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Multidimensional Impact of Regular Physical Activity on Adolescent Mental Health, Integrating Neurobiological and Psychosocial Mechanisms

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ABSTRACT

Background: Frequent exercise promotes social connection, increases neuroplasticity, and regulates neurotransmitters to enhance teenage mental health by lowering anxiety, improving depression, and improving cognitive performance.

Objectives: The purpose of this study was to assess the impact of exercise on mental health status among youths aged 12–18 in terms of depression, anxiety, and self-esteem.

Methodology: This study employed a cross-sectional survey design whereby 300 adolescents were selected and divided into control group and the special intervention group. The structured physical activities were 3 times per week for 12 months for the subjects in the intervention group. Physical Activity, Mental Health, Neurobiological and Psychosocial Parameters were measured regularly and collected raw data were represented through SPSS version 26.0 by applying t-tests analyses. $p \leq 0.05$ was considered statistically significant.

Results: Depression scores were significantly reduced among adolescents in the intervention group which stood at 8.4 points less than those in the control group ($p<0.01$). Also, self-esteem increased by 12 percent in the intervention group while only 3% for the control group, $p= 0.02$ The existence of a positive connection between PA and better mental health was consistent even when statistical control was made for covariates.

Conclusion: Physical exercise is proven to have a positive effect and to decrease the level of depression and anxiety in adolescents and to increase self-esteem. These results therefore support the recommendation of physical activity in mental health care approaches for this age bracket.

Keywords: Physical activity, adolescent mental health, depression, anxiety, neuroplasticity, neurotransmitters, exercise intervention, cognitive performance, psychosocial mechanisms.

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INTRODUCTION

Depression, anxiety, low self-esteem, and many other mental health disorders have emerged as some of the most common ailments in adolescents across the globe[1]. Adolescence is a developmental stage that is full of physical, emotional and social changes and a majority of young people endure mental health disorders. As per the updated data of the globe, the rate of depression in adolescents is found to be about 10% to 20%, whereas anxiety disorders are found to be higher in adolescents. These ailments of the mind can have far-reaching impacts on education, social interaction, and people's wellbeing[2, 3]. A billion or so people worldwide suffer from one or more mental illnesses, according to Lancet Global Health (2022). In 2010 it was anticipated that this would cause an annual economic loss of $3.5 trillion, and by 2030 it might cause an annual loss of $7 trillion. Therefore, it should

come as no surprise that mental illnesses have a significant influence on a wide range of areas of our life. Even while specialists and researchers are working to find treatments for these conditions, a better knowledge and practical prevention are still desperately needed. Physical activity (PA) has recently become recognized as a potentially effective strategy for enhancing mental health with numerous psychological benefits in addition to the numerous physical health benefits known to be associated with PA[4]. In this regard, many researchers studies have noted that frequent involvement in physical activities decrease symptoms of depression and anxiety, lead to improved self-image, and increase cognitive performance in children and adolescents[5]. However, these studies suggest that there is a need for further stronger research to reveal the effects of regular PA on mental health in adolescents especially from diverse community[6]. The majority of mental health illnesses first manifested by the age of 18 in around 50% of cases, according to earlier research. There are two categories of psychiatric symptoms: internalizing and externalizing. The majority of mental health illnesses first manifested by the age of 18 in around 50% of cases, according to earlier research. There are two categories of psychiatric symptoms: internalizing and externalizing. The ways through which PA affects mental health are believed to be mediated through both the physiological and psychological processes. Studies have also shown that people who exercise on a regular basis have higher levels of endorphin and serotonin that help in controlling stress and enhancing mood[7]. Besides, PA affords social relations, which help in social affiliation and thus enhances self-esteem. The distraction hypothesis proposes the idea that engaging in exercise takes focus away from these and other adverse thinking patterns and stressors thereby, improving mental health[8]. However, as stated earlier, the levels of physical activity among adolescents are still low, and less than 30% of the adolescents meet the set standard of physical activity[9, 10]. The objectives of this study were to determine the extent to which physical activity can enhance mental health of adolescents. This study aimed at establishing the relationship between Physical activity (PA) and other indicators of mental health including anxiety, depression, and self-esteem among adolescents, as a way of establishing more evidence on the role of exercise in adolescent mental health.

