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Original Research Article

Relationship of aerobic fitness and self-reported physical activity with academic achievement among school children of Surat city, Gujarat: a correlation study

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ABSTRACT

Background: Aerobic fitness (AF) and Physical activity (PA) has shown a numerous valuable effects on physical and mental health of school children. However, research on relationship of AF and PA with Academic achievement (AA) has been less explored in the developing countries. So the present study was undertaken to examine the relationship of AF and PA with AA among school children of Surat city, Western India.
Methods: A total of 579 children aged between 10 to 14 years, were enrolled from 14 granted/nongranted schools of Surat city. Data on children's demographics, anthropometric measures (height, weight, Body Mass Index), AF (20m shuttle run test) were abstracted. Information regarding head of the family, parents' education, occupation and monthly income along with physical activity readiness questionnaire (PARQ) were also noted from the parents. PA was measured with cross culturally adapted English and Gujarati version of Physical activity questionnaire – children (PAQ-C). Children's AA was measured by their recent examination results in mathematics, science, social study and language (Gujarati and English) subjects along with overall grades provided by the administrative services of the schools participating in the study. Spearmen's correlation coefficient was used to assess relationship of AF and PA with AA among children.
Results: Overall, mean VO2max for 20m shuttle run test among the children was 35.33±2.20 ml/kg/minute. Results of the study showed a significant moderate positive association of AF (VO2max and no.of laps) and PA (PAQ-C) with mathematics (rho=0.46, p<0.0001 for VO2max, rho=0.51, p<0.0001for no. of laps, rho=0.42, p<0.0001 for PA) and significant weak positive association of AF (VO2max and no.of laps) and PA (PAQ-C) with science (rho=0.34, p<0.0001 for VO2max, rho=0.32, p<0.0001for no.of laps, rho=0.36, p<0.0001 for PA) ,English (rho=0.35, p<0.0001 for VO2max, rho=0.34, p<0.0001for no. of laps, rho=0.35, p<0.0001 for PA), Gujarati (rho=0.39, p<0.0001 for VO2max, rho=0.33, p<0.0001for no. of laps, rho=0.38, p<0.0001 for PA) ,social study (rho=0.22, p<0.0001 for VO2max, rho=0.32, p<0.0001for no. of laps, rho=0.36, p<0.0001 for PA) and overall grades (rho=0.32, p<0.0001 for VO2max, rho=0.31, p<0.0001 for no. of laps, rho=0.34, p<0.0001 for PA) amongst all the children. All the correlations remain significant even after controlling socio-economical status and age.
Conclusions: The present study concluded that AF and PA has more impact on mathematics subject compared to science, language, social study and overall grades among school children. Academic success is associated with higher

INTRODUCTION

Health is basically related with physical activity (PA) and aerobic fitness (AF).[1] PA also increases general physical fitness (PF) and self-esteem and reduces stress and anxiety. Moreover, there is evidence that PA in childhood and adolescence is related to AF.[2] Regular practice of PA and a healthy cardiorespiratory fitness

(CRF) in school-age children are linked with health benefits, including improved bone mineral density, cardiovascular risk profiles, cardiorespiratory and muscular fitness, mental and brain health and body composition.[3] Many previous studies in neuroscience have shown that PA and AF are also related to brain structure and function, via thickness of gray matter in specific cortical regions and integrity of white matter tracts that support executive function, and also through alterations in brain plasticity that change the structure of the neuron and strengthening its signalling capability.[4,5] PA and AF also contribute to improve attention, memory and learning.[1]

