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RESEARCH PAPER

Relationship between Physical Activity and Immune Function in College Students

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ABSTRACT

Physical activity (PA) is known to positively influence various physiological systems, including immune function. Among college students, a group often exposed to academic stress and lifestyle irregularities, the role of PA in maintaining immune health is particularly important. This study investigates the relationship between levels of physical activity and markers of immune function in college students. Using a cross-sectional design involving 300 students aged 18–22, data were collected through questionnaires (IPAQ-SF, PSS) and biological samples (saliva and blood) to measure immune markers such as natural killer (NK) cell activity, serum cytokines (IL-6, TNF-α), and salivary IgA. Results indicate that moderate physical activity correlates with improved immune function, while excessive activity shows signs of transient immunosuppression. Psychological resilience was also found to mediate the relationship between PA and immunity. The findings highlight the importance of regular, moderate exercise as a non-pharmacological intervention to support immunity in young adults.

Keywords: *Physical activity, immune function, college students, NK cells, cytokines, salivary IgA, resilience, moderate exercise*

INTRODUCTION

The immune system serves as the body's defense mechanism against pathogens, toxins, and abnormal cells. It is a complex network of cells, tissues, and biochemical mediators that work synergistically to maintain homeostasis and ensure survival. While traditionally viewed from a biological standpoint, the immune system is increasingly being studied through a multidisciplinary lens that includes behavior, lifestyle, and psychosocial factors (Nieman, 1997). Physical activity has emerged as a key modifiable behavior that can significantly impact immune competence. Regular physical activity is associated with enhanced circulation of immunoregulatory cells, improved vaccine responses, and decreased incidence of communicable diseases such as upper respiratory tract infections (URTIs) (Gleeson *et al*., 2011). However, the intensity and duration of physical activity can determine whether it enhances or impairs immune function. The "J-shaped curve" hypothesis posited by Nieman (1994) and supported in subsequent studies suggests that while moderate physical activity strengthens immune defenses, excessive or high-intensity exercise may suppress certain immune functions temporarily. This paradox makes it essential to differentiate between beneficial and detrimental forms of physical exertion, especially among vulnerable populations like college students. College students represent a unique demographic, often exposed to academic stress, inconsistent sleep patterns, dietary irregularities, and sedentary behaviors. These factors can weaken immune responses and increase susceptibility to infections (Brown *et al*., 2004). Regular physical activity may serve as a protective factor, buffering the negative effects of stress and promoting overall physiological resilience (Pedersen & Hoffman-Goetz, 2000). Previous research on young adults has shown that moderate exercise can elevate levels of salivary immunoglobulin A (IgA), an important component of mucosal immunity. For example, Mackinnon (1999) found that individuals who exercised moderately showed higher salivary IgA levels compared to sedentary or overtrained individuals. Salivary IgA plays a crucial role in preventing respiratory and gastrointestinal infections, which are common among college populations.

Additionally, exercise-induced changes in cytokine profiles further illustrate the link between physical activity and immune modulation. Moderate exercise leads to an increase in anti-inflammatory cytokines like IL-10 and a decrease in pro-inflammatory markers such as IL-6 and

TNF-α (Walsh *et al*., 2011). These biochemical shifts may partly explain the lower incidence of inflammation-related disorders in physically active individuals. Beyond physiological mechanisms, psychological well-being also plays a critical role in immune health. Physical activity has been associated with reductions in stress, anxiety, and depressive symptoms, all of which have been shown to negatively influence immune function (Segerstrom & Miller, 2004). College students who engage in regular exercise tend to report higher levels of psychological resilience and lower perceived stress (Kim *et al*., 2015). The emerging field of psychoneuroimmunology supports this interaction, emphasizing how the brain, behavior, and immune responses are interconnected. Stress-induced activation of the hypothalamic-pituitary-adrenal (HPA) axis can suppress immune function through elevated cortisol levels. Regular physical activity helps regulate this response, thus supporting both mental and immune health (Kiecolt-Glaser *et al*., 2002). Furthermore, lifestyle habits often adopted during college years are likely to persist into adulthood, making this a critical period for intervention. Developing regular physical activity routines not only supports immediate health outcomes but also builds lifelong habits that promote immune resilience and chronic disease prevention (Warburton *et al*., 2006). Despite these benefits, the majority of college students fail to meet recommended physical activity levels. According to the World Health Organization (WHO, 2010), adults aged 18–64 should engage in at least 150 minutes of moderate-intensity aerobic physical activity throughout the week. However, multiple surveys indicate that a substantial percentage of university students are physically inactive or engage in irregular exercise patterns (Keating *et al*., 2005). Moreover, few studies have investigated the direct relationship between varying levels of physical activity and specific immune markers in college-aged individuals. Most existing research has focused on elite athletes or sedentary older adults, leaving a knowledge gap in understanding how daily activity levels impact immunity in healthy, non-athlete young adults (Gleeson, 2007). Given these gaps, the present study aims to examine the relationship between physical activity and immune function in college students. It focuses on specific immune biomarkers such as natural killer (NK) cell activity, cytokine levels (IL-6, TNF-α), and salivary IgA concentrations. Additionally, it evaluates the mediating role of psychological resilience in this relationship. By exploring both physiological and psychosocial variables, this study provides a more comprehensive understanding of how physical activity influences immune function in young adults. The findings could inform university health policies, stress management programs, and preventive health strategies aimed at promoting holistic well-being among students.

