Effect of physical activities on working memory: A comparative study between children active and not active in regular physical activities

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Submission date: 08-Mar-2018 02:49PM (UTC+0530)
Submission ID: 927173716
File name: Paper3.docx (53.94K)
Word count: 5152
Character count: 29892

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Abstract

Researchers have reported the influence of various factors affecting scholastic performance in children, but there appears to be limited literature reporting the influence of physical activities on working memory. Hence the present study was planned to see the difference in performance between children who regularly engaged in physical activities and children with no regular physical activities. A total of 160 native Kannada speaking children within the age range of 8 to 12 years were selected for the study and were divided into 2 groups. Group 1 consisted of 80 children who engaged in regular physical activities for 1-2 hour per day and group 2 consistedof 80 children who did not engage in any regular physical activities other than school physical education hour. Auditory working memory task and digit ordering task were administered on the selected participants. The analyzed data was subjected to appropriate statistical analysis. Results showed significant differences in the working memory tasks between two groups. Children participating in regular physical activity had better working memory which can enhance learning experience and academic achievement. The above study results support the fact that physical activities have positive influence on working memory. Increased participation in sport and other physical activity improves attention, memory and various other cognitive functions which are vital for academic achievement. Thus, it is equitable to recommend regular physical activities for children as an evidence-based strategy for better scholastic performance.

Key Words: *Working memory, Physical activities, academic performance.*

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Introduction

Cognition involves a wide range of mental processes such as attention, pattern recognition, memory, organization of knowledge, language, reasoning, problem solving, classification, concept and categorization (Best, 1999). These cognitive processes are interrelated with one another. Memory is an aspect of cognition that regularly intrudes into everyday activities (Owens, 2012). Specifically, cognitive psychologists have identified three common operations of memory namely encoding, storage and retrieval. Each operation represents a stage in memory processing. In encoding, sensory data is transformed into a form of mental representation. In storage, encoded information is kept in memory. In retrieval, information which is stored is used (Baddeley, 1998, 1999, 2000; Brown & Craik, 2000).

Based on the processing, memory can be divided into three types. Short-term memory, long-term memory and working memory. "Short-term memory" is the active process of storing and retaining information for a limited period of time. The information is temporarily available but not yet stored for long-term retention. "Long-term memory" refers to information that has been stored and available over a long period of time. Whereas "Working memory" (WM) refers to the temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities(Baddeley, 2003).

A rapidly growing body of literature has focused on the relation between cognition and academic achievement especially highlighting role of WM for better scholastic performance (Gathercole et al., 2003; Gathercole et al., 2004;Geary, 2004; Adams & Hitch, 1998). Children at school need WM on a daily basis for a variety of tasks such as language comprehension, vocabulary development, reading, writing, arithmetic, following instructions, spelling achievement, note taking and various other tasks. (Alloway, 2010; Engle, Tuholski, Laughlin, and Conway, 1999).Alloway et.al (2009) investigated 308 childrenwho were identified as having WM impairments. Results revealed poor cognitive and behavioral profiles and as well aspoor learning measures and verbal ability. Children with working memory deficits were judged to have short attention spans,difficulties in generating new solutions to problems, high levels of distractibility, and problems in monitoring the quality of their work. Gathercole (2007), Alloway (2010),Tariq & Noor (2012) also reports academic failures in children with poor WM.

Various factors have been reported to have effects on cognitionviz.emotional issues, sleep quality, developmental disorders, neuroanatomical and neurophysiological changes (Christopher & Mc Donald, 2005; Owens et.al. 2012; Steenariet.al. 2003;Achibad& Gathercole, 2007; yarrow et.al. 2009). Among various factors one factor which is attaining much attention is physical activities and its influence on cognitive abilities. An emerging body of multidisciplinary literature has documented the beneficial influence of physical activity, physical fitness on cognitive functioning (Sibley &Beilock, 2007; Brisswalter, Collardeau, &Arcelin, 2002; Tomporowski, 2003; Lambourne, 2006; Kamijo et. al., 2004).

