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Original Article

Impact of physical activity on the working memory of 10–11year-old children from the Colombo Educational Zone

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Key words: physical activity, childhood, working memory, cognitive function, memory

Abstract

Background and Objectives

Physical activity has a great influence on children's health and cognition. Working memory, a key aspect of cognitive function, is heavily implicated in classroom activities. As cognitive function improves in younger ages, identifying a relationship between physical activity and working memory would be beneficial to the child population. The objective of the study was to describe physical activity level and working memory capacity and to determine their relationship in 10–11-year-old children.

Methods

A cross sectional study was done involving 180 (90 boys) 10–11-year-old children randomly selected from six schools in Colombo, Sri Lanka. A physical activity questionnaire for children (PAQ-C) was used to assess the physical activity level. A wall mounted stadiometer and an electronic weighing scale were used to assess height and weight. To assess verbal and nonverbal components of working memory, the digit span test (forward and backward) and Corsi block tapping test (forward and backward) were used. Ethics clearance was obtained from the Faculty of Medicine, University of Colombo. Data was analyzed using the independent sample t test, Pearson correlation test and one way ANOVA test on SPSS version 25.

Results

Mean PAQ-C score and mean scores for digit span tests and Corsi block tapping forward test were significantly higher in boys compared to girls ($p<0.05$). Positive correlations were found between physical activity level and digit span forward test ($r=0.49$; $p<0.01$), Corsi block tapping forward test ($r = 0.31$; $p<0.01$) and Corsi block tapping backward test ($r=0.52$; $p<001$).

Conclusions

Increased physical activity levels lead to increase in working memory capacity. Sex difference was observed in physical activity level and working memory capacity where boys outperformed girls.

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Introduction

Physical activity is defined as any bodily movement produced by skeletal muscles which results in energy expenditure [1]. Physical inactivity is said to be the fourth leading risk factor for global mortality [2] and is associated with an increased incidence of disability

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and non-communicable diseases (NCD) including hypertension, diabetes mellitus and obesity [3]. Three fourth of NCD deaths occur in low- and middle-income countries and the greatest increase of NCD deaths was recorded in WHO Southeast Asia region [4]. Moreover, due to lack of physical activity, overweight and obesity have become major health concerns in modern society, not only in developed countries but also in developing countries.

Levels of physical activity have been shown to decrease during adolescence [5] and in Sri Lanka only 38% adolescent school children were reported to be getting sufficiently physically active [6]. However, the benefits of physical activity go beyond physical health and extend to psychosocial benefits [7] and increased cognitive function and academic performance [8].

Working memory is the ability to retain information in memory over a short period of time, which is a key aspect of cognitive functioning [9]. Baddeley defines working memory as "the brain system that provides temporary storage and manipulation of information necessary for such complex cognitive tasks as language, comprehension, learning and reasoning" [10]. Working memory is believed to support cognitive behaviors ranging from reading and comprehension to solving mathematical problems [11]. Furthermore, it is heavily implicated in classroom activities that involve focusing and completing tasks [12]. It is said that children with working memory difficulties are common in every classroom and are at a risk of poor academic performance if their working memory difficulties are not addressed [13].

Several studies have shown a positive correlation between physical activity level and working memory [14,15,16] Although most studies on working memory have focused predominantly on adult populations, it is more important to study children as their working memory can be improved which will benefit their classroom activities [15,16]. Therefore, the objective of the study was to determine the relationship between physical activity and the working memory of 10-11 years old children.

Methodology

A cross sectional study was designed to identify the impact of physical activity on the working memory of 10–11-year-old children from the Colombo Educational Zone, Sri Lanka. The study setting was six schools in the Colombo Educational zone including two national, two non-national and two semi government schools which were selected using stratified random sampling. A list of schools was taken from the Colombo Educational Zone and schools were divided into 6 strata as National Girls', National Boys', Non-National (Provincial) Girls', Non-National Boys', Semi government Girls' and Semi government Boys' schools. Schools under each stratum were listed and numbered separately. Numbers were then written on small papers of same size, and they were put into 6 boxes of same size. From each box one paper was selected randomly.

Inclusion criteria were children between 10-11 years. Children who had physical or mental disabilities, were ill during the study or were having a severe illness were

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excluded. Information sheets, proxy consent forms and questionnaires were given to parent/guardian to gather information on physical or mental disabilities and illness during the preceding two weeks. Further, we inquired from teachers about the educational abilities of children and anyone below the standard of an average child for the age were excluded.