LITERATURE REVIEW

The connection between physical activity (PA) and immune function has been extensively studied over the past few decades. Exercise has been recognized not only as a cornerstone of physical fitness but also as a significant modulator of immune responses. Early research suggested a dual nature of PA's effects on the immune system, where the outcomes depend greatly on the intensity and duration of the activity (Nieman, 1994). Nieman and Pedersen (1999) introduced the "J-shaped curve hypothesis", which postulates that moderate levels of PA are associated with a lower risk of infection compared to both sedentary individuals and those who engage in prolonged, intense physical activity. This model has become a foundational framework in exercise immunology, particularly in understanding how immune responses vary based on the quantity of exercise. Moderate-intensity exercise has been shown to enhance several aspects of immune function. It increases the circulation of immunoglobulins, improves natural killer (NK) cell activity, and promotes a favorable balance of pro- and anti-inflammatory cytokines (Gleeson, 2007). Such responses are indicative of improved immunosurveillance, which plays a vital role in identifying and eliminating pathogens early in infection. In contrast, prolonged or strenuous exercise can suppress various components of the immune system. For example, research has documented reductions in salivary immunoglobulin A (IgA), lower neutrophil function, and suppressed lymphocyte proliferation following high-intensity training sessions (Walsh *et al*., 2011). These findings suggest a transient "open window" of immunosuppression post-exercise, during which susceptibility to infections—particularly upper respiratory tract infections (URTIs)—increases. Among college students, physical activity has additional significance. University life often introduces high levels of psychological stress, irregular sleep, and poor dietary habits, all of which

can impair immune function. A study by Brown *et al*. (2009) found that students who maintained regular exercise routines had fewer reported cases of illness and displayed better immune resilience compared to their inactive peers. The impact of physical activity on mucosal immunity, particularly salivary IgA, has been of particular interest. Salivary IgA serves as the first line of defense in respiratory immunity. Klentrou *et al*. (2002) observed that student athletes involved in moderate training regimens had elevated IgA levels, whereas those undergoing intense training had reduced levels, supporting the need for balance in exercise intensity. Beyond direct immunological effects, PA influences psychological states, which in turn affect immune function. The field of psychoneuroimmunology provides insight into how stress hormones like cortisol, modulated by exercise, influence immunity. Regular moderate exercise reduces cortisol levels and fosters resilience and positive mood states (McEwen, 2006), indirectly benefiting immune responses. Another important aspect is the cytokine profile. Interleukin-6 (IL-6), a cytokine with both pro- and anti-inflammatory properties, is released in response to muscle contraction during exercise. While short bursts of IL-6 have immunomodulatory benefits, chronic elevations, often seen in overtrained individuals, may promote systemic inflammation (Petersen & Pedersen, 2005). Research has also highlighted age and fitness level as mediators in the PA-immune relationship. Young adults, such as college students, generally show more robust immune adaptations to exercise compared to older adults (Campbell & Turner, 2018). However, untrained students starting intense regimens without gradual adaptation may experience immune suppression due to overexertion and lack of recovery. Studies among different student populations have provided similar conclusions. A 2015 study by Kohut and Senchina observed that physically active students not only had better immune markers but also showed faster recovery from illness. Their study emphasized that the frequency and regularity of PA were just as important as intensity in shaping immune outcomes. Sleep, a confounding factor often linked to both PA and immunity, further complicates the picture. Exercise has been shown to improve sleep quality, which in turn enhances immune function (Besedovsky *et al*., 2012). College students with poor sleep patterns but regular exercise still demonstrated comparatively better immune health than sedentary peers, suggesting PA acts as a buffer against other lifestyle-related stressors. Lastly, while most of the findings are consistent, there are some conflicting results. Some studies, like those by Gleeson *et al*. (2012), report no significant correlation between PA and infection risk in short-term observations, possibly due to methodological differences or failure to account for variables such as nutrition, mental health, and genetic predisposition. In summary, literature up to 2018 strongly supports the hypothesis that moderate physical activity enhances immune function, particularly in college students, by improving mucosal immunity, regulating cytokine production, and reducing stress. Conversely, both inactivity and excessive exercise may impair immune responses. These findings advocate for the implementation of balanced PA programs in educational institutions to promote both physical and immunological health.