Regular physical activity during a person's childhood and adolescence is widely acknowledged as essential for healthy growth and development as well as for cognitive and neuro cognitive functioning (Hills, King, and Armstrong, 2007; Pesce&Audiffren, 2011; Verburgh et al., 2016). Increased participation in sport and other forms of physical activity enhances attention and concentration, behavior, cognitive flexibility, planning, problem solving, memory which are key factors for academic achievement (Diamond, 2013).Both behavioral and neuroscientific evidence supports this association (Khan & Hillman, 2014; Tomporowski et al., 2011). Differences at brain structural and cognitive functional levels, higher efficiency in cognitive control and motor preparation, memory and learning, and higher academic performances has been reported in children who are engaged in physical activities compared to sedentary children (Berchicci et al., 2015; Chaddock et al., 2010; Chaddock, Hillman et al., 2011; Pontifex et al., 2011; Raine et al., 2013; Howie & Pate, 2012; Singh et al., 2012).

World Health Organization (2016) recommends years at least 60 minutes of moderate-to-vigorous-intensity physical activity daily for children and youth aged 5 to 17. Moderate-to-vigorous physical activity encompasses a wide variety of activities that could range from a brisk walk to intensive exercise, such as running along with aerobic and strengthening exercises. But review of literature confirms the fact that in present days children are involved in more sedentary behaviors than being active.A survey was conducted by Tarun et al, (2016) to evaluate Physical Activity in Children and Youth in India. The survey was done across nationwide including children from rural as well as urban areas. Results revealed that most Indian children do not achieve recommended levels of physical activity and spend most of their day in sedentary pursuits. According to accelerometry-based ISCOLE studies in the city of Bengaluru, children aged 9 to 11 years spent an average of 9 hours of their waking time in sedentary pursuits (Denstal et.al.2015; Chaputet.al. 2015).Kehoe et.al (2012) reportschildren aged 6 to 10 yearsin or around the city of Mysuru were sedentary for an average of 5.3 hours per day.Swaminathan et al (2011)studied sedentary behavior in the city of New Delhi to show that children aged 8 to 15 years accumulated less than 1 hour/day.

Though extensive research has been done on physical activities and cognitive functioning, there is a dearth of literature which highlights the relation between physical activities and WM precisely.There is a need for evidence that can help shed light on the effect of physical activities onWM.In the attempt to contribute unifying the views on the physical exercises and WM performances in childrenthe present study was planned.

Need for the study:

While the benefits of physical activity on children's physical development have been studied extensively, only recently researchers have started to study the relationship between physical activity and children's cognitive abilities. Few studies havebeendocumented onthe influence of physical activities on cognitive and neurocognitive functioning, but relatively limited attempts have been made to document effects of physical activities on WM. Review of research showed studies related to physical activities and cognitive aspects in elderly population but there is a dearth of literature on the relationship between physical activities and WM functioning in typically growing children. Due to change of lifestyle and as well as school curriculum children are less engaged in physical activities which can have a negative impact on children physical and as well as mental health which in turn can affect their academic achievement. Hence there is an increasing need to study the effect of physical activities on WM in children. The present study is an attempt in this direction.

Aim & Objective:

To investigate the influence of physical activity on WM in typically developing children who are regularly engaged in physical activities and children with no regular physical activities.

Method:

Participants: A total of 160 typically developing native Kannada speaking children within the age range of 8 to 12 years who had no speech, language, hearing, neurological, academic and intellectual disorders participated in the study. The participants were selected from schools in the city of Dharwad. Group 1 consisted of eighty (40 males and 40 females) children who engaged in regular physical activities for 1-2 hour per day for the past 1-2 years. (Badminton, basketball, throw-ball, volleyball, football, Taekwondo, and athletics).Group 2 consisted of eighty (40 males and 40 females) children who did not engage in any regular physical activities other than school physical education hour. Permission was taken from the school authority and also from parents through informed consents.

***Table 1:** Number of participants in each age group*

Age range (years)	**Group I** (Children engaged in regular physical activities)			**Group II** (Children with no regular physical activities)		
	Males	Females	Total	Males	Females	Total
8-9	10	10	20	10	10	20
9-10	10	10	20	10	10	20
10-11	10	10	20	10	10	20
11-12	10	10	20	10	10	20
Total	40	40	80	40	40	80
Grand Total	80			80		160

Material and instructions:

Auditory working memory (AWM) task and digit ordering task (DOT) were selected from previous study by Anjali (2010). Test material is given in appendix. The AWM stimuli consisted of 10 series with each series consisting of three nouns and three digits randomly arranged. Subjects were instructed to listen to the stimuli and to repeat the nouns first followed by numbers in the same sequence of presentation. For example in the series 3-8-

vÁ¬Ä-9-HgÀÄ-ZÀªÀÄZÀ the participant was required to recall the words vÁ¬Ä, HgÀÄ, ZÀªÀÄZÀ followed by the numbers 3, 8 and 9.

