Int. J. School. Health. 2020; 7(4)

Published online 2020 October.

Research Article

The Relationship between the Physical Fitness and Academic Performance of Students in Douala, Cameroon: A Cross-Sectional Study

Joseph Koupele Mouna[1], MSc; Peguy Brice Assomo Ndemba[1,2], PhD; Ernest Dalle[2], PhD; Jerson Mekoulou Ndongo[1], PhD; Wiliam Richard Guessogo[3], PhD; Claude Elysée Bika Lélé[1], PhD; William Mbang Bian[3], MSc; Samuel Honoré Mandengue[1], PhD; Laurent Serge Etoundi Ngoa[2], PhD; Abdou Temfemo[1,4,5]*, PhD

[1]Exercise and Sport Physiology Unit, Faculty of Sciences, University of Douala, Cameroon
[2]Department of Physiology, Faculty of Medicine and Biomedical Sciences, University of Yaounde I, Yaounde, Cameroon
[3]Department of Applied Biology of Sports and Physical Education, National Institute of Youth and Sports, Yaounde, Cameroon
[4]Department of Biological Sciences, Faculty of Medicine and Pharmaceutical Sciences, University of Douala, Douala, Cameroon
[5]Exercise Physiology and Rehabilitation Laboratory, Faculty of Sports Sciences, University of Picardie Jules Vernes, Cedex, Amiens, France

Corresponding author: Abdou Temfemo, PhD; Exercise Physiology and Rehabilitation Laboratory, Faculty of Sports Sciences, 21/400 Blaise Pascale Road, Amiens, France. **Tel:** +336-50889274; **Email:** temfemo@hotmail.com

Received July 16, 2020; **Revised** August 2, 2020; **Accepted** August 19, 2020

Abstract

Background: Academic success in Cameroon is more focused on the pedagogical aspects of classical subjects such as mathematics and English. Physical and sports education is only a recreational activity in the Cameroonian school context. The aim of this study was to investigate the relationship between physical fitness (cardiorespiratory fitness and motor skills) and academic performance.
Methods: In this cross-sectional study, a total of 643 pupils with a mean age of 12.4±1.3 years were included. The cardiorespiratory fitness (VO_2pic) was measured using the 20 m shuttle run test. Motor skills (e.g. speed and agility) were assessed with 4x10 m shuttle test. The students 'academic performance in trimestral average, science and literacy was evaluated based on school records.
Results: Boys had significantly higher anthropometrics (height and weight) and performance parameters (VO_2pic and duration). As far as teaching disciplines are concerned, significant differences also existed between the genders. There was no significant association in terms of VO_2pic and literacy (r=0.017; P=0.6625), english (r=0.052; P=0.1879), and mathematics (r=0.070; P=0.0767) subjects. However, in science (r=0.080; P=0.0418) and trimestral average (r=0.087; P=0.0273) subjects, a significant association with VO_2pic was found. Besides, significant relationships were observed between the duration of the physical and sport education activity and the academic performance. Higher VO_2pic values were found in younger students (r=0.252; P=0.0001). For all grades, VO_2pic decreased with age.
Conclusion: The minor effects of physical fitness on academic performance among young Cameroonian pupils were linked to specific socio-cultural and socio-economic contexts. This study showed the beneficial effects of extra-curricular activities on academic performance.

Keywords: Academic performance, Adolescent, Child, Physical fitness, Cameroon

How to Cite: Koupele Mouna J, Assomo Ndemba PB, Dalle E, Mekoulou Ndongo J, Guessogo WR, Bika Lélé CE, Mbang Bian W, Mandengue SH, Etoundi Ngoa LS, Temfemo A. The Relationship between the Physical Fitness and Academic Performance of Students in Douala, Cameroon: A Cross-Sectional Study. Int. J. School. Health. 2020;7(4):31-38.

1. Introduction

The health benefits of regular physical and sports activities (PSA) include reduced risk of cardiovascular disease, type 2 diabetes, metabolic syndrome, and cancer, eventually improving mental health and mood (1-3). This explains why cardiovascular, metabolic, bone, and mental health diseases remain among the top priorities of our community (3). There are extensive studies that highlight the positive effects of physical and sport activities in reducing obesity, hypertension, or dyslipidemia, thereby showing protection against psychological, social, and cognitive distresses (1-3).

