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Original Article

Acute Pilates and plyometric exercise in school-based settings improve attention and mathematics performance in high school students

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ABSTRACT

The aim of this study was to examine the effects of acute Pilates and plyometric exercise in a school-based setting on attention and mathematics test performance in high school students. Forty 10th-grade students (21 females and 19 males; age: [15.0 ± 0.5] years, body mass index: [21.4 ± 2.8] kg/m^2) participated in this crossover and quasi-experimental study. In week 1, students were familiarized with the d2 test of attention and Pilates and plyometric exercises activities, and body composition measurements were taken. In both weeks 2 and 3, students completed the d2 test of attention and mathematics test with 20 questions following a single session of low-to-moderate-intensity exercise and a classroom-based non-exercise activity, in a non-randomized order. The exercise sessions included 30 mins of plyometric exercises for male students and Pilates exercise for female students, with intensities corresponding to 10–14 on the Borg rating of perceived exertion scale$_{6\text{-}20}$. Compared to the non-exercise activity, a 30-min of Pilates and plyometric exercise resulted in significant improvements in attention score (mean difference [Δ] = 54.5 score; $p < 0.001$; Cohen's effect sizes [d] = 1.26) and concentration performance (Δ = 20.7 score; $p = 0.003$; $d = 0.51$). The students scored significantly higher on the mathematics test after participating in the exercise sessions compared to the non-exercise condition (Δ% = 11.7; $p < 0.001$; $d = 0.76$). There were no significant differences between genders ($p > 0.05$). These findings demonstrate the effectiveness of acute light-to-moderate-intensity Pilates and plyometric exercises in school-based settings for improving attention and mathematics performance in adolescents.

1. Introduction

Engaging in physical activity offers significant health benefits, including a reduction in obesity, relief from anxiety and depression, and improvements in cardiovascular health, muscular fitness, bone health, and self-esteem, academic performance and cognitive functions (*e.g.,* attention, memory, planning, and learning) in various populations, including children, adolescents, and young adults.[1–5] Indeed, students who regularly engage in higher levels of exercise achieve higher scores in academic achievements, as measured by grades and cognitive test scores, compared to their less active peers.[6–9] In the context of these exercise-related benefits, the intensity of exercise plays a pivotal role in influencing behavioral outcomes, as underscored by the inverted-U hypothesis, which posits that exercise intensity affects the extent of effects on the examined variables. For example, Chang and colleagues reported that cognitive function was positively impacted by all exercise intensities, except for very light intensity, if there was a delay between the exercise session and the cognitive task performance.[10] This implies that an exercise intervention, administered at a light or moderate intensity, may serve as an attractive strategy for improving cognitive function. The mechanisms underlying the cognitive benefits of exercise involve physiological responses to the exercise, such as increased cerebral blood cells, neurotransmitter release, neurogenesis, the release of brain-derived neurotrophic factor, stimulation of neurotrophic factors, and changes in heart rate.[4,11,12]

Pilates, a floor-based mind-body exercise, is a form of exercise that involves a sequence of movements to enhance strength, flexibility, endurance, mobility, efficiency, muscle power, and the mind-body connection.[13–15] Pilates provides the holistic coordination of the body, mind, and spirit and is based on six principles that improve attention, and motivation and mental health, cognitive and functional capabilities, while concurrently mitigating physical stress on the body across various populations, from college-age individuals to the elderly.[14,16–22] Similar to Pilates exercise, plyometric exercise is a popular form of physical conditioning for healthy individuals and is commonly used in sports

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List of abbreviations

ACSM	American College of Sports Medicine
CP	Concentration performance
95% *CI*	95% confidence interval
d	Cohen's effect sizes
df	*Degrees* of freedom
d2	d2 test of attention
E2	Errors of commission
E1	Errors of omission
Δ	Mean difference
n_p^2	Partial eta squared
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences
TN	Total number of characters processed
TN-E	Total number of items scanned minus error scores

conditioning and rehabilitation programs. Plyometric exercise mainly involves high-impact, explosive bodyweight activities that consist of stretching of a muscle followed by a forceful contraction to enhance athletic performance and memory.[23,24] Ample evidence suggests that plyometric exercises enhance memory, cognitive function, attention, and psychological states.[23,25,26] Nevertheless, to date, there has been no research examining the impact of a single session of plyometric and Pilates exercise on cognitive function and academic performance, particularly when implemented in school-based settings, in adolescents, underscoring the necessity for further research in this area.

