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Evaluating the impact of physical activity levels on oxidative stress and inflammation markers as early health indicators in healthy adults

Afnan Yaldrum Baker *

Department of Pharmaceutical and Toxicology, College of pharmacy, University of Kirkuk, Kirkuk, Iraq.

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Abstract

This is a cross-sectional study involving 100 adults aged 20-40 years who were classified as low, moderate, and high physical activity groups through IPAQ. The markers of oxidative stress (MDA, SOD, and TAC) and inflammatory markers (CRP, IL-6, TNF-α) were assessed through standard biochemical measurements while Statistical analysis was done through SPSS software (one-way ANOVA, Pearson correlation analysis, multiple regression analysis). This revealed that there were significant differences among physical activities, such that increased physical activities were correlated to reduced MDA, and increased levels of SOD and TAC ($p < 0.001$). Inflammatory biomarkers (CRP, IL-6, TNF-α) decreased in high activity individuals ($p < 0.001$). There was a correlation between inflammatory biomarkers and oxidative stress biomarkers and physical activities as predictors of both inflammation and oxidative stress through multiple regression analysis.

Keywords: Physical Activity; Oxidative Stress; Inflammation; MDA; CRP; IL-6; TNF-α; Antioxidants; Healthy Adults

1. Introduction

Physical activity has long been known as an essential contributor to health since it affects different physiological processes, such as cardiovascular system function, metabolism, and immunity, among others [1]. Recently, physical activity has attracted more attention in relation to its effect on oxidative stress and inflammation, the two processes viewed as important factors in the development of various chronic conditions, such as cardiovascular disease, diabetes, and neurodegenerative disorders [2].

Oxidative stress is defined as an imbalance in the production of reactive oxygen species (ROS) and the antioxidant systems in the body [3]. Though ROS play an important role in signaling and maintaining cell equilibrium at low levels, high levels may cause cell injury, lipid peroxidation, protein oxidation, and DNA damage [4,5]. Some of the biomarkers that are considered in measuring oxidative stress include malondialdehyde (MDA), total antioxidant capacity (TAC), and superoxide dismutase (SOD) [6].

Inflammation, specifically chronic low-grade inflammation, can be considered another important parameter responsible for the development of pathology [7]. Various pro-inflammatory cytokines, including interleukin-6 (IL-6) and tumor necrosis factor alpha (TNF-α), as well as the presence of acute phase proteins, such as C-reactive protein (CRP), have proven to be effective biomarkers of inflammation [8;9].

Physical activity has been found to produce a bidirectional impact on oxidative stress and inflammation. While acute bouts of physical activity can temporarily increase oxidative stress and inflammation, regular physical activity improves the ability to counteract oxidative stress and decreases basal inflammation levels [10]. People who engage in more regular physical activity exhibit a decreased level of oxidative stress and inflammatory markers in their bodies [11].

* Corresponding author: Afnan Yaldrum Baker

Even with all this information at hand, however, there is still room for further research that investigates both oxidative stress and inflammation markers in connection with exercise intensity on a single population sample. In fact, studying how these factors affect healthy adults could provide early physiological indications of potential health issues that may arise in the future [12,13]. This study aims to evaluate the impact of different physical activity levels on biomarkers of oxidative stress and inflammation in healthy adults, exploring their potential as early diagnostic indicators of general health status.

2. Materials and Methods

2.1. Study Design

The study design adopted in this research is that of a cross-sectional study whose purpose was to analyze the effects of varying degrees of physical activity on oxidative stress and inflammatory markers in healthy individuals. The study was carried out using established scientific procedures.

2.2. Study Population

The number of healthy volunteers was 100 and their ages ranged between 20 to 40 years old. The participants were chosen for homogenization purposes of the study population and to reduce the chance of having variables that may confound the results concerning the oxidative or inflammatory reactions. Individuals who were apparently healthy and free from chronic diseases such as heart conditions, metabolic conditions, autoimmune diseases, or those under medication affecting their immune system and/or metabolism were only considered as candidates. Those with smoking habits, obesity (BMI $\geq 30kg/m^2$), had recently been ill or had any infection during the last two weeks, and those on antioxidant and anti-inflammatory drugs were excluded from being participants.

