:10.1123/pes.2015-0265.