In the current literature, attention and problem-solving abilities, which are known to have reciprocal and dynamic relationships, are frequently assessed for academic achievement due to their substantial effects on academic achievement.[27] Additionally, it is known that there is an increasing attention deficit associated with electronic screen time exposure, and the excessive use of technology such as smartphones, tablets, videogame consoles in children and adolescents has been reported to negatively affect the academic success of this age group.[28] Evaluated from this perspective, exercise can serve as an effective approach to mitigate the impact of this disorder on attention levels, particularly during the exam preparation period and important examinations for high school students, thereby enhancing academic achievement. Therefore, given that a light 10-min exercise is known to significantly increase memory and cognitive functions in young men,[29] short-term and light-to-moderate-intensity exercises before important academic exams might directly affect the scores of the exams, thus obtaining better academic achievement.

Mathematics is a core academic subject with global recognition that forms the basis for various disciplines, such as science and engineering. Proficiency in mathematics has the potential to enhance the self-confidence and self-esteem of adolescents, with the capacity to influence their overall academic achievement. Therefore, it is imperative to recognize the multifaceted importance of mathematics in adolescents' lives and to promote its effective teaching and learning. On the other hand, math-related anxiety can negatively impact math academic performance, mainly due to changes in neural activities in brain regions associated with negative emotions and numerical computations.[30] Hence, there has been a recent increase in research focusing on interventions, including exercise, with the aim of alleviating anxiety and, in turn, enhancing mathematical skills and academic achievements. Notably, a systematic review and meta-analysis by Sneck and associates documented that regular participation in exercise can increase mathematics performance in children aged 4 to 16.[31] However, the impact of acute light-to-moderate intensity exercise interventions in school-based settings, specifically involving plyometric and Pilates exercises, which are easy to do and require no equipment, on the enhancement of mathematics performance in high school students remains largely unexplored.

Taken together, despite some attempts that investigated the effects of light-to-moderate-intensity exercise on mathematics performance and cognitive function (*i.e.,* attention) in high school students,[31,32] to date, there has been no study that has examined whether light-to-moderate-intensity exercise, which necessitates no equipment and can be implemented in school-based settings, could improve attention and math test performance in adolescents. Therefore, the aim of this study was to investigate the effects of acute Pilates and plyometric exercises with light-to-moderate intensity on attention and mathematics test scores in high school students. We hypothesized that a single session of light-to-moderate-intensity exercise would improve attention and mathematics performance in adolescents, aged 14–16.

2. Material and methods

2.1. Participants

A total of 52 10th-grade students volunteered to participate in this study with a combined research design, integrating elements of a crossover and a quasi-experimental. This research was conducted at a high school situated in Keçiören, Ankara. Twelve students out of 52 were excluded from the study because they did not complete the exercise sessions ($n = 8$; 5 males, 3 females) or attend the non-exercise condition ($n = 4$; 1 males, 3 females); consequently, 40 students were included in the data analysis (21 females and 19 males; age: [15.0 ± 0.5] years, body mass index: [21.4 ± 2.8] kg/m^2, body fat percentage: 17.9 ± 7.7). Students were all apparently healthy, as defined by their enrollment in physical activity class, and able to participate in regular exercise. No other inclusion or exclusion criteria were applied. All students and parents provided written informed consent for their children's participation.

2.2. Ethical approval

All students and parents provided written informed consent for their children's participation. This study was conducted following the principles of the Declaration of Helsinki, and approved by the Committee of Strategy Development Department, Directorate of National Education for Keçiören District in Ankara (2204-A/2022), Turkey.

2.3. Procedure

The research design is presented in Fig. 1. On day 1, we determined students' demographic information, physical activity levels, and readiness for physical activity, using different questionnaires and forms. The administration of the questionnaires was carried out online through Google Forms, which was accompanied by the researchers. This was followed by the familiarisation session of the d2 attention test, performed face-to-face after giving the necessary information regarding the test. Subsequently, the students' body stature and body mass were measured and the familiarisation session for the exercise protocols was performed.

