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EFFECT OF MUSIC ON CARDIOVASCULAR REACTIVITY AND PAIN TOLERANCE DURING COLD PRESSOR TEST

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ABSTRACT

Background

Music has been proposed as a low-cost non-pharmacological intervention for stress and pain reduction. This study evaluated the effects of music on blood pressure, pulse, and pain tolerance during the cold pressor test (CPT) in healthy adults.

Methods

A within-subject crossover study was conducted on 80 healthy medical students (20–30 years). Four randomized conditions were tested: rest, music, CPT, and CPT+music. Blood pressure, pulse, SpO_2, and pain tolerance were measured. Paired t-tests compared conditions.

Results

Music significantly reduced resting systolic BP and pulse, attenuated CPT-induced increases in BP and pulse, and markedly increased pain tolerance. SpO_2 remained stable. Effect sizes were large.

Conclusion

Music reduces cardiovascular reactivity and enhances pain tolerance during CPT. It may serve as a safe, low-cost adjunct in stress and pain management.

Keywords: *Music therapy, Cold Pressor Test, Cardiovascular Reactivity, Blood Pressure, Pulse Rate, Pain Tolerance*

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INTRODUCTION

Globally, chronic pain (CP) affects an estimated 20–30% of adults, with systematic reviews reporting a weighted mean prevalence of around 30% and contributing substantially to disability, reduced productivity, and diminished quality of life [1]. Pain is a multidimensional phenomenon, encompassing physiological, psychological, and emotional components, and its perception can be influenced by cognitive appraisal, mood, attention, and social context [2].Traditional management of CP has often relied on pharmacological interventions, including non-steroidal anti-inflammatory drugs, opioids, and adjuvant medications. However, these approaches are frequently associated with side effects, risk of dependency, and variable efficacy, prompting increased interest in non-pharmacological and complementary therapies.

Among these interventions, music therapy has emerged as a promising adjunct for pain and stress management. Music is not only culturally universal but also readily accessible, cost-effective, and devoid of pharmacological side effects. Evidence from both clinical and experimental settings suggests that listening to music can modulate autonomic nervous system activity, lower blood pressure, reduce heart rate, improve oxygen saturation, and alleviate subjective pain and anxiety. [3-5] Music exerts its effects through multiple mechanisms, including attentional distraction from painful stimuli, activation of the parasympathetic nervous system, modulation of cortical and subcortical pain pathways, and engagement of reward and emotional networks in the brain [6-9]. Functional neuroimaging studies indicate that music can influence regions such as the anterior cingulate cortex, insula, and periaqueductal gray, which are implicated in pain perception and analgesia [10-11].

The cold pressor test (CPT) is a well-established experimental model for inducing acute pain and sympathetic activation. By immersing a hand or forearm in ice water maintained at 1–5 °C, the CPT reliably triggers nociceptive pathways and evokes robust cardiovascular responses, including elevations in blood pressure and heart rate [12-13]. This test provides a controlled environment to examine physiological and subjective responses to acute pain, allowing researchers to evaluate potential modulatory interventions. Several studies have investigated the effects of music on CPT-induced stress, demonstrating that listening to music can attenuate hypertensive and tachycardic responses and increase pain tolerance, although results vary depending on music type, tempo, and individual preferences [14-16].

Despite growing evidence from Western and East Asian populations, data on the effects of music on pain and autonomic responses in South Asian populations, including Nepal, remain limited. This gap is significant given the cultural, social, and physiological differences that may influence pain perception and stress reactivity. In Nepal, the relevance of such non-pharmacological interventions is further underscored by limited access to advanced pain management resources and specialized mental health services, particularly in rural and peripheral health centers. Young adults, including university and medical students, often experience high levels of academic stress, sleep deprivation, and restricted coping mechanisms, making them a vulnerable group for stress-related cardiovascular changes and pain sensitivity. Accessible interventions such as music therapy could therefore provide a practical strategy for stress reduction and pain modulation in this population.