The cognitive aspects of the benefits associated with regular PSA practice are still sparse. The positive effects of physical activity on physical and mental health are widely recognized, but less is known about the potential effects of physical activity on cognitive and academic performance (3, 4).

In children and adolescents, higher physical fitness scores correlate with better academic performance whereas the progression and aggravation of some diseases in adults originate from childhood and adolescence (5). It has become clear that there is a strong link between cardiorespiratory fitness and academic performance in children and adolescents. However, the positive associations between physical activity, and academic performance of students in a country with

multiple socioeconomic challenges have never been reported by any research (6).

In assessing children's physical fitness, three major components are regularly tested: the morphological component, the motor component, and the cardiorespiratory component. Among these physical fitness assessments, the maximum oxygen uptake (VO_2pic), a cardiorespiratory component, is the one that is often related to academic performance (7, 8).

In Cameroon, academic success focuses mainly on the differences between the two existing education subsystems (French and English), the plethora in class, the efficiency of denominational or public institutions, the educational aspects of subjects such as mathematics, French or English, and the socio-economic status (9, 10). The module related to physical and sports activities is of minor interest as evidenced by the low coefficient given to this discipline in contrast to other subjects such as mathematics, natural sciences, English, or French. Previous studies conducted in Cameroon linked this alarming fact to the high prevalence of overweight students (with regard to the body mass index), and thus suggested more physical activity to be included in the academic program (11-15). The objective assessment of physical activity in Cameroonian schools has so far benefited from only two studies that have investigated the electrocardiographic profiles of students in response to the physical and sports education (PSE) tests (16, 17). Furthermore, to the best of our knowledge, no studies on physical fitness and academic performance have been reported in Cameroon. Our study is the first to link student's academic performance to sport activities. The positive relationship observed between physical fitness and academic performance in the studies of Caucasians might be partly related to the high level of economic development. The precarious conditions that are prevalent in African environments such as limited access to textbooks and unfavorable socio-economic conditions have a negative impact on the academic performance of children despite adequate physical fitness. We hypothesized that the positive association between academic performance and physical fitness was weaker among African students.

Therefore, the purpose of this study was to investigate the relationship between physical fitness (cardiorespiratory fitness and motor skills) and academic performance among students in the city of Douala, Cameroon.

2. Methods

Participants

We randomly selected five secondary schools (public and private) in Douala (one school per district). A total of 643 students in grades 6, 5, and 4 were recruited.

The study was conducted between October 2018 and January 2019; all activities were carried out during sports and physical education (SPE) sessions.

Procedure

The head of each school was formally contacted a month prior to the study for their consent, availability, and collaboration. Each sports activity was planned in collaboration with each class' sport and physical education teachers. The teachers were asked to inform the students of the day chosen for the physical fitness session and the dress code (sportswear, sports shoes) that was appropriate.

Every student was briefed on the various modalities of each activity and the study objectives before their anthropometric data (weight, size) were obtained. The 4x10 m shuttle test or 20 m shuttle run test was subsequently conducted depending on the school's sports and physical education timetable. In general, a minimum of 48 hours or a maximum of one week always separated the two field tests. Given our limited technical means and the small number of our experimental team members (three or four), some sessions only consisted of obtaining the anthropometric data (at off-peak hours and especially when the sports and physical education course was to take place). All missing data (4x10 m test and 20 m test) were completed during the subsequent SPE sessions.

4x10 m Shuttle Test

The 4x10 m shuttle test was set to evaluate the speed and agility of the students. Two round trips of 10 meters each, or 4 lengths of 10 m, were to be completed as quickly as possible. At the end of every 10 m run, the subject was requested to block one foot beyond the end line to change his direction. The test was considered over when the subject crossed the finish line with his first foot. The time taken to travel back and forth was scored with a stopwatch and recorded on the performance recording sheet.