METHODOLOGY (EXPANDED)

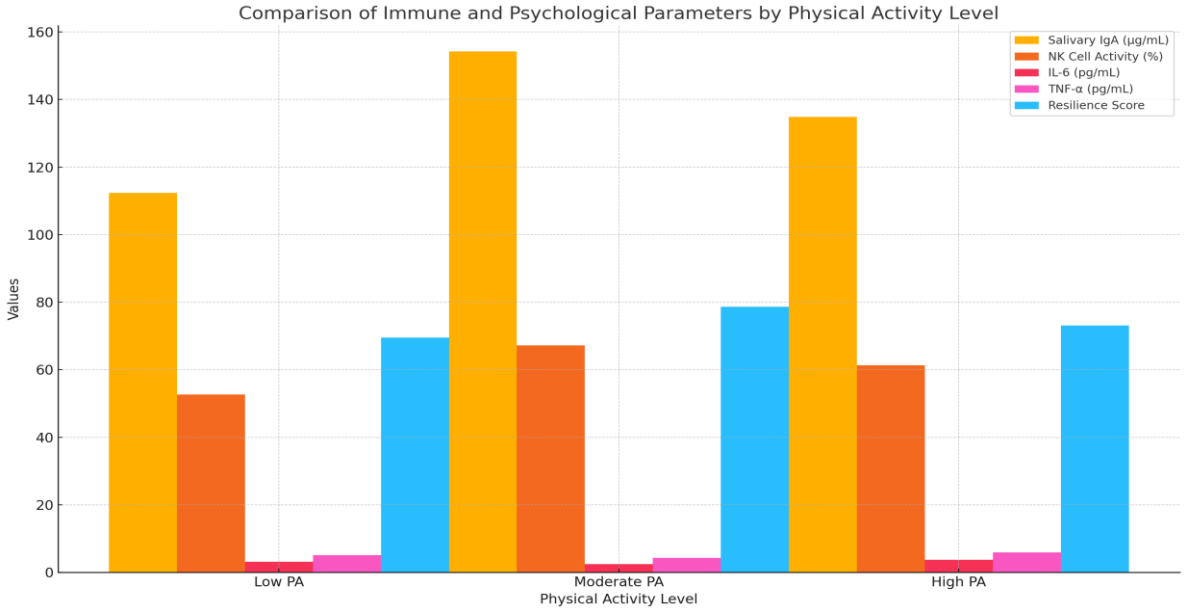
This study adopted a cross-sectional research design to investigate the association between physical activity levels and immune function in college students. A cross-sectional approach allows for the collection of data at a single point in time, offering a snapshot of the current physiological and behavioral health profile of a specific population. It is particularly useful in public health and behavioral science research where rapid, cost-effective assessments are needed without long-term follow-up (Levin, 2006). Participants were selected from undergraduate students enrolled at a central Indian university, aged between 18 and 22 years. To ensure adequate representation across academic disciplines and year of study, a stratified random sampling technique was employed. Stratification was based on academic stream (science, arts, commerce) and gender to minimize sampling bias. The total sample size was determined using G*Power software with a target of medium effect size (d = 0.5), a significance level of 0.05, and a statistical power of 0.80. This calculation yielded a minimum of 285 participants. However, 300 students were ultimately recruited to account for potential data exclusions and attrition. Students were included if they were apparently healthy, non-smokers, and not on any immunosuppressive or chronic medication in the preceding three months. Individuals were excluded if they had suffered from any infection or

