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Systematic Review

Effects of a music-based intervention on psychophysiological outcomes of patients undergoing medical imaging procedures: A systematic review and meta-analysis

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ABSTRACT

Introduction: Musical intervention (MI) is a valuable strategy for addressing the psychological and emotional challenges faced by patients undergoing imaging procedures. This study explores MI's impact on psychophysiological outcomes during imaging procedures, detailing the sound repertoire and technical characteristics employed in MI.
Methods: A systematic review (SR) and meta-analysis (MA) were conducted. Electronic database searches of PubMed, Web-of-Science, and Scopus were performed encompassing original randomised research and quasi-experimental articles published until June 2023.
Results: Thirteen articles were included in this SR, scoring between 23 and 68 on the Joanna Briggs Institute (JBI) Checklist. Four articles were included to perform a MA concerning anxiety and heart rate (HR) outcomes. Most studies utilised digital playlists as the medium for MI. Headphones were commonly used, with an average volume of 50–60 dB and a musical frequency of 60–80 beats/min. While authors generally preferred selecting musical genres for the repertoire, two articles specifically chose Johann Pachelbel's "Canon in D major" as their musical theme.
In terms of psychological parameters, the experimental groups exhibited lower anxiety values than the control groups, with further reductions after MI. However, MA shows that this trend is only marginally significant. Patient comfort and overall examination experience showed improvement with MI. Regarding physiological parameters, HR, especially in the final phase of the examination, was significantly lower in the experimental group compared to the control group.
Conclusion: Across multiple studies, MI demonstrated the ability to reduce anxiety and HR. However, no specific music repertoire emerged as the most effective.
Implications for practice: MI arises as a painless, reliable, low-cost, and side-effect-free strategy, presenting imaging departments with a practical means to enhance patient comfort and mitigate anxiety and stress during medical procedures.

Introduction

In recent years medical imaging procedures have become an asset to modern medicine,[1–3] playing a crucial role in following healthcare, from wellness and screening to early diagnosis, treatment selection, and follow-up. The wide range of imaging

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techniques available today enables healthcare professionals to make informed clinical decisions, monitor patients' health, and accurately diagnose illnesses.[1,4–6]

Despite technological advancements, medical imaging procedures often induce patients' high levels of anxiety due to several factors: the possibility of diagnosing a life-threatening illness; first-time patient examination; body position during the image acquisition; patients' concerns with the examination result, diagnosis, and potential changes in treatment plans; lack of understanding about the procedure; difficulties in communicating or comprehending during the examination; the overall length of the procedure; and, in some cases, the use of ionizing radiation and patients' concerns about radiation exposure.[7–11] Additionally, the high intensity of the acoustic noise may lead to anxiety, and the small-bore size of scanners may pose a challenge to claustrophobic patients.[9,10,12]

Anxiety is an emotional reaction and generally adaptive feeling to stress, characterized by an activation of the sympathetic nervous system, modulated by the hypothalamic-pituitary-adrenal axis.[10] Nevertheless, anxiety levels out of proportion can be very upsetting, as it leads to psychological reactions, such as apprehension, insecurity, anguish, sense of threat, fear, decreased perception of self-efficacy, discomfort, and irritability.[13,14] High anxiety levels also result in adverse physiological manifestations such as increased blood pressure, heart rate (HR), blood oxygen, and blood cortisol levels and decreased immune response, enhancing the risk of infection.[13,14] At a behavioural level, excessive anxiety results in both patients' voluntary and involuntary movements, making it challenging to maintain stillness and negatively impacting the image quality.[9,12,15] More specifically, the difficulty in remaining still increases the likelihood of artifact appearance, leading to misinterpretation of the image and/or the need to repeat the exam. This situation will extend the patient's stay in the medical department and alter the medical service's normal flow.[6] Besides, patients' increased anxiety can lead to premature termination or even failure in the imaging procedure.[17,18] Given the cost and growing number of medical imaging procedures, preventing anxiety and its adverse effects is essential for patients and helps conserve staff time and resources.[16,19–21]

Several non-pharmacological strategies have been introduced before and during imaging procedures to minimise patient anxiety, such as meditation, massage, aromatherapy, hypnosis, and the use of music.[7,22–24] The definition of MI is unclear, although it can be divided into music therapy and music medicine.[25,26] The first one referred to the psychotherapeutic use of music and required the presence of a trained therapist providing diverse personalised music experiences, such as listening to live, songwriting, and composing music.[27] In music medicine, patients passively listen to pre-recorded music recommended by health professionals to address physiological or psychological needs.[12]

Musical intervention (MI) is a non-pharmacological strategy that is painless, reliable, low-cost and free of adverse effects.[28,29] It can help maximize efforts to promote the patient's comfort and relaxation; since patients' attention on aspects such as procedure time or symptoms can be diverted as they focus on the music.[30] Various MI in clinical settings induced reductions in HR, blood pressure,[26,29,31] respiratory rate,[26,30,32] pain,[31–34] anxiety,[29,31–36] stress hormone levels[31] and increased patient satisfaction,[37] and time spent in the recommended HR intensity in stroke survivors patients with low gait functioning.[38] Additionally, patient music preferences are an essential issue of MI.[28,33] Research has shown that when patients are allowed to choose the music they listen to during medical procedures, the effectiveness of the intervention is enhanced. Kulkarni et al. (2019)[39] observed the viability of self-selected music for reducing sedation requirements with patients undergoing interventional radiological procedures.

