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Physical Activity Increases Oxidative Stress Biomarker and Enhance the Academic Performance in Primary School Children

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Abstract

This study aimed to develop a conceptual model to examine the relationship between physical activity (PA), oxidative stress biomarkers, and academic performance. A total of 200 primary school children (100 boys and 100 girls), aged 10–11 years, were randomly assigned to four groups: boys with exercise (boy+Ex), boys without exercise (boy+nonEx), girls with exercise (girl+Ex), and girls without exercise (girl+nonEx). Participants underwent a 12-week treadmill-based running program. Oxidative stress was evaluated through lipid peroxidation by measuring malondialdehyde (MDA) levels. Academic stress was assessed using the Perceived Stress Scale, while academic performance was measured in relation to attention and stress levels. There were significant differences in the concentrations of MDA (mmol/ L) between boy+Ex compared to boy+non Ex, however, the mean MDA in boy +Ex were significantly higher than that in girl +Ex ($P<0.01$). There was a significant increasing in TC >200mg/dl in boy+Ex compared to boy+non Ex. The mean concentrations of TC significantly differed between the boy+Ex compared to girl+Ex. No significant differences were found in the concentrations of LDL >100mg/dl, HDL and TG >150mg/dl <40mg/dl among groups. No statistical differences were showed in academic stress levels between boys and girls. Although, the performance was significantly higher in the girl+Ex group compared to the boy+Ex group. Academic stress levels did not differ significantly by gender, whereas academic performance was significantly higher in the girl+Ex group. The findings suggest that oxidative stress is not directly associated with academic achievement, while physical activity demonstrates an independent relationship with academic performance in primary school children.

Fiziksel Aktivite, Oksidatif Stres Biyobelirteçlerini Artırır ve İlkokul Öğrencilerinde Akademik Başarıyı Geliştirir

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Özet

Bu çalışma, fiziksel aktivite (PA), oksidatif stres biyobelirteçleri ve akademik performans arasındaki ilişkiyi araştıran kavramsal bir model geliştirmeyi amaçlamıştır. Çalışmaya ilkokuldan toplam 200 çocuk (100 erkek ve 100 kız, 10-11 yaş aralığında) katılmış ve rastgele olarak dört gruba ayrılmıştır: erkek egzersiz grubu (boy+Ex), egzersiz yapmayan erkek grubu (boy+non Ex), kız egzersiz grubu (girl+Ex) ve egzersiz yapmayan kız grubu (girl+non Ex). Katılımcılar 12 haftalık bir koşu bandı programına katılmıştır Oksidatif stres, lipid peroksidasyonu (MDA düzeyleri) ile değerlendirilmiştir. Akademik stresi değerlendirmek için Algılanan Stres Ölçeği kullanılmış, akademik performans ise dikkat ve stres düzeyleriyle ilişkili olarak ölçülmüştür. Bulgulara göre, erkek egzersiz grubu ile egzersiz yapmayan erkek grubu arasında MDA (mmol/L) düzeylerinde anlamlı farklar bulunmuştur; ayrıca, erkek egzersiz grubundaki ortalama MDA düzeyi, kız egzersiz grubuna kıyasla anlamlı şekilde daha yüksektir. Toplam kolesterol (TC) >200 mg/dl düzeyinde, egzersiz yapan erkek grubunda, egzersiz yapmayan erkek grubuna kıyasla anlamlı bir artış gözlenmiştir. TC ortalama düzeyleri açısından da erkek egzersiz grubu ile kız egzersiz grubu arasında anlamlı farklar bulunmuştur. LDL >100 mg/dl, HDL ve TG >150 mg/dl <40 mg/dl düzeyleri arasında gruplar arasında anlamlı fark tespit edilmemiştir. Akademik stres düzeyleri cinsiyete göre farklılık göstermemiştir. Ancak, akademik performans kız egzersiz grubunda anlamlı düzeyde daha yüksektir. Sonuç olarak, oksidatif stresin akademik başarıyla doğrudan ilişkili olmadığını; buna karşın fiziksel aktivitenin akademik performansla bağımsız bir ilişki gösterdiğini ortaya koymaktadır.