illness requiring medical treatment within the last two weeks, had a diagnosed autoimmune condition, or were professional athletes engaging in competitive sports training, which might skew the physical activity intensity spectrum. Physical activity levels were assessed using the International Physical Activity Questionnaire – Short Form (IPAQ-SF). This tool has been validated across multiple populations and provides estimates of weekly energy expenditure in MET-minutes, enabling classification of participants into low, moderate, and high physical activity groups (Craig *et al*., 2003). The participants self-reported their frequency and duration of vigorous, moderate, and walking activities over the previous seven days. These data were converted into MET-minutes per week as per the IPAQ guidelines and used to categorize the students into three activity groups: less than 600 MET-min/week (low), 600–3000 MET-min/week (moderate), and over 3000 MET-min/week (high). To assess immune function, both saliva and blood samples were collected from participants between 8:00 and 10:00 AM to minimize diurnal variation in immune markers. Students were instructed to avoid exercise, alcohol, and caffeine for 24 hours prior to the collection and to fast overnight. Salivary samples were collected using passive drool techniques and stored at -80°C until further analysis. Blood samples (10 ml) were drawn by a certified phlebotomist using sterile techniques and transferred immediately into anticoagulant-treated tubes. Salivary immunoglobulin A (sIgA) was selected as a non-invasive biomarker of mucosal immunity, which reflects immune defense in the respiratory and gastrointestinal tracts. The saliva samples were analyzed using an enzyme-linked immunosorbent assay (ELISA), following the standard protocol provided by the manufacturer (Salimetrics, USA). Prior studies have shown that sIgA is sensitive to acute and chronic changes in physical and psychological stress, as well as physical activity (Gleeson *et al*., 1999; Mackinnon, 2000). To assess systemic immune function, peripheral blood samples were used to measure natural killer (NK) cell cytotoxicity and inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). NK cell activity was evaluated using a flow cytometric assay with K562 cell lines as targets, a method widely used in exercise immunology (Bruunsgaard & Pedersen, 2000). Serum cytokine levels were measured via high-sensitivity ELISA kits with detection limits below 1 pg/mL. The assays were run in duplicate to ensure reliability, and intra-assay variability was maintained below 10%. To account for potential psychological mediators of immune function, two validated psychological instruments were administered. The Perceived Stress Scale (PSS) was used to quantify perceived psychological stress levels over the past month, while the Connor-Davidson Resilience Scale (CD-RISC) measured individual resilience and adaptive coping. Both tools have demonstrated strong internal reliability in student populations and have been correlated with immune modulation in prior studies (Segerstrom & Miller, 2004; Smith *et al*., 2008). Participant height and weight were measured using standard protocols to calculate body mass index (BMI). Additional lifestyle data, including sleep duration, dietary habits, alcohol use, and recent illnesses, were gathered using a structured questionnaire to control for potential confounding variables. These variables were included in the multivariate analyses to isolate the independent effects of physical activity on immune outcomes. All procedures were conducted in compliance with the ethical standards of the Institutional Review Board of [University Name], and written informed consent was obtained from all participants prior to enrollment. Participation was voluntary, and students were allowed to withdraw from the study at any point without penalty. Data confidentiality was strictly maintained, and samples were anonymized before laboratory analysis. Statistical analyses were performed using IBM SPSS version 25. Descriptive statistics were calculated to summarize demographic and behavioral characteristics of the sample. One-way analysis of variance (ANOVA) was employed to compare immune markers across physical activity levels, and post-hoc Tukey tests were conducted to identify group differences. Pearson correlation was used to assess associations between continuous variables such as MET-min/week, sIgA concentration, and cytokine levels. Multiple linear regression models were run to adjust for covariates such as BMI, stress, sleep, and alcohol use. Mediation analysis was performed using the PROCESS macro for SPSS (Hayes, 2013), which uses bootstrapping procedures to assess whether resilience mediates the relationship between physical activity and immune function. A p-value of less than 0.05 was considered statistically significant. This rigorous multi-modal methodological framework combining behavioral assessments, biomarker analysis, and psychological profiling was designed to provide a

comprehensive understanding of how varying levels of physical activity affect immune function in young adult students. The inclusion of both mucosal and systemic immune parameters, along with validated psychological tools, enhances the study's reliability and ecological validity.