This study aimed to explore the physiological and analgesic effects of music listening in young Nepali adults. Specifically, it tested three primary hypotheses: (1) music listening reduces resting blood pressure and pulse rate, (2) music attenuates hypertensive and tachycardic responses to the cold pressor test, and (3) music increases pain tolerance. By examining these outcomes, the study seeks to contribute to the global evidence base while providing culturally relevant insights that may inform the adoption of low-cost, non-pharmacological strategies for stress and pain management in Nepal.

METHODS

Study design and participants: The study protocol was approved by the Institutional Ethical Committee (Approval No. Ref 44/081-082). This prospective, within-subject crossover study was conducted among 80 healthy medical students (40 males and 40 females), aged 20–30 years, from Nepalgunj Medical College, Banke, Nepal. Participants with a history of cardiopulmonary or neurological disorders were excluded from the study. Data collection was conducted between April 2025 and May 2025. Written informed consent was obtained from all participants prior to their inclusion in the study.

Sample Size: Sample size was calculated using the formula described by Al-Metha et al. [17] with a population of 100 first-year MBBS students. The required sample was 80.

Procedure: Each participant completed four experimental conditions in randomized order on the same day with sufficient rest between conditions:

- (A) Rest (10 minutes quiet rest)
- (B) Music (listening to slow-tempo/relaxing music via headphones)
- (C) CPT without music (foot immersion in ice

water at 1–5 °C)
- (D) CPT with music (same CPT while listening to music)

Pain tolerance during CPT (C and D) was recorded using a stopwatch from immersion to withdrawal of the foot. Participants were instructed to withdraw the foot at intolerable pain.

Measurements: Systolic and diastolic blood pressure (mmHg) were measured with an automated clinically approved sphygmomanometer on the right upper arm. Pulse rate (bpm) and peripheral oxygen saturation (SpO_2, %) were continuously recorded via a fingertip pulse oximeter on the left thumb. All devices were calibrated according to manufacturer recommendations.

Statistical analysis: Data were analyzed using SPSS. Descriptive statistics (mean ± SD) are presented. Paired t-tests compared conditions (Rest vs Music; CPT vs CPT + Music). Cohen's d was calculated for effect sizes. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

All 80 participants completed the study, and their data were included in the analyses.

Physiological Parameters at Rest and During Cold Pressor Test

As summarized in **Table 1** and illustrated in **Figures 1 and 2**, music listening produced significant reductions in resting cardiovascular parameters. At rest, systolic blood pressure decreased from 116.75 ± 8.48 mmHg to 113.51 ± 8.49 mmHg (p < 0.001, Cohen's d = −1.66), and pulse rate decreased from 77.92 ± 5.41 bpm to 74.68 ± 5.85 bpm (p < 0.001, Cohen's d = −1.70). Diastolic blood pressure also showed a modest reduction from 75.15 ± 5.35 mmHg to 73.31 ± 5.55 mmHg, while oxygen saturation remained within normal limits. These findings indicate a pronounced calming effect of music on baseline cardiovascular activity.

During the cold pressor test (CPT), participants exhibited the expected elevations in systolic blood pressure and pulse. Systolic BP increased to 131.09 ± 10.13 mmHg during CPT alone but was significantly attenuated to 124.80 ± 9.68 mmHg when music was provided (p < 0.001, Cohen's d = −0.94). Similarly, pulse rate increased to 89.55 ± 6.36 bpm during CPT without music and decreased to 84.26 ± 6.27 bpm with music (p < 0.001, Cohen's d = −1.07). Diastolic BP also decreased from 84.90 ± 7.18 mmHg to 79.93 ± 6.00 mmHg, while SpO_2 remained stable (97.50% vs 97.75%). **Figure 1** illustrates the reductions in systolic BP across conditions, and **Figure 2** depicts corresponding changes in pulse rate, highlighting the modulatory effect of music on acute pain-induced cardiovascular responses.

Pain Tolerance During CPT

Music had a marked effect on pain perception and tolerance, as shown in **Table 3**. The mean pain tolerance increased significantly from 51.49 ± 9.95 seconds in the CPT without music to 80.64 ± 11.00 seconds during CPT with music (p < 0.001, Cohen's d = 5.77), indicating a very large effect. This demonstrates that music not only attenuates physiological responses but also enhances the ability to tolerate pain.