One week later, students engaged in two sessions, each separated by a week. During each session, they completed the d2 attention test and answered 20 multiple-choice math questions in the classroom. In the first session, male students performed plyometric exercise, whilst female students received Pilates exercise for 30 mins. The intensity of both exercise sessions corresponded to 10–14 on the Borg rating of perceived exertion scale$_{6\text{-}20}$,[33] showing that the intensities of both exercise protocols were light-to-moderate-intensity. Following the completion of the exercises, a period of 5-min was given before all students were instructed to take the d2 attention test. This was followed by a 40-min math exam consisting of 20 multiple-choice math questions. The 5-min interval between exercise and testing was chosen based on previous findings that reported noncerebral hemodynamic variables, such as middle cerebral

artery mean blood velocity and skin blood flow, did increase within 10 mins of light-to-moderate-intensity exercise and return to baseline levels within 8 mins.[34] In the subsequent session, occurring one week later, the same students, who had previously rested in the classroom for 30 mins, completed the d2 attention and math tests once more to compare the impact of the applied exercise protocols on attention and math test scores with a non-exercise condition (Fig. 1).

2.4. Questionnaires administration

Demographic information, physical activity levels, and readiness for physical activity were determined using questionnaires prepared on Google forms. The Physical Activity Questionnaire for Adolescents developed by Kowalski et al. was used to determine the physical activity level of students.[35] Polat and associates conducted the validity and reliability study of the questionnaire in the Turkish population aged 14–18.[36] The Physical Activity Readiness Questionnaire, developed by the American College of Sports Medicine (ACSM), was employed to assess students' readiness for the planned exercises.[37]

2.5. Measurement of body composition

Body stature (Holtain stadiometer, UK) and body composition (Tanita SC330, Japan) of the students were measured. Body mass (kg), fat-free mass (kg), lean mass (kg), fat mass (kg), and the percentage of body fat (%) were determined from the body composition assessment via a digital scale (Tanita SC330, Japan). The body mass index of students was calculated with the standard method: body weight (kg)/height squared(m^2).

2.6. Familiarisation sessions

Following the body composition assessment, students participated in familiarisation sessions that involved Pilates exercise for female students and plyometric exercise for male students, who were accompanied by two expert trainers. The familiarisation sessions were similar to the main exercise protocols and involved a 5-min of warm-up, 20-min of active exercise, and 5-min of cool-down periods during which students were asked about their perceived level of exertion on the Borg $scale_{6\text{-}20}$ every 5 mins,[33] thus enabling students to become familiar with the Borg scale for the main exercise sessions.

2.7. Exercise protocols

In order to accommodate the diverse interests of male and female students and to ensure the exercise sessions were engaging for both genders,[38] male students engaged in plyometric exercises, while female students participated in Pilates exercises. This approach was corroborated by studies showing that boys generally preferred weight training, running, and cycling, while girls typically leaned towards activities like dance, aerobics, and jogging.[39,40]

The plyometric exercise session consisted of jumping jack, jump squat, plyometric lunge, mountain climbers, push up, high knee, and burpees, whilst the Pilates exercise session mainly involved pelvic curl, toe top, press and point, side leg lift, inner thigh circles, T press, back lift, Ab scoop, shoulder bridge, spine twist, single leg kick, inner thigh leg lift, and mermaid. One min of passive rest interval was allowed between the moves. The duration of the exercise sessions was 30 mins, which involved 5 mins of warm-up, 20 mins of active exercise and 5 mins of cool-down periods. Given that exercise durations above 20 mins have substantial impacts on cognitive performance and attention,[10,41] we purposefully selected a 30-min exercise length. During the 20 mins of constituting the active period of the exercise, the perceived level of exertion of all students was asked on the Borg scale every 5 mins to determine the intensity of the sessions and to perform both plyometric and Pilates exercise sessions at similar intensity for both sexes.[33] Data on Borg scale scores showed that exercise intensities in the first 15 mins of exercise were 10–11 and 11–12, increasing to 13–14 in the last 5 mins of exercise sessions, showing that both exercise protocols had a similar metabolic stress and the exercise intensities were low to moderate. Students were instructed to only exercise at light to moderate intensity; hence, when they reported a 15 or higher on the Borg scale during the exercise sessions, they were asked to reduce the intensity to keep the exercise intensity lighter. During the exercise sessions, apart from the expert trainers, 2 independent researchers circulated among students doing the exercises, ensuring that the exercises shown by the experts were performed correctly by students. All students were asked not to participate in any exercise activities 24 h prior to the exercise and the sessions were performed about 2 h after lunch, between 14:00 and 15:00.