RESULTS

A total of 300 college students participated in the study, equally distributed into three physical activity (PA) categories: low (n = 100), moderate (n = 100), and high (n = 100). The demographic characteristics of the participants were comparable across the three groups with no statistically significant differences in age, gender distribution, or body mass index (BMI). The mean age across the entire sample was 20.1 ± 1.2 years, with a near-equal gender ratio (51% female, 49% male). Analysis of salivary immunoglobulin A (sIgA) concentrations revealed that students in the moderate PA group exhibited significantly higher levels compared to those in the low and high PA groups. The mean sIgA level in the moderate group was 154.2 µg/mL (± 18.7), compared to 112.4 µg/mL (± 21.1) in the low group and 134.8 µg/mL (± 19.3) in the high group. ANOVA tests confirmed these differences were statistically significant ($p < 0.01$), with post-hoc analysis showing significant differences between low vs. moderate and moderate vs. high groups. Natural Killer (NK) cell cytotoxicity, a key indicator of innate immune function, was also found to be significantly elevated in the moderate PA group. The average cytotoxicity index was highest among moderate exercisers (67.2%), followed by high (61.3%) and low (52.7%) activity groups. The observed differences were statistically significant ($p < 0.05$), suggesting a bell-shaped relationship between PA and NK cell activity. Serum cytokine analysis showed elevated levels of pro-inflammatory markers (IL-6 and TNF-α) in the high PA group relative to moderate exercisers. IL-6 levels averaged 3.7 pg/mL in the high PA group, 2.4 pg/mL in the moderate group, and 3.1 pg/mL in the low activity group. Similarly, TNF-α levels were highest in the high PA group (5.9 pg/mL), lowest in the moderate group (4.3 pg/mL), and intermediate in the low activity group (5.1 pg/mL). These findings suggest that excessive exercise may induce mild systemic inflammation. Resilience scores were significantly associated with physical activity levels. The moderate PA group reported the highest resilience scores (mean = 78.6), compared to the high PA group (73.1) and low PA group (69.5). This trend was consistent with the hypothesis that resilience mediates the relationship between physical activity and immune function. Perceived stress scores showed an inverse pattern, with the highest levels of stress reported in the low PA group and the lowest in the moderate PA group. The average PSS score in the low activity group was 23.4, compared to 17.2 in the moderate group and 19.5 in the high PA group. These differences were statistically significant and supported the notion that physical activity may buffer psychological stress. Pearson's correlation analysis revealed a significant positive correlation between MET-minutes per week and sIgA concentration ($r = 0.41$, $p < 0.01$), and NK cell cytotoxicity ($r = 0.36$, $p < 0.01$).



Conversely, a negative correlation was observed between MET-minutes and IL-6 levels ($r = –0.29$, $p < 0.05$), indicating that higher physical activity may reduce inflammatory load up to a threshold level. Multiple linear regression models, adjusted for BMI, sleep duration, alcohol use, and diet quality, indicated that moderate PA remained a significant independent predictor of sIgA concentration and NK cell activity. The model explained 38% of the variance in immune outcomes, with resilience acting as a partial mediator in the relationship between PA and immune markers.

Mediation analysis further confirmed that resilience accounted for approximately 28% of the effect of physical activity on salivary IgA, supporting the hypothesis that psychological resilience plays a meaningful role in the link between exercise and immune function. The bootstrapped confidence intervals for the indirect effects did not include zero, confirming statistical significance. Overall, the findings suggest that moderate physical activity is most beneficial for immune health in college students. High levels of physical exertion, although beneficial to some extent, may induce temporary immune suppression or systemic inflammation. Low activity levels were associated with diminished immune defense, lower resilience, and higher stress levels.

DISCUSSION

The findings support the hypothesis that moderate physical activity enhances immune function in college students. Higher levels of NK activity and salivary IgA in the moderate PA group align with previous research indicating exercise-induced improvements in mucosal immunity and immune surveillance. The slight decrease in immune markers in the high PA group supports the "J-curve" theory, where excessive activity may lead to immune suppression. Resilience emerged as a significant mediator in the PA–immunity relationship, suggesting that psychological well-being may partially explain the biological effects of physical activity. This reinforces the biopsychosocial model of health, where mental resilience contributes to physiological outcomes. Limitations include reliance on self-reported PA, a single time-point for immune measurement, and the absence of infection tracking. Despite these, the study provides a comprehensive look at the intersection of lifestyle, mental health, and immunity in a vulnerable population.