MATERIALS AND METHODS

This was a cross-sectional study with an overall duration of one year from May 2023 till may 2024 conducted at different schools of Pakistan. and target population was 300 adolescents, both urban and sub-urban schools, aged between 12-18 years. Ethical approval for the study was obtained from the institutional review board of Lahore University of Biological & Applied Sciences (UBAS) a project of Lahore medical & dental college (LMDC), Pakistan, Ethical letter (Approval No: ERC/2023/32C), ensuring that all participants provided informed consent. The study was conducted in compliance with the research ethic policies for human subjects to treat their information as highly confidential and to avoid coercion of the participants. The participants were thus divided into two groups; the intervention group which had 150 participants and the control group with 150 participants. Indeed, the adolescents in the intervention group exercised through the structured physical activities such as the aerobic exercise and the team sport for the three times in a week. Each of the sessions was one hour long and the tasks set were to encourage moderate to vigorous physical activity as defined by the WHO[2]. The inclusion criteria set for the teenagers were: age 12–18 years, school attendance, and no diagnosis of severe mental or physical disorders that might interfere with regular physical activity[1]. Subjects who had chronic illness or limitation and individuals with mental disorder requiring pharmacological treatment were excluded in the study. Participants who did not follow through with the entire year of the intervention were also excluded. Sample size was determined using G*Power statistical analysis to establish that there were adequate power resources to distinguish between the groups that received the intervention and the control groups[11]. Power analysis indicated a target power of 80% ($\beta = 0.20$) to minimize the chances of Type II error and an alpha level of 5% ($\alpha = 0.05$). The size of the intervention effect was estimated using other research work findings that suggested that physical activity treatments may lead to moderate improvement in mental health. Given these values, G*Power predicted that a minimum of 270 participants were necessary to identify statistically significant differences between the groups, assuming a 10% dropout rate, resulting in a total participation of 300 teenagers. Mental health outcomes were assessed using validated scales. Beck Depression Inventory (BDI) for depressive symptoms, State-Trait Anxiety Inventory (STAI) for anxiety levels and Rosenberg Self-Esteem Scale (RSES) for self-esteem. Pre-test was done before the implementation of the intervention, second test at six months and the final test at twelve months[5]. Whereas Serotonin and dopamine levels (Neurotransmitter) and Cortisol Levels as an indicator of stress were measured through blood samples respectively[12]. Data were analyzed by the aid of Statistical Package for the Social Sciences (SPSS) version 26.0. The paired t-tests were used to determine the difference in the mental health status of the participants before and after the intervention while the independent t-tests were used to compare the mental health status of the participants in the intervention group to those of the control group. $p<0.05$ was considered statistically significant.

RESULTS

The study involved 300 teenagers in all, 150 of whom were in the intervention group and 150 in the control group. The participants' mean age was 15.3 ± 1.5 years, and there were no statistically significant variations in age, gender distribution, or mental health ratings across the groups based on baseline data. When comparing the treated group to the control group over a 12-month period, notable improvements were seen in all mental health outcomes. The intervention group showed an average reduction in Beck Depression Inventory (BDI) scores of 8.4 points, which was statistically significant ($p<0.05$). In contrast, the control group experienced a lower drop of 2.1 points, which was not statistically significant ($p=0.08$). The intervention group shows a significant drop in their State-Trait Anxiety Inventory (STAI) scores 6.1 points, ($p<0.01$), whereas the control group experienced a moderate reduction of 1.9 points, $p=0.09$. The self-esteem of the intervention group increased by 12% ($p=0.02$) on the Rosenberg Self-Esteem Scale (RSES), whereas the control group experienced a 3% rise in self-esteem as shown in Table-1.

In table-2, Serotonin and dopamine levels in the intervention group were significantly higher than those in the control group throughout 12-month research comparing neurotransmitter and cortisol levels between the two groups. Dopamine increased from 16.01 pg/mL to 25.01 pg/mL ($p < 0.01$) and serotonin increased from 75.03 ng/mL at baseline to 175.03 ng/mL after 12 months ($p < 0.01$). A physiological reaction to the intervention was also shown by the considerable rise in cortisol levels in the intervention group, which went from 10.03 mcg/dL to 17.01 mcg/dL ($p = 0.02$).