2.8. d2 test of attention

The impact of acute Pilates and plyometric exercises on attention was assessed through the d2 attention test.[42] This test is a measure of selective attention and mental concentration, which is widely used in different fields including clinical and educational settings, pharmaceutical and transport industries, and sports psychology and is suitable for individuals aged 9 to 60.[42] The test measures a variety of facets that include concentration, attention, sustained attention, mental speed, processing speed, working speed, perceptual speed, and general performance capacity. The d2 test of attention involves 14 test lines with 47 characters in each line, with the letter “d” or “p” marked with one, two, three, or four small dashes (Fig. 2). The test taker is asked to scan the lines and cross out all occurrences of the letter “d” with two dashes directly above and/or

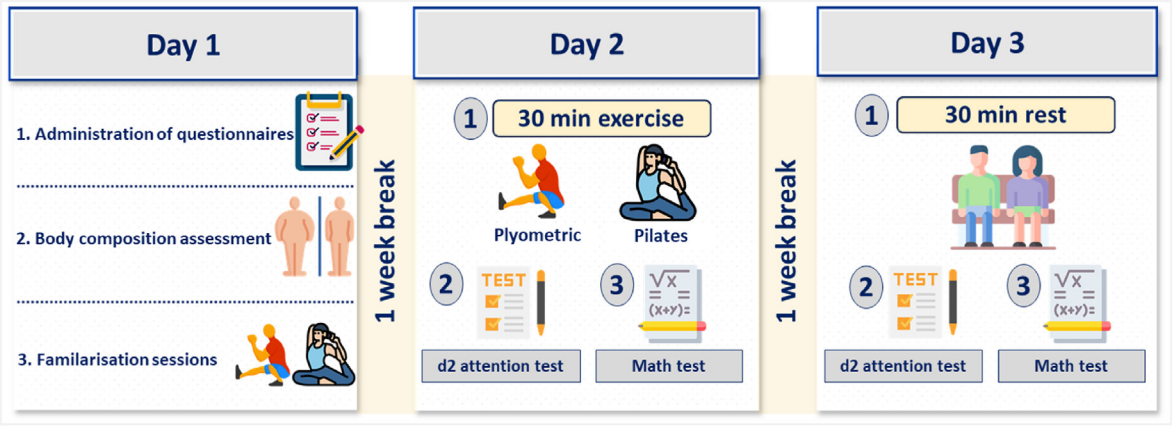

Fig. 1. Research design.

Fig. 2. Cutout of correctly marked the d2 attention test.

below the letter, while ignoring all other symbols. A span of 20 s is given for each sequence whereas pauses between rows are not allowed. The total duration of the test is 4.67 mins. The d2 tests were scored for the total number of characters processed (TN), errors of omission (E_1; the number of mistakes made by missing relevant symbols), errors of commission (E_2; the number of mistakes made by including irrelevant symbols), total number of items scanned minus error scores (TN-E), and concentration performance (CP; number of correctly crossed out relevant items minus errors of commission).[42] In the present study, an acoustic signal was also used instructing students to continue with the next line.

2.9. Preparation and application of math questions

Following 30 mins of acute light-to-moderate-intensity exercise, students solved 20 multiple-choice math questions in 40 mins to determine the effect of the applied exercise sessions on mathematics test scores. To eliminate the possibility of the choices being memorized one week before, and therefore giving correct answers to the questions, another 20-question math test was prepared and solved by students following 30 mins of sitting in the classroom, which was considered as a control condition. A high school math teacher with over 10 years of experience prepared the questions, and two experienced independent math teachers scanned them to provide feedback. Accordingly, the required revisions were addressed where necessary. The questions were prepared to cover the mathematics subjects that students had studied in the first semester of the 2022–2023 academic year.