1. INTRODUCTION

The World Health Organization (WHO) and other international institutions have recommended that children should perform at least an average of 60 min per day of moderate to vigorous-intensity, mostly aerobic activities across the week, in order to achieve several positive outcomes regarding cardiovascular, metabolic, and musculoskeletal health (Chaput et al., 2020). In line with this, physical activity is generally considered one of the most important health markers as well as predictor of health-threatening conditions (Booth et al., 2017). Over the course of the last century, a multidisciplinary field of knowledge has identified several cognitive and academic benefits of regular physical activity (Best, 2017; Trudeau and Shephard, 2008).

The idea that PA can enhance cognitive and academic ability has consequently received significant attention in health and education fields (Hillman et al., 2009; Shephard, 1997). It is recognized that PA triggers change in the human brain due to increases in metabolism, oxygenation and blood flow providing hormones that promote neurological health (Whiteman et al., 2014; Khan and Hillman, 2014). Those changes are particularly important for the developing pediatric brain (Khan and Hillman, 2014; Chaddock et al., 2010). Further, it is possible that low physical fitness levels and low academic performance co-occur in preadolescent children. In preadolescent children, a small number of studies reported a global positive association between physical fitness and academic performance (De Greeff et al., 2014). The studies were inconclusive regarding the possible specific association. The disturbance in some of biological cells may be related to several reasons such as age-related diseases, metabolic disorders, sedentary lifestyle like poor physical activity, or mental stress (Abdullah et al., 2012; Aouadi et al., 2015). Motor development and brain function have been shown to correlate with active physical performance, especially among children and adolescents with lower motor abilities (Carmeli et al., 2012; Alghadir et al., 2016). This was significantly associated with a sedentary lifestyle or low physical activity (Alghadir et al., 2016). However, the physiological and biochemical effects of physical exercise on the status of intellectual abilities among young individuals still have to be fully elucidated. In contrast, practice of physical activity, both in adults and children, has been associated with an increase in antioxidants and a reduction of pro-oxidants (Llorente-Cantarero et al., 2021). The effect of acute and chronic physical activity practice on oxidative stress responses in children and adolescents has been recently reviewed (Avloniti et al., 2017). Acute exercise seems to induce a relevant, but transient, increase in markers of oxidative stress. In contrast, regular exercise appears to be associated with increased antioxidants and reduced systemic oxidative biomarkers, even independently of body weight status. However, the studies included in that review are heterogeneous in terms of the type of exercise, intensity, and time of physical activity practiced (Avloniti et al., 2017). Physical activity practice also seems to reduce lipid peroxidation and improve the antioxidant defense system, resulting in the maintenance of redox homeostasis (Sutkowy et al., 2021). In addition, some studies suggest that the cognitive demands that underlie exercise might improve cognitive performance (Fisher et al., 2017). For example, team sport games or physical education contains several cognitive challenging demands, such as setting goals, making decisions, employing different strategies and working together with teammates. The cognitive skills learned during these activities are assumed to benefit academic performance (Hanushek, 2012). To summarize, regular participation in exercise will lead to morphological brain changes, which benefit academic performance. There is evidence that through regular participation in physical exercise of moderate or vigorous intensity changes in cardiovascular fitness occur, leading to short and long-term effects on cognitive performance (Erickson et al., 2019). Regarding the short-term effects immediate changes in concentration levels of neurotransmitters follow after exercise. For example, exercise increases concentrations

of the brain-derived neurotrophic factor (BDNF), which stimulates learning and memory (Hafedh & Parnow, 2022).

Clarifying the relationship between physical activity and academic performance along with some physiological parameters such as oxidative stress in children is an important in developing academic field. Therefore, the present study was to determine a possible correlation between the Oxidative Stress and the academic performance in primary school children.

2. METHOD

2.1. Research Design

The present study employed a randomised controlled experimental design to examine the effects of a 12-week treadmill-based physical activity intervention on oxidative stress biomarkers and academic performance in primary school children aged 10–11. The exercise intervention was the independent variable, while the dependent variables included oxidative stress markers (MDA, TC, TG, LDL, HDL), perceived academic stress (measured using the Perceived Stress Scale), and academic performance (based on final grades and attention-related indicators). The random assignment of participants to the intervention groups was used to reduce selection bias, and all data were collected under standardised conditions before and after the intervention.

