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RESEARCH ARTICLE

Association of Serum Testosterone, Cortisol, and C-Reactive Protein (CRP) Levels with Moderate Exercise in Young Adults in India

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Abstract: ***Introduction***: Moderate exercise influences endocrine and inflammatory responses, particularly in young adults whose physiological systems are still in developmental flux. This study investigates the association between serum testosterone, cortisol, and C-reactive protein (CRP) levels with moderate exercise among young adults in India. ***Materials & Methods***: The study employed a Randomized Control Trial research design, involving first-year MBBS students aged 17-25 at G.S.V.M. Medical College, Kanpur, UP. Study participants were engaged in moderate exercise (Harvard step test) Anthropometric data such as height, weight, BMI, and body fat percentage were recorded. Blood samples were collected before and after moderate exercise and also at twelve week of moderate exercise (testosterone, cortisol) and inflammatory marker (CRP) levels. ***Results***: Findings indicated a statistically significant increase in testosterone and a significant reduction in CRP post-exercise at twelve weeks while cortisol levels demonstrated a transient increase that stabilized over time. ***Conclusion***: Findings of this research suggest that moderate exercise may enhance endocrine function and reduce systemic inflammation in young adults, reinforcing its importance in preventive health strategies in the Indian context. The study supports public health initiatives advocating for regular exercise among young adults and underscores the need for targeted interventions addressing sedentary behaviors.

Keywords: Testosterone, Cortisol, CRP, Moderate Exercise, Inflammation, Young Adults, India.

INTRODUCTION

The interaction between physical activity and endocrine as well as inflammatory responses has attracted significant interest in recent biomedical research. Hormones such as testosterone and cortisol play vital roles in muscle metabolism, stress regulation, and immune function, while inflammatory markers like C-reactive protein (CRP) indicate systemic inflammation and cardiovascular risk (Pedersen & Saltin, 2015). Moderate exercise, defined by the American College of Sports Medicine (2011) as physical activity that elevates heart rate to 50–70% of its maximum, has been shown to modulate these biomarkers positively (Kraemer et al., 2004).

However, there is limited region-specific data on this subject, particularly in South Asian populations. India's unique socio- cultural and dietary landscape, along with increasing sedentary lifestyles among youth, warrants a contextual investigation of these biological variables. This study explores the association of moderate exercise with testosterone, cortisol, and CRP levels in young adults in India, aiming to contribute to preventive health discourse and guide exercise recommendations for youth.

Testosterone and Exercise

Testosterone, an anabolic steroid hormone, increases following resistance and endurance exercises due to neuromuscular adaptation and energy metabolism demands (Hackney, 2001). Previous studies have shown that consistent moderate exercise leads to elevated resting testosterone levels (Hayes et al., 2015). Optimal levels of testosterone promote the synthesis of "muscle proteins", "increase bone density", and "stimulate the production of red blood cells", all of which contribute to improved athletic performance and faster recovery. On the other hand, insufficient amounts of testosteronemight hinder the process of muscle repair and development, resulting in reduced exercise capacity and performance (Bhasin, S. et al (2001).

Cortisol as a Stress Biomarker

Cortisol, secreted by the adrenal cortex, responds to both physical and psychological stressors. Acute exercise elevates cortisol transiently; however, chronic exercise may downregulate its baseline levels, reflecting adaptive stress resilience (Hill et al., 2008). An important factor in the control of energy metabolism during physical exercise is the impact of hormones. Exercise stress triggers the release of hormones including adrenaline (epinephrine) and cortisol, which activate energy reserves to power muscular contractions. Adrenaline triggers the conversion of glycogen into glucose, which quickly supplies fuel to active muscles. Meanwhile, cortisol facilitates the breakdown of lipids and proteins to maintain energy production over extended periods of exercise. (Hill, E. et al. 2008)

CRP and Inflammatory Modulation

CRP is a sensitive marker of systemic inflammation. Epidemiological studies indicate that moderate physical activity reduces CRP concentrations, thus mitigating the risk of atherosclerosis and metabolic syndrome (Kasapis & Thompson, 2005). CRP, a hepatically synthesized acute-phase protein, is involved in the body's reaction to exercise in addition to its function in inflammation and tissue damage. During physical activity, levels of CRP may temporarily rise because of small muscle injuries and the body's inflammatory reaction to effort. Slight elevations in CRP levels after exercising are typical and signify the body's adaptive reaction to training stimuli, promoting muscle repair and adaptation. However, consistently high levels of CRP may indicate excessive inflammation, insufficient healing, or underlying health issues, which might possibly hinder exercise performance and recovery. (Vingren, J. L. et al 2010). This study is necessary to establish a clear link between moderate exercise and hormonal/ inflammatory responses in young adults in North India. The findings could help in Developing exercise guidelines for hormonal balance and stress Management. Preventing inflammation-related diseases through physical activity. Personalizing fitness recommendations for young individuals based on their biological responses.

