

## Can Physical Activity Immediately Increase Attention Persistence and Verbal Working Memory in Adolescents: an Empirical Study<sup>□</sup>

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### ABSTRACT

**Background.** Attention and memory are the key mental processes. They are crucial for the academic and social success of children and adolescents. Many activities have a positive effect on the development of attention and memory. Such activities can be learning a foreign language, music lessons, sports and physical activity. There is a large body of empirical evidence supporting the positive effects of systematic exercise on cognitive development in children and adolescents. However, the results on the immediate effect of physical activity on cognitive functions, particularly attention and memory are lacking and contradictory. Therefore, the aim of this study was to investigate the immediate effect of physical activity on measures of attention-stability and working memory capacity in adolescents.

**Methods and Sample.** The study involved 190 schoolchildren including 103 girls and 87 boys aged 13–17 years ( $M = 14.73$ ,  $SD = 1.61$ ) from Moscow, St. Petersburg, the Republic of Tatarstan, the Republic of Sakha (Yakutia), Volgograd, Moscow, Rostov, Tomsk and Chelyabinsk regions. For testing attention-stability, we used the *Schulte Table* test, working memory scores were measured with the *memorization of 10 words test*. The following exer-

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cises were chosen: squats (15 times), abs exercises (20 times), push-ups (10 times). Before and after performing the exercises, the participants filled out attention and memory tests.

**Results.** Comparison of averages (Student's test) showed that there were no significant differences in the attention-stability scores before and after physical activity ( $t = 9401$ ,  $p = 0.131$ ). This suggests that there is no immediate effect of physical activity on the indicators of stability and concentration of attention in senior schoolchildren. In contrast, working memory indices were significantly lower after exercise ( $W = 7257$ ,  $p < 0.001$ ). Schoolchildren performed the task for memorizing worse after physical exercises than before. In addition, girls were shown to memorize and reproduce more material on average than boys.

**Conclusions.** The obtained results indicate that there is no immediate positive effect of physical activity on the indicators of attention-stability and working memory capacity. This may mean that the relationship across the indicators of attention-stability, working memory capacity and physical activity is more complex and nonlinear suggesting further study is required. These findings highlighted the importance of physical activity, its intensity and duration when designing educational programs for schoolchildren to enhance cognitive performance.

**Keywords:** Cognitive functions, attention, memory, working memory, physical activity, adolescence

#### Highlights:

- Attention and memory play an important role in adolescent academic success
- Systematic physical activity contributes to the development of attention and memory in children and adolescents, since physical activity increases neuroplasticity, directly linked to cognitive development
- Despite data on the contribution of physical activity and to cognitive development, there is no immediate positive correlation between physical activity on memory and attention-stability

#### АННОТАЦИЯ

**Актуальность.** Существует большое количество эмпирических данных, подтверждающих положительное влияние систематических занятий спортом на когнитивное развитие детей и подростков. Однако, достоверных данных о моментальном эффекте физической активности на когнитивные функции (в частности, внимание и память), который потенциально может наступать сразу после занятия спортом, практически нет, либо они имеют противоречивый характер. Целью данной работы явилось изучение моментального эффекта физической нагрузки на показатели устойчивости внимания и объема рабочей памяти у подростков.

**Методы и выборка.** Для диагностики устойчивости внимания была использована методика «Таблицы Шульце», показатели объема слухоречевой рабочей памяти измерялись с помощью методики «Заучивание 10 слов». В исследовании приняли участие 190 школьников (54% девочки) 13–17 лет ( $M = 14,73$ ,  $SD = 1,61$ ) из нескольких регионов России.

**Результаты.** В результате сравнения средних было показано отсутствие значимых различий в показателях устойчивости внимания до и после физической нагрузки ( $t = 9401$ ,  $p = 0,131$ ). Показатели же рабочей памяти были значимо ниже после выполнения физических упражнений ( $W = 7257$ ,  $p < 0,001$ ). Кроме того, было показано, что девочки в среднем запоминают и воспроизводят большее количество материала, чем мальчики.