2.2. Participants

A total of 200 children from five school aged (10-11 years) were randomly divided to four groups: non boys exercise (boy+nonEx), boys with exercise (boy+Ex), non-girls exercise (girl +nonEx) and girls with exercise (girl+Ex). Each group consisted of 50 participants.

2.3. Exercise Program

Children were allowed to hold onto the treadmill handrail at a 0% incline and walk for 2 minutes to regain balance before speed adjustments. Afterward, participants were running for 15-17 minutes 4 times per week for 12 weeks using motor-driven treadmill (En Mill, Enraf Nonius, and Rotterdam, Netherlands). Before and during the test we monitored heart rate and transcutaneous oxygen saturation with a pulse Oximeter motion artifact system, type 2001, Respironics Novametrix, Murrysville, PA, USA).

2.4. Lipid Profile and MDA

5 mL of venous blood were collected into tubes. The serum was allowed to clot for 15 min then centrifuged at 4000 rpm for 15min following the instructions of the kit manufacturer and stored at −80°c until assayed. The serum used to assess the levels of (lipid profile) that determined by enzymatic method. Kits were supplied by Spin react company – Spin. The concentration was estimated in the serum of the participants as a quantitative measure of lipid peroxidation using high-performance liquid chromatography as mentioned previously (Reitznerová et al., 2017).

2.5. Data Collection Tools

2.5.1. Academic Performance

Academic performance was evaluated using data obtained from the academic office, including each participant's mean final grade (on a scale from 1 to 7) and the number of courses enrolled, passed, or failed during the first academic term. These indicators were used to explore the potential influence of attention levels on academic achievement.

2.5.2. Perceived Academic Stress

Perceived academic stress was assessed using a 31-item Likert-type questionnaire, with responses ranging from 1 (never) to 5 (always). Based on the total score, stress levels were categorized as mild (0–33%), moderate (34–66%), and high (67–100%). Additionally, the scale included items evaluating perceived nervousness on a scale from 1 (low) to 5 (high).

2.6. Statistical Analysis

Data are presented as means ± standard deviation. Data distribution was assessed using the Shapiro-Wilk test. Chi-square test was used to compare the distribution of gender in the groups. Two-way analysis of variance (ANOVA). Followed by post-hoc test was also used for biomarker assessment. Significance level was set at $P<0.05$.

2.7. Ethical Considerations

All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Prior to participation, written informed consent was obtained from the parents of all children involved in the study. The research was conducted in accordance with the ethical principles outlined by the Ethics Committee of Basra University of Medical Sciences. All personal data were kept strictly confidential and used solely for academic and scientific purposes. No form of coercion or manipulation was applied at any stage of the research process.

3. FINDINGS

3.1. Oxidative Stress Outcomes

Table 1 presents the oxidative stress biomarker levels, including total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and malondialdehyde (MDA), stratified by gender and exercise status. The aim is to compare the biochemical responses to the 12-week physical activity intervention among male and female students.

Table 1. Demonstrated the oxidative stress outcomes parameters among group

Parameters	Boys	Range	Girls	Range	Suggested cut-off value
TC (mg/ dl)	159.88 ± 5 .58	92-199	194.48 ± 3 .71	88-210	190
TG (mg/ dl)	158.20 ± 10 .01	28-201	193.51 ± 7.12	30-185	150
HDL (mg/ dl)	42.50 ± 8.14	24-72	37.33 ± 4.09	20-90	20
LDL (mg/ dl)	104.23 ± 21.10	29-121	112.54 ± 28.27	34-200	110
MDA	1.35	1.40-1.78	0.09	0.05-1.10	0.12

As shown in Table 1, there was a significant increase in MDA concentrations (mmol/L) in the boy+Ex group compared to the boy+nonEx group ($P < 0.04$). Additionally, MDA levels in the boy+Ex group were significantly higher than those in the girl+Ex group ($P < 0.01$). A significant elevation in total cholesterol (TC > 200 mg/dL) was also observed in the girl+Ex group compared to the girl+nonEx group ($P < 0.01$). Moreover, the mean TC levels differed significantly between the boy+Ex and girl+Ex groups ($P < 0.01$). However, no significant differences were found among

groups in terms of LDL (>100 mg/dL), HDL, or triglyceride (TG >150 mg/dL or <40 mg/dL) concentrations.