Table 1: Descriptive statistics of physiological parameters across conditions (n = 80).

Measure	Rest	Music	CPT	CPT + Music
Systolic BP (mmHg)	116.75 ± 8.48	113.51 ± 8.49	131.09 ± 10.13	124.80 ± 9.68
Diastolic BP (mmHg)	75.15 ± 5.35	73.31 ± 5.55	84.90 ± 7.18	79.93 ± 6.00
Pulse (bpm)	77.92 ± 5.41	74.68 ± 5.85	89.55 ± 6.36	84.26 ± 6.27
SpO2 (%)	97.96 ± 0.99	98.22 ± 1.09	97.50 ± 1.04	97.75 ± 0.99
Pain Tolerance (s)	–	–	51.49 ± 9.95	80.64 ± 11.00

Table 2: Effects of Music on Resting and Cold Pressor Test (CPT) Physiological Parameters

Parameter	Rest / CPT	Music	Mean ± SD (No Music)	Mean ± SD (Music)	p-value	Cohen's d
Systolic BP (mmHg)	Rest	Music	116.75 ± 8.48	113.51 ± 8.49	<0.001	- 1.66
Pulse (bpm)	Rest	Music	77.92 ± 5.41	74.68 ± 5.85	<0.001	- 1.70
Systolic BP (mmHg)	CPT	CPT + Music	131.09 ± 10.13	124.80 ± 9.68	<0.001	- 0.94
Pulse (bpm)	CPT	CPT + Music	89.55 ± 6.36	84.26 ± 6.27	<0.001	- 1.07

Table 3: Effects of Music on Pain Tolerance During CPT

Parameter	Condition	Mean ± SD	p-value	Cohen's d
Pain Tolerance (s)	CPT (No Music)	51.49 ± 9.95	<0.001	5.77
Pain Tolerance (s)	CPT + Music	80.64 ± 11.00		

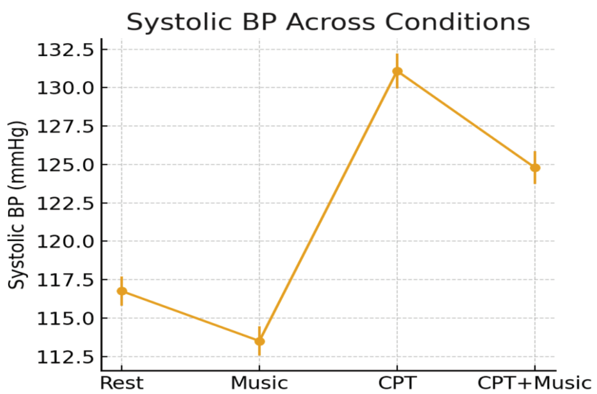

Figure 1: Changes in systolic blood pressure across conditions (n = 80).

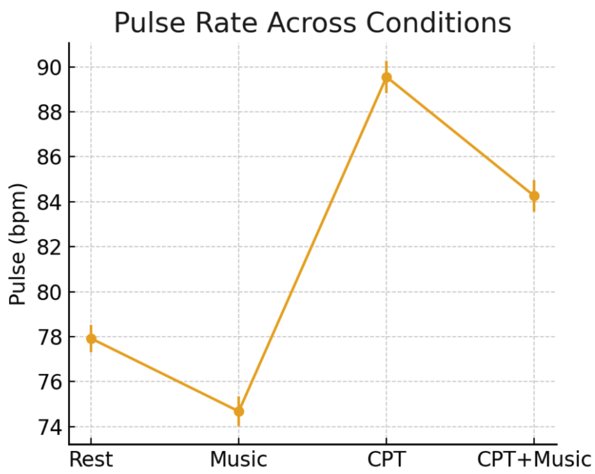

Figure 2: Changes in pulse rate across conditions (n = 80).

DISCUSSION

This study demonstrated that music listening significantly reduced systolic and diastolic blood pressure and pulse rate at rest, attenuated cold pressor test (CPT)–induced cardiovascular responses, and substantially increased pain tolerance [18-20]. A recent randomized trial among pre-hypertensive young adults also reported that relaxing music reduced blood pressure and heart rate, comparable to our observations in healthy Nepali medical students [21].

