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The Effect of Moderate-Intensity Exercise on Cortisol Levels in Moderate to Heavy Male Smokers

Rayna Milena Ekaterina
Faculty of Public Health with the speciality Nursing, Medical University Pleven, Bulgaria

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ABSTRACT

This study examines the effect of moderate-intensity exercise on cortisol levels in moderate to heavy male smokers. Smoking is known to elevate cortisol levels, contributing to chronic stress and adverse health outcomes. The purpose of this research was to assess whether regular moderate-intensity aerobic exercise could reduce cortisol levels and mitigate stress in smokers. A total of 30 male smokers, aged 25 to 45 years, participated in a four-week exercise program. Participants were divided into an experimental group, which engaged in 30 minutes of moderate-intensity aerobic exercise three times a week, and a control group, which maintained their usual activities without intervention. Cortisol levels were measured through salivary samples taken before and after the intervention. Results showed a significant reduction in cortisol levels in the experimental group, from 18.5 nmol/L to 13.1 nmol/L ($p < 0.01$), compared to no significant change in the control group. These findings suggest that moderate-intensity exercise can effectively reduce cortisol levels in male smokers, providing a potential non-pharmacological approach to managing stress and improving hormonal balance in this population. Further research is needed to explore the long-term effects and potential benefits of exercise in smokers, as well as its role in improving overall health outcomes.

Corresponding Author:

Rayna Milena Ekaterina
Faculty of Public Health with the speciality Nursing,
Medical University Pleven, Bulgaria
1, Saint Kliment Ohridski Street, 5800 Pleven, Bulgaria
raynamilenaekaterina@mu-pleven.bg

1. INTRODUCTION

Cortisol is a glucocorticoid hormone produced by the adrenal glands in response to stress and low blood glucose levels. It is often referred to as the “stress hormone” because of its central role in the body’s stress response. Cortisol is released through the activation of the hypothalamic-pituitary-adrenal (HPA) axis, a complex neuroendocrine system that helps the body cope with physical and emotional challenges(Herman et al., 2016). While cortisol is essential for maintaining homeostasis, its dysregulation particularly due to chronic stress can have significant negative impacts on health.

Under normal conditions, cortisol follows a diurnal rhythm, peaking in the early morning to help promote alertness and gradually decreasing throughout the day. It plays a crucial role in various bodily functions, including regulating metabolism, reducing inflammation, controlling blood pressure, and supporting immune function. During stressful situations, cortisol helps mobilize energy by increasing blood sugar, enhances brain function, and temporarily suppresses non-essential processes such as digestion and reproduction to prioritize survival.

However, when cortisol levels remain elevated for extended periods as is often the case in individuals experiencing chronic stress this adaptive hormone can become harmful. Prolonged high cortisol levels have been associated with a wide range of health issues. These include increased risk of hypertension, obesity, type 2 diabetes, suppressed immune function, and mood disorders such as anxiety and depression(Stuart & Baune, 2012). Moreover, elevated cortisol can negatively affect brain structures such as the hippocampus, leading to impairments in memory and cognitive function.

Chronic cortisol elevation also contributes to systemic inflammation, which plays a role in the development of various chronic diseases, including cardiovascular disease and autoimmune disorders(Black & Garbutt, 2002). Additionally, long-term cortisol imbalance can disrupt sleep patterns, increase fatigue, and reduce overall quality of life.

Cortisol, commonly referred to as the "stress hormone," plays a vital role in regulating various physiological processes including metabolism, immune response, and the body's stress response. Under normal conditions, cortisol levels fluctuate throughout the day in response to physical and psychological demands(Adam et al., 2006). However, prolonged exposure to stressors such as chronic smoking can disrupt this balance, leading to persistently elevated cortisol levels, which are associated with negative health outcomes such as hypertension, impaired cognitive function, and increased risk of cardiovascular disease.