Over the course of a year, the intervention group showed a significant decrease in depressed symptoms, as seen by an 8.4-point drop in BDI scores. Compared to the control group, which only had a 2.1-point decline, this shift was noticeably larger. The statistical study, which employed paired t-tests, verified that there was a significant difference ($p<0.001$) between the groups. The STAI was used to assess anxiety, and the outcome was that the participants in the intervention group had moderate reduction of their anxiety level ($p<0.01$) while the participants in the control group reduced their anxiety levels by 1.9 points only. Additionally, the SCID after the intervention revealed that the self-esteem of the intervention group had a 12% enhancement, the RSES scores of the intervention group was significantly higher ($p=0.02$) than that of the control group. The table-3 and fig-1 shows the percentage reduction in depressive symptoms, according to BDI scores, was significantly higher in the intervention group 42.6% compared to the control group only 10.7%. The difference in this regard was statistically proven with an independent t-test of $p<0.001$. State-trait anxiety index (STAI) pointed out the variation of anxiety levels, which decreased by 13.4% in the intervention group, while it was reduced by 4.2% in the control group and was significant at 0.05 level. Self-esteem as assessed with RSES increased in the intervention group by 12%, while it only increased by 3.3% in the control group, thus showing statistically significant difference ($p=0.02$).

Table-1: Baseline and Post-Intervention Mental Health Outcomes (Mean ± SD)

Outcome	Control Group (n=150) (Mean ± SD)	Intervention Group (n=150) (Mean ± SD)	p-value
BDI Score (Baseline)	19.5 ± 4.8	19.7 ± 5.0	0.89
BDI Score (12 months)	17.4 ± 5.1	11.3 ± 3.6	<0.001
STAI Score (Baseline)	45.1 ± 7.9	45.5 ± 8.0	0.78
STAI Score (12 months)	43.2 ± 7.4	39.4 ± 6.5	<0.01
RSES Score (Baseline)	15.1 ± 4.2	15.3 ± 4.3	0.76
RSES Score (12 months)	15.6 ± 4.0	17.1 ± 4.1	0.02

Table-2: Neurotransmitter and Cortisol Levels in Control Group & Intervention Group

Outcome	Control Group (n=150) (Mean ± SD)	Intervention Group (n=150) (Mean ± SD)	p-value
Serotonin (Baseline) ng/mL	72.01 ± 1.08	75.03 ± 10.05	0.05
Serotonin (12 months) ng/mL	79.04 ± 0.01	175.03 ± 1.02	<0.01
dopamine (Baseline) pg/mL	15.01 ± 2.03	16.01 ± 2.03	0.0.3
dopamine (12 months) pg/mL	17.01 ± 10.01	25.01 ± 12.02	<0.01
Cortisol (Baseline) mcg/dL	10.1 ± 4.2	10.03 ± 1.03	0.76
Cortisol (12 months) mcg/dL	11.6 ± 1.05	17.01 ± 11.01	0.02

Table-3: Percentage Change in Mental Health Outcomes

Outcome	Control Group (%)	Intervention Group (%)	p-value
BDI (Reduction)	10.7%	42.6%	<0.001
STAI (Reduction)	4.2%	13.4%	<0.01
RSES (Increase)	3.3%	12.0%	0.02