20 m Shuttle Run Test

The 20 m shuttle test was set to assess the

pupil's aerobic capacity (VO_2pic) through their cardiorespiratory endurance. The test started with a walk or a very slow run, and the students were gradually asked to run as fast as possible following the required pace. This test was performed on a 20 m track marked by visual cues (the studs). The subject had to go back and forth on this track with an imposed pace and following the rhythm of the beep sound signal emitted by a speaker. To start the return, he had to block the foot behind the stud and make a U-turn. The test started at a speed of 8.5 km/h (first tier speed), which was increased by 0.5 km/h every minute. The test ended when the subject was no longer able to keep up with the required pace and rhythm. Afterwards, the last level shuttle was scored on the performance recording sheet. The maximum oxygen uptake (VO_2pic) was estimated as per the regression equation developed by Leger and colleagues (18).

Academic Performance

The students' academic performance was assessed using the academic grades obtained from different schools. The grades were categorized into science subjects (mathematics and sciences for the sixth and fifth grades; mathematics, physics, chemistry, technology, life and earth sciences, environmental education, hygiene, and biotechnology for the fourth grade) and literary subjects (English, French, history-geography, citizenship education for all these classes). Mathematics and English scores were considered separately. The academic record (trimestral grade) was provided by the authorized official of each school.

Statistical Analyses

All data were entered into an Excel sheet (Microsoft Office 2016) before being exported to StatView 5.0 statistical analysis software (SAS Institute, Inc., IL, USA). The quantitative data (age, height, weight, BMI, duration, and VO_2pic) were expressed as the mean ± standard deviation. ANOVA and T-test were used to compare unpaired groups (boys and girls). Polynomial regression was used to assess the relationship between age or performance (VO_2pic and duration) and the teaching disciplines (literacy, English, science, mathematical, and Trimestral average). The regression coefficient r and the P-values were used to determine the degree of association between parameters. The significance level was considered $P<0.05$ for all statistical tests.

3. Results

Descriptive Statistics

Table 1 depicts the descriptive characteristics of the study samples. There were differences between sexes in the components of physical fitness. Male students had a better performance in both cardiorespiratory (44.7±3.7 vs 40.0±3.9; P=0.0001) and motor fitness tests (9.5±0.8 vs 10.7±0.9, P=0.0001). Significant differences also existed between the males and females regarding all the studied academic subjects with better results observed in girls.

Academic Performance and Physical Fitness

Literary subjects, science subjects, mathematics, and English had a non-significant positive correlation with VO_2pic. Significant associations were also found between all academic subjects (except for sciences) and performance time (4x10 m) (r=0.058; P=0.142). Trimestral grade showed a significant positive association with VO_2pic (r=0.087; P=0.0273) and the performance time (4x10 m) (r=0.099; P=0.011). In general, all the associations between physical fitness and all academics subjects were very weak (Table 2).

Table 1: Descriptive characteristics of the study sample (n=643)

Variables	Girls (n=338)	Boys (n=305)	P value
Height (cm)	155.6±8.2	153.2±10.5	0.0014
Weight (kg)	48.4±11.9	43.3±9.7	0.0001
BMI (kg/m^2)	19.8±3.8	18.2±2.4	0.0001
4x10m (sec)	10.7±0.9	9.5± 0.8	0.0001
VO_2pic (mlO_2/kg/min)	40.0±3.9	44.7±3.7	0.0001
Maths	11.1± 1.9	10.6± 1.7	0.0018
English	11.2± 1.9	10.6± 1.7	0.0003
Science	8.0± 2.5	7.9± 2.3	0.0001
Literacy	11.3± 2.0	10.6± 1.9	0.0001
Trimestral average	11.0± 1.9	10.6± 1.7	0.0001

VO_2pic: maximum oxygen uptake; BMI: body max index; sec: second

Table 2: Linear regression analyses between fitness and academic performance (n=643)

	Duration (sec) : 4x10m	P	VO_2pic (mlO_2/kg/min)	P
	r		r	
Science	0.058	0.142	0.080	0.0418
Literacy	0.158	0.0001	0.017	0.6625
Trimestral average	0.099	0.011	0.087	0.0273
English	0.133	0.0007	0.052	0.187
Mathematics	0.117	0.0030	0.070	0.0767