2.3. Group Classification

The subjects were grouped into three categories depending on the level of physical activity based on the International Physical Activity Questionnaire (IPAQ), which is a validated tool for measuring physical activity levels. These groups were divided depending on how the scores in the questionnaire translated.

2.4. Data Collection

The collection of data was conducted in a controlled environment for consistency and reliability purposes. The demographic characteristics of the study subjects were gathered using a questionnaire that included parameters such as age and sex. Body mass index was computed from the anthropometric data, which included the body weight and height of the respondents. The venous blood sample was taken from each patient after an overnight fasting period of eight to twelve hour [14].

2.5. Biochemical Measurements

2.5.1. Oxidative Stress Markers

The oxidative status was determined by means of several biochemical parameters. MDA was used to evaluate lipid peroxidation; superoxide dismutase (SOD) was studied as a significant enzymatic antioxidant. Total antioxidant capacity (TAC) was determined to reveal the level of antioxidants in the body [15].

2.5.2. Inflammatory Markers

The inflammatory response was measured based on the levels of the systemic inflammatory biomarker, C-reactive protein (CRP); IL-6 as a pro-inflammatory cytokine; and tumor necrosis factor alpha (TNF-α) as an inflammatory mediator [16]. All the biochemical measurements were conducted using commercial ELISA kits according to the manufacturer's protocol.

2.6. Statistical Analysis

The data was analyzed by SPSS 26. For quantitative variables, mean and SD values were used. The statistical analysis to compare means of different groups was performed using one-way ANOVA while correlations and predictors were checked with Pearson correlation and multiple regressions. $p<0.05$ was set as a statistically significant difference.

3. Results

3.1. Baseline Characteristics of Participants

The sample size of this experiment comprised 100 subjects, which were further divided into three groups depending upon their physical activity levels. According to Table 1, no statistical differences could be found among the groups with respect to age and body mass index (BMI) ($p > 0.05$).

On the other hand, resting heart rate showed a significant decline with increasing physical activity ($p < 0.01$), where the minimum values were recorded in the case of high activity.

Table 1 Baseline Characteristics of Participants

Variable	Low Activity (n=33)	Moderate Activity (n=34)	High Activity (n=33)	p-value
Age (years)	28.4 ± 4.2	29.1 ± 3.8	28.7 ± 4.0	0.62
BMI (kg/m^2)	25.8 ± 2.9	24.9 ± 2.5	24.2 ± 2.3	0.09
Resting HR (bpm)	78 ± 9	72 ± 8	66 ± 7	<0.01