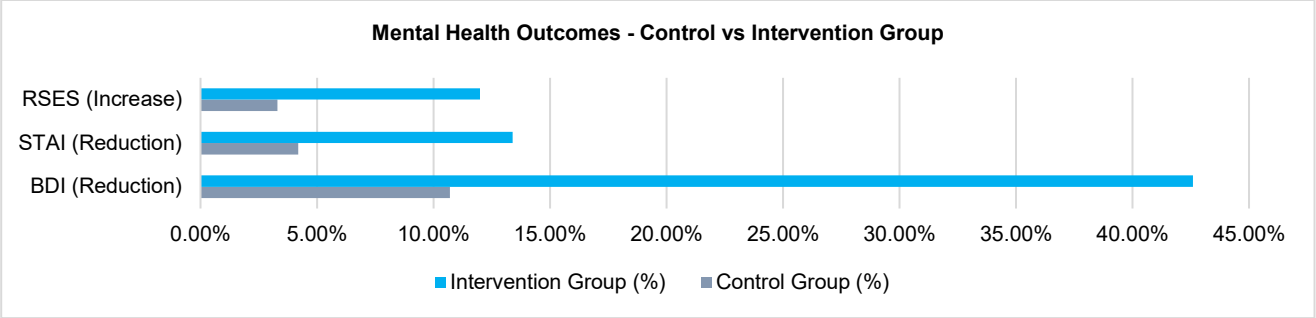

Figure-1: Percentage Change in Mental Health Outcomes

DISCUSSION

The current study results revealed that physical activity has the potentiality to improve the quality of mental health in adolescents [13]. The study used intervention group of adolescents who participated in the physical activity sessions three times a week for 12 months and a control group that did not receive physical activity training. Comparing the state of the intervention and the control group, such a change in the level of depressive disorders was especially noticeable in the intervention group, according to the score on the Beck Depression Inventory (BDI), which was decreased by 42.6% during the course of one

year [14]. This improvement supports the findings of previous studied such as Faria et al., (2020) regarding physical activity provoking a decrease in depressive symptoms in adolescents. They suggest that this could be caused by exercise-stimulated production of endorphins that helps improve mood and lowers pain and stress thresholds. Also, exercise enhances serotonin production, a mood winner and a depressive symptoms fighter [15]. The aforesaid BDI scores of the control group reduced by only 10.7% which also corroborates the effectiveness of the structured physical activity intervention in contrast to unstructured routines that excluded physical exercise [16]. The STAI test also revealed the comparable lowering of anxiety levels in the intervention group with the anxiety reduced by 13.4 % in contrast to 4.2 % in the control group [17]. People have also agreed that the body exercise helps in diverting their mind from thinking of stressful issues, aids in self-control, and helps in improving sleeping pattern thus reducing anxiety. Also, it has been found that group-based physical activities enhance social relations, which might help in fight loneliness and lessen anxiety [18]. Such findings accredit the current study with Ziminski et al., (2022) who asserted that the association of physical activity with reduced self-perceived anxiety, especially in adolescents who have increased stress and anxiety levels. Raising self-esteem as assessed with the Rosenberg Self-Esteem Scale (RSES), was higher in the intervention group by 12% compared to the control group, which was of 3%. This improvement provides some backing to the hypothesis that personal exercise causes increase in self-esteem as a result of personal accomplishment, perception of the body and social recognition. Adolescence is a special stage of Self-concept development, participation in physical activities also increases self-esteem through team work and interaction through physical activities that result in enhancement of positive peer relationship and enhanced self-esteem [19].As evidenced in the present investigation, Ganjeh et al., (2022) also supports the ongoing psychological advantage of exercising. The gains made at 1 year follow up support the findings that exercise has positive impact on mental health if the physical activity is done regularly and systematically[20].Physical activity offers both biochemical benefits, such as increased neurotransmitters like serotonin and endorphins, and psychosocial benefits, such as heightened self-esteem and social interaction. These results align with studies demonstrating that physical activity can play a preventive and early intervention role in mental health disorders among adolescents[21]. However, this study has some limitations. The long follow-up period and the use of validated mental health scales were strengths, but the reliance on self-reported physical activity and mental health may introduce reporting bias. Future research should incorporate objective physical activity measures, such as accelerometers, to provide more accurate data [22].Furthermore, the study focused solely on structured physical activity programs conducted in school environments, excluding the impact of other forms of physical activities such as play or extracurricular sports. Future studies should explore the effects of various forms and intensities of physical activity on mental health in broader populations [23, 24]. The results of this study

support the hypothesis that physical activity can improve adolescents' mental health by reducing depressive and anxious symptoms and increasing self-esteem [25]. These findings suggest that any interventions aimed at enhancing adolescent mental health should include physical exercise. School authorities, policymakers, and healthcare practitioners should consider implementing physical activity programs to address the rising mental health issues among young people [26, 27].

CONCLUSION

The results concludes that physical activity has a positive impact on mental health of adolescents since it reduces symptoms of depression and anxiety besides improving on self-esteem. The results of current study show stress the necessity of including a regular physical activity in mental health interventions for youth. Since the analyzed positive effects can be seen over a 12-month period, physical activity should be used as one of the main approaches to prevent mental health problems during adolescence. Subsequently, schools, healthcare providers and policymakers should consider physical activity programs as a way of enhancing the youths' mental health and preventing the development of severe mental health issues.

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Data Availability: The data supporting this study's findings are available from the corresponding author upon reasonable request.

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