*VO_2pic: maximum oxygen uptake; sec: second; mlO: milliliter of oxygen

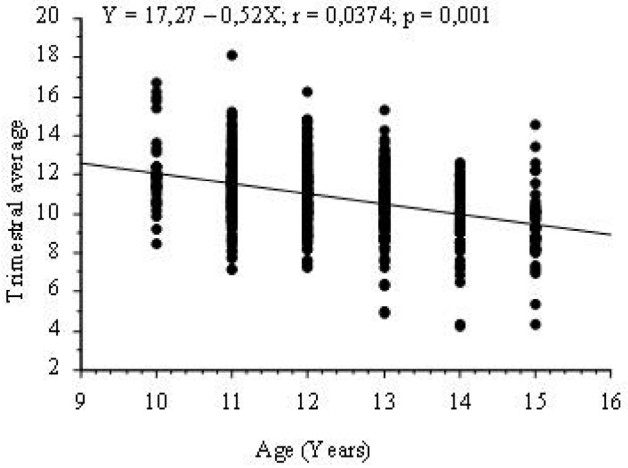

Figure 1: Association between Trimestral average and age

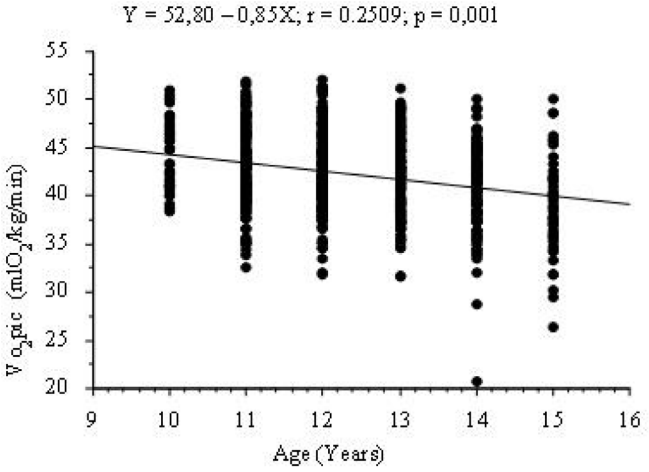

Figure 2: Association between VO_2pic and age. VO_2pic: maximum oxygen uptake

The trimestral grade was the only academic performance with a significant relationship with one component of physical fitness (VO_2pic), hence considered in this study. The relationship between the trimestral grade and the age showed that younger students had a better performance (Figure 1). The relationship between VO_2pic and age was significant; however, VO_2pic decreased with the increase in age (Figure 2), which was observed in all grades (sixth, fifth, fourth). Meanwhile, Figure 3 shows that older students had a better performance regarding this physical activity.

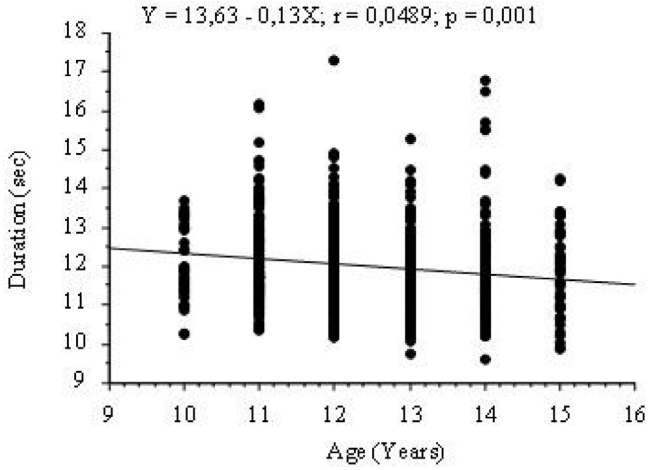

Figure 3: Association between duration and age

4. Discussion

The main objective of this study was to assess the relationship between physical fitness and academic performance among the students of Douala, Cameroon.