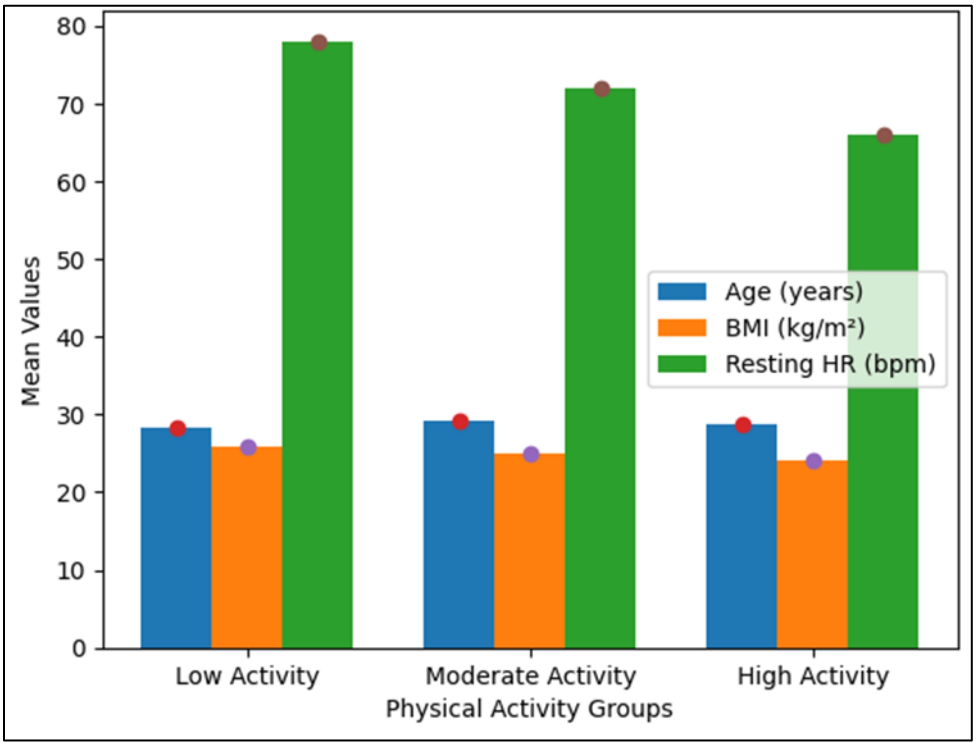

Figure 1 Resting Heart Rate Across Physical Activity Levels

3.2. Oxidative Stress Markers

There were significant differences in oxidative stress parameters among the three groups. Individuals with low physical activity showed higher MDA levels than those with high physical activity, which was found to be highly significant ($p < 0.001$). On the other hand, antioxidant parameters (SOD and TAC) showed highly significant differences between the two groups ($p < 0.001$).

Table 2 Oxidative Stress Markers

Marker	Low Activity	Moderate Activity	High Activity	p-value
MDA (nmol/mL)	5.9 ± 1.3	4.6 ± 1.1	3.3 ± 0.9	<0.001
SOD (U/mL)	118 ± 22	148 ± 26	182 ± 31	<0.001
TAC (mmol/L)	0.88 ± 0.20	1.18 ± 0.28	1.52 ± 0.35	<0.001

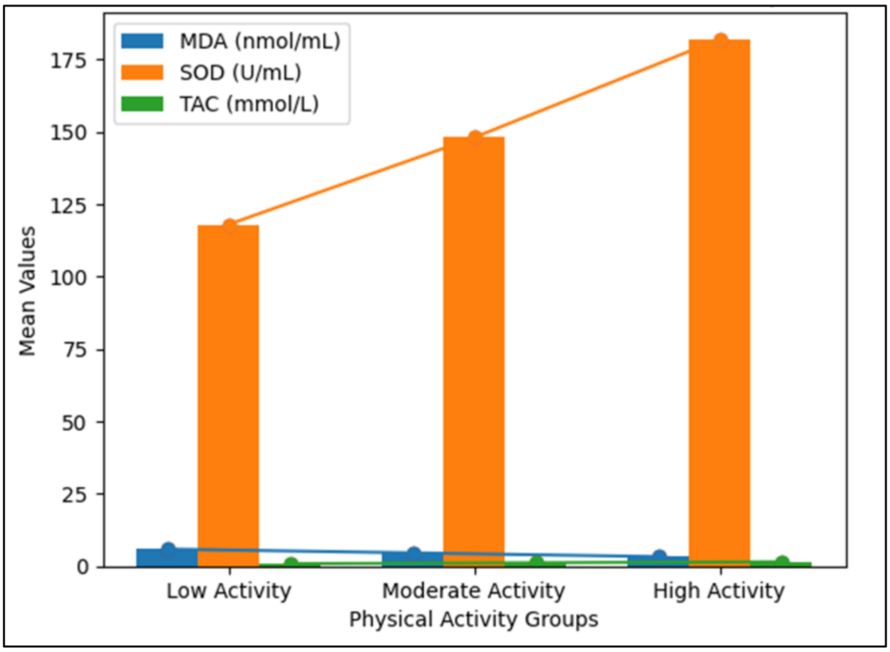

Figure 2 Oxidative Stress and Antioxidant Markers Across Physical Activity Levels

3.3. Inflammatory Markers

Significant decreases in inflammatory biomarkers were observed with increased physical activity. Individuals with low physical activity had higher levels of CRP, IL-6, and TNF-α than individuals with high physical activity levels ($p < 0.001$).