MATERIALS & METHODS:

Study Area & design:

The study employed a Randomized Control Trial research design at G.S.V.M. Medical College in Kanpur, Uttar Pradesh.

Study population:

Study participants were 96 first-year MBBS students aged 18-25 years at G.S.V.M. Medical College, Kanpur. Participants engaged in moderate exercise (Harvard step test).

Inclusion Criteria:

- Participants aged between 17 to 25 years were included
- Participants willing and able to provide informed consent to participate in the study
- Healthy individuals without any chronic illnesses or significant medical conditions were included.

Exclusion criteria

- Individuals who were engage in regular exercise as defined were excluded.
- Individuals who have previously consumed exogenous hormones, such as testosterone supplements or corticosteroids, were not included in the study.

Anthropometric Measurements:

The research rigorously gathered biometric data, such as height, weight, Body Mass Index (BMI), and body fat percentage, from each participant using established protocols. BMI was calculated using height and weight measurements (weight in kilograms divided by height in meters squared). Body fat percentage was determined using bioelectrical impedance analysis (BIA), Body Composition Monitor (HBF214) Karada Scan OMRONE a non-invasive approach that measures tissue resistance to electrical currents".

LaboratoryMeasurements:

Testosterone (T) levels in the blood were determined using competitive electro chemiluminescent immunoassays provided by Roche Diagnostics.

These assays are highly acknowledged for their precision and responsiveness in quantifying hormone concentrations in biological materials. Cortisol levels were measured using a chemiluminescent immunoassays). This method is chosen for its accuracy and reliability in quantifying cortisol levels in serum samples. The blood samples were taken from a vein and non-fasting samples used for hormone tests. The non-fasting samples were scheduled to be taken close to waking up in order to reduce the effects of daily variations.

The Anthropometric and physical measures included height, weight, hip and waist circumference, as well as averaged blood pressure readings. Blood samples were collected before the start of the workouts and just after the moderate exercise. "Time of the day was recorded for the first workout so that the midway workout and the final work out were performed at the same time of the day. This is important because of the circadian rhythm that affects free testosterone and cortisol levels. Subjects were asked to ensure they were fully hydrated before hormone assessment sessions. A food record was recorded one day before the hormone collection so that the same food could be ingested on each of the days before the next 2 hormone collection days". Data was gathered at three specific time intervals: baseline, post-exercise, and after 12 weeks of activity.

CRP Measurement:

The levels of High-sensitivity C-Reactive Protein (CRP) were meticulously assessed using an immuneturbidimetric test performed on a Hitachi 917 analyzer. The selection of this approach was based on the objective of ensuring exact measurements that possess both sensitivity and precision, while also preserving low coefficients of variation. As an instance, the test showed very little fluctuation even at higher doses, with coefficients as low as 1.1%. This meticulous analytical methodology not only guarantees accurate identification of CRP levels but also emphasizes the method's strength in clinical and research environments where exact measurement is crucial.

Excercise Protocol:
"The exercise program lasted for 12 weeks and consisted of a 3 days on and one day off cycle. Twelve weeks was chosen as it is an adequate amount of time to realize hypertrophy and increases in strength for most muscle groups".

