Music Therapy and Its Effect on Serum Testosterone Levels among Paramilitary Soldiers under Stress

Jyoti Sharma[1], Dinesh C. Sharma[2], Jaidev Kesri[2,3]*, Anuradha Singh[4], Anupam Prakash[1]

1. *Department of Life sciences, School of Biosciences and Technology, Galgotias University, Greater Noida, India*
2. *Department of Zoology, K.M. Govt. Girls P.G. College, Badalpur, GB Nagar, India*
3. *Dy Inspector General of Police, CRPF, India*
4. *Department of Biotechnology, Jaypee Institute of Information and Technology, Noida, India*

**Corresponding Author: Email: jaidevkesri@gmail.com*

Abstract

Testosterone is an androgenic hormone primarily secreted by the gonads under the control of the hypothalamic–pituitary–gonadal (HPG) axis. It is essential for maintaining various physiological and reproductive functions and also influences behavioral traits such as aggression, competitiveness, dominance, and the ability to cope with stress. Circulating testosterone follows a diurnal rhythm, with peak levels in the early morning and a gradual decline as the day progresses. This study was conducted on paramilitary soldiers, a population with high working stress. Recent studies show the increasing incidence of Suicide and Fratricide among paramilitary personnel and soldiers, which is a issue of serious concern. It is a scientifically established fact that music is used as a coping mechanism to reduce stress and anxiety. The study was conducted to validate the scientific fact of music to control anxiety through music. In the present study serum testosterone was measured as an important hormone for activeness and physical performance, and it is known to decrease under stressful conditions, making it a useful marker of stress. In the present investigation the average serum testosterone levels were recorded at 0, 30, 60, 90, and 120 days of music therapy. The result shows that the mean level increased from 484.29 ± 26.42 ng/dL at day 0 to 515.09 ± 41.24, 528.20 ± 55.46, 549.60 ± 71.39, and 554.63 ± 102.74 ng/dL at 30, 60, 90, and 120 days, respectively. A significant increasing trend was observed over time. The study suggests that music is not only a source of entertainment but can also be used as an alternative and complementary therapy for reducing stress and improving hormonal balance in soldiers.

Keywords: Music therapy; Testosterone; Stress; Paramilitary soldiers; HPG axis; Mental health

Introduction

Stress is an unavoidable part of human life. In simple terms stress, is anything that makes a person feel anxious, uneasy, or uncomfortable. It is a normal physiological and psychological reaction that has a great effect on the health and performance especially in high stress occupational groups such as paramilitary soldiers [1]. Scientifically, the natural reaction of the body to perceived danger or obstacles that are perceived to be a challenge, referred to as stressors, is the so-called fight-or-flight response. Stress is no longer an occasional phenomenon to soldiers in the Central Armed Police Forces (CAPFs). The demands of the long deployments, separation, hostile environment, unpredictable tasks and high expectations exert overwhelming psychological and physiological pressures on the personnel [2]. Stress can be useful in short periods of time as it enhances focus and performance. But in a chronic stress, as is common among the soldiers of the CAPF, this may be very harmful both to mental and physical health.

Stress within the Armed Forces as well as Paramilitary Forces has become a serious issue in India. The reports in the past decade have shown the increasing number of suicides, fratricide, psychiatric, substance abuses, and physical disorders associated with stress. The report indicated over 1,532 cases of suicide among the Indian paramilitary forces between the years 2011 and 2023; the figures are very high in forces like CRPF and BSF [3]. These statistics demonstrate the immediate necessity of effective, convenient, and non-stigmatizing stress management techniques among the soldiers.

Normal stressful reaction is necessary in order to survive and be in harmony or homeostasis. Nevertheless, failure to control the stress may cause endocrine, immune, cardiovascular, and mental diseases, such as anxiety, depression, cardiovascular diseases [4]. The hormones that are released into the body during stress include adrenaline and cortisol, which keep an individual on his /her toes and ready to react. But in the case of chronic stress, there is continuous secretion of cortisol which can interfere with the normal secretion of other hormones, weaken the immune system, change metabolism, and have adverse effects on mental health, sleep habits, and the general physiological equilibrium [1].