Smoking is widely recognized as a major risk factor for numerous health conditions, including respiratory diseases, cardiovascular problems, and cancer(Adam et al., 2006). Beyond these well-known effects, smoking also exerts significant influence on the body's hormonal system, particularly the endocrine axis that regulates stress responses. One of the most critical hormones affected by smoking is cortisol, often referred to as the body's primary stress hormone. Smoking-induced alterations in cortisol secretion can disrupt the delicate balance of the endocrine system and contribute to a range of health complications.

Nicotine, the primary psychoactive component of tobacco, acts as a potent stimulant of the central nervous system(Tiwari et al., 2020). It activates the hypothalamic-pituitary-adrenal (HPA) axis, a major neuroendocrine system responsible for controlling stress responses. When nicotine is inhaled, it stimulates the hypothalamus to release corticotropin-releasing hormone (CRH), which in turn prompts the pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH then signals the adrenal glands to secrete cortisol. This chain reaction leads to a spike in cortisol levels, even in the absence of an actual stressor.

In moderate to heavy smokers, repeated and prolonged exposure to nicotine results in chronic activation of the HPA axis(Chen et al., 2008). This can lead to persistently elevated basal cortisol levels and a blunted cortisol response to acute stress. Over time, this dysregulation can impair the body's ability to manage stress effectively. Moreover, high cortisol levels are known to suppress the immune system, increase blood pressure, promote fat accumulation especially in the abdominal area and contribute to insulin resistance. These physiological changes collectively increase the risk of metabolic syndrome and cardiovascular disease, which are already prevalent in smokers.

In addition to affecting cortisol, smoking also interferes with the regulation of other key hormones, including insulin, adrenaline, testosterone, and estrogen. For instance, nicotine has been shown to impair insulin sensitivity, contributing to glucose metabolism disturbances. It may also alter reproductive hormone levels, leading to issues with fertility and sexual function in both men and women(Østensen, 2004). These disruptions reflect a broader impact on the endocrine system, which relies on hormonal balance to maintain optimal function across multiple organ systems.

In conclusion, smoking significantly alters cortisol production and overall endocrine balance by chronically activating the body's stress pathways. These hormonal disturbances not only undermine the body's ability to cope with stress but also contribute to the development of various chronic diseases. Understanding these effects highlights the importance of smoking cessation and stress management strategies, including exercise and behavioral interventions, to restore hormonal equilibrium and improve overall health outcomes.

Over the past decade, considerable research has been devoted to understanding the interplay between physical activity, cortisol regulation, and the physiological effects of smoking(Kassel et al., 2003). Research has consistently demonstrated that chronic smoking leads to dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, which governs the body's stress response. A study by al'Absi et al. (2015) found that smokers exhibit significantly higher basal cortisol levels compared to non-smokers, and that their response to acute stress is often exaggerated or delayed. This disruption can have far-reaching consequences on mood, cognition, and metabolic health. In particular, moderate to heavy smokers are more likely to suffer from chronic stress and related disorders, which are exacerbated by sustained high cortisol levels.

In contrast, moderate-intensity exercise has been widely shown to have a regulatory effect on cortisol. According to Hill et al. (2019), regular moderate aerobic exercise helps modulate the HPA axis, promoting a healthier cortisol rhythm and improving the body's resilience to stress. Another study by Zschucke et al. (2015) emphasized that exercise not only reduces stress-induced cortisol reactivity but also improves psychological well-being in populations exposed to chronic stress. These findings are particularly relevant to smokers, who often use nicotine as a coping mechanism for stress.

Specific studies focusing on smokers are fewer, but growing. A notable study by Rethorst et al. (2016) investigated the effect of a structured exercise program on mood and stress biomarkers in individuals with nicotine dependence. Their results indicated that moderate-intensity exercise significantly reduced cortisol levels and improved mood, suggesting a potential role in smoking cessation strategies. Similarly, a 2020 study by Kim and colleagues examined the combined effect of smoking status and physical activity on cortisol rhythms, finding that smokers who engaged in regular physical activity showed more normalized cortisol patterns than sedentary smokers.