Harvard Step Test :
"Harvard step test was performed on a 50-cm bench for male and 40 cm for female to assess cardiovascular fitness and to perform moderate exercise. After completing the Harvard Step test for 5 min, heart rate was measured. The participants steps up and down the bench at a steady pace of 30 steps per minute".
MHR(Maximum Heart Rate) = 220- Age

Data analysis

Variables		At Baseline	Post exercise	After 12 Week	F-Test	P - Value	Significance
Control Group	Serum Testosterone (ng/ml)	2.74±2.14	2.72±2.11	2.66±2.09	0.023	0.97755	Not Significant
	Serum Cortisol (ng/ml)	149.9±36.89	153±39.06	146.9±36.1	0.325	0.72291	
	C-reactive Protein (mg/L)	0.965±0.867	0.85±0.615	0.85±0.756	0.286	0.75164	
Experimental Group	Serum Testosterone (ng/ml)	2.54±2.12	4.66±3.89	4.18±3.55	5.547	0.0048	Significant
	Serum Cortisol (ng/ml)	146±31.95	199.5±33.3	127.3±28.04	69.13	< 0.0001	
	C-reactive Protein (mg/L)	0.687±0.428	1.44±0.65	0.948±0.496	24.888	< 0.0001	

Following the collection of data collected from semi-structured interviews, data was entered in MSExcel spreadsheet and analysis was done by usinga statistical data analysis tool such as IBM SPSS Statistics "Statistical Package for the Social Sciences".Descriptive statistics and statistical tests are the two primary statistical methods used in data analysis. Descriptive statistics provide a summary of data using measures such as the mean and median, while statistical tests derive conclusions from data using tests like the student's t-test.The chi-squared test was used to quantifies the discrepancy between the actual and expected values.

RESULTS

The Participants in both groups are predominantly between age 18-21 years old with a small number in the 22-25 age range [table 1] The gender distribution is nearly equal between the control and experimental groups (p= 0.6831, not significant)

Table 1: Frequency distribution of age of subject of both groups

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Age Interval (In Yrs.)	Control Group		Experimental Group	
	n = 48	In %	n = 48	In %
18 - 19	13	27.08%	14	29.17%
20 - 21	27	56.25%	26	54.17%
22 - 23	6	12.50%	6	12.50%
24 - 25	2	4.17%	2	4.17%

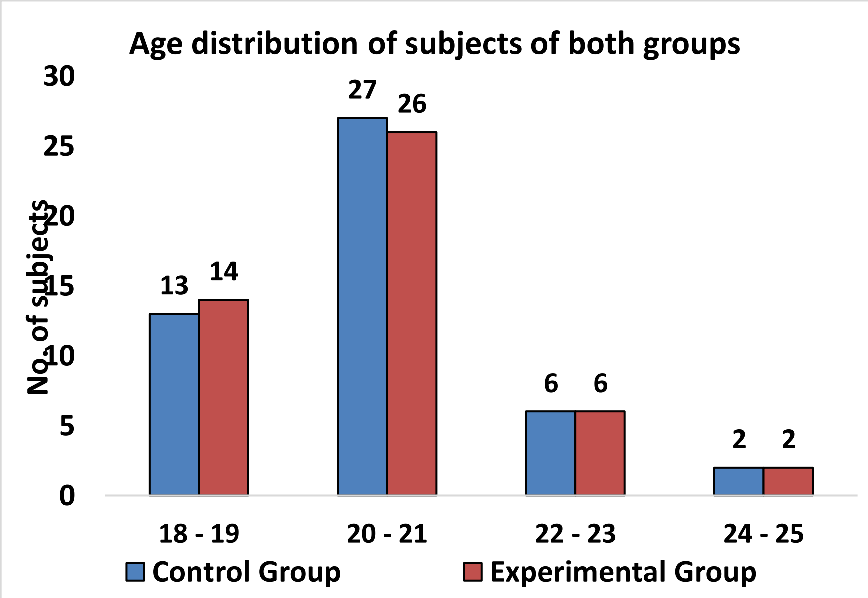

Fig 1: Frequency distribution of age of subject of both groups

TABLE – 2: Comparing Mean of Serum Testosterone, Serum Cortisol and C Reactive Protein at Different Time Interval of Both Groups By Using Analysis Of Variance

Testosterone

Mean testosterone levels increased from 2.54±2.12 ng/dL at baseline to 4.66±3.89ng/dL post exercise and 4.18±3.55 ng/dL ($p<0.01$). Male participants showed more pronounced increases compared to females.