The endocrine reactions of stress include HPG axis and stress pathway interplay [5]. The hypothalamic-pituitary-gonadal (HPG) axis is one of the most important systems that are influenced by the long-term stress and controls the amount of testosterone that is released. Stress that is chronic or severe has been demonstrated to reduce the levels of testosterone which could lead to fatigue, loss of motivation, poor physical performance, mood swings, poor emotional control and overall wellbeing. Testosterone plays a vital role in energy, muscle strength, and cognitive performance and changes in his levels are the clinically meaningful indicators of stress status. There is a definite diurnal variation in testosterone levels with the highest levels in the early morning and lowest levels at the evening [6]. Conversely, acute stressors like competitions or temporarily oriented problems have a mixed and an inconsistent effect on the testosterone level [7]. Testosterone is also very relevant in physical strength, stamina, mood, confidence, motivation and resilience all of which are very essential to soldiers. Thus, the operational effectiveness and general well-being of CAPF staff depend on the healthy levels of testosterone.

In this regard, music comes out as a viable, affordable and culturally permissible intervention. Music has been known to affect emotions and physiological systems of human beings. Music may lessen the perceived stress, decrease cortisol levels, normalize heart rate, and bring on relaxation. Music can indirectly assist in the normal functioning of the HPG axis by reducing stress response, which, in its turn, can prevent the impact of stress on testosterone suppression. Music therapy was used since the early clinical and wellness contexts in order to relieve stress, anxiety, physiological arousal etc. According to meta-analytic evidence, music can have a moderate effect of reducing physiological measures of stress metrics and a strong effect of reducing psychological stress experience in varied groups (e.g., listening, guided session, interactive music therapy) [8].

Music can be used as an effective and yet simple coping tool by the CAPF soldiers dealing with stresses of their daily life. Plastic, low-tempo music possibly assists soldiers to relax after work-hours, enhance the quality of sleep, and minimize the anxiety. Motivational or rhythmic music can be utilized to improve mood, confidence and physical preparedness during training or physical exercise. These positive emotional and physiological effects might

eventually lead to improved hormonal balance, such as healthier testosterone levels. Notably, the interventions based on music do not presuppose any specific infrastructure or medical control and may be implemented in the everyday activities of soldiers with ease. Listening group sessions and music during relaxation times, or individualized playlists of music could be useful in promoting emotional expression, social connection, and psychological resilience, which uniformed services tend to ignore due to the stigma associated with mental health.

Materials and Methods

Phase I: Screening and Selection

- **Recruitment:** Outreach via digital forms to CAPF personnel (N=468 volunteers).
- **Psychological Profiling:** Standardized psychometric testing to assess baseline stress.
- **Selection: 69 participants** identified with "High Stress" indicators for biochemical intervention.

Phase II: Standardized Music Intervention

- **Medium:** Bollywood song-based **Raga 'Bhairavi'** (selected for calming properties).
- **Volume Control: Sharma and Zehra (2022) [9] Mechanism** (The Finger-Snap Technique).
  Protocol: Adjust volume until a finger snap near the ear remains clearly audible (ensures, approx 60-70 dB).
- **Duration:** 120 days of daily prescribed listening, guided by online workshops.

Phase III: Biochemical Analysis (Serum Testosterone)

- **Sampling:** Morning blood draws at **Day 0, 30, 60, 90, and 120**.
- **Technique: Enzyme-Linked Immunoassay (ELISA): Kit based**
  - **Binding:** Capture of testosterone using specific antibodies on microtiter plates.
  - **Detection:** Signal generation via enzyme-linked secondary antibodies.
  - **Measurement:** The intensity of the signal is measured using a ELISA plate reader.

Result and Observation

The table 1 shows the mean serum testosterone of the study participants at baseline and 30, 60, 90 and 120 days following the music therapy. The testosterone levels were also seen to increase steadily over time, and the test results were much better than those at the beginning. The increase was regulated after the 90th day, which is indicative of a plateau effect, with the long-term intervention (Figure-1).

Table 1 Average level (N=69) of testosterone measured at different time intervals

S. No	Days	Range	Mean testosterone level (ng/dL) + SD	Sig. (2-tailed)*
1	0	402-525	484.29±26.42	-
2	30	438-798	515.09±41.24	0.00
3	60	400-863	528.2±55.46	0.001
4	90	365-899	549.6±71.39	0.00
5	120	325-964	554.63±102.74	0.485