Moreover, exercise interventions have shown promise in aiding smoking cessation. A systematic review by Roberts et al. (2020) concluded that aerobic exercise could alleviate nicotine withdrawal symptoms and reduce cravings, potentially by regulating stress hormone levels. This aligns with findings by Ussher et al. (2016), who reported that exercise acts as a non-pharmacological strategy to manage the stress and anxiety associated with quitting smoking.

Despite these promising results, there remains a lack of targeted studies focusing exclusively on the impact of moderate-intensity exercise on cortisol levels in moderate to heavy male smokers—a group particularly vulnerable to the negative health consequences of smoking and chronic stress. Most existing studies either include general populations or do not distinguish between smoking intensity levels and gender differences in hormonal response.

Given the increasing prevalence of smoking among adult males and the associated health risks, it is crucial to explore accessible interventions that can potentially reduce its impact. This research aims to investigate the effect of moderate-intensity exercise on cortisol levels in moderate to heavy male smokers, thereby providing insights into whether exercise can serve as a beneficial stress management strategy in this at-risk population.

2. RESEARCH METHOD

This research employs a quantitative experimental approach to investigate the effect of moderate-intensity exercise on cortisol levels in moderate to heavy male smokers(Scerbo et al., 2010). The experimental design allows for a direct comparison between groups, enabling the assessment of cause-and-effect relationships between physical activity and hormonal changes in the target population.

The study involves a purposive sample of adult male smokers aged 25 to 45 years, categorized as moderate to heavy smokers defined as individuals who consume between 10 to 20 or more cigarettes per day for at least the past year. Participants are selected based on inclusion criteria that ensure the homogeneity of the sample, including stable smoking habits, absence of chronic diseases, and no current participation in regular physical activity or exercise programs(Mozaffarian et al., 2012).

Exclusion criteria include the use of corticosteroid medications, known endocrine disorders, and recent history of psychological distress or psychiatric treatment.

A pretest-posttest control group design is used in this study. Participants are randomly assigned to either the experimental group or the control group(Zientek et al., 2016). The experimental group undergoes a supervised moderate-intensity exercise program, while the control group maintains their usual daily activities without structured physical exercise.

The exercise intervention consists of 30 minutes of moderate-intensity aerobic activity (such as brisk walking or stationary cycling), performed 4 times a week over a period of 4 weeks(Slaght et al., 2017). Exercise intensity is monitored using heart rate zones, targeting 50–70% of the maximum heart rate (HRmax), calculated using the standard formula of 220 minus the participant's age. Each session includes a 5-minute warm-up, 20 minutes of continuous aerobic activity, and a 5-minute cool-down.

Salivary cortisol levels are used as the primary biomarker for assessing physiological stress. Saliva samples are collected from both groups at baseline (pretest) and after the 4-week intervention (posttest), using standardized collection kits(Weeks et al., 2016). To ensure consistency, samples are collected at the same time each morning, ideally between 7:00–9:00 AM, when cortisol levels are naturally at their peak. Samples are then stored at appropriate temperatures and analyzed using enzyme-linked immunosorbent assay (ELISA) techniques.

In addition to cortisol measurement, participants complete a brief questionnaire covering demographic information, smoking history, physical activity levels, and perceived stress (using a validated scale such as the Perceived Stress Scale, or PSS) to account for confounding variables.

The data collected is analyzed using statistical software such as SPSS. Descriptive statistics are used to summarize the characteristics of the participants(Kim et al., 2017). Paired sample t-tests are conducted to examine changes in cortisol levels within each group before and after the intervention, while independent sample t-tests are used to compare differences between the experimental and control groups. A significance level of $p < 0.05$ is used to determine the statistical significance of the results.

All procedures in the study are conducted in accordance with ethical research guidelines. Informed consent is obtained from all participants prior to the study(Nijhawan et al., 2013). Participants are informed about the purpose of the study, the procedures involved, potential risks and benefits, and their right to withdraw at any time without penalty. The research protocol is reviewed and approved by an institutional ethics committee to ensure compliance with ethical standards for research involving human subjects.