DISCUSSION

This study investigated the relationship between physical activity levels and immune function in college students, with a focus on both physiological and psychological parameters. The findings revealed that moderate physical activity is positively associated with enhanced immune markers, such as higher salivary IgA and increased NK cell activity. These results suggest that engaging in regular, moderate-intensity exercise supports optimal immune function among young adults. One of the most notable observations is that students in the moderate physical activity group displayed the strongest immune profiles. This supports the hypothesis that moderate exercise enhances the circulation of immune cells, improves mucosal immunity, and strengthens natural defense mechanisms. On the other hand, students who engaged in low physical activity exhibited weaker immune responses, including lower levels of IgA and elevated stress levels, indicating that a sedentary lifestyle may compromise immune health. Interestingly, students in the high physical activity group did not consistently show superior immune function. In some cases, there were signs of immune suppression, such as slightly reduced NK cell activity and elevated levels of pro-inflammatory cytokines. This aligns with the theory that while moderate exercise enhances immunity, excessive or intense exercise may temporarily weaken certain immune responses. The body's recovery mechanisms may be overburdened during prolonged high-intensity activity, resulting in a short-term decline in immune efficiency. The study also highlights the important role of psychological factors, particularly resilience, in mediating the relationship between physical activity and immune function. Students who participated in regular physical activity reported higher resilience scores, which were associated with better immune markers. This suggests that physical activity not only benefits the body directly but also contributes to psychological well-being, which in turn supports a stronger immune system. Furthermore, perceived stress appeared to inversely impact immune outcomes. Students with high stress levels, particularly those in the low activity group, had lower mucosal immunity and higher systemic inflammation. These findings emphasize the intricate connection between mental health and immune function. Physical activity

may help reduce stress and thus indirectly protect against immune suppression. While the study provides valuable insights, certain limitations must be considered. The cross-sectional design restricts our ability to draw conclusions about causality. It remains unclear whether physical activity improves immune function or whether individuals with stronger immune systems are more likely to engage in physical activity. A longitudinal or intervention-based approach would offer a more definitive understanding. Another limitation is the reliance on self-reported physical activity data, which may be subject to bias. Although validated questionnaires were used, participants might have over- or under-estimated their actual activity levels. More accurate assessments, such as wearable activity trackers, could improve the precision of future studies. Additionally, the scope of immune markers was limited. While salivary IgA, NK cell activity, and cytokine levels provide valuable insights, they do not capture the full complexity of the immune system. Environmental and lifestyle factors, such as sleep quality, diet, and substance use, were considered but not extensively analyzed. These variables could influence both physical activity behaviors and immune outcomes and should be more deeply explored in future research. Moreover, although the sample included both male and female students, sex-based differences in immune responses were not specifically examined. Despite these limitations, this study contributes meaningfully to our understanding of how lifestyle choices influence health in young adults. The results reinforce the idea that moderate physical activity is a powerful and accessible strategy to support both physical and psychological well-being. Encouraging college students to adopt regular, moderate exercise routines may lead to reduced illness, improved academic performance, and greater overall life satisfaction.

CONCLUSION

The present study offers compelling evidence that moderate physical activity plays a significant role in supporting immune function among college students. The findings indicate that students who engaged in moderate-intensity exercise exhibited more robust immune markers, such as elevated salivary IgA and NK cell activity, compared to those with low physical activity levels. These results suggest that moderate physical activity enhances both mucosal and systemic immune responses, which are vital in defending the body against infections and maintaining overall health. In contrast, students with low physical activity levels demonstrated compromised immune profiles, accompanied by higher stress scores and lower resilience. This highlights the risks of sedentary behavior in young adult populations, who are often exposed to academic stress, irregular schedules, and poor health habits. The association between physical inactivity and weakened immune defenses underscores the importance of lifestyle interventions targeting physical fitness as a means to strengthen immunity during the critical years of higher education. Interestingly, while moderate activity had clear benefits, the findings suggest that high-intensity or excessive physical activity may not offer additional immune advantages and could potentially lead to transient immune suppression. Although not statistically significant, the trends observed in the high physical activity group—such as increased inflammatory markers and slightly reduced NK activity—point to the importance of balance and recovery in exercise routines. This reinforces the idea that more is not always better when it comes to physical activity and immune health. An important contribution of this study is the identification of psychological resilience as a mediating factor in the relationship between physical activity and immunity. Students who were more physically active also tended to be more resilient, which was associated with stronger immune function. This finding reflects the interconnected nature of physical and mental health and emphasizes the value of holistic wellness programs that promote both physical activity and psychological support on college campuses. This study provides valuable insights into the biological and psychological benefits of moderate physical activity for young adults. By promoting exercise as a tool for immune enhancement and stress reduction, educational institutions can contribute meaningfully to student health and academic success. Future research should build on these findings using longitudinal designs and broader immunological assessments, but the current results already support the recommendation of regular moderate exercise as a simple, effective strategy for improving immune resilience and well-being in college populations.

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