**p>0.05*

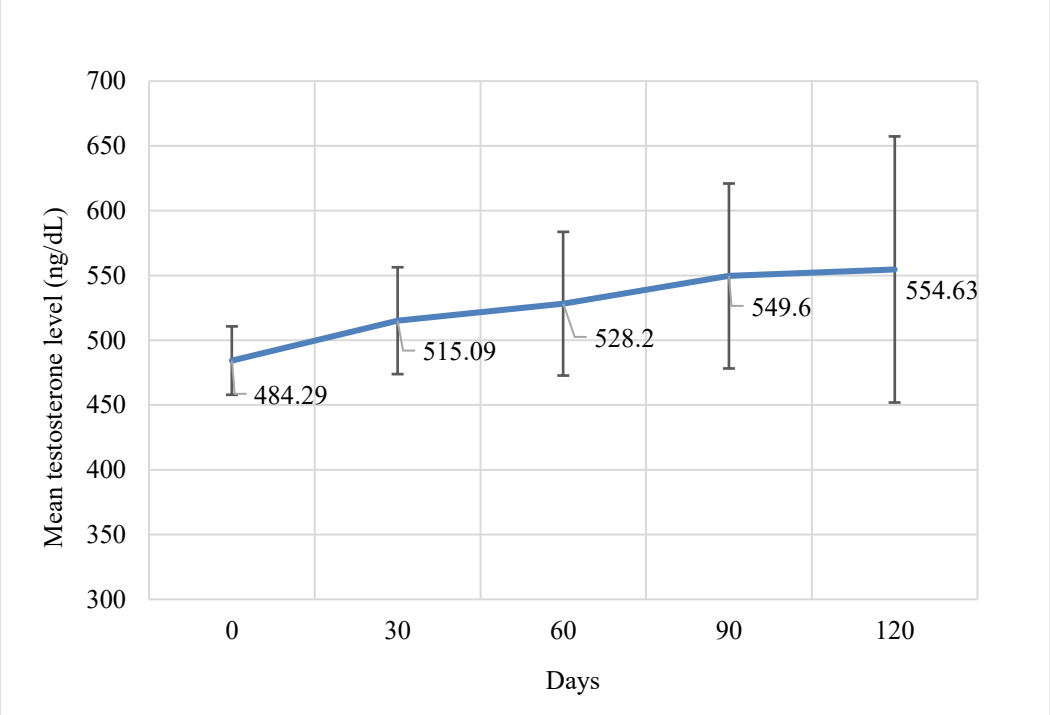

Figure 1. Temporal changes in testosterone concentration over a 120-day period

- After 30 days of music therapy, the mean serum testosterone level increased to 515.09 ± 41.24 ng/dL compared to baseline (484.29 ± 26.42 ng/dL). The increase in testosterone after 30 days was statistically significant compared to day 0 (484.29 vs 515.09 ng/dL; $P < 0.05$).
- After 60 days of music therapy, the mean testosterone level further increased to 528.20 ± 55.46 ng/dL. This increase was statistically significant compared to baseline (484.29 ± 26.42 ng/dL; $P < 0.01$) and 30-day values (515.09 ± 41.24 ng/dL; $P < 0.05$).
- After 90 days of music therapy, the mean serum testosterone level rose to 549.60 ± 71.39 ng/dL. The increase was statistically significant compared to baseline ($P < 0.001$), 30 days ($P < 0.01$), and 60 days ($P < 0.05$).
- After 120 days of music therapy, the mean testosterone level reached 554.63 ± 102.74 ng/dL. Testosterone levels at 120 days were statistically significant compared to baseline ($P < 0.001$), 30 days ($P < 0.01$), and 60 days ($P < 0.05$). However, the difference between 90 and 120 days was not statistically significant ($P > 0.05$), indicating a plateau effect in testosterone levels after 90 days.

Overall, a progressive and sustained increase in serum testosterone levels was observed with continued music therapy.

Discussion

The present longitudinal study shows that structured music therapy, using culturally familiar *Raga Bhairavi* based Bollywood songs over a 120-day period, led to a steady increase in serum testosterone levels among chronically stressed paramilitary personnel. Testosterone levels increased at each assessment point (30, 60, 90, and 120 days) compared to baseline. The rise continued up to Day 90, after which the levels remained almost stable through Day 120. This suggests that long-term music listening may support hormonal recovery, but after a certain point, further increase may become limited, and become adopted for that.

The current findings support the positive role of music therapy in reducing stress and improving body functions linked to stress. Research suggests that music interventions can help people recover from stress and may influence endocrine hormones, including testosterone. Several clinical studies have shown that music can reduce stress

markers such as cortisol and salivary α-amylase and also improve psychological stress. Nonetheless, the findings of tests have not consistently been identical, and the results obtained are dependent on the group of participants that the study is conducted and the form or period of intervention [10].