A physical examination was performed to look for any significant physical abnormality which would hinder normal physical activity. Children were informed about the study and the first 30 10–11-year-old students with parents/guardians consent and student's assent to participate were selected on a first come first served basis in each school. This age group was selected as the data collection tools used in the study were mainly designed to suit this age group and also because understanding and logical ability is higher in this age group compared to students in primary classes. Further, early interventions which will benefit the children's physical and mental health can be implemented at this age.

Sample size was calculated to determine the expected correlation between physical activity and working memory. A previous study has reported correlations in the magnitude of 0.26 between physical activity and working memory [17]. Therefore, a correlation of 0.25 between the two parameters was considered to be realistic. Using this and an alpha error of 0.05 and a beta error of 0.9, the sample size required was calculated as 164 according to the following formula: Total sample size = $[(Z_\alpha+Z_\beta)/C]^2 + 3$ and $C = 0.5 * \ln[(1+r)/(1-r)]$, where Z_α =standard normal deviate for α error (1.96), Z_β = standard normal deviate for β error (1.28) and r =expected correlation (0.25). Allowing for a non-response rate of 10%, the final sample size was calculated as 180.

A self-administered physical activity questionnaire for children (PAQ-C), was used to assess the physical activity (PA) level. The first question was adjusted according to the sociocultural conditions and available sport activities in Sri Lanka. PAQ-C questionnaire has been ranked as one of the very few self-report instruments, which has acceptable validity, reliability and practicality [18]. Bervotes and coworkers have validated the PAQ-C questionnaire as a very useful tool in clinical practice with excellent content validity [19].

Working memory capacity was measured using the Corsi block tapping forward and backward tests (for nonverbal memory) and Digit span forward and backward tests (for verbal memory). Digital weighing machine (Model: EB9380H, Brand: Etekcity, Country: China) was used to measure the weight and wall mounted stadiometer (Model: STADIO-21, Brand: Axpert, Country: India) was used to measure the height. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m) and BMI for age charts available in the Sri Lanka Child Health Record (WHO 2007 standards) were used to categorize as wasting, normal, overweight, and obese. Statistical analysis was done using the statistical package for social sciences (SPSS) version 25.0 and the level of significance was considered to be at $p<0.05$. Demographic characteristics of the study participants were examined using appropriate descriptive statistics. Independent sample t test was used to identify the gender difference in PAQ-C score and scores of Corsi block tapping tests and Digit span tests. Pearson correlation was used to assess the relationship

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between the PAQ-C score and the scores of each working memory test. Ethics clearance was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Colombo.

Results

The mean age of the sample was 10.5 years (SD = 0.27). The mean height and weight were 1.3(SD=0.06) m and 28.0(SD=3.22) kg, respectively. Mean BMI of the sample was 16.1(SD=2.2) kg/m^2. Demographic characteristics of the study sample according to gender are shown in Table 1.

Table 1: Distribution of demographic characteristics of the study participants.

Demographic characteristics	Male	Female
Age(years)	10.5 (±0.27)	10.5 (±0.26)
Weight (kg)	28.7 (±3.3)	27.3 (±3.0)
Height (m)	1.3 (±0.05)	1.3 (±0.06)
BMI (kg/m^2)	16.0 (±2.1)	16.2 (±2.2)

Kg: kilograms; m: meter

Nutritional assessment revealed that 25 were wasted, four were overweight and four were obese. PAQ-C score, digit span forward test (DSFT) and digit span backward test (DSBT) scores and Corsi block tapping forward test (CBTFT) and Corsi block tapping backward test (CBTBT) scores for each gender and for the whole study sample is shown in Table 2.

Table 2: Distribution of the mean physical activity level, Digit span scores and, Corsi block tapping scores for each gender.