2.10. Internal consistency and reliability of two different math exams

Following incorporating the necessary revisions suggested by independent math teachers into the two math exam papers, a total of 29 10^{th}-grade students, who weren't participants in the main study, solved two different exam papers at least 1 week apart prior to the commencement of the primary study. The coefficient of variation and the standard error of the scores calculated from the two exam papers were 6.02% and 1.96, respectively. The mean difference between the two exam papers was 6.7%, showing that the two exam papers were similar in terms of subject and content, while they consisted of different questions and correct answers. This pre-study eliminated the possibility of the choices being memorized one week beforehand and therefore giving correct answers to the questions.

2.11. Statistical analysis

Shapiro – Wilk test was performed to determine if the data set was well-modelled by a normal distribution. A paired *t*-test was used to compare exercise and non-exercise conditions for all variables, including Math test scores, concentration performance. Independent-sample *t* tests were used to analyze the difference in the mean between exercise and non-exercise conditions across genders. The source of explained variance was estimated by partial eta squared (n_p^2). Benchmarks for n_p^2 values are: 0.01, 0.06, and 0.14 for small, medium, and large effects, respectively.[43] Cohen's effect sizes (*d*) for paired data (*e. g.*, pre vs. post) were derived from mean differences and the standard deviation of these differences[44] and were classified as small (0.20), moderate (0.60), and large (0.80).[43] All data are presented mean ± standard deviation (*SD*) as well as 95% confidence interval (95% *CI*) and mean difference (Δ). Statistical analyses were computed using Statistical Package for the Social Sciences (SPSS) for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA), and the level of significance was set at $p < 0.05$.

Table 1
Students' demographics, body composition and physical activity status.

Variables	Males	Females	*F*	*p*
Demographics				
Age, y	15.1 ± 0.44	14.8 ± 0.46	0.886	0.96
Body stature, cm	174.4 ± 7.14	156.7 ± 5.36	1.600	< 0.001
Body composition				
Body mass, kg	64.9 ± 9.7	53.1 ± 9.9	0.356	< 0.001
Body mass index, kg/m^2	21.3 ± 2.5	21.5 ± 3.1	1.934	0.71
Lean mass, kg	53.9 ± 6.7	38.0 ± 4.5	6.772	< 0.001
Fat-free mass, kg	56.7 ± 7.0	40.1 ± 4.8	6.785	< 0.001
Fat mass, kg	8.2 ± 4.3	13.0 ± 6.2	1.128	0.002
Body fat percentage, %	12.1 ± 8.4	23.6 ± 6.9	1.575	< 0.001
Physical activity level, score	2.5 ± 0.51	2.2 ± 0.59	0.149	0.11
Low, *n*	0	2	—	—
Low-moderate, *n*	9	12	—	—
Moderate, *n*	11	6	—	—

Note: Values are mean ± *SD* ($n = 40$).

3. Results

General characteristics of students are presented in Table 1. Male and female students had similar age, body mass index and physical activity level for the last 7 days, and had a middle socio-economic status ($p > 0.05$). Males had higher ($p < 0.001$) body stature, body mass, fat-free mass and lean mass than female students, who had significantly higher fat mass and body fat percentage ($p < 0.01$).

Compared to the non-exercise condition, both acute exercise sessions significantly increased the attention score (Δ = 54.5 score; [95% *CI*: 40.7 to 68.4], $p < 0001$; $n_p^2 = 0.620$; $d = 1.26$; large effect) (Fig. 3A) and the concentration performance (Δ = 20.7 score; [95% *CI*: 7.58 to 33.7], $p = 0.003$; $n_p^2 = 0.208$; $d = 0.51$; small effect) (Fig. 3B). Math test scores were higher following exercise sessions compared to the non-exercise condition (Δ = 11.7%; [95% *CI*: 6.71 to 16.7], $p < 0.001$; $n_p^2 = 0.372$; $d = 0.76$; medium effect) (Fig. 3C). There was no significant difference observed between males and females ($p > 0.05$) (Fig. 3D). After the exercise activities, TN, E_1, E_2, TN-E, and CP showed improvement compared to the non-exercise activity in both males and females, with E_2 in males ($p = 0.051$) and CP in females ($p = 0.068$), displaying a trend toward significance (Table 2). Independent sample *t*-test revealed that improvements in TN, E_1, E_2, TN-E, and CP following the exercise activities were similar between genders ($p > 0.05$) (Table 2).