In DOT,single digit numbers ranging from a series of three to eight numbers were presented to the participant. Digits were presented at a rate of about one digit per second. The participant was required to report them back immediately in ascending numerical order.

For example: Stimuli: 9 4 0 6

Correct Response: 0 4 6 9

Procedure:

Test stimuli were pre-recorded using Sony MP3 digital voice recorder in a sound-treated room. The nouns and digits were recorded at a rate of one per second by the examiner.Pre-recorded stimuli were transferred to dell laptop and were presented to the subjects at comfortable intensity level using Sennheiser headphone. Each child was tested individually. The subject was seated comfortably on a chair facing the investigator across the table in a quiet and distraction-free room in the school. The examiner ensured that there was no interference from extraneous noise or visual distraction, so as to derive their concentration and complete attention towards the task and to control the effect of variables that would affect the subject's performance.A trial test was given for every child to confirm the understanding of instructions.

Scoring:

AWM task: Each response was scored live by the investigator on a score sheet. A score of one was assigned to each series for a correct recall of digits and nouns in the same sequence of presentation. When the participant was not able to recall the digits and nouns separately in the sequence of presentation, then a score of zero was assigned and the next series was presented to the participant. The task was continued until all the ten series of noun and digit combinations were presented to the participant. The scores for each of the series were summed to provide the total score out of ten which represented the participant's performance for the auditory working memory task.

DOT task: The participant was assigned a score of three when the participant was able to recall a series of three digits correctly in the ascending order. The investigator presented the next series of four numbers and when the participant recalled the digits correctly in the ascending order a score of four was assigned. Similarly, the scoring was done for other levels until the participant was able to recall the last series of eight numbers. When the participant made an error at any of the levels the test was terminated and the participant was assigned a score that corresponded to the previous correct level. Thus, all the 6 series were presented to the participant and the responses were obtained.

The scores obtained for both the tasks were tabulated and subjected to statistical analysis using IBM SPSS software (version 20).

Results:

The Mean and standard deviation (SD) were calculated for the scores obtained by both the groups for each task. Univariate Analysis of variance (UNIANOVA) was carried out to find the differences between both the groups followed by Bonferroni post hoc test.Table 2 and 3 depict the results for the AWM task and DOT in both the groups.

Table 2: Mean scores and SD values for AWM and DOT task for group 1 and group 2

Groups	**AWM task**	**DOT task**
	Mean (SD)	**Mean (SD)**
Group 1	3.54 (1.19)	15.85 (4.2)
Group 2	0.84 (1.17)	10.45 (6.1)

Table 3: Mean scores and SD values for AWM and DOT task for group 1 and group 2 across age groups

Age range	**Group**	**AWM Task** Mean (SD)	**DOT Task** Mean (SD)
8-9	Group 1	3.40(0.94)	13.15(1.75)
	Group 2	0.15(0.36)	5.60(4.45)
9-10	Group 1	3.55(1.23)	15.80(4.15)
	Group 2	0.60(0.94)	9.75(5.03)
10-11	Group 1	4.55 (1.46)	5.80 (1.29)
	Group 2	1.05 (1.14)	4.98 (1.11)
11-12	Group 1	7.13 (0.25)	17.60 (4.14)
	Group 2	1.55 (1.50)	11.90 (4.15)

From table 2 it can be inferred that for AWM task group 1 children performed better with mean & SD of 3.54 & 1.19 compared to group 2 children who scored poor with mean and SD of 0.84 & 1.17. Scores of DOT task was also better in group 1 children with mean & SD of 15.85 & 4.2, whereas group 2 children obtained poor scores with mean and SD of 10.45 & 6.1.For both the tasks no gender difference was observed. When compared to performance between AWM and DOT task both the groups performed better in DOT task compared to AWM task in all the age groups

As a part of inferential statistics, multivariate ANOVA was done to find the effect of physical activity, gender and age for WM tasks. The results showed significant difference in performance across age ($F=3.67$, $p<0.05$; $F=14.47$, $p<0.05$) and between both the groups ($F=220.0$, $p<0.05$; $F=53.98$, $p<0.05$) for both the tasks. Combined effect of age and groups also showed significant difference ($F=4.67$, $p<0.05$; $F=15.34$, $p<0.05$) for both the tasks.