	Male		Female		Total		p value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
PAQ-C score	2.6	±0.66	2.1	±0.61	2.4	±0.68	0.001*
DSFT score	6.2	±1.2	5.4	±1.2	5.8	±1.3	0.001*
DSBT score	4.0	±1.2	3.4	±0.90	4.0	±1.1	0.001*
CBTFT score	5.9	±0.86	5.5	±0.85	5.7	±0.87	0.01*
CBTBT score	4.7	±1.0	4.7	±0.96	4.7	±0.99	0.88

PAQ-C: Physical activity questionnaire for children; DSFT: Digit span forward test; DSBT: Digit span backward test; CBTFT: Corsi block tapping forward test; CBTBT: Corsi block tapping backward test

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Mean PAQ-C score of the sample was 2.4(±0.68). Mean scores of the digit span forward test and digit span backward test were 5.8(±1.3) and 4.0(±1.1) respectively while the mean scores of Corsi block tapping forward test and backward test were 5.7(±0.87) and 4.7(±0.99) respectively.

Male students had a mean PAQ-C score of 2.6(±0.66) and female students had a mean PAQ-C score of 2.1(±0.61). Male students had significantly higher PAQ-C scores (t = 5.0; df = 178; p = 0.001) compared to the female students.

Male students had significantly higher scores in the digit span forward test (t = 4.0; df = 178; p = 0.001), digit span backward test (t = 3.7; df= 178; p =0.001) and in Corsi block tapping forward test (t = 2.6; df= 178; p = 0.01). But there was no significant difference in Corsi block tapping backward test among the two groups (t = 0.15; df= 178; p = 0.88).

Relationship of PA level with digit span forward and backward test scores, Corsi block tapping forward and backward test scores and BMI for the study sample and for each sex is shown in Table 3.

Table 3: The correlation between PA level with digit span test scores, Corsi block tapping test scores and BMI for the whole population and each gender.

	Total		Male		Female	
	Pearson Correlation	**Significance (2 tailed)**	**Pearson Correlation**	**Significance (2 tailed)**	**Pearson Correlation**	**Significance (2 tailed)**
PAQ-C score and DSFT	0.49*	0.00	0.40*	0.00	0.46*	0.00
PAQ-C score and DSBT	0.03	0.70	-0.23	0.03	0.14	0.18
PAQ-C score and CBTFT	0.31*	0.00	0.15	0.16	0.39*	0.00
PAQ-C score and CBTBT	0.52*	0.00	0.61*	0.00	0.48*	0.00
PAQ-C score and BMI	-0.12	0.12	-0.12	0.28	-0.09	0.38

PAQ-C: Physical activity questionnaire for children; DSFT: Digit span forward test; DSBT: Digit span backward test; CBTFT: Corsi block tapping forward test; CBTBT: Corsi block tapping backward test

Significant positive correlations were found between PAQ-C score and the scores of digit span forward test (r=0.49; p<0.01), Corsi block tapping forward test (r = 0.31; p<0.01) and

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Corsi block tapping backward test (r=0.52; p<0.01) as shown in Figures 1, 2 and 3, respectively.

No significant correlation was found between PAQ-C score and the score of digit span backward test. When the relationship was considered for each sex separately, similar relationships were observed in the girls. Therefore, the girls demonstrated a significant positive linear relationships between PAQ-C score and DSFT score, CBTFT score and CBTBT score. But in the male participants, significant positive linear relationships were found only between PAQ-C score and DSFT and CBTBT scores but not between PAQ-C score and CBTFT scores. Further, no significant positive correlation was found between PAQ-C score and DSBT score for both groups.