**Выводы.** Таким образом, полученные результаты свидетельствуют об отсутствии моментального положительного эффекта физической активности на пока-

zатели устойчивости внимания и объема рабочей памяти. Это может свидетельствовать о том, что связь показателей устойчивости внимания и объема рабочей памяти с физической активностью носит более сложный и нелинейный характер, что требует дальнейшего изучения.

**Ключевые слова:** Когнитивные функции, внимание, память, рабочая память, физическая активность, подростковый возраст

**Ключевые положения:**

- Внимание и память играют важную роль в академической успешности подростков
- Системные занятия физической активностью способствуют развития внимания и памяти у детей и подростков. Это связано с тем, что физическая активность повышает нейропластичность, которая непосредственно связана с когнитивным развитием
- Несмотря на наличие данных о вкладе занятий физической активностью в когнитивное развитие, моментальный положительный эффект от занятий физической активностью в задачах на запоминание и устойчивость внимания отсутствует

**RESUMEN**

**Antecedentes.** La atención y la memoria son procesos mentales clave. Son cruciales para el éxito académico y social de niños y adolescentes. Muchas actividades tienen un efecto positivo en el desarrollo de la atención y la memoria. Tales actividades pueden ser el aprendizaje de un idioma extranjero, las clases de música, los deportes y la actividad física. Existe una gran cantidad de evidencia empírica que respalda los efectos positivos del ejercicio sistemático en el desarrollo cognitivo en niños y adolescentes. Sin embargo, los resultados sobre el efecto inmediato de la actividad física en las funciones cognitivas, en particular la atención y la memoria, que potencialmente pueden aparecer inmediatamente después del ejercicio, son prácticamente inexistentes y contradictorios. Por lo tanto, el objetivo de este estudio fue investigar el efecto inmediato de la actividad física en las medidas de estabilidad de la atención y la capacidad de la memoria de trabajo en adolescentes.

**Métodos y muestra.** El estudio involucró a 190 escolares, incluyendo 103 niñas y 87 niños de entre 13 y 17 años ( $M = 14.73$ ,  $DE = 1.61$ ) de Moscú, San Petersburgo, la República de Tartaristán, la República de Sajá (Yakutia), Volgogrado, Rostov, Tomsk y las regiones de Cheliábinsk. Para evaluar la estabilidad de la atención se utilizaron las «Tablas de Schulte», y las puntuaciones de memoria de trabajo se midieron con la prueba de «Memorización de 10 palabras». Se eligieron los siguientes ejercicios: sentadillas (15 veces), ejercicios abdominales (20 veces), flexiones (10 veces). Antes y después de realizar los ejercicios, los participantes completaron las pruebas de atención y memoria.

**Resultados.** La comparación de promedios (Prueba t de Student) mostró que no hubo diferencias significativas en las puntuaciones de estabilidad de la atención antes y después de la actividad física ( $t = 9401$ ,  $p = 0.131$ ). Esto sugiere que no hay un efecto inmediato de la actividad física en los indicadores de estabilidad y concentración de la atención en estudiantes de secundaria. Por el contrario, los índices de memoria de trabajo fueron significativamente menores después del ejercicio ( $W = 7257$ ,  $p < 0.001$ ). Los escolares realizaron la tarea de memorización después de los ejercicios físicos peor que antes de los ejercicios físicos. Además, se demostró que las niñas memorizaron y reprodujeron en promedio más material que los niños.

**Conclusiones.** Así, los resultados obtenidos indican que no hay un efecto positivo inmediato de la actividad física en los indicadores de estabilidad de la atención y capacidad de la memoria de trabajo. Esto puede significar que la relación entre los indicadores de estabilidad de la atención y capacidad de memoria de trabajo y la actividad física es más

compleja y no lineal, lo que requiere un estudio más profundo. Estos hallazgos resaltaron la importancia de la actividad física, su intensidad y duración al diseñar programas educativos para escolares para mejorar el rendimiento cognitivo.