Table 4: *Results of MANOVA for AWM and DOT task between the groups across the age*

Source of variations	***AWM task***		***DOT task***	
	F	***Significance***	***F***	***Significance***
AGE	**3.67**	**0.01**	**14.47**	**0.00**
GENDER	0.30	0.58	1.26	0.26
GROUPS	**220.0**	**0.00**	**53.98**	**0.00**
AGE* GENDER	0.66	0.57	1.07	0.36
AGE*GROUP	**4.67**	**0.02**	**15.34**	**0.00**
GENDER*GROUP	0.01	0.89	0.84	0.36
AGE*GENDER*GROUP	1.16	0.32	1.75	0.15

As there was significant interaction between age and groups, UNIANOVAwas carried out as a part of statistical analysis to check the effect of age on both the tasks and across the groups. UNIANOVA results revealed significant difference in performance between age groups for both AWM and DOT tasks($F= 10.48$, $p<0.05$& $F = 6.28$, $p<0.05$) and compared to group II, group I children outperformed in both the tasks.

Table 5: *UNIANOVA results of*effect of age on AWM task and DOT task in group I and group II

Group	***Task***	***F***	***Significance***
Group-I Children engaged in Physical activities	AWM	6.28	0.00
	DOT	10.09	0.00
Group-II Children with no physical activities	AWM	0.14	0.03
	DOT	4.85	0.00

Bonferroni post hoc test was done to compare the performance of children in AWM and DOT task between all the four age groups. Results showed significant difference in the performance of children between 8-9 years and other age groups, whereas children between age group 9-10 years, 10-11 years and 11-12 years did not show significant difference ($p<0.05$) indicating similar performance across higher age groups for both the tasks.

Table 6:*Bonferroni post hoc test results across age for AWM task*

Age in years	8-9	9-10	10-11	11-12
8-9		S	S	S
9-10			NS	NS
10-11				NS

*Note: S= significant NS= No Significant

***Table** 7: Bonferroni post hoc test results across age for DOT task*

Age in years	8-9	9-10	10-11	11-12
8-9		S	S	S
9-10			NS	NS
10-11				NS

Bonferroni test results for AWMand DOT task between all the four age groups for group I and II have been presented in Table and . Unexpectedly diverse performance has been noted for AWM and DOT tasks by group I and group II children. Results for group I children showed significant difference in the performance of children between 8-9 years and older age groups, whereas higher age groups showed similar performance for both AWM and DOT task. However group II children did not show significant difference in performance between younger and older age groups for AWM task but for DOT task difference was seen in performance between 8-9 years and older age groups.

Table 8: *Bonferroni post hoc test results across age for Group I children for AWM task*

Age in years	8-9	9-10	10-11	11-12
8-9		NS	S	S
9-10			NS	S
10-11				NS

Table 9: *Bonferroni post hoc test results across age for Group I children for DOT task*

Age in years	8-9	9-10	10-11	11-12
8-9		S	S	S
9-10			S	NS
10-11				NS

Table 10: *Bonferroni post hoc test results across age for Group II children for AWM task*

Age in years	8-9	9-10	10-11	11-12
8-9		NS	NS	NS
9-10			NS	NS
10-11				NS

Table 11: *Bonferroni post hoc test results across age for Group II children for DOT task*

Age in years	8-9	9-10	10-11	11-12
8-9		NS	S	S
9-10			NS	NS
10-11				NS

Discussions:

The present study aimed at investigating the influence of physical activity on WM in typically developing children who are regularly engaged in physical activities and children with no regular physical activities. Auditory working memory (AWM) and Digit ordering tasks (DOT) were administered to the selected group of children. While AWM task reflects the storage and processing functions to measure each individual'sWM capacity, DOT comprises coordination of several simultaneous storage and retrieval processes as required by the continuous updating of the encoded digit series.Both the tasks tapverbal and auditory short-term storageWM.Results showed that children who regularly engaged in physical activities performed better in both the tasks compared to the other group.Better performance in WM tasks by group 1 children can be attributed to the positive effect of regular physical activities. Present findings are in consonance with the study done by Hillman et al (2017), Kasper et al (2012), Pesce et al (2009), Ahamed et al (2007) and Lambourne (2006) who reports positive effects of physical activities on various cognitive functions including WM and academic achievement.Children from both the groups performed better in DOT task compared to AWM task. This can be attributed to the task complexity. DOT task involves recalling only digits while AWM task involves recalling words as well as digits in an orderly fashion which requires complex processing.