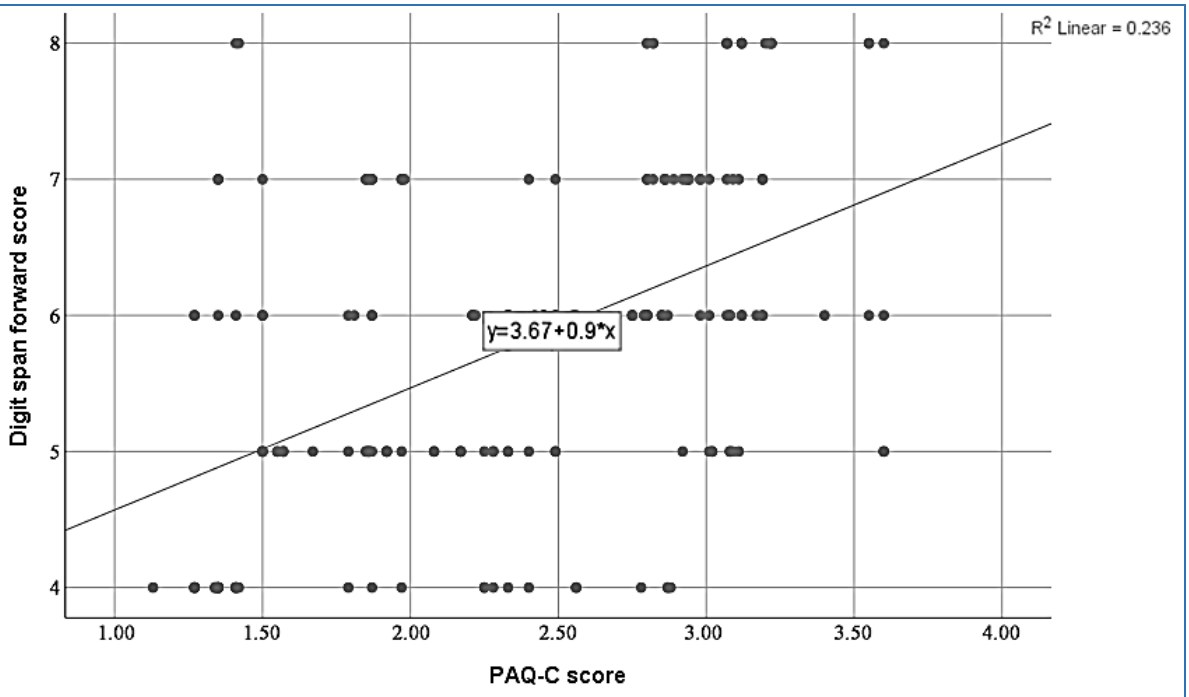

Figure 1: PAQ-C score and Digit span forward test score

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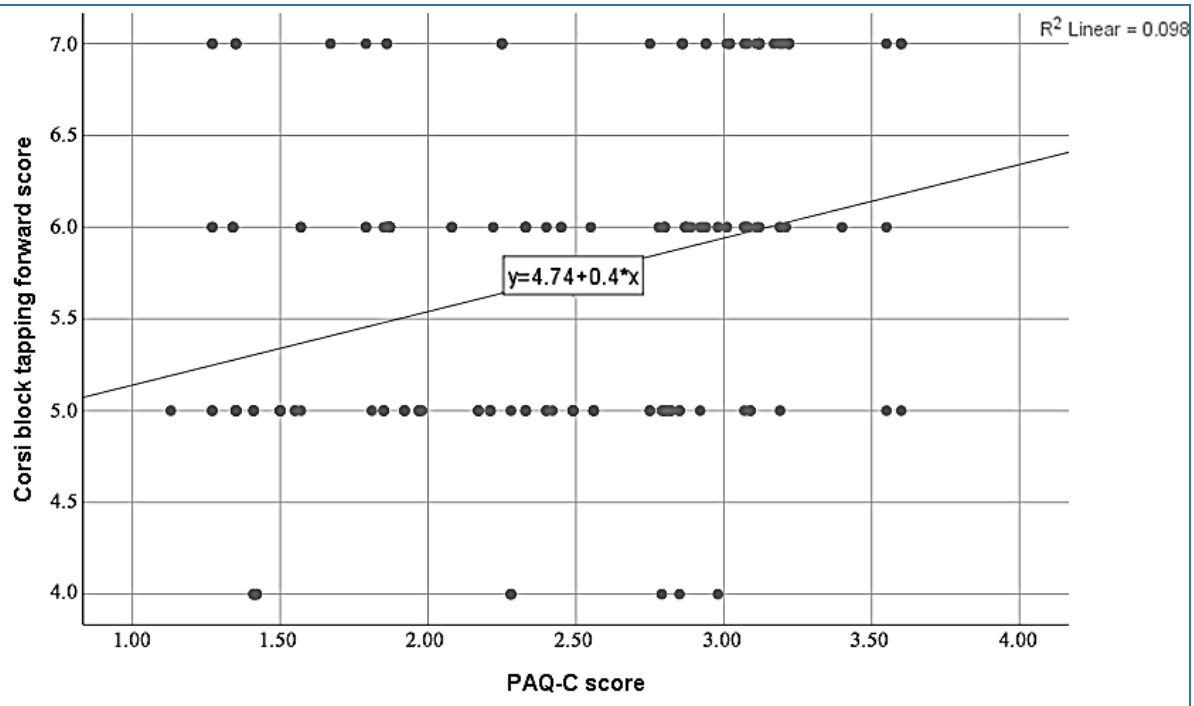