In general, very weak associations existed between physical fitness studied and academic performance. However, it is important to note that younger students had higher levels of VO_2pic compared with their older counterparts. On the contrary, younger pupils had a poor time performance compared to older ones. Despite these conflicting results between younger and older students, academic performance remained better among the younger students. These major findings shed light on the important role of physical fitness in enhancing cognitive processes.

There is extensive literature demonstrating that physically active students have a better academic performance in comparison to their less active peers (7, 8, 19). Physiologically, there is evidence that a high supply of oxygen is beneficial for angiogenesis in the motor cortex, increasing the blood flow (20-23). For instance, it is accepted that cerebral vascularization taking place during angiogenesis may ameliorate the

cognitive performance. Furthermore, aerobic physical activity is known to augment brain-derived neurotropic factor, which promotes survival and neuronal differentiation (24). Cognition is continuously peaking throughout childhood; therefore, cardiorespiratory fitness, measured as VO_2pic, body mass index (muscle mass), physical activity, and cognition function, maybe associated with positive cognitive performance (given the ability of the brain to modulate neuroelectric cues from cognitive control) (25-27).

The absence of a strong relationship between VO_2pic or time performance and academic performance might be attributed to socioeconomic factors (Table 2). Previous studies highlighted the strong correlation between socioeconomic status and prevalence of obesity among Cameroonian students (12, 15). Navti and colleagues (12) recommended the no-self-reported measures of physical activity due to the inverse relationships between body mass index and physical activity. Thus, the low socioeconomic status combined with the high prevalence of overweight participants in these studies may have reduced the physical performance. Accordingly, a low socioeconomic status can undermine the positive associations generally observed between physical fitness and academic performance (28-30). In Cameroonian, it is known that the most disadvantaged groups have limited access to the numerous, rare, and expensive textbooks (31). This explains the 2017 government action taken on the adoption of a single book by subject. In fact, according to the Maslow's hierarchy of needs (32), children with biological and physiological needs (food, warmth, shelter, sleep) may have difficulties succeeding academically regardless of their apparent physical fitness. With the increase in age, we found that Trimestral average, VO_2pic, and duration time decreased (Figures 1, 2, and 3). These results illustrated the negative effect of increase age on intelligence and endurance and its positive effect on velocity performance. Older students are believed to be affected by the onset of pubertal crisis. This period is characterized by physical and psychological changes where most children tend to have reduced physical activity through sedentary behaviors (time spent on watching TV, playing video games, and using mobile phones) (33, 34). Weight gain is often observed in girls during this period, which explains the significant negative correlation we found between body mass index and academic outcomes. Our results also showed that female students' body mass index was higher than boys. These results are in line with Ramos-Sepulveda and colleagues (35) who found a body mass index superiority among Colombian and Indian girl students over boys. In fact, it is known that cardiorespiratory fitness triggers the secretion of hormones such as estrogen, which promote the development of adipose tissue at the expense of lean mass in girls (35, 36). On the other hand, in boys, the secretion of testosterone, which is a double androgenic and anabolic hormone, allows for muscle development and decreased fat mass (35, 36).

Concerning cardiorespiratory parameters, as expected, we found that boys had a maximum oxygen uptake (VO_2pic) and a better time performance compared with girls. Our findings have been confirmed by several comparative studies on the cardiorespiratory performance of boys and girls (7, 8). It is known that VO_2pic increases with age although this is only valid for a comparative approach between subjects with similar training levels. Other factors that could explain the superiority of the VO_2pic in younger students are their higher propensity, enthusiasm, and enjoyment for activities beyond those practiced during physical education and sports lessons. Before pubertal crisis, students are able to concentrate all their attention and energy towards performing different physical activities. It was established that physical activities other than those in sports classes were widely encouraged to further optimize the VO_2pic (19, 37). Physical activities can induce synaptogenesis where the increase in neurotropic factor receptors may reorganize and/or promote neuronal survival in the motor cortex (34). Furthermore, during a motor activity, the spinal cord plays a central role in coordinating neural changes related to motor skills and cognitive development. The good performance of older pupils over younger ones is, therefore, linked to the development of their organism. It is understandable that bodily and muscular aspects (height or size of the limbs) grow with age, which is important for resistance or strength activities.