3. RESULTS AND DISCUSSIONS

Result

The findings of this study provide compelling evidence that moderate-intensity exercise has a significant impact on reducing cortisol levels among moderate to heavy male smokers. A total of 30 participants were involved in the study, with 15 assigned to the experimental group and 15 to the control group. Both groups had similar demographic and baseline characteristics, including age, smoking intensity, and initial cortisol levels, ensuring that any observed effects could be primarily attributed to the exercise intervention.

At the beginning of the study, salivary cortisol levels in both groups were within a comparable range, with the experimental group averaging 18.5 nmol/L and the control group averaging 18.2 nmol/L. After four weeks of consistent moderate-intensity aerobic exercise, the posttest results revealed a marked decrease in cortisol levels among the experimental group, with an average reduction to 13.1 nmol/L. In contrast, the control group showed only a negligible change, with posttest levels averaging 17.9 nmol/L.

Statistical analysis using a paired sample t-test indicated that the reduction in cortisol levels within the experimental group was statistically significant ($p < 0.01$), whereas the control group's change was not significant ($p > 0.05$). Furthermore, an independent sample t-test comparing postintervention cortisol levels between the two groups confirmed a significant difference ($p < 0.01$), highlighting the effectiveness of moderate-intensity exercise in lowering cortisol concentrations.

In addition to biochemical measures, participants in the experimental group also reported improvements in perceived stress levels, as assessed by the Perceived Stress Scale (PSS). These self-reported reductions in stress paralleled the physiological findings, reinforcing the idea that physical activity contributes to both hormonal and psychological stress regulation.

These results align with previous studies that have identified moderate-intensity exercise as a non-pharmacological method to modulate HPA axis activity and reduce cortisol levels. Importantly, this research adds to the body of knowledge by focusing specifically on a high-risk population moderate to heavy male smokers who are known to exhibit chronically elevated cortisol levels due to the stimulating effects of nicotine and the psychological stress associated with tobacco dependence.

Risk Management During Exercise

Risk management is a critical component of any exercise intervention, particularly when involving individuals with known health risks, such as moderate to heavy smokers. This population may have underlying cardiovascular, respiratory, or metabolic vulnerabilities due to prolonged exposure to the harmful effects of tobacco(Raghuveer et al., 2016). Therefore, ensuring participant safety during exercise is a top priority and must be integrated into the planning, implementation, and monitoring of the intervention.

The first step in managing risk is thorough pre-screening and health assessment of all participants before the exercise program begins. This includes gathering medical history, assessing smoking duration and intensity, and evaluating cardiovascular risk factors such as hypertension, chest pain, shortness of breath, and known heart conditions. Participants with existing medical conditions that contraindicate moderate-intensity exercise are excluded or referred for medical clearance before joining the study(Pedersen & Saltin, 2006).

Once participants are deemed fit to participate, the next key step is to design a safe and appropriate exercise regimen. Moderate-intensity exercise, such as brisk walking or cycling at 50–70% of the individual's maximum heart rate, is selected because it balances effectiveness with safety(Reed & Pipe, 2016). This intensity level has been shown to improve cardiovascular and hormonal health without imposing excessive physical strain, particularly for individuals who are not accustomed to regular exercise.

Monitoring during exercise sessions is essential. Participants' heart rates, breathing, signs of fatigue, and any discomfort are closely observed by trained personnel(Fletcher et al., 2001). Immediate access to basic medical equipment (e.g., first aid kit, blood pressure monitor, pulse oximeter) and clear emergency procedures ensure that any adverse events can be managed promptly and effectively. Furthermore, sessions are conducted in a safe and well-ventilated environment to minimize exposure to air pollutants and to support adequate oxygen intake, especially crucial for smokers with reduced lung function.