With respect to the age related performance older children performed better compared to younger children in both the tasks. This can be attributed to the fact that WM improves as the age progresses. This age- related progress in WM is supported from previous studies by Linda, Siegel & Ryan (1989), Vuontela et.al (2003), Gathercole (2004), Anjali (2010), Cowan et al, (2010), Finn et al., (2010) who also reports better performance for WM as age increases. Contrary to these findings no changes was seen across age in auditory working memory task for Group II children.

No significant gender differences were seen in performance for both the tasks ($F=0.302$, $p>0.05$; $F=1.260$, $p>0.05$). This result is in accordance with the studies done by Harness et al (2008), Tende et al (2010), and Tariq & Noor (2012) who also reported no differences for WM tasks between males and females.

Thus our results clearlyindicate that regular physical activities have a positive effect on WM which is important for learning and academic achievement in children. The outcome of this study is expected to contribute towards creating awareness about the importance of physical activities for children. Recent research evidence shows more sedentary behaviors in children and leading cause is attributed to technology such as television, computer and mobile phones (Katapally&Muhajarine, 2015; Tremblay et.al. 2011; Biddle et.al. 2010). Irrespective of physical activity level, sedentary behaviors are associated with increased risk of both physiological and psychological problems including negative effects on cognitive abilities.

A longitudinal survey by CentersforDiseaseControl and Prevention (2003, 2007 & 2008) reports reduced participation in physical activity by children at schools.Due to growing demand for higher academic scores children are refused by parents to engage in sports activities after school hours with the concern of decrease in academic performance. In contrary to above notion research shows that children and youth whospent moretimein physicaleducation class did not havelowertestscorescompared to individuals whospendlesstimeinphysicaleducationclass (Sallis et.al. 1999; Shephard, 1997; Carlson et.al. 2008).

Further studies exploring the association between physical activities and WM aspects in children will strengthen the present areaof research. The study could be extended toinclude not only a larger sample but also differentWM tasks as well as comparison of performance between individual sports/physical activities.

Summary and conclusion

While the benefits of physical activities on health have been unequivocally proven, relatively low attention isdevoted to the association between physical fitness and working memory aspects in children. Present study is an attempt to provide insight into the relationships between regular physical activity and working memory in children.Results showed significant differences in the working memory tasks in the children who regularly engaged in physical activities viz. sports and athletes compared to children who did not engage in regular physical activities. The above study results support the fact that regular physical activities have positive influence on WM which is crucial for academic achievement. Thus, it is equitable to recommend regular physical activities for children as an evidence-based strategy for better scholastic performance and further attempts should be made to create awareness among parents and school about positive effects of regular physical activities.

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APPENDIX

Task 1: Auditory working memory

The list of ten series used in the auditory memory task

1. **7-2-ªÀÄgÀ-ºÀÄqÀÄUÀ-5-£Á¬Ä**
2. **¸ÉÃ§Ä-1-¯ÉÆÃl-3-4-mÉÆÃ¦**
3. **PÀtÄÚ-2-8-ºÀÄ°-6-¤ÃgÀÄ**
4. **9-0-PÀÄað-5-¨Á¼ÉºÀtÄÚ- ªÀÄ£É**
5. **ºÀ¸ÀÄ-PÀ¥ÀÅöà-4-2-C£Àß-1**
6. **3-8-vÁ¬Ä-9-HgÀÄ-ZÀªÀÄZÀ**
7. **PÀÄzÀÄgÉ-6-lªÉÆÃmÉÆÃ-9-1-PÀwÛ**
8. **vÀmÉÖ-7-ªÀÄÄR-0-PÉÆÃw-5**
9. **PÉA¥ÀÅ-PÁgÀÄ-2-zÁæQë-8-4**
10. **¸ÀgÀ-3-9-D£É-6-§zÀ£ÉPÁ¬Ä**

Task 2: Digit ordering test

Level 1: Three digits

2 9 5

Level 2: Four digits

9 4 0 6

Level 3: Five digits

4 2 5 8 6

Level 4: Six digits

2 9 6 5 1 8

Level 5: Seven digits

3 8 5 9 6 2 4

Level 6: Eight digits

5 9 6 2 4 8 3 7

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