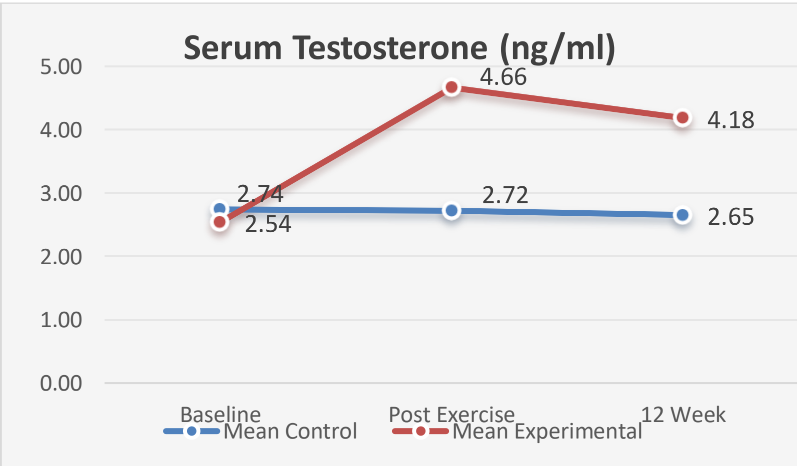

Fig 2: Frequency distribution of age of subject of both groups

Cortisol

Cortisol levels increased transiently after the first two weeks (from 146±31.95 to 1199.5±33.3 µg/dL) and by week twelve (127.3±28.04 µg/dL), indicating adaptation.

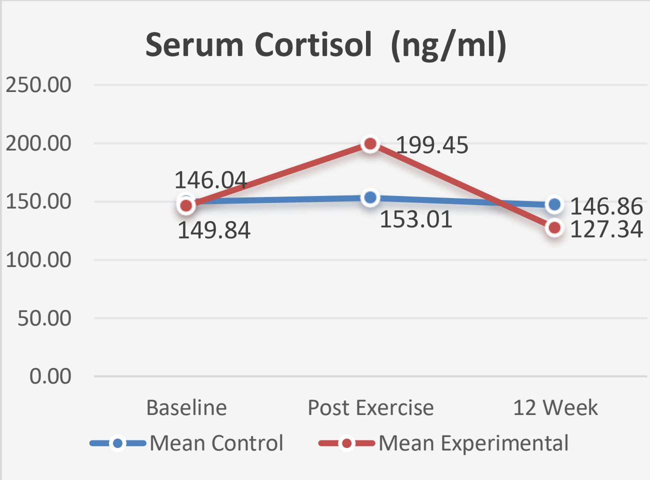

Fig 3: Frequency distribution of age of subject of both groups

CRP

CRP levels significantly increased from 0.687±0.428 mg/L to 1.44±0.65 mg/L ($p < 0.001$),and then decreased by twelve weeks (0.948±0.496) suggesting reduced systemic inflammation by time.

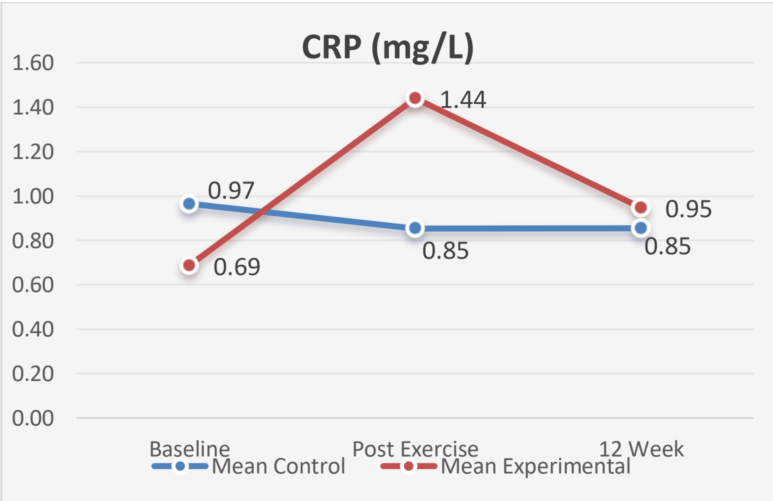

Fig 4: Frequency distribution of age of subject of both groups

In addition the changes in testosterone and cortisol level in the experimental group in comparisson of control group are significant ($p<0.0001$).