Figure 2: PAQ-C score and Corsi block tapping forward test score

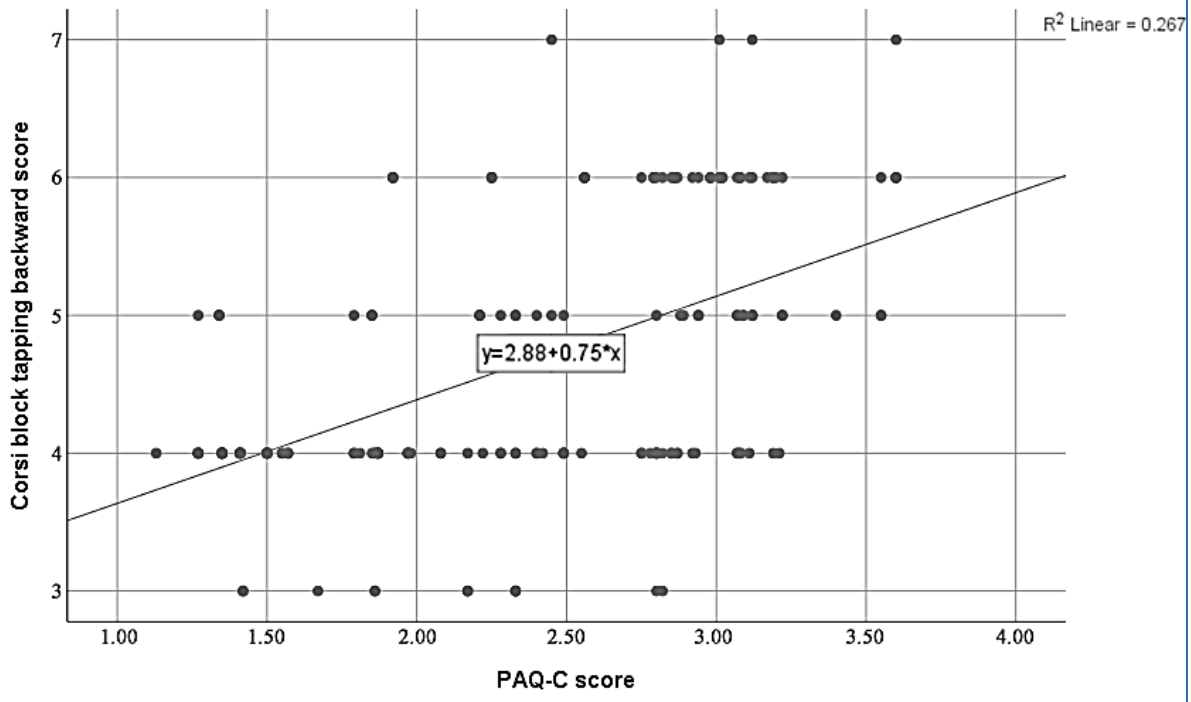

Figure 3: PAQ-C score and Corsi block tapping backward test score

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Discussion

Physical activity level

The mean PAQ-C score of the ~~current~~ study population was slightly lower than that reported in other studies. A study done in Saudi Arabia, has reported a mean PAQ-C score of 2.5 for normal weight, healthy, 10–16-year-old children [20]. Similar results were found in another study, which reported a mean PAQ score (PAQ-C & PAQ-A combined) of 2.6 for children and adolescents of 9–18-year-old with congenital heart disease [21]. A cross sectional study done in Spain showed a mean PAQ-C score of 3.1(±0.64) [21]. A possible explanation for the relatively low PAQ-C score reported in the current study might be due to the socio-cultural situation in the different countries and in the different age ranges concerned as genetic, environmental and socio demographic characteristics can affect the scores of physical activity level [20], Asian school aged children and adolescents have reported low physical activity levels [23].

When considering the sex difference in physical activity level, the results of the current study are in good agreement with other studies which have shown that the physical activity level of boys is higher than girls. Results show that boys had a mean PAQ-C score of 2.6(±0.66) vs girls (2.1(±0.61)). A study done in New Zealand using 20 children between 10-14 years old, to evaluate the effect of active video games on children's physical activity levels has reported that when considering the overall PA levels assed by accelerometer and PAQ-C scores, boys were more active than girls [23]. Another study involving 215, 9–15-year-old children has also revealed that boys were significantly more active (mean PAQ-C scores 3.4(±0.68)) than girls (mean PAQ-C scores 3.0(±0.69)) [25].