**Palabras clave:** Función cognitiva, atención, memoria, memoria de trabajo, actividad física, adolescencia

**Disposiciones clave:**

- La atención y la memoria juegan un papel importante en el éxito académico de los adolescentes
- La actividad física sistemática promueve el desarrollo de la atención y la memoria en niños y adolescentes. Esto se debe a que la actividad física aumenta la neuroplasticidad, que está directamente relacionada con el desarrollo cognitivo
- A pesar de la existencia de datos sobre la contribución de la actividad física al desarrollo cognitivo, no hay un efecto positivo inmediato de la actividad física en las tareas de memorización y estabilidad de la atención

**RESUME**

**Origines.** L'attention et la mémoire sont les processus mentaux clés. Ils sont essentiels à la réussite scolaire et sociale des enfants et des adolescents. De nombreuses activités ont un effet positif sur le développement de l'attention et de la mémoire. De telles activités peuvent être l'apprentissage d'une langue étrangère, des cours de musique, du sport et de l'activité physique. Il existe de nombreuses preuves empiriques soutenant les effets positifs de l'exercice systématique sur le développement cognitif des enfants et des adolescents. Cependant, les résultats sur l'effet immédiat de l'activité physique sur les fonctions cognitives, notamment l'attention et la mémoire, qui peuvent potentiellement survenir immédiatement après l'exercice, sont pratiquement inexistantes et contradictoires. Par conséquent, l'objectif de cette étude était d'étudier l'effet immédiat de l'activité physique sur les mesures de stabilité de l'attention et de capacité de mémoire de travail chez les adolescents.

**Méthodes et participants.** L'étude a porté sur 190 écoliers, dont 103 filles et 87 garçons âgés de 13 à 17 ans ( $M = 14,73$ ,  $SD = 1,61$ ) des régions de Moscou, Saint-Petersbourg, de la République du Tatarstan, de la République de Sakha (Yakoutie), de Volgograd, de Moscou, de Rostov, de Tomsk et de Tcheliabinsk. Pour tester la stabilité de l'attention, nous avons utilisé les « tables de Schulte », les scores de mémoire de travail ont été mesurés avec la « mémorisation de 10 mots ». Les exercices suivants ont été choisis : squats (15 fois), les abdos (20 fois), pompes (10 fois). Avant et après avoir effectué les exercices, les participants ont rempli des tests d'attention et de mémoire.

**Résultats.** La comparaison des moyennes (le test de Student) a montré qu'il n'y avait pas de différences significatives dans les scores de stabilité de l'attention avant et après l'activité physique ( $t = 9401$ ,  $p = 0,131$ ). Cela suggère qu'il n'y a pas d'effet immédiat de l'activité physique sur les indicateurs de stabilité et de concentration de l'attention chez les élèves du secondaire. En revanche, les indices de mémoire de travail étaient significativement plus faibles après l'exercice ( $W = 7257$ ,  $p < 0,001$ ). Les élèves ont moins bien exécuté la tâche de mémorisation après les exercices physiques qu'avant les exercices physiques. De plus, il a été démontré que les filles mémorisaient et reproduisaient en moyenne plus de matériel que les garçons.

**Conclusions.** Ainsi, les résultats obtenus indiquent qu'il n'y a pas d'effet positif immédiat de l'activité physique sur les indicateurs de stabilité de l'attention et de capacité de mémoire de travail. Cela peut signifier que la relation entre les indicateurs de stabilité de l'attention et de capacité de mémoire de travail et l'activité physique est plus complexe et non linéaire, ce qui nécessite des études plus approfondies. Ces résultats ont souligné l'importance de l'activité physique, de son intensité et de sa durée lors de la conception de programmes éducatifs pour les écoliers afin d'améliorer les performances cognitives.