The cross-sectional nature of the study did not allow us to draw conclusions about the direct causes of the associations/correlations we found. Another limitation was the impossibility of considering the socio-economic status of each student and using academic records instead of standardized tests.

5. Conclusions

The findings of this study showed that physical fitness among high-school children could have beneficial effects on academic performance. More research on the ability to develop, improve, and maintain a good academic performance is required to determine the direct impacts of physical health

conditions; however, aerobic physical activities should be encouraged throughout the school year together with academic activities. Our study suggested that cardiorespiratory fitness might trigger the brain's components for learning and memory in students. Thus, it is clear that socioeconomic status might have a negative impact on both physical health conditions and academic performance.

Acknowledgement

The authors wish to acknowledge all the principals, teachers, and parents of children who participated in this study.

Ethical Approval

The Institutional Ethics Committee for Human Health Research at the University of Douala approved this study under the reference number: 1670 CEI-Udo/12/2018/M.

Funding

This study received no grant from any institution/company/university.

Conflicts of interest: None to declare.

References

1. Andersen LB, Sardinha LB, Froberg K, Riddoch CJ, Page AS, Anderssen SA. Fitness, fatness and clustering of cardiovascular risk factors in children from Denmark, Estonia and Portugal: the European Youth Heart Study. Int J Pediatr Obes. 2008; 3(1):58–66. doi: 10.1080/17477160801896366. PubMed PMID: 18278634.
2. Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, et al. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. Eur J Cardiovasc Prev Rehabil. 2007; 14 (4):526–31. doi: 10.1097/HJR.0b013e328011efc1. PubMed PMID: 17667643.
3. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40. doi: 10.1186/1479-5868-7-40. PubMed PMID: 20459784; PubMed Central PMCID: PMC2885312.
4. Biddle SJH, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. Br J Sports Med. 2011;45 (11):886-95. doi: 10.1136/bjsports-2011-090185. PubMed PMID: 21807669.
5. Ruiz JR, Cavero-Redondo I, Ortega FB, Welk GJ, Andersen LB, Martinez-Vizcaino V. Cardiorespiratory fitness cut points to avoid cardiovascular disease risk in children and adolescents; what level of fitness should raise a red flag? A systematic review and meta-analysis. Br J Sports Med. 2016; 50 (23):1451-1458. doi: 10.1136/bjsports-2015-095903. PubMed PMID: 27670254.
6. Singh AS, Saliasi E, Van den Berg V, Uijtdewilligen L, de Groot RHM, Jolles J. et al. Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. Br J Sports Med. 2019;53 (10):640-647. doi: 10.1136/bjsports-2017-098136. PubMed PMID: 30061304.
7. Esteban-Cornejo I, Tejero-González CM, Martinez-Gomez D, del-Campo J, González-Galo A, Padilla-Moledo C, et al. Independent and combined influence of the components of physical fitness on academic performance in youth. J Pediatr. 2014;165(2):306-312. e2. doi: 10.1016/j.jpeds.2014.04.044. PubMed PMID: 24952710.
8. Gil-Espinosa FJ, Cadenas-Sanchez C, Chillón P. Physical fitness predicts the academic achievement over one-school year follow-up period in adolescents. J Sports Sci. 2019;37(4):452-457. doi: 10.1080/02640414.2018.1505184. PubMed PMID: 30084752.
9. Nalova EM. School Type and Mathematics Achievement in English-Speaking Primary Schools in Cameroon: Implications for Technological Development. American Journal of Educational Research. 2017; 5(5):568-573. doi: 10.12691/education-5-5-15
10. Yakum IM, Kifem FL. Education and Earnings Inequality in Cameroon. American Journal of Humanities and Social Sciences Research. 2018: (2):1-11.
11. Wamba, PC, Enyong Oben J, Cianflone K. Prevalence of overweight, obesity, and thinness in Cameroon urban children and adolescents. J Obes. 2013;2013:737592. doi: 10.1155/2013/737592. PubMed PMID: 23862056; PubMed Central PMCID: PMC3703727.
12. Navti LK, Ferrari U, Tange E, Parhofer KG, Pozza SB, Parhofer KG. Contribution of socioeconomic status, stature and birth weight to obesity in Sub-Saharan Africa: cross-sectional data from primary school-age children in Cameroon. BMC Public Health. 2014;14:320. doi: 10.1186/1471-2458-14-320.
13. Navti LK, Ferrari U, Tange E, Parhofer KG, Pozza SB. Height-obesity relationship in school children in Sub-Saharan Africa: results of a cross-sectional study in Cameroon. BMC Res Notes. 2015;8:98. doi: 10.1186/s13104-015-1073-4.
14. Navti LK, Atanga MB, Niba LL. Associations of out