PA and AF have encouraging role on brain structure, function, plasticity and cognition might translate to an improvement in Academic achievement (AA).[4] Regular practice of PA is important to maintain or improve AF. Although AF is determined by non-modifiable factors such as growth, maturation, sex, age and heredity, it is also influenced by moderate-to-vigorous PA and sedentary time.[6] Despite genetic contributions to AF, high levels of PA are related with improved AF, which means that PA and AF are closely related with each other.[7] Many previous different studies have independently examined the relationship between PA and AF with AA. The results of a systematic review of studies from 19 countries in children and adolescents showed an unclear relationship between PA and AA.[8] These differences were because of the different tools used to measure PA. In most studies where PA was self-reported showed a positive relationship with AA and when PA was objectively measured showed not significant relationship with AA or found a negative association.[8] On the other hand, the relationship between CRF and AA has also been studied. The same systematic review focused on children and adolescents aged 6-18 years, where 22 studies were included, and found in most of them a positive association between CRF and AA.[8]

Regarding the Indian studies, literature focused on the relationship of AF and PA with AA among children and adolescents is scarce. In our previous study conducted on school children of Surat city,Gujarat showed a positive correlation between PA and AA among school children.[9] A study conducted on children of three primary schools of Bangalore, significant positive correlations between aerobic capacity (VO2 peak) and academic scores in math and Kannada were noted.[10] According to the scientific literature presented above, it is observed that the relationship between AF and PA in children want more evidence because there are only few studies focused on Indian children and adolescents as compared to other countries. Both PA levels and AF change from childhood to adolescence. Thus, their relationship could also vary, in addition to their influence on AA. Therefore, the aim of this study was to analyze the relationship of AF and self -reported PA with AA in school children of Surat city (Gujarat).

METHODS

The present study is the part of the large study. The study is registered under the clinical trial registry of India with registration no. CTRI/2018/12/016800. A cross sectional (correlation) study was conducted to analyze the relationship of AF and self -reported PA with AA on 579 school children of Surat city (Gujarat). Total duration of the study was from October 2018 to December 2020. The school authorities and principals were explained about the purpose and procedure of the study in their vernacular language. After obtaining written and verbal permission from school authorities/principals, a total of 14 granted /non granted schools (Gujarat board secondary education) were recruited for the study (2 schools from each zone of Surat city). Inclusion Criteria for the study was 6th, 7th and 8th standards children (girls and boys) from various state board schools (granted/non granted) located in seven (West zone, Central zone, North zone, East zone-A and East zone -B, South zone, South West and South East) zones of Surat city. Exclusion Criteria for the study were Children with any history of /diagnosed case of- diabetes, children with an acute or chronic respiratory disorder, children with cardio-vascular disorder, children with neurophysiological disorder, children with musculoskeletal disorder, children with any other known medical/systemic condition, children on any regular medication, children who are currently engaged in a regular basis in sports, parents who answered “yes to one or more questions” on children’s physical activity readiness questionnaire (PARQ), children diagnosed with any medical conditions or any health issues in annual health examination conducted by Surat municipal corporation which may affect test measures. Then parents of the children from the 6th, 7th, 8th standard received a leaflet including the brief description of the study along with exclusion criteria. Because of large number of responses from parents, a sample of 45 children (stratified by standard, 15 from each standard) from each school were selected randomly by lottery method from those who provided parental/guardians consent and child assent to complete the outcome measures used in the study. Once the permission is granted to recruit children from the school principal, requirement and schedule of the testing procedure were explained to principals and physical education (PE) teachers. Parents of the selected children were contacted by the principal investigator and trained research volunteers to obtain the information regarding head of the family, parents’ age, education, occupation and monthly income along with PARQ (physical activity readiness questionnaire). Principal investigator and trained research volunteers have completed all the assessment at the respective schools who granted permission to collect data from children. Testing of the study procedure was completed with a course of 2 days, with each visit lasted for approximately 3-4 hours. Anthropometric measures and 20m shuttle run test were assessed on first visit. Necessary information for proforma and fill up of physical activity questionnaire

for children (PAQ-C) to measure PA by children were completed on second visit. The children, absent on the day of CRF and PA measurement were excluded from the study. 51 students were absent on the day of survey so they were excluded. A total of 579 children were included in the study.