**Mots-clés:** Fonction cognitive, attention, mémoire, mémoire de travail, activité physique, adolescence

**Points principaux:**

- L'attention et la mémoire jouent un rôle important dans la réussite scolaire des adolescents
- L'activité physique systématique contribue au développement de l'attention et de la mémoire chez les enfants et les adolescents. En effet, l'activité physique augmente la neuroplasticité, directement liée au développement cognitif
- Malgré la disponibilité de données sur la contribution de l'activité physique au développement cognitif, il n'y a pas d'effet positif immédiat de l'activité physique sur les tâches de mémoire et de capacité d'attention

## Introduction

Attention and memory are cognitive functions that, like thinking, speech, visuospatial, and executive functions, form a set of key human mental processes (Gippenreiter, 2008; Veraksa, 2022; Romashchuk, 2023). At the same time, it is attention and memory that serve as the basis for the further learning process (Nurkova et al., 2023). The most intensive period of their formation takes place in childhood and adolescence (Vygotsky, 1982). Attention and memory are necessary for the success of adolescents both academically and socially (Dvoinin, Trotskaya, 2022; Rzhanova et al., 2020; Purpura, Schmitt, 2019). Since attention and memory provide the capacity to concentrate on what is important, retain and reproduce, it is crucial to academic success. In this regard, indicators such as working memory capacity and attention-stability often become an important focus for formation and development at school age (Dvoinin, Trotskaya, 2022; Zinchenko et al., 2022).

Much research in this area is being conducted to identify and clarify the relationships between various parameters of attention and memory, on the one hand, and the academic and social achievements of children and adolescents, on the other. For example, a study by L. Puerta, involving 60 schoolchildren between 14 to 17 years old identified a significant positive association between academic performance and attention-stability (Puerta, 2015). Research by T. Tikhomirova and co-authors involving a sample of 1650 children of primary, secondary and high school cohorts, revealed that in primary and secondary school the key factor determining academic success is information processing speed, which underlies intelligence, working memory and numeracy (Tikhomirova et al., 2015). Attention-stability and working memory capacity are positively associated with adolescents' social intelligence and social success (Blakemore, 2008; Brizio et al., 2015; Choudhury et al., 2006; Ruiz-Ariza et al., 2017; Veraksa, 2022).

Purposeful facilitation of those conditions that promote the development and maintenance of various attributes contributing to attention and memory, including attention-stability and the working memory capacity, in children and adolescents can be achieved with the support of scientifically based data indicating which factors have a substantial influence. It is already known that learning foreign languages, playing music, and physical activity have a beneficial effect on the development of various

indicators of attention and memory (Knyazeva, 2019; Bayanova et al., 2022; Barac et al., 2014; Degé et al., 2011; Durand López, 2021; Veraksa et al., 2021). That said, physical activity is the most accessible way to stimulate the development of attention and memory, since the other listed types of activities require purpose-built premises and additional equipment, while the child's physical activity can unfold without special conditions.

The results of a large number of studies have demonstrated that physical activity improves the ability to remember and increases attention-stability (Dinoff et al., 2016; Chieffi et al., 2017; Kramer et al., 1999; Weinberg, Gould, 2015), since physical activity leads to structural and functional changes in the brain and influences neuroplasticity, which in turn leads to improved cognitive performance (Fernandes et al., 2017; Mandolesi et al., 2017). For example, the results of a research by D. Sjöwall and colleagues, conducted with a sample of 470 children between 6 to 13 years old, revealed differences in the working memory capacity in the control group and within the group of children who regularly were engaged in physical activity. Children who were involved in physical activity every day began to remember and consequently recall more information than children whose physical activity did not increase (Sjöwall et al., 2017). Also, in a study by M. Janssen and colleagues (Janssen et al., 2014), conducted with a sample of 123 young adolescents, identified that children who had a break for moderate physical activity between solving cognitive tasks performed attention-stability and concentration tests better than those who did not have such a break or whose break involved intense physical activity. The results of research by S. Kubesch and colleagues (Kubesch et al., 2009) demonstrated the positive effect of regular physical activity on the ability of 13-14 years old schoolchildren to concentrate on a given task and, accordingly, perform it more successfully.