Working memory capacity

Another aim of the current study was to assess the verbal and nonverbal components of the working memory. Mean scores for the DSFT and DSBT reported in the current study were 5.8(±1.3) and 4.0(±1.1) respectively. A study done to identify the racial differences on digit span test showed 6.9(±2.2) for DSFT and 5.3(±1.9) for DSBT for Asian and Native Americans and 6.3(±2.3) and 5.1(±1.8) for Hispanic children for DSFT and DSBT respectively [25]. A study done in North America had identified a mean score of 4.1(±0.78) for DSFT and 3.1(±0.92) for DSBT, which are relatively lower when compared to the current study [27]. Another study had found mean scores of 5.2(±1.6) and 3.3(±1.6) for DSFT and DSBT respectively [28]. As DSFT and DSBT are influenced by ethnicity [24], the relatively higher scores of the current study might be due to the racial differences of the study participants concerned.

For the nonverbal component, mean scores of 5.7(±0.87) and 4.7(±0.99) were reported respectively for the CBTFT and CBTBT. A study done in Brazil has found similar results in which a mean score of 5.3(±0.94) for CBTFT and 4.8(±0.55) for CBTBT were reported [29]. However, some studies have found lower mean scores for Corsi block tapping test compared to the present study. A study done to identify cross-cultural differences in visual memory tasks, has found comparatively lower mean scores compared to the present study [30]. These differences can be accounted, in part, by the age ranges concerned.

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Previous research studies have stated that there is no sex difference in visuospatial memory according to Corsi block tapping test. Studies conducted in Brazil involving 60, 6- to 18-year-old children and adolescents [29] and 127, 7- to 10-year-old children [30], have also concluded that there is no gender difference in CBTF and CBTB test. Similar results were found in another study done in Netherland, involving 246 healthy adults of 50 to 92 years of age [31]. However, the present study revealed gender difference in CBTFT and this rather contradictory result could be due to the different age ranges concerned. In the present study only 10–11-year-old children were involved but in the other studies participants of a wide age range had been taken into account. Another possible explanation might be the cross-cultural differences of the study participants concerned as other studies have been carried out in Western countries.

Many studies did not show sex difference in short term verbal memory measured by digit span test [31, 32, 33]. But sex difference in DSFT & DSBT was identified in the present study where boys outperformed girls. In contrast Temple & Cornish, in their study has found that girls outperformed boys on a verbal memory recognition task [34]. These contradictory results might be due to the different study tools used.

Correlation between physical activity level and working memory capacity

It was hypothesized that a relationship would exist between physical activity and working memory and the present data supported the hypothesis. Significant positive correlations were found between PAQ-C score and DSFT ($r = 0.49$; $p<0.01$), CBTFT ($r = 0.31$; $p<0.01$) and CBTBT ($r = 0.52$; $p<001$). However no significant correlation was found between physical activity and DSBT. It was difficult to compare the present findings with those of the literature as most of the studies have used different data collection tools to assess physical activity level and working memory capacity. Despite the discrepancies in the data collection tools used, the result of the present study was consistent with previous research on the topic [15,16].

Therefore, it appeared that physical activity may have an impact on working memory which is a part of cognitive functioning that requires effortful processing, and this impact would be more in preadolescent children as their working memory develops at this age [14]. The present investigation not only supports the importance of regular physical activities in preadolescent children but also reveals the need for strategies to implement physical activity programs at school level.

Conclusions

According to the results, male students had higher physical activity levels compared to girls. Also, as three out of four working memory tests showed significant positive correlations with physical activity level it is important to provide adequate facilities to school children to engage in physical activities which would in turn improve their working memory thus leading to better academic achievements.

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Limitations

The generalizability of these results is subject to certain limitations. The main limitation is the relatively small sample size. Another limitation of the study is the narrow age range of the participants. Therefore, the findings might not be transferable to children in other age groups. Even though the PAQ-C questionnaire is a valid and reliable subjective tool to assess physical activity levels in children, it is unfortunate that the study did not include any objective measure of assessing physical activity level like accelerometer, pedometer etc. due to scarcity of resources.

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