Table 3 Inflammatory Markers

Marker	Low Activity	Moderate Activity	High Activity	p-value
CRP (mg/L)	3.6 ± 1.1	2.3 ± 0.9	1.5 ± 0.6	<0.001
IL-6 (pg/mL)	6.2 ± 1.6	4.3 ± 1.3	2.9 ± 1.0	<0.001
TNF-α (pg/mL)	8.7 ± 2.1	6.6 ± 1.6	4.6 ± 1.3	<0.001

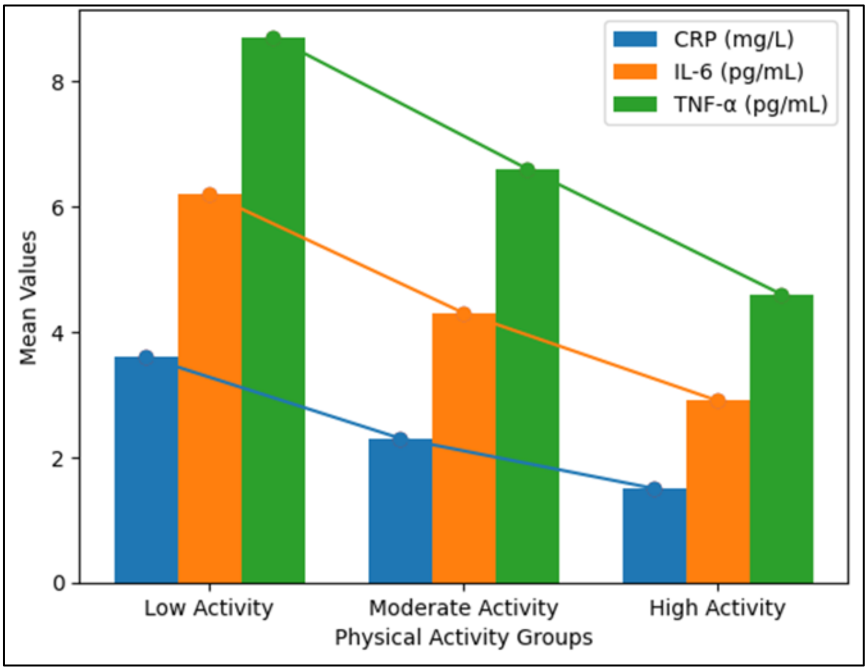

Figure 3 Inflammatory Biomarkers Across Physical Activity Levels

3.4. Correlation Analysis

Statistical correlations were found using Pearson correlation analyses between oxidative stress and inflammation markers. Significant positive correlation was found between MDA and CRP levels ($r = 0.60$, $p < 0.001$) whereas SOD levels exhibited significant negative correlation with CRP ($r = -0.55$, $p < 0.001$). Furthermore, significant negative correlation was observed between level of physical activity and IL-6 levels ($r = -0.65$, $p < 0.001$).