Outcome measures

AF of the children was assessed with 20 m shuttle run test. The children ran from one line to another line placed 20 m apart. The speed was increased progressively and announced with a sound signal. The initial speed of the signal was 8.5 km/h and it was increased by 0.5 km/h per minute (1 min was 1 stage). The test ended when the child was not able to reach one of the lines before the audio signal.[11] Score was noted in data recording sheet of 20 m shuttle run test as the total number of shuttles/laps (20 m) reached before the child was unable to keep up with the recording along with last level (stage) completed (not necessarily the level stopped at). This level score was converted to a VO_{2max} equivalent score using equation reported by Leger.[12] This test was conducted on a group of 3 children together. Immediately after body composition (Height and Weight) measurement and before continuing with 20 m shuttle run, children were asked to carry out 5-10 minutes warm up exercises. While conducting 20 m shuttle run test, the testing procedure was stopped immediately if subjective symptoms such as skin pallor, dizziness, syncope and dyspnea or any sign of discomfort were observed.

PA was measured with the self-reported PAQ-C which is a valid and reliable tool.[13,14] Cross culturally adapted English version of PAQ-C was used for the English medium students and Cross culturally adapted English PAQ-C was translated in Gujarati and validated by researchers for ease of use in Gujarati medium school children.[15] The PAQ-C includes nine items, each scored on a 5-point likert scale. The last question asks children about their health. This question was not used to score the PA level. A score of 1 indicates low PA, whereas a score of 5 indicates high PA.[16] The researchers obtained the verbal consent of the classroom teachers and children before administering the questionnaire. Necessary instructions to fill up PAQ-C were explained to the children and all of the questions were read out loud and any questions if they had been answered. The 15-20 minutes were given to fill up the questionnaire in the classroom.

Children's AA was measured by their recent examination results in core subjects like mathematics, science, language (Gujarati and English) and social study along with overall grades provided by the administrative services of the schools participating in the study.[17,18] For analysis, each of the subject grades and overall grades were rated as follows: Grade A^+=7, Grade A=6, B^+ =5 Grade B =4, Grade C^+=3, Grade C =2, Grade D =1, Grade E= 0.

Statistical analysis

Data analysis was done using SPSS version 21. Descriptive statistics were used to depict the characteristics of the study population, AF levels and PA levels. Spearmen's correlation coefficient was used to assess relationship between variables. Level of significant was kept as 5%.

RESULTS

A total of 579 students participated in the study out of which 263 were boys and 316 were girls. Number of students in grade 6th, 7th and 8th were 190,197 and 192 respectively in the present study. The students' details based on different variables like socioeconomical status (SES), doing homework or study, screen time (TV/mobile), attending tuitions and mode of transport for reaching to the school is depicted in (Table 1). Gender based descriptive statistics of the students for different variables (age, height, weight, BMI, $VO_{2\ max,}$ no. of shuttles and PAQ-C score) is shown in (Table 2). Correlation of AF (VO_{2max} and no. of shuttles) and self - reported PA with AA is depicted in (Table 3). All the correlations remain significant(less in strength, $p<0.05$) even after controlling for Age and SES for all the students (Table 4).

Table 1: Details of students' characteristics (n=579).

Variables	N
SES (according to Kuppuswami criteria)	
Upper (26-29)	005
Upper middle (16-25)	123
Lower middle (11-15)	125
Upper lower (5-10)	320
Lower (<5)	006
Doing homework/study (hours/day)	
None	006
<30 minutes	100
<1	190
1-2	145
2-3	124

Continued.

Variables	N
>3	014
Screen time (television) (hours/day)	
None	093
<30	193
<1	222
1-2	042
2-3	021
>3	008
Screen time (mobile/videogames) (hours/day)	
None	101
<30 minutes	350
<1	121
1-2	020
2-3	014
>3	023
Attending tuition	
Yes	369
No	210
Mode of transport usage for reaching school	
Fuel vehicle	258
Physical mode (cycling/walking)	321

Table 2: Gender based descriptive statistics of the students for different variables.