Education is also a part of risk management. Participants are informed about warning signs to watch for, such as dizziness, chest pain, excessive shortness of breath, and palpitations(Conaghan, 2017). They are instructed to report these symptoms immediately. Hydration and proper warm-up and cool-down routines are incorporated to prevent injury and promote recovery.

Another key aspect of risk management is individualization and progression. The exercise load is adjusted according to each participant's fitness level and physiological response. While the program is standardized in structure, it allows flexibility in terms of intensity and pacing, which helps minimize the risk of overexertion.

Lastly, psychological safety is also considered. Some participants may experience anxiety or fear when engaging in physical activity for the first time in years. Supportive supervision, encouragement, and gradual exposure help to build confidence and reduce psychological stress during exercise.

Limitations and Delimitations

The limitations of this study refer to the potential weaknesses or external factors that may affect the interpretation or generalization of the results. One of the primary limitations is the sample size, which, although adequate for preliminary investigation, may not fully represent the broader population of male smokers(Peto et al., 2000). A relatively small number of participants reduces the statistical power and may limit the applicability of findings to other age groups, genders, or cultural backgrounds.

Another limitation involves the short duration of the intervention. The study spans only four weeks, which may not be sufficient to observe long-term physiological adaptations or sustained behavioral changes in cortisol regulation and stress management. Chronic stress and hormonal changes, especially in smokers, often develop over extended periods, and short-term interventions may not capture the full scope of potential benefits or drawbacks(Richards et al., 2011).

Self-reported data, such as perceived stress levels and smoking habits, also present a limitation. These data may be subject to bias, including underreporting or overreporting due to social desirability or inaccurate recall. Although biological measures like salivary cortisol provide objective evidence, the reliance on some subjective measures can influence data integrity.

Environmental and lifestyle factors, such as diet, sleep quality, work-related stress, and caffeine intake, were not strictly controlled in this study. These variables can independently affect cortisol levels and may confound the results. Additionally, smoking behavior during the study was not altered or monitored strictly, meaning that fluctuations in smoking frequency could also affect cortisol measurements.

Lastly, the absence of female participants limits the ability to generalize the results across genders. Hormonal differences between men and women, especially in relation to stress response, could yield different outcomes, necessitating separate investigations in female populations.

Delimitations, on the other hand, are the boundaries intentionally set by the researcher to narrow the scope of the study. One major delimitation is the focus exclusively on male smokers aged 25 to 45 years. This decision was made to control for age-related hormonal variation and to reduce the variability associated with gender differences in endocrine response. While this enhances the internal validity of the study, it inherently limits the generalizability of the findings.

Another delimitation is the specific choice of moderate-intensity aerobic exercise(Raj, 2018). This decision was based on prior evidence indicating that this intensity level is both safe and effective for influencing cortisol levels without causing excessive physiological stress. However, it excludes the possibility of exploring the effects of low- or high-intensity exercise, which could produce different outcomes.

The study also delimits itself by examining only salivary cortisol as the primary biomarker of stress. While cortisol is a reliable indicator of HPA axis activity, other hormones and physiological indicators such as adrenaline, heart rate variability, or blood pressure could have provided a more comprehensive picture of the stress response.

Finally, the intervention is limited to a four-week period and involves only one type of exercise modality. While this helps maintain a controlled setting, it excludes longer-term interventions or diverse exercise programs that might have varying effects on stress and cortisol.

Comparison of Research Results with Previous Research

One of the most notable similarities between this study and previous research is the observed reduction in cortisol levels following exercise. For instance, a study by Chen et al. (2016) found that participants engaging in 30 minutes of moderate-intensity aerobic exercise exhibited a significant decrease in salivary cortisol levels post-exercise. This is consistent with the results of the current study, where the experimental group demonstrated a significant reduction in cortisol from 18.5 nmol/L to 13.1 nmol/L after four weeks of exercise ($p < 0.01$)(Karakoc et al., n.d.). Both studies indicate that regular moderate-intensity aerobic activity can effectively modulate the HPA axis, promoting a reduction in the stress hormone cortisol.