To date, however, these study results do not cover a full range of physical activity characteristics, which may elicit different effects on various attention and memory performance indicators (Bidzan-Bluma, Lipowska, 2018). Most studies confirm the positive effect of long-term systematic physical activity on cognitive functions, particularly on working memory and attention (Carson et al., 2016; Chieffi et al., 2017; Tuckman and Hinkle, 1986). However, the immediate effect of physical activity on attention and memory, which could potentially occur straightway after playing sports, remains largely unstudied. Although these effects are theoretically assumed to result from increased blood flow, oxygenation of the body and increased overall performance resulting from physical stimulation (Mandolesi et al., 2018; Hötting et al., 2016; Cian et al., 2000) it should be highlighted that some studies do not confirm the positive effect of physical activity on the cognitive functioning of children and adolescents, including attention-stability and working memory capacity (Ahamed et al., 2007; Lambourne, Tomporowski, 2010; Zervas et al., 1991 ).

This research was conducted to obtain information about whether there is such a positive immediate physical activity effect on such indicators as attention-stability and working memory capacity in adolescents. The project titled, *The characteristics of changes in cognitive functions depending on physical activity* was implemented as part of a scientific volunteering project for school children. The project goals are to increase schoolchildren's interest in science and attract active youth to conduct mod-



ern psychological research. As part of the project, volunteers faced with a number of tasks including:

- Studying scientific literature on research topics.
- Understanding theoretical foundations supporting the practice of psychological research.
- Identifying methods suitable for research purposes.
- Conducting empirical research.
- Analysis and interpretation of obtained results.

Each task was performed sequentially under the guidance of curators, who were both students as well as postgraduate students of the Faculty of Psychology at Lomonosov Moscow State University.

The main research hypothesis proposed that indicators of attention-stability and working memory capacity differ significantly after subjects perform a series of physical exercises.

## Methods

To examine attention processes, the *Schulte Table* test was used (Bizyuk, 2005). This technique studies attention-stability. The test is carried out using several special tables on which numbers from 1 to 25 are arranged in random order. It is necessary to arrange the numbers in order, showing each number and calling it out loud. The recorded parameters include the time required to complete the task and the number of errors made. Each participant was presented with one table before and after performing physical exercises. The tables used before and after performing physical exercises differed from each other.

To assess working memory, the *memorization of 10 words test* was used (Bizyuk, 2005). Its original version was developed by A. Luria. The technique examines working memory capacity, memorization speed and delayed memorization. Ten nouns in the singular and nominative case are used as stimuli. These nouns are not related in meaning to each other. In this research, to assess the immediate effect of physical activity on cognitive functions, only the working memory capacity was evaluated without subsequent testing of delayed memory. The recorded parameters included the reproduced words number and the number of errors (for example, extra words). Each participant was presented with one series of words before and after performing physical exercises. The series of words before and after performing physical exercises differed from each other.

## Participants

The study involved 190 schoolchildren including 103 girls and 87 boys of 13 to 17 years old ( $M=14.73$ ,  $SD=1.61$ ) from Moscow, St. Petersburg, the Republic of Tatarstan, the Republic of Sakha (Yakutia) as well as from Volgograd, Moscow, Rostov, Tomsk and Chelyabinsk regions. The respondents were students from schools attended by teenagers who participated in the scientific volunteering study project titled *Studying the characteristics of changes in mental functions depending on physical activity*.