Our results further align with meta-analytic evidence. Hole et al. (2015), Kühlmann et al. (2018), and McConnell et al. (2016) reported music reduced perioperative pain, anxiety, and cardiovascular parameters in surgical patients [22-24]. A large 2023 meta-analysis including 2,306 hypertensive patients reported that adjuvant music therapy lowered systolic BP by approximately 9 mmHg and diastolic BP by 6.5 mmHg, with additional reductions in heart rate and improvements in psychological outcomes [25]. Although our study examined acute effects in young adults rather than chronic therapy in hypertensive patients, the similarity in direction highlights the broad applicability of music across populations. The attenuation of BP elevation during CPT (from 131 to 125 mmHg) reflects a clinically relevant reduction, particularly in individuals near diagnostic thresholds.

With respect to pain tolerance, the effect size observed in our study (Cohen's d = 5.77) is remarkably larger than that typically reported in clinical populations. For instance, a 2025 meta-analysis of nine randomized controlled trials (787 participants) showed that music therapy significantly reduced chronic pain with a pooled effect size of −0.51, and was most effective when patient-preferred music was used [26]. Our robust findings may reflect the acute, experimental design and the within-subject crossover model, which reduced inter-individual variability. Cheng et al. (2023) similarly found that recorded music increased pain endurance during CPT, supporting the analgesic benefits of music in experimental pain paradigms [27].

The observed reductions in cardiovascular responses are also consistent with systematic reviews in surgical patients. Liang et al. (2024) and Chen et al. (2025) reported that music therapy reduced anxiety, pain, SBP, DBP, HR, and in some cases improved SpO_2. [28-30]. Notably, some procedural studies have shown that while music reduces perceived pain, it may not always reduce analgesic consumption [29]. This suggests that music primarily enhances tolerance and coping rather than directly substituting for pharmacological therapy. Our finding of longer pain endurance during CPT supports this interpretation, as music appeared to modulate the subjective threshold of tolerable discomfort.

Clinically, the findings are especially important for Nepal. Chronic pain, hypertension, and stress-related disorders are rising, yet access to advanced pharmacological or psychological interventions is limited, particularly outside major cities. Music interventions are inexpensive, culturally adaptable, and safe, making them feasible for integration into outpatient care, perioperative protocols, and community health programs [31,32]. For medical students and young adults—groups often facing high academic and psychological stress—structured music listening may provide an accessible coping tool. In hospitals, music can reduce peri-procedural anxiety, complement analgesics, and improve patient satisfaction. At the community level, it may support individuals with chronic pain by offering a non-pharmacological strategy aligned with local cultural practices.

Limitations include the absence of blinding, no assessment of heart rate variability or biochemical stress markers, and the lack of exploration of patient-preferred versus standardized music. Future research in Nepal should examine different genres, evaluate patients with chronic pain or hypertension, and assess the long-term outcomes of repeated music exposure. Overall, this study reinforces international findings while extending evidence to a young South Asian population, highlighting music as a feasible, low-cost adjunct in Nepal's healthcare system.

CONCLUSION

This study demonstrated that music listening significantly reduced blood pressure and pulse rate at rest, attenuated cardiovascular responses to acute pain during the cold pressor test, and markedly increased pain tolerance. These findings align with international evidence showing that music modulates autonomic activity and provides analgesic effects, while extending the data to a young South Asian population. Compared with previous reports, our results showed larger effect sizes for pain tolerance, likely reflecting the strength of the within-subject design, and support the concept of audioanalgesia even with standardized relaxing music.

Clinically, the outcomes are highly relevant to Nepal, where music represents an inexpensive, safe, and culturally adaptable non-pharmacological tool. It can be integrated into hospitals, outpatient clinics, and community health programs to reduce pre-procedural anxiety, complement pharmacological therapies, and support stress management in medical students and the general population. In resource-limited settings, such interventions may enhance patient satisfaction and promote holistic care.

Future research should examine patient-preferred music, evaluate populations with chronic pain or hypertension, and explore long-term effects of repeated exposure. Overall, music-based interventions appear feasible, cost-effective, and promising as an adjunct in pain and stress management within the Nepali medical field.

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