of school physical activity, sedentary lifestyle and socioeconomic status with weight status and adiposity of Cameroon children. BMC Obes. 2017;4:35. doi: 10.1186/s40608-017-0171-3.

15. Choukem SP, Kamdeu-Chedeu J, Leary SD, Mboue-Djieka Y, Nebongo DN, Akazong C, et al. Overweight and obesity in children aged 3–13 years in urban Cameroon: a cross sectional study of prevalence and association with socio-economic status. BMC Obes. 2017;4:7. doi: 10.1186/s40608-017-0146-4.
16. Mekoulou Ndongo, J, Assomo Ndemba, PB, Temfemo, A, DzudieTamdja, A, Abanda, MH, Bika Lele, et al. Pre- and post-exercise electrocardiogram pattern modifications in apparently healthy school adolescents in Cameroon. Int J Adolesc Med Health. 2017;31(6). doi: 10.1515/ijamh-2017-0071.
17. Bika Lele EC, Pepouomi MN, Temfemo A, Mekoulou J, Assomo Ndemba P, Mandengue SH. Effet d'un effort intermittent d'intensité variable sur la variation du QT et du risque de mort subite chez des élèves camerounais. Ann Cardiol Angeiol. 2018; 67 (1): 48-53. Doi : 10.1016/j.ancard.2017.03.003.
18. Leger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci. 1988;6(2):93-101. doi:10.1080/02640418808729800. PubMed PMID: 3184250.
19. Marques A, Santos DA, Hillman CH, Sardinha LB. How does academic achievement relate to cardiorespiratory fitness, self-reported physical activity and objectively reported physical activity: a systematic review in children and adolescents aged 6-18 years. Br J Sports Med. 2018;52 (16):1039. doi: 10.1136/bjsports-2016-097361. PubMed PMID: 29032365.
20. Swain RA, Harris AB, Wiener EC, Dutka MV, Morris HD, Heien ET. Prolonged exercise induces angiogenesis and increases cerebral blood volume in primary motor cortex of the rat. Neuroscience.2003;117(4):1037-46. doi:10.1016/s0306-4522(02)00664-4. PubMed PMID: 12654355.
21. Fraisl P, Mazzone M, Schmidt T, Carmeliet P. Regulation of angiogenesis by oxygen and metabolism. Dev Cell. 2009;16 (2):167-79. doi:10.1016/j.devcel.2009.01.003. PubMed PMID: 19217420.
22. Zimna A, Kurpisz M. Hypoxia-Inducible Factor-1 in Physiological and Pathophysiological Angiogenesis: Applications and Therapies. Biomed Res Int. 2015;2015:549412. doi: 10.1155/2015/549412. PubMed PMID: 26146622; PubMed Central PMCID: PMC4471260.
23. Rossi Dare L, Garcia A, Alves N, Ventura Dias D, de Souza MA, Mello-Carpes PB. Physical and cognitive training are able to prevent recognition memory deficits related to amyloid beta neurotoxicity. Behav Brain Res. 2019;365:190-197. doi: 10.1016/j.bbr.2019.03.007. PubMed PMID: 30844418.
24. Enette L, Vogel T, Merle S, Valard-Guiguet AG, Ozier-Lafontaine N, Neviere R. Effect of 9 weeks continuous vs. interval aerobic training on plasma BDNF levels, aerobic fitness, cognitive capacity and quality of life among seniors with mild to moderate Alzheimer's disease: a randomized controlled trial. Eur Rev Aging Phys Act. 2020;17:2. doi: 10.1186/s11556-019-0234-1. PubMed PMID: 31921371; PubMed Central PMCID: PMC6945614.
25. Pontifex MB, Raine LB, Johnson CR, Chaddock L, Voss MW, Cohen NJ. et al. Cardiorespiratory fitness and the flexible modulation of cognitive control in preadolescent children. J Cogn Neurosci. 2011;23 (6):1332-45. doi: 10.1162/jocn.2010.21528. PubMed PMID: 20521857.
26. Chaddock L, Erickson KI, Prakash RS, Kim JS, Voss MW, Van Patter M, et al. A neuroimaging investigation of the association betweenaerobic fitness, hippocampal volume, and memory performance in preadolescent children. Brain Res. 2010; 1358: 172–183. doi: 10.1016/j.brainres.2010.08.049. PubMed PMID: 20735996; PubMed Central PMCID: PMC3953557.
27. Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Dev. 2000;71 (1):44-56. doi: 10.1111/1467-8624.00117. PubMed PMID: 10836557.
28. Abdurrahman A. Socioeconomic status, physical fitness, self-concept, attitude toward physical education, and academic achievement of children. Percept Mot Skills. 2010 110 (2):531-46. doi: 10.2466/PMS.110.2.531-546. PubMed PMID: 20499564.
29. de Greeff JW, Hartman E, Mullender-Wijnsma MJ, Bosker RJ, Doolaard S, Visscher C. Physical fitness and academic performance in primary school children with and without a social disadvantage. *Health Educ Res*. 2014 ; 29 (5) : 853–860. doi: 10.1093/her/cyu043. PubMed PMID: 25092881.
30. Toru I, Noriteru M, Toshihiro N, Koichi O, Koji Y, Masato S. Direct and indirect relationships of physical fitness, weight status, and learning duration to academic performance in Japanese schoolchildren. Eur J Sport Sci. 2018 ; 18 (2):286-294.doi:10.1080/17461391.2017.1409273. PubMed PMID: 29220310.
31. Read T. Where Have All the Textbooks Gone? The Affordable and Sustainable Provision of Learning and Teaching Materials in Sub-Saharan Africa. Washington, DC: World Bank Group. 2015. doi : 10.1596/978-1-4648-0572-1.
32. Maslow A. A Theory of Human Motivation.