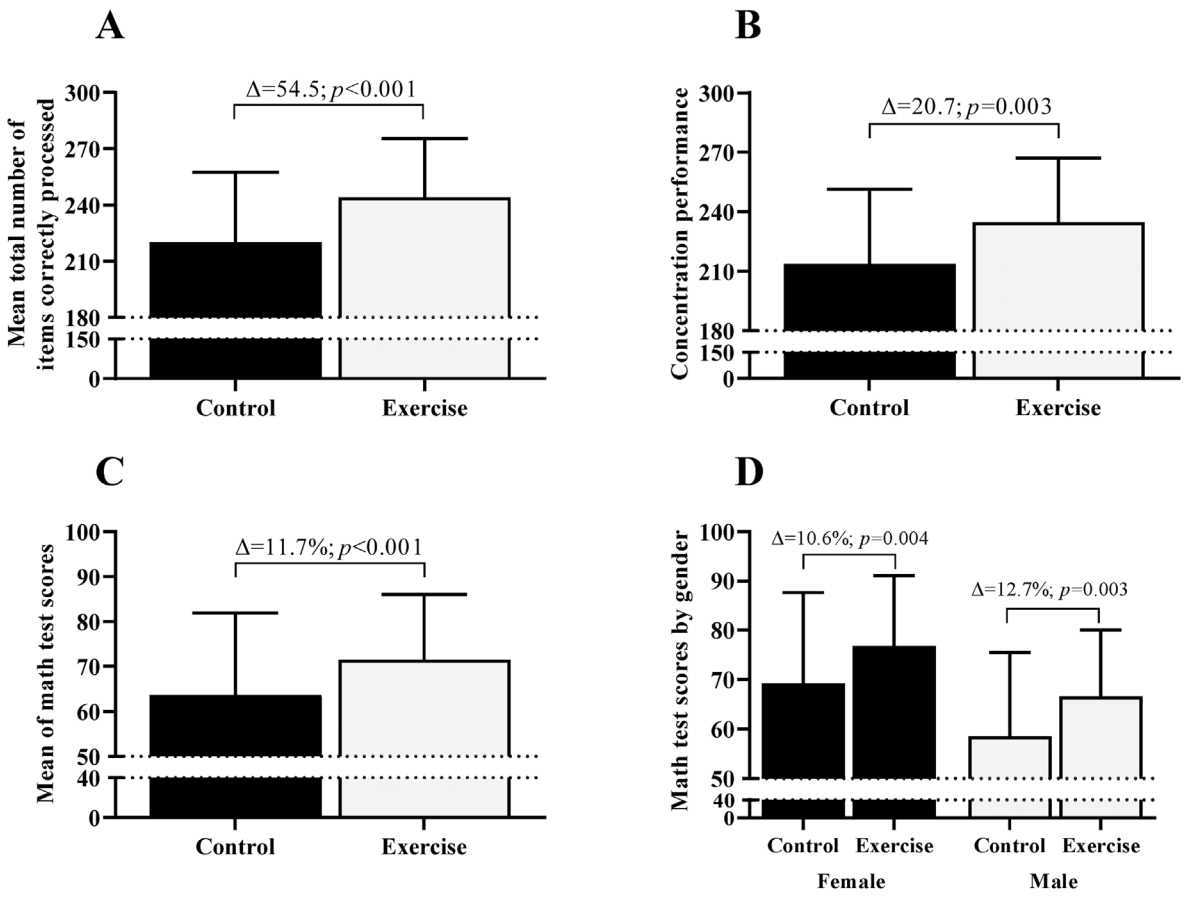

Fig. 3. Effects of exercise on attention (A–B) and math test scores (C–D). Δ: mean difference. Data shown are presented as mean ± *SD*.

Table 2
Changes in adolescents' attention and concentration performance assessed via the d2 attention test.