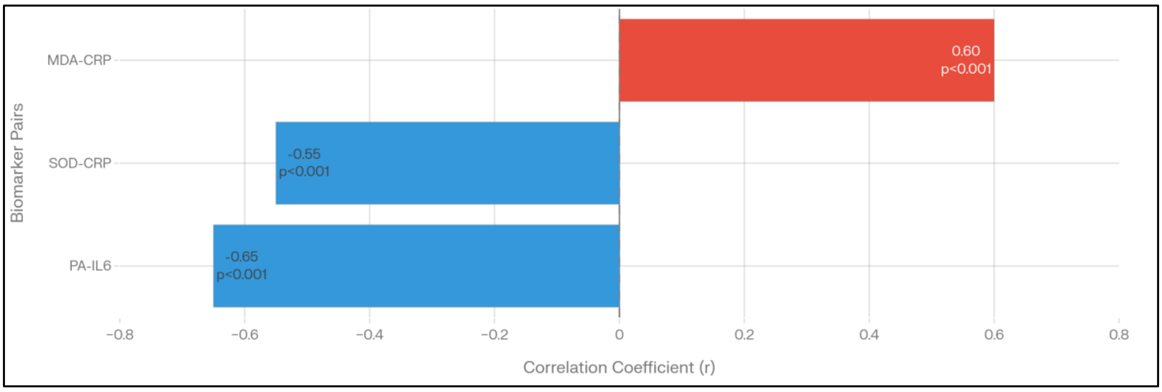

Figure 4 Correlation Between Oxidative Stress and Inflammatory Markers

3.5. Multiple Regression Analysis

Analysis using multiple regressions revealed physical activity to be an independent predictor of both oxidative stress and inflammatory parameters. There was a statistically significant negative correlation between physical activity and MDA levels ($\beta = -0.48$; $p < 0.001$) and CRP levels ($\beta = -0.52$; $p < 0.001$) as shown in Table 4.

Table 4 Multiple Regression Analysis

Dependent Variable	Predictor	β	p-value
MDA	Physical Activity	-0.48	<0.001
CRP	Physical Activity	-0.52	<0.001

4. Discussion

The results from this current research show convincing evidence that higher levels of physical activity are significantly correlated with improvements in oxidative stress homeostasis and inflammation in healthy individuals [17]. The results show that participants having higher physical activity levels possess lower lipid peroxidation measured by lower MDA values along with increased antioxidants activity measured by higher SOD and total antioxidant status [18]. The findings provide evidence for the idea that physical activity leads to adaptation through the up-regulation of endogenous antioxidant systems, which facilitates better control of ROS production and redox balance [19].

Furthermore, apart from its antioxidant properties, physical exercise was found to produce a significant anti-inflammatory effect. The noted decrease in CRP, IL-6, and TNF-α concentrations in physically active persons suggests that there is less systemic inflammation [20;21]. This is especially significant because chronic low-level inflammation plays an essential role in causing cardiovascular and metabolic disorders [22]. Various mechanisms have been hypothesized that can mediate the anti-inflammatory effects of exercise, which include reduction of visceral adiposity, improvement in endothelial health, and modification of cytokine secretion [23].

As evidenced from the correlations found between the two, the interdependence of these physiological mechanisms cannot be ignored [24]. An increase in oxidative stress may lead to activation of inflammatory mechanisms, whereas inflammatory reactions also result in an increased production of reactive oxygen species, creating a cycle that reinforces itself [25]. The results obtained in the current study show that exercise effectively breaks this cycle through reduction of both oxidative stress and inflammation [26].

In addition, the outcomes of the regression analysis prove that physical activity acts independently as a determinant of both oxidative stress and inflammation. The important contribution of exercise to the maintenance of physiological health through acting as a modifiable lifestyle variable can therefore be highlighted.[27] Previous research has confirmed that exercise improves mitochondrial function, prevents oxidation and fosters an anti-inflammatory state [28].

Even though this research has several positive aspects, for example, the analysis of many biomarkers, its cross-sectional approach makes it difficult to prove any cause-and-effect relationship between the factors under investigation [29]. In order to find out more about these connections, additional longitudinal and intervention studies should be carried out [30].

5. Conclusion

This study demonstrates that higher levels of physical activity are independently associated with oxidative stress and inflammatory biomarkers in healthy adults. The results highlight the importance of regular physical activity as an essential preventive measure against early pathophysiology. Notably, the observed reduction in inflammatory markers such as CRP and pro-inflammatory cytokines (IL-6, TNF-α), coupled with enhancement of antioxidant defenses as indicated by SOD and TAC up-regulation, indicates that these biomarkers function as robust early indicators of health status and practical information for monitoring lifestyle interventions. In the end, exercise is a primary factor in achieving physiological balance and preventing chronic disease.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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