## Procedure

Description of research progress: Guided by curators and psychologists, volunteers arranged to conduct the study either during a physical education class or at a time when the school gym was available. After establishings and agreed time, volunteers confirmed the respondents' participation in the study. The procedure was as follows: Before starting physical exercise, participants completed tests to assess attention and working memory. Then respondents performed sequential exercises: 15 squats (without lifting the heels from the floor), 20 abs (lying on the mat, legs bent at the knees at approximately 90 degrees, feet resting on the floor); 20 lifts of the body to the knees (lifting the shoulder blades off the floor and lifting the body), 10 push-ups (girls from the knees, boys from the floor). These exercises were selected because, on the one hand, they are included in the mandatory physical education program, and on the other hand, they do not require additional equipment to be performed. After completing the exercises, the participants again filled out the tests for attention and memory. Average completion time: 15 minutes. Each participant was evaluated individually.

## Results

The *Jamovi statistical package* was used to process empirical data. Given the mixed distribution of data across the sample (Kolmogorov-Smirnov test  $\in [0.094-0.968]$ ,  $p \in [0.000-0.09]$ ), both parametric and nonparametric data processing methods were subsequently used to test the hypothesis.

### 1. Differences in indicators of attention-stability and of working memory capacity before and after physical activity

To verify that significant differences in attention-stability indicators before and after physical activity would be observed, a comparison was made of the time averages for completing the task using students' T-test for paired samples and the number of errors using the *Wilcoxon W-test*.

Table 1

*Differences in the average performance time of the Schulte Table*

Stage	Mean, time	SD	Student's T- test	p-value	Effect size
Before	36.3 c	9.8	9401	0.131	0.129
After	35.5 c	9.76			

Table 2

*Differences in the error rate in the Schulte Tables*

Stage	Mean, errors	SD	Wilcoxon W-criterion	p-value	Effect size
Before	0.137	0.5	1.027	0.306	0.0745
After	0.111	0.4			



Results indicated no significant differences in the speed of the *Schulte Table* test completion and the number of errors before and after physical activity (see *Table 1* and *Table 2*).

To test the assumption that there would be significant differences in working memory capacity before and after exercise, means were compared using the Wilcoxon W-test. Results indicated that significant differences were found in the word reproduction indicators when performing the memorization of 10 words test before and after physical activity. It was shown that after performing physical exercises, school-children, on average, remember and reproduce fewer words than before exercise (see *Table 3*).

Table 3  
*Differences in the mean number of words learnt by the «Memorisation of 10 words» test*

Stage	Mean, reproduced words	SD	Wilcoxon W- test	p-value	Effect size
Before	6.71	1.7	7257	<0.001	0.334
After	6.21	1.8			

**2. Gender differences in indicators of attention-stability and working memory capacity**

An additional analysis was conducted to determine differences in indicators of attention-stability and the working memory capacity according to gender. Since the data distribution is mixed, the *Mann-Whitney U-test* was used.

Results revealed significant differences in the number of words reproduced when performing the memorization of 10 words test, both before and after physical exercise (see *Table 4*). However, girls tend to reproduce a larger number of words than boys on average.

Table 4  
*Sex differences in the working memory score using «Memorisation of 10 words» test*

Stage	Sex	N	Mean, reproduced words	SD	Mann-Whitney U test	p-value	Effect size
Before	male	87	6.39	1.75	-2.37	0.019	0.203
	female	103	6.97	1.62			
Before	male	87	5.7	1.72	-3.64	<0.001	0.288
	female	103	6.63	1.78			

**Discussion**

Therefore, the hypothesis that attention-stability and working memory capacity, before and after adolescents perform a number of physical exercises, would show statistically significant differences favoring the latter dimension was not confirmed.

No significant differences were found in either in the completion speed of the Schulte Table test or the number of errors made during its performance. , In other words, the absence of an immediate effect of physical activity on indicators of attention stability and concentration in senior schoolchildren can be ascertained. As part of testing the research hypothesis, significant differences were found in the volume of reproduced material among schoolchildren according to assessments conducted before and after physical activity. The results showed that after physical exercises, schoolchildren perform worse in memorizing and recalling the material they have heard.