Variables	Control	Exercise	p^a	Δ	95% *CI*	*t*	*df*	p^b
TN								
Males	217.3 ± 37.0	241.4 ± 31.8	< 0.001	24.1	13.7 to 34.4	0.05	38	0.96
Females	222.3 ± 38.6	246.1 ± 31.8	< 0.001	23.8	13.8 to 33.7			
E_1								
Males	86.1 ± 34.0	58.4 ± 31.2	< 0.001	−27.6	−37.6 to −17.5	0.03	38	0.97
Females	85.7 ± 35.9	57.9 ± 30.9	< 0.001	−27.9	−37.8 to −17.8			
E_2								
Males	5.9 ± 6.7	2.4 ± 2.5	0.051	−3.5	−7.1 to 0.2	0.46	38	0.64
Females	8.9 ± 8.8	4.2 ± 2.2	0.028	−4.8	−9.0 to −0.6			
TN-E								
Males	125.4 ± 69.9	180.6 ± 63.1	< 0.001	55.2	34.7 to 75.6	0.26	38	0.80
Females	130.1 ± 74.7	184.1 ± 62.8	< 0.001	54.0	33.5 to 74.5			
CP								
Males	234.4 ± 37.0	233.8 ± 32.4	0.015	22.4	4.8 to 40.0	0.08	38	0.93
Females	215.8 ± 39.1	234.8 ± 32.8	0.068	19.0	−1.57 to 39.7			

Note: *CI* = Confidence interval, CP = Concentration performance, *df* = Degrees of freedom, E_1 = Errors of commission, E_2 = Errors of omission, TN-E = Total number of characters minus total number of errors, TN = Total number of characters processed, Δ = Mean difference between conditions, p^a indicates the difference between exercise and control conditions for males and females, p^b indicates the difference in the mean between exercise and control conditions across genders. Values are mean ± *SD* (Males, $n = 19$; Females, $n = 21$).

4. Discussion

This study aimed to determine the impact of acute light-to-moderate-intensity exercise on the attention and mathematics performance of adolescents aged 14–16. Results revealed both exercise protocols, involving 30 mins of acute light-to-moderate-intensity Pilates and plyometric exercises performed in a school-based setting, are effective interventions for enhancing students' attention and math test scores. These findings strengthen the growing body of evidence on the benefits of exercise on cognitive function and mathematics test scores in high school students, with the novelty of performing Pilates and plyometric exercise as effective intervention strategies in school-based settings.

4.1. Effect of acute pilates and plyometric exercise on attention

Ample evidence suggests that exercise and fitness levels have an overall small, but significantly positive effect on cognitive functioning.[3,10,41,45–47] This effect is greatly associated with an increase

in cerebral blood flow post-exercise, which in turn enhances the cognitive functions of the organism as a result of an increased supply of essential nutrients into the brain.[48,49] Indeed, Suwabe et al. documented that a 10-min of very light-intensity exercise at 30% of individually-determined peak oxygen uptake did enhance hippocampal memory function, likely through increasing dentate gyrus/CA3−neocortical functional connectivity,[29] which showed rapid enhancement of memory function with acute light exercise. Furthermore, supporting our findings, moderate-intensity exercise is known to lead to significantly higher performance of well-perceived and cognitive functions than those induced by low-to-high intensity exercise,[47] mainly due to increased catecholamines neurotransmitters availability in the brain and increased arousal after moderate-intensity exercise, facilitating the cognition and speed of processing.[47] Additionally, acute exercise-induced increase in the concentration of brain-derived neurotrophic factor may be another pivotal factor with a significant role in improved attention post-exercise.[50,51] A meta-analysis by Chang et al. revealed that exercise intensities ranging from very low to vigorous could improve cognitive function as well as noted that light exercise might not have a significant effect on cognitive functioning,[10] hence requiring more intense exercise for a major effect. Nevertheless, in the current study, we observed a significant enhancement in adolescent attention with acute light-to-moderate-intensity exercise. Further research is required to elucidate the disparities in studies that present contradictory results concerning the effect of exercise intensity on cognitive function. In support of our findings, accumulating evidence suggests a single session of intermittent incremental exercise, high-intensity interval exercise, and coordinative exercise could enhance selected cognitive processes (*e.g.,* attention) in physically active students,[11] inactive adult men with overweight aged 18–30,[52] and students aged 9 to 20.[53–55] For example, a recent study by Altermann and Gröpel found that a 25-min of acute exercise sessions, including endurance, strength, and coordination, at varying intensities, significantly increased the attention levels of adolescent students aged 15 to 18.[8] Similarly, Kao and colleagues also reported that a 24-min of acute interval exercise session, performed at a high level of intensity, corresponding to a rating of 14 or higher on the BORG scale, enhanced scores on the d2 attention test in college students.[56] Collectively, the findings from these studies align with the current research, in which we show that acute exercise interventions, even at lower intensity levels, which can be readily implemented in school-based settings, can effectively enhance attention in adolescents. Our findings present considerable support to the literature that participation in light-to-moderate-intensity physical activity may facilitate selected cognitive processes (*e.g.,* attention) among adolescents.