Furthermore, Smits et al. (2014) also conducted a randomized controlled trial that examined the effects of aerobic exercise on cortisol levels in smokers. Their research demonstrated that chronic physical activity was associated with a significant reduction in cortisol secretion, particularly in individuals who smoked. This is consistent with the findings in this study, where moderate to heavy male smokers showed a marked decrease in cortisol after engaging in moderate-intensity exercise. The similarity between these findings reinforces the idea that physical activity may help mitigate some of the endocrine imbalances associated with smoking.

However, the current study diverges from some previous studies in the duration of the intervention. While studies like that of Lovallo et al. (2015), which followed participants for several months, found that long-term exercise interventions provided more substantial reductions in cortisol, this study focused on a shorter, four-week intervention. Despite the shorter duration, significant reductions in cortisol were still observed in the experimental group, suggesting that even relatively brief periods of moderate-intensity exercise can have beneficial effects on stress hormone regulation in smokers. This finding could have practical implications for smokers who may be reluctant to engage in long-term programs or those seeking short-term benefits.

In contrast to some studies that use high-intensity exercise (e.g., Heil et al., 2018), which may show more dramatic fluctuations in cortisol levels, the moderate-intensity focus of this study emphasizes sustainability and safety, particularly for individuals with a history of smoking. High-intensity exercise is known to induce more significant cortisol spikes during and after activity, especially in individuals unaccustomed to regular physical exertion(Bažantová, 2018). By focusing on moderate-intensity exercise, this study aligns with previous research suggesting that moderate physical activity offers an optimal balance between stress reduction and safety, especially in vulnerable populations.

Moreover, while the existing literature often investigates cortisol in isolation, this study also observed self-reported stress levels alongside the physiological changes. Studies such as Smith and Johnson (2017) have suggested a link between reductions in cortisol and improvements in perceived stress. The findings in this study further support this notion, as participants in the experimental group reported significant reductions in perceived stress in line with the drop in cortisol levels. This reinforces the dual benefit of exercise in managing both physiological and psychological stress, as noted in prior research on stress management interventions.

However, it is important to note the limitations of previous studies, which may have influenced their results in ways that the current research sought to avoid. For example, many studies rely on heterogeneous participant groups with varying levels of smoking intensity, fitness, and age. By focusing exclusively on male smokers aged 25-45 who have a consistent smoking history of 10-20 cigarettes per day, this study narrows the demographic to ensure more homogeneous results and reduce variability.

4. CONCLUSION

This research has provided valuable insights into the impact of moderate-intensity exercise on cortisol levels in moderate to heavy male smokers. The study demonstrates that regular participation in moderate-intensity aerobic exercise significantly reduces cortisol levels, a key stress hormone that is often elevated in smokers due to the physiological effects of nicotine and smoking-related stress. The results of this study align with existing literature suggesting that exercise can mitigate stress, improve hormonal balance, and promote overall well-being, particularly in individuals with heightened stress responses such as smokers. The findings also highlight the potential of moderate-intensity exercise as a non-pharmacological intervention for managing cortisol levels in smokers, which could have far-reaching implications for public health. By reducing cortisol, exercise not only addresses one of the immediate physiological consequences of smoking but also offers a sustainable approach to improving both physical and mental health. This approach can be particularly beneficial for smokers who may face barriers to quitting, offering a complementary strategy to reduce stress and improve their overall quality of life. While this study focused on a relatively short intervention period, the significant reduction in cortisol levels observed in the experimental group suggests that even brief periods of exercise can have meaningful effects. Future research should explore the long-term impact of exercise on cortisol regulation, the optimal intensity and duration of exercise, and whether these effects extend to other markers of health, such as cardiovascular function and overall stress levels. Overall, this research underscores the importance of incorporating physical activity into lifestyle interventions for smokers, particularly those who are looking for practical ways to reduce stress and improve health. Further studies should continue to explore the complex relationship between exercise, smoking, and endocrine health, and refine strategies for utilizing exercise as an effective tool in managing smoking-related stress.

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