DISCUSSION

Exercise induces a variety of physiological changes, particularly in the endocrine and immune systems, where hormone and inflammatory responses play crucial roles. Hormones such as cortisol and testosterone, along with markers of inflammation like C-reactive protein (CRP), are key indicators of the body's response to and recovery from physical activity. Understanding the interaction between exercise and these biomarkers is essential for optimizing athletic performance, improving recovery strategies, and enhancing overall health.

The present investigation discovered a significant rise in testosterone levels just after exercise, with average increases from baseline to immediate and post-exercise evaluations of 2.70 nmol/L and 3.56 nmol/L, respectively. Ambrozy et al (2021) findings, on the other hand, aligned with their findings from research on resistance training in young men. Their findings demonstrated that moderate physical activity is enough to stimulate the HPG (hypothalamic-pituitary gonadal) axis but not so intense that cortisol (Testosterone suppressing hormone). Moderate-intensity resistance training was shown to cause temporary increase in testosterone levels. This response is consistent with the hypothesis that moderate exercise activates the sympathetic nervous system leading to increase release of anabolic hormones like testosterone.. The increase in testosterone following moderate exercise aligns with literature suggesting anabolic adaptation and enhanced muscle repair (Ahtiainen et al., 2003).

In contrast to previous studies that demonstrate an increase in cortisol after physical activity, the present study found a rise in cortisol level immediately after the exercise but substantial drop in cortisol levels following 12 wks post-exercise.

According to Patrick Wahl et al (2010) the HPA axis is activated in response to physical stress, which causes cortisol levels to rise right away after moderate to intense exercise. A rise in cortisol is necessary to support energy availability and glucose metabolism, ensuring that the body has what it needs to meet the demands of exercise. The present study's findings are consistent with Marwah's (2020) findings, which demonstrated that those with higher levels of cortisol control are often well-conditioned individuals or those who engage in continuous moderate exercise. Cortisol levels in these groups either plateau over time or rise less after exercise, which is indicative of better stress tolerance and decreased HPA axis reactivity. This phenomenon implies that regular exercise promotes quicker cortisol level normalization and increased recovery, which is in line with the better cortisol control shown in the research subjects.Cortisol's initial rise followed by stabilization highlights the body's adaptive response to physical stress, consistent with allostatic load theory (McEwen, 2004).

According to the present study, there was a noticeable increase in CRP levels just after exercise, which is consistent with other research identifying CRP as a critical indicator of inflammation brought on by exercise. According to Li et al (2020), after vigorous exercise, CRP levels rise due to the deterioration of muscle fibers and the ensuing inflammatory response required for tissue repair. This inflammatory response is a typical physiological reaction to physical exertion-induced muscle injury, particularly in those who are not acclimated to high-intensity exercise. Despite being acute, the inflammatory response is essential to the healing process because it initiates pathways for tissue repair. They pointed out that those who exercise frequently usually had lower baseline CRP levels, indicating that regular exercise may result in decreased chronic inflammation and corroborating the findings of the present research.

The present investigation revealed increased CRP levels after physical activity, which might indicate an immediate inflammatory reaction to the physical demands of the exercise regimen, especially if the participants were not completely acclimated to the intensity of the exercise. Windsor et al (2018), in contrast, highlighted the anti-inflammatory advantages of consistent exercise, pointing out that whereas short-term physical activity raises CRP levels momentarily, prolonged physical activity gradually lowers CRP. In contrast to the acute reaction seen in our participants, this adaptation demonstrates the body's greater efficiency in regulating inflammation due to continuous physical exercise.

This marked decline in CRP underscores the anti-inflammatory benefits of regular exercise and its role in reducing cardiovascular risk, particularly in sedentary young populations. These findings are particularly significant in the Indian context where youth physical inactivity is rising due to academic pressures and digital screen time. Incorporating moderate exercise into daily routines can foster both physiological and psychological well-being.

CONCLUSION

The current study aimed to explore the substantial correlation between exercise and the body's hormonal and inflammatory responses, with a particular focus on key biomarkers like testosterone, cortisol, and C-reactive protein (CRP). This study offers essential insights into how exercise-induced stress affects hormone regulation and inflammatory processes by examining the early effects of exercise on these biomarkers. Findings suggests that moderate exercise positively modulates serum testosterone, cortisol, and CRP levels among Indian young adults. These endocrine and inflammatory responses support exercise as a cost-effective, non-pharmacological strategy to promote health and prevent chronic diseases in youth populations.

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