Persistent work stress has a very powerful impact on hormonal equilibrium in the body. It primarily works by stimulating the hypothalamic-pituitary-adrenal (HPA) axis that elevates the release of stress hormones known as glucocorticoids [11,12]. Such stress hormones have the potential to harm Leydig cells in the testes, leading to the death of the cells (apoptosis), which decreases the production of testosterone [13]. Stress also impacts the mitochondria within these cells and reduces significant proteins required to produce testosterone such as *StAR* and *CYP11A1*. This has been associated with decreased activity of *Atp5a1*, which results in a low production of testosterone [14]. These processes can be used to understand why stress can be commonly associated with the reduced androgen levels.

The gradual recovery of testosterone observed in our subjects can be attributed to the fact that the hormone was suppressed by hormones due to stress. When the stress levels decrease, there is a possibility that the hormonal regulation system involving the HPG axis will start functioning normally once again, which will enable Leydig cells to produce testosterone more efficiently. The levels observed to stay constant by Day 120 could also be a sign that the body had entered a new balanced condition following the recovery.

The results of this study are backed up by previous studies that indicate that there is a possibility of using music-based interventions in order to enhance the stress-related body responses. The majority of earlier researches have centred primarily on cortisol and other stress biomarkers that are reduced. Systematic reviews prove that music interventions produce a stress-biomarker decrease and enhance emotional health in both clinical and healthy groups [10,15]. The same stress relieving effect can be indirectly used to bring hormonal balance. Nevertheless, the results of testosterone in music studies remain scarce and even ambiguous. Numerous studies of music in the short term indicate that there are only short-term hormonal modifications which implies that more time of intervention may be necessary in order to achieve endocrine stability.

Conversely, the current research demonstrates that a continuous music therapy of more than 120 days resulted in a gradual and significant testosterone increment. This is backed by experimental evidence. Xiong et al. (2022) discovered in male rats that chronic stress suppresses the synthesis of testosterone by destroying mitochondria in Leydig cells by dysfunctioning *Atp5a1*. This confirms that stress suppresses testosterone and that, maybe, by reducing stress, music can assist in recovery.

It is also the paramilitary environment. Soldiers undergo continuous stress that is caused by operational tasks, and hormonal suppression is more severe. Thus, the improvement of testosterone was observed and could not only be due to relaxation but also could be a product of long-term neuroendocrine stress. It is possible that the emotional attachment and compliance of participants could have been promoted due to the Raga Bhairavi that was culturally familiar, thereby turning the therapy process into a success.

Biologically, music stimulates the parts of the brain that are related to emotion and stress management including the hypothalamus and limbic system. Music can help eliminate chronic stress by lowering the activity of the HPG axis and enhancing the testosterone level by relaxing the body and stimulating the parasympathetic nervous system.

In general, the current study provides supplementary evidence where previous studies focused primarily on cortisol and autonomic responses, whereas the current study presents proof of the value of long-term music therapy as a method of supporting testosterone recovery among defense personnel subjected to stress as a result of their duties, which is a relatively simple and culturally acceptable intervention.

Limitations

Even though the results are encouraging, the current research has several limitations that it must be taken into account. First, the biochemical phase utilized a rather small sample size of 69 respondents that can restrict the generalizability of the findings to the broader population of paramilitary personnel. Second, the standard deviation of

the phenomena showed at Day 120 is higher, which means that there are more individual differences in the responses to music therapy, so soldiers might not all respond in the same way to the long-term music therapy interventions. This inconsistency may be affected by the severity of the baseline stress, lifestyle, sleep patterns, or personal activities related to the intervention. Also, the present-day research was exclusively aimed at male paramilitary members and the impacts of music therapy on endocrine testosterone and stress-related outcomes in female staff are not thoroughly studied yet. More diverse and larger samples, including females, should be used in future studies to learn more about the generalizability of these results.

We acknowledge that repeated-measures ANOVA or mixed-effects models would provide a more robust statistical framework for longitudinal data. Due to the current sample size and study design, a paired t-test approach was adopted. Future studies with larger datasets will incorporate advanced statistical models to strengthen inference. Additionally, the Finger-Snap Technique, while novel and patented, requires further independent validation to establish its reliability and reproducibility across different populations and settings.