3.2. Academic Performance & Perceived Academic Stress

The graph below illustrates the effect of physical activity on academic performance by gender. It presents a comparative overview of academic achievement levels among male and female students who participated in or did not participate in the exercise intervention.

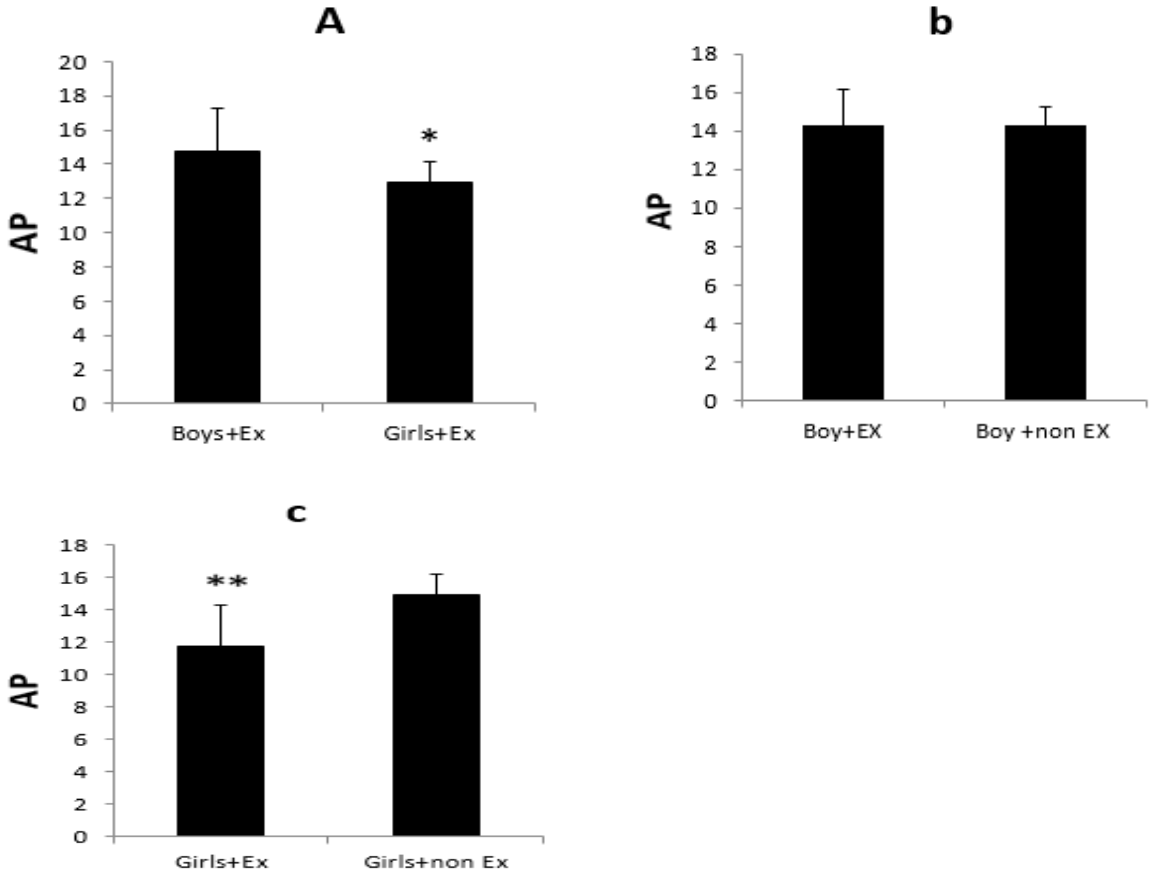

Figure 1. Comparative academic performance scores of exercise and non-exercise groups by gender.
(A) A statistically significant difference was observed between the girls+Ex and boys+Ex groups in academic performance ($P < 0.05$).
(b) No significant difference was found between the boys+Ex and boys+nonEx groups.
(c) A significant decrease in academic performance was observed in the girls+Ex group compared to the girls+nonEx group ($P < 0.01$).
Data are presented as group means ± standard error of the mean (± S.E.M).