Parameters	Overall	Boys	Girls	Gender differences
N	579	263	316	-
Age (years)	12.42(0.95)	12.46(1.03)	12.40(0.89)	=
Weight (Kg)	34.26 (8.92)	34.08 (5.70)	34.85 (08.06)	=
Height(cm)	140.16 (10.53)	139.46 (12.26)	135.36 (12.63)	>
BMI (Kg/m^2)	18.56 (3.18)	18.22 (3.72)	19.36 (5.39)	<
20m Shuttle run test				
VO_2 max (ml/kg/minute)	35.33 (2.20)	37.26 (3.26)	34.25 (1.47)	>
No. of laps (shuttles)	16.12 (9.94)	18.86 (12.19)	14.30 (7.59)	>
PAQ-C score	2.20 (0.64)	2.25 (0.36)	2.01 (0.62)	>

Values are mean (standard deviation, SD) or number (%). In the "gender differences" column: symbol >, indicates the variable is significantly ($p<0.05$) higher in boys than in girls; <, the opposite; =, the non-significant differences; - , not applicable.

Table 3: Correlation of aerobic fitness and physical activity with academic achievement among students (n=579).

Parameters		Mathematics	Science	Language		Social study	Overall grades	P value
				English	Gujarati			
Aerobic fitness	**VO_2 max (ml/kg/minute)**	0.46	0.34	0.35	0.39	0.22	0.32	<0.0001
	No. of laps (shuttles)	0.51	0.32	0.34	0.33	0.32	0.31	<0.0001
Physical activity	**PAQ-C score**	0.42	0.36	0.35	0.38	0.36	0.34	<0.0001

Table 4: Spearmen's partial correlations of aerobic fitness and physical activity with academic achievement after adjusting age and SES among students (n=579).

Parameters		Mathematics	Science	Language		Social study	Overall grades	P value
				English	Gujarati			
Aerobic fitness	**VO_2 max (ml/kg/minute)**	0.41	0.29	0.12	0.24	0.11	0.26	<0.05
	No. of laps(shuttles)	0.43	0.30	0.22	0.21	0.13	0.22	<0.05
Physical activity	**PAQ-C score**	0.40	0.23	0.34	0.25	0.29	0.27	<0.05

DISCUSSION

The main aim of the present study was to find the relationship of AF and self-reported PA with AA in school going children. Results of the study showed a significant moderate positive association of AF (VO_2 max and no. of shuttles) and self- reported PA with mathematics and significant weak positive association of AF and self -reported PA with science, language, social study and overall grades. All the correlations remain significant (less in strength, $p<0.05$) even after controlling for age and SES for all the students.

In line with the present study, previous studies have also shown a positive association between AF and AA.[19-30] AF has been consistently reported to exhibit a positive association with mathematics.[19,21,22,25,27,28] A study done by de Greeff et al and Eveland-Sayers et al examined the 20-m endurance shuttle run and one-mile run, respectively, and reported a relationship of AF to mathematics and language/reading/spelling art achievement scores.[25,27] Wittberg et al also observed a positive association between AF and performance on AA tests in the areas of science and social studies in a sample of 968 preadolescent children. A similar positive association of AF with mathematics, reading and spelling has also been reported by Hansen et al.[2,28]