Psychological Review. 1943 ; 50 (4) : 370-396. doi :10.1037/h0054346.

33. Ardoy DN, Fernandez-Rodriguez JM, Jimenez-Pavon D, Castillo R, Ruiz JR, Ortega FB. A physical education trial improves adolescents cognitive performance and academic achievement: the EDUFIT study. Scand J Med Sci Sports. 2014;24 (1):e52-61. doi: 10.1111/sms.12093. PubMed PMID: 23826633.
34. Sleiman SF, Henry J, Al-Haddad R, El Hayek L, Abou Haidar E, Stringer T. Exercise promotes the expression of brain derived neurotrophic factor (BDNF) through the action of the ketone body β-hydroxybutyrate. eLife. 2016; 5: e15092. doi: 10.7554/eLife.15092. PubMed PMID: 27253067; PubMed Central PMCID: PMC4915811.
35. Ramos-Sepulveda JA, Ramerez-velez R, Correa-Bautista JE, Izquierdo M, Garcia-Hermoso A. Physical fitness and anthropometric normative values among colombian-indian schoolchildren. BMC Public Health. 2016;16:962. doi: 10.1186/s12889-016-3652-2. PubMed PMID: 27619491; PubMed Central PMCID: PMC5020445.
36. Paludo AC, Bastista MB, Junior HS, Cyrino ES, Vaz Rongue ER. (2012). Estimation of cardiorespiratory fitness in adolescents with the 9-minute run/walk test. Revista Brasileira Cineantropometria e Desempenho Humano. 2012; 14(4):401-408.
37. Grissom BJ. Physical fitness and academic achievement. JEP online. 2005; 8:11-25.