4.2. Effect of acute pilates and plyometric exercise on mathematics test performance

It is acknowledged that there may exist a positive correlation between engaging in moderate-to-vigorous physical activity and achieving higher scores on mathematical academic performance tests, with the potential effects up to at least 30 mins after exercise.[32,57] Indeed, comprehensive systematic reviews, along with recommendations from an expert panel, underscored the robust body of evidence supporting the positive impact of physical activity on academic performance, particularly in the context of mathematics-related outcomes.[9,31,58] A recent systematic review involving 29 studies with 11 264 participants reported that exercise may enhance mathematics learning in those aged 4–16.[31] Consistent with previous research, the present study reveals that students between the ages of 14 and 16, who engaged in 30 mins of light-to-moderate-intensity exercise within a school environment, achieved higher scores on mathematics tests, likely attributed to enhanced attention and concentration. Similar to our findings, recent research reported that a 10-min and 20-min of having low, moderate, or high intensity exercise breaks resulted in higher math scores in children.[59,60] Similarly, Phillips et al. documented an 11%–22% higher rate in math scores at 30 mins post a single session of vigorous exercise among 8th-grade students.[57] These findings support acute moderate-intensity exercise may facilitate academic performance in math.

4.3. Limitations

The present study is subject to a number of potential methodological weaknesses. First, the sample size in this study was relatively small, showing the need for further studies with a larger sample size that would present more solid conclusions regarding the effects of light-to-moderate-intensity exercise applied in school-based settings on attention and mathematics performance in adolescents. Second, future research should consider utilizing a more precise method than the Borg scale such as maximal oxygen uptake, power output or heart rate to assess the exercise intensities. Third, beyond the assessment of attention and mathematical performance conducted in this study, further research, that takes other variables into account, such as cognitive skills, executive functions, and brain activation, could offer a more comprehensive perspective into a deeper understanding of how exercise might affect cognitive functions and mathematics performance. Forth, in this study, we employed a quasi-experimental study design, which has certain limitations, such as the lack of randomization. Therefore, future research might benefit from considering a cross-over and randomized controlled design. Moreover, we assessed the cognitive function with the d2 test, making it difficult to form a generalized statement of changing cognitive functions. Hence, further research that could assess neuropsychological functions beyond the d2 test would be welcomed. Finally, further research should consider controlling important factors, including the sleep patterns and physical activity levels of the participants, as these factors are highly probable to exert a substantial impact on the variables under investigation.

5. Conclusions

The findings of this study suggest that acute light-to-moderate-intensity Pilates and plyometric exercise interventions, which require no equipment and can be implemented in a school-based setting, can improve selective attention and mathematics test performance in adolescents. This conclusion agrees with the current literature, suggesting that engaging in acute exercise can enhance academic achievements and cognitive functions. Our conclusions extend the current knowledge base by supporting the prescription of exercise interventions within school settings with the aim of developing academic performance. The findings of this study offer significant practical implications for enhancing cognitive performance and academic achievement among adolescents. For instance, our findings could help both to prioritize the inclusion of exercise within school curricula as well as encourage engaging in light-to-moderate-intensity exercise among adolescents, potentially boosting their cognitive and mathematics performance. In particular, this research could serve as a starting point for incorporating brief, practical, and engaging exercise forms, such as plyometric and Pilates, into the daily school schedules. This approach benefits not only physical health but also cognitive well-being among adolescents. Moreover, this study highlights the necessity of designing physical education curricula that include a diverse range of exercises, including plyometric and Pilates, while considering the specific needs and interests of students.

Submission statement

All authors have read and agree with manuscript content and this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

Ethical approval statement

All students and parents provided written informed consent for their children's participation. This study was conducted following the

principles of the Declaration of Helsinki, and approved by the Committee of Strategy Development Department, Directorate of National Education for Keçiören District in Ankara (2204-A/2022), Turkey.

Authors' contributions

Muhammed M. Atakan: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Betül Atakan:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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