In the United States, Castelli et al found that physical fitness was generally associated with AA and in particular AF was associated with AA in students from grades 3 and 5.[19] Similar results were observed by other authors.[25,31] Two studies performed with huge samples of Texas students corroborate previous observations, demonstrating a positive association between AF and AA.[32,33] Even when analyses were adjusted for potential confounders, the results remained significant.[32,33] Few studies have shown positive relationships between PA and AA whereas some have revealed no correlation or an inverse relationship among school children/adolescents and also reported that the relationship between academic performance and PA needs to be examined by longitudinal studies.[9,17,34-40] However in most of the studies with positive association between PA and AA, subjective assessment measures were used to measure the PA. A study done by Syväoja et al in Finnish adolescents and a study done by Oliveira et al in Portugal children did not found any significant association between PA and AA.[2,41] A similar sample found that self-reported PA was directly associated with AA, however when PA was objectively assessed positive associations were not found. A longitudinal study done by Esteban-Cornejo et al and a study done by Booth et al found that PA and AA were negatively associated.[38,39]

Several mechanisms have been suggested to explain possible associations between AA and PA and AF. On the physiological level, studies have revealed that PA and AF persuade angiogenesis in the motor cortex as well as there is increase in the blood flow to the brain.[39,42,43] PA and AF also encourage neural development by increasing the thickness of neural synapses and influence the levels of neurotransmitters in the brain, such as serotonin and/or norepinephrine, thereby facilitating information processing.[44,45] It is thought that there is an important role of neurotoxins in inducing neurogenesis in response to PA .PA and AF also increase the synthesis of brain-derived neurotrophic growth factor (BDNF), which has a key role in brain plasticity, learning and memory.[46,47] It is even noted that the benefits of PA have a particular effect on the frontal lobes of the brain that are involved in the regulation of decision-making functions, which is also important in school success. Lastly, cross-sectional studies recommend that children with higher AF, when compared to children with a lower AF, have a higher volume of the hippocampus, as well as bigger basal ganglia, more efficient brain activation and higher neuroelectrical efficiency during cognitive tasks.[48] Psychologically it is believed there is crucial role of PA and physical fitness in reducing stress and anxiety, have valuable effects on mood due to the increased levels of norepinephrine and endorphins, increasing self- esteem and improving cognitive functions, in particular attention and working memory.[2,49,50] On a behavioural level, it has been suggested that PA and AF can improve students' behaviour in a learning context, as well as attention and concentration in classroom.[51] Furthermore, with a cross-talk mechanistic approach between organs, PA may induce systemic factors released from peripheral organs such as muscle (myokines), liver (hepato- kines) and adipose tissue (adipokines) that may contribute to neurotrophin and neurogenesis, as well as cognition and memory function.[52] Previous studies have shown that increasing AF and PA has more impact on mathematics and reading/spelling skills among school children In the present study AA was noted with written recent examination results in the core subjects which rarely focus on the reading (oral) and spelling skills. This could be one probable reason for the moderate association of AF and PA with mathematics compared to weak association of AF and PA with other core subjects and overall grades.[10,27,28,53] Though the strengths of the present study are its sample size and considering the potential confounder (Age and SES) however the study has several limitations, results need to be interpreted with caution. For example, the cross-sectional nature of the study limits the possibility to draw conclusions about causality of any of the observed relationships. The second limitation was gender-based analysis of the data was not done in the present study. The third limitation of the study was using self-reported questionnaire for obtaining PA while, objective measure of PA such as accelerometry could produce much more reliable results. In the present study, mediating effects of executive functions for the improvement in AA were not analyzed.

CONCLUSION

AF and self-reported PA are considered to be a predictor for the academic success in school children. Results of

the study concluded that significant positive moderate relationship of AF and PA with mathematics and significant positive weak relationship of AF and PA with science, language, social study and overall grades in the school going children. Considering the relationship between AF, PA and AA, low levels of AF and PA can jeopardized students' academic future. Therefore, an investment in physical education is important, because it might play a role in the positive effect of PA, fitness and consequently on cognition and academic success. These findings support the need to modify public health and educational policy to encourage schools and physical education teachers to work in order to improve children and adolescents' physical fitness. Outside school, the promotion of physical activity is also important, that does not appear to be detrimental to children and adolescence academic performance rather contribute to improve AF and overall physical fitness.

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