The authors declare that some of the cited references (3,9) include their own previously published work. This has been transparently reported to maintain academic integrity. No financial or commercial conflicts of interest are associated with this study.

Conclusion

This research shows that a 120 days structured music therapy is linked to a great deal of rise in serum levels of testosterone in paramilitary soldiers, and this designates its importance as a non-invasive treatment to avert stress and improve hormonal equilibrium. These results can be added to the accumulating body of evidence concerning the therapeutic effect of music on physiological responses to stress and provide opportunities to conduct future studies such as randomized controlled trials and mechanistic research.

References

1. Mbiydzenyuy NE, Qulu LA. Stress, hypothalamic-pituitary-adrenal axis, hypothalamic-pituitary-gonadal axis, and aggression. Metab Brain Dis. 39(8):1613–1636. (2024) doi:10.1007/s11011-024-01393-w
2. Sharma S. Occupational stress in the armed forces: An Indian Army perspective. IIMB Manag Rev. 27(3):185–195. (2015) doi:10.1016/j.iimb.2015.06.002
3. Sharma DC, Kesri J, Zehra S. Analysis of suicide rates among Central Armed Police Forces (CAPF) personnel: A decade of data. J Exp Zool India. 27(2):1977–1981. (2024) doi:10.51470/jez.2024.27.2.1977
4. Kutlikova HH, Babková Durdiaková J, Wagner B, Vlček M, Eisenegger C, Lamm C, Riečanský I. The effects of testosterone on the physiological response to social and somatic stressors. Psychoneuroendocrinology. 117:104693. (2020) doi:10.1016/j.psyneuen.2020.104693
5. Domes G, Linnig K, von Dawans B. Gonads under stress: A systematic review and meta-analysis on the effects of acute psychosocial stress on gonadal steroids secretion in humans. Psychoneuroendocrinology. 164:107004. (2024) doi:10.1016/j.psyneuen.2024.107004
6. Afrisham R, Sadegh-Nejadi S, SoliemaniFar O, Kooti W, Ashtary-Larky D, Alamiri F, Aberomand M, Najjar-Asl S, Khaneh-Keshi A. Salivary testosterone levels under psychological stress and its relationship with rumination and five personality traits in medical students. Psychiatry Investig. 13(6):637–643. (2016) doi:10.4306/pi.2016.13.6.637
7. Zueger R, Annen H, Ehlert U. Testosterone and cortisol responses to acute and prolonged stress during officer training school. Stress. 26(1):2199886. (2023) doi:10.1080/10253890.2023.2199886
8. Maratos AS, Gold C, Wang X, Thompson T. Effects of music interventions on stress-related outcomes: A systematic review and two meta-analyses. J Music Ther. 56(3):243–280. (2019)
9. Sharma DC, Zehra S. Mechanism to control music frequency for music therapy. Patent Office J. 42(2022):67371. (2022)
10. Ishak MW, Herrera N, Halbert A, Tu J, Gao W. Music and biomarkers of stress: A systematic review. Int J Healthc Med Sci. 6(5):82–92. (2020) doi:10.32861/ijhms.65.82.92

11. Hardy MP, Gao HB, Dong Q, Ge R. Stress hormone and male reproductive function. Cell Tissue Res. 322(1):147–153. (2005) doi:10.1007/s00441-005-0006-2
12. Son YL, Ubuka T, Tsutsui K. Regulation of stress response on the hypothalamic–pituitary–gonadal axis via gonadotropin-inhibitory hormone. Front Neuroendocrinol. 64:100953. (2021) doi:10.1016/j.yfrne.2021.100953
13. Chen Y, Wang Q, Wang F, Gao H. Stress induces glucocorticoid-mediated apoptosis of rat Leydig cells in vivo. Stress. 15(1):74–84. (2012) doi:10.3109/10253890.2011.585188
14. Xiong X, Wu Q, Zhang L, Gao S, Li R, Han L, Fan M, Wang M, Liu L, Wang X, Zhang C, Xin Y, Li Z, Huang C, Yang J. Chronic stress inhibits testosterone synthesis in Leydig cells through mitochondrial damage via Atp5a1. J Cell Mol Med. 26(2):354–363. (2022) doi:10.1111/jcmm.17085
15. Mitsui Wong M, Tahir T, Finnerty R, O'Brien N. Biomarkers of stress in music interventions: A systematic review. J Music Ther. 58(3):241–277. (2021) doi:10.1093/jmt/thab003