A significant difference in academic performance was observed between the girls+Ex and boys+Ex groups, with the girls+Ex group showing lower performance scores ($P < 0.05$) (Figure 1.A). As illustrated in Figure 1.b, no statistically significant difference was found between the boys+Ex and boys+nonEx groups. However, the girls+nonEx group demonstrated significantly higher academic performance compared to the girls+Ex group ($P < 0.01$) (Figure 1.c).

4. DISCUSSION AND CONCLUSIONS

Our results indicated that the concentrations of MDA in exercise boys group were significantly higher than that in girls group. We suggesting that, the boys school usually a tend to exercise activity such as football and running etc...

As physiological conditions, the statistically insignificant gender difference findings from the present study are not congruous to other results in literature: this may be due to the fact that gender differentiation process is a continuous one; gender role development and functioning are not confined to childhood but rather evolve throughout the lifespan Bussey and Bandura, 1999). The present findings differ from a similar model tested by Van der Niet et al. (2014) that characterized the relationship between physical fitness, executive function and academic achievement in 263 children. In their two-variable model of physical fitness and academic achievement, the relationship was slightly greater than the equivalent PA-academic performance relationship for model.

in this study. When executive function was added to their model, the relationship between physical fitness and executive function was stronger than that between physical activity and cognition, consistent with findings from Model 2 in this study. Our results indicate that 12-weeks of regular physical training may mitigate the negative effect that acute academic stress has on cortisol and attention levels and furthermore that cognitive function is closely associated with cortisol levels during acute stress. These results are consistent with a previous study by Phan et al. (2018) which reported that students with shorter attention spans engaged in less physical activity.

Consequently, exercise training could improve academic performance during periods of academic stress by boosting attention levels (Dubuc et al., 2020). This could be due to hormesis, in which exposure to an acute, intermittent, low dose stressor (physical training) results in positive biological responses that allow the body to become more resilient to other stressors, either physiological or psychological. however, in a previous study Caputo et al., (2020) it was suggested that the hermetic effect of physiological stimuli on psychological resilience may be mediated by modulating mitochondrial activity, which in turn affects catecholaminergic responses and glucocorticoid synthesis and metabolism. As such, exercise, and endurance activity in particular are known to affect mitochondrial function (Peake et al., 2015). Which is a fundamental part of the adaptive responses to psycho-physiological challenges (Caputo et al., 2020). Acute stress affects cognitive function by increasing cortisol levels, reducing cerebral pre-frontal cortex activity (Tapia et al., 2022). Physical exercise in general, and acute moderate-intensity resistance or endurance exercise in particular, may acutely improve cognitive function (Cooper et al., 2018). In this study we further extend this knowledge by demonstrating that 12 weeks of training improves attention levels during a stressful exam period.

A limitation of our study is that sleep time was not controlled. Sleep may affect cortisol levels and stress (Sohail, 2013). Furthermore, we did not randomly assign participants to the experimental groups as those students who were already engaged in physical exercise were assigned. Future research may establish optimal programming variables (e.g., intensity) during regular exercise to maximize reduction of stress and improvements in attention levels and academic performance of university students during final exams, considering potential moderators (e.g., sleep habits) which may help to uncover further underlying mechanisms involved with cortisol concentrations changes and academic performance (Stults-Kolehmainen and Sinha, 2013).

Studies that investigate the effect of specific training variables (duration, intensity, volume and frequency) and participant characteristics (age, training status, sex) on cortisol synthesis, are

required for a more detailed understanding of the relationship between exercise and cortisol levels. It would also be of interest to explore the effect of sleep on stress, cognitive function and academic performance in combination with different exercise training modalities. synthesis, are required for a more detailed understanding of the relationship between exercise and cortisol levels. It would also be of interest to explore the effect of sleep on stress, cognitive function and academic performance in combination with different exercise training modalities.

Conclusions

This study shows a positive association between PA and academic performance for the whole study cohort. Importantly, this study further shows that relationship remains when considering the mediating effect of cognition. Thus, the model tested identifies physical activity is associated with academic performance both directly and indirectly through cognitive function. Studies with larger sample sizes are needed to investigate important confounding factors such as gender, age.

Conflict of Interest

The authors declare no conflict of interest.

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Author Biography and Contributions

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Author Contributions

The sole author was responsible for the conception, design, data collection, analysis, interpretation, and writing of the manuscript.

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