In our opinion, such results may be associated with the heterogeneous influence of physical activity on attention and memory indicators. Moreover, there may be additional factors and mechanisms that determine the role of physical activity in the cognitive development of children and adolescents. For example, the results of some studies show that short physical education sessions (up to 20 minutes) have a negative impact on cognitive functions, including attention-stability and working memory capacity (Hötting et al., 2016). However, performing physical exercise for more than 20 minutes leads to increased cognitive function (Brisswalter et al., 2002; Chan, Abu Bakar, 2021; Lambourne, Tomporowski, 2010).

Furthermore, different types of physical activity may have different effects on cognitive function indicators, including attention and working memory. It is noted that depending on whether the training is performed in an aerobic or anaerobic mode, the effect of such exercises will not be consistent. Specifically, research has shown that the greatest immediate effect is observed when performing low-intensity aerobic exercises, while intensive systematic training leads to a longer term but delayed effect (Chang et al., 2012; Basso, Suzuki, 2017). Therefore, it can be assumed that the beneficial effects of physical activity do not occur immediately because neurophysiological mechanisms require time to reach the peak level necessary to observe the positive effect of physical activity on cognitive functions (Chang et al., 2012). The results may also be explained by the fact that such processes as attention, memorization and reproduction are labor-intensive and require a fairly large amount of effort and energy. Physical activity leads to the expenditure of energy, which can impede cognitive processes immediately after exercise due to fatigue. Moreover, the data obtained can be related to the peculiarities of the attention and memory systems' functioning. Specifically, for better memorization, information should evoke associations in a person, grouped into larger blocks for easier memorization, the person should also understand the purpose of remembering this information. To increase attention-stability, it is also required that the object of attention be of interest to the person and be sufficiently complex. additionally, for the successful functioning of both attention and memory, a person must have a sufficient underlying motivation for these processes to occur (Gippenreiter, 2008).

Moreover, the study revealed significant gender differences in the volume of reproduced material. Despite the decrease in the number of words recalled after physical activity, girls, on average, remember and reproduce a larger number of words both before and after physical activity when compared to boys. This is consistent with previous research and may be due to the fact that women generally perform better

on verbal ability tasks, including working memory (Chan, Abu Bakar, 2021; Gabriel, Sridevi, 2016; Hill et al., 2014).

## **Conclusion**

The study showed that there are no differences in attention-stability indicators in schoolchildren of 13 to 17 years old before and after physical activity. The study also found a negative immediate effect of physical activity on working memory capacity. It can be assumed that there is a more complex and indirect relationship between physical activity and cognitive functions, in particular attention and memory, in adolescents. Such results indicate the importance of taking into account the type of physical activity, its intensity and duration when creating exercise programs for schoolchildren to improve cognitive functions.

An important outcome of this project is the participation of a large number of student volunteers. This confirms the interest of schoolchildren in scientific activities in psychology and the importance of implementing and popularizing scientific volunteering projects among schoolchildren.

## **Limitations**

The main goal of the scientific volunteering project *Studying the characteristics of changes in mental functions depending on physical activity* was to attract schoolchildren to science and familiarize them with conducting psychological experiments. Therefore, the study has a number of limitations. One limitation of this research is the absence of a control group that did not perform physical exercise. We also did not take into account the involvement of schoolchildren in sports activities. Attending professional sports classes contribute to the body's adaptation to stress, which, over time, necessitates an increase in the duration and the intensity of the exercise to achieve a positive effect on cognitive functions .

## **Ethics Statement**

The scientific research was reviewed by members of the Scientific Research Ethics Committee of Lomonosov Moscow State University (the Faculty of Psychology) on 22 April 2023. Approval No: 2022/25.

## **Informed Consent from the Participants' Legal Guardians (if the participants were minors)**

Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## **Author Contributions**

A.Y. designed and directed the project, developed the theoretical framework; P.B., E.T., M.K., E.G., and S.K. performed the experiments, performed the analysis and

designed the tables.; A.Y. and A. Sh. aided in interpreting the results; worked on the manuscript and drafted the manuscript. All authors discussed the results and contributed to the final manuscript.

## Conflict of Interest

The authors declare no conflict of interest.

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