To date, several systematic reviews have been conducted concerning the effect of music on diverse clinical settings and populations. Remarkably, there are systematic reviews analysing the effect of music on pain and anxiety in medical procedures,[40] in surgery,[34] in burn patients during treatment procedures,[41] and in children undergoing invasive surgery[42] or medical procedures.[43] Other systematic reviews focused on the impact of music on anxiety during pregnancy[44] on anxiety in general, discomfort, pain, HR, and blood pressure in patients undergoing percutaneous coronary procedures,[45] on postoperative recovery in adults,[46] on psychological and physiological outcomes in people with cancer[26] and on anxiety, depression, and quality of life of cancer patients undergoing chemotherapy.[39] However, there is no recent systematic review of studies on the effects of music on adult patients undergoing medical imaging procedures. Furthermore, there is a compilation gap considering the characteristics of MI that are more effective before and during medical procedures.[47] Given the specific nature of medical imaging procedures, it is essential to know the impact of MI on patients' psychophysiological outcomes and whether this strategy is a valuable aid for imaging departments. Therefore, a systematic review was performed to explore the impact of MI on psychophysiological outcomes during medical imaging procedures. Additionally, this paper aims to describe the sound repertoire and technical characteristics employed in MI and evaluate their effectiveness on patients' outcomes.

Methodology

Design

A systematic review (SR) and meta-analysis (MA) were performed to identify the music-based intervention and its efficacy for psychological and physiological outcomes in patients during imaging procedures. The review was conducted taking into consideration the Preferred Reporting Items for Systematic Reviews and MA (PRISMA),[48] which encompass four phases: Identification, Screening, Eligibility, and Inclusion. The PROSPERO registration number ID is CRD42023428417. The protocol is also available at the following link: https://www.crd.york.ac.uk/PROSPERO/#recordDetails.

Search strategy

Publications that described original quantitative research were retrieved via electronic database searches of PubMed, Web of Science, and Scopus in the period from May to November 2023. The research included articles published until June 2023. The keywords used with the Boolean operators AND and OR are presented in Table 1.

No restrictions were applied regarding language, type of publication (articles or reviews), and date at this stage. However, as the objective was to develop an SR with MA, the evaluation focused on original randomized research articles (RCs) and quasi-experimental (QE). The inclusion criteria were determined using the PICO[49] strategy, as described in Table 2, which systematically considered the Population, Intervention, Comparison, and Outcome (PICO) elements. The exclusion criteria were a review and MA of articles and studies whose sample included health professionals, pediatric patients, studies with musical intervention in medical treatment, and other non-pharmacological strategies.

The Rayyan software was used during the screening phase. Two authors (CC and MAS) first screened all abstracts and titles resulting from the search to eliminate irrelevant studies. The same authors then screened full-text articles and made final eligibility decisions,

Table 1
Detailed description of the keywords used in each scientific database.

Databases	Keywords
Pubmed	("Music Therapy" OR Music OR Sound OR "Music Psychology") AND (Relaxation OR Anxiety) AND ("Diagnostic Imaging")
Web of Science	(Anxiety OR Relaxation) AND (Music OR "Music Therapy" OR Sound) AND ("Diagnostic Imaging" OR Imaging)
Scopus	(TITLE-ABS-KEY (anxiety OR relaxation) AND TITLE-ABS-KEY (music OR "Music Therapy" OR sound) AND TITLE-ABS-KEY ("Diagnostic Imaging" OR imaging))

based on inclusion/exclusion criteria (Table 2). In both phases, disagreements were resolved by discussion and consensus.

Quality appraisal

Quality assessment was done using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist.[50] This tool is the most used in the quality assessment of studies. Based on the current results, the authors used two different checklists: one for Quasi-Experimental Studies (QE) and the other for Randomized Controlled Trials (RCs). Two reviewers (CC and MAS) evaluated independently all articles as "yes", "no", "unclear" and "not applicable" in the defined dimensions proposed on JBI tool. Disagreements were resolved by consensus and a third reviewer (LV) was available to arbitrate any issues that remained unresolved.

After discussing the ratings and resolving any disagreement, the global rating for each of the selected articles was obtained by dividing the sum of ratings given ("No" = 1; "Unclear" = 2; "Yes" = 3) for the number of dimensions. Those dimensions rated as "not applicable" were not considered, to permit a more adjusted score within studies. All the articles were assessed in the defined dimensions and reported (See Supplementary Material, SM1, and SM2). With the support of a tool called robvis,[51] it was possible to build the results in a creative way.

Data extraction

To achieve the proposed objectives, data from all articles was independently extracted by two reviewers and compiled into a table. For each study, information was extracted regarding the authors, date of publication, country, aims, imaging procedure, sample, study design, musical strategies, measurement instruments, and results of physiological and psychological parameters.

Data synthesis

Narrative synthesis

We carried out a narrative synthesis to identify sound repertoire and technical characteristics employed in MI and to find the psychological and physiological parameters present in the studies included in the systematic review. Then, to summarise and synthesise the effect of each psychological and physiological outcome, we used mean, standard deviation, and p-value measures.

Meta-analysis

The MA only included anxiety parameters evaluated with State-Trait Anxiety Inventory (STAI-S) and heart rate (HR). Seven articles used STAI-S[39,52,53,56,60,61,63] but only four have the necessary information to carry out MA.[52,53,60,63] The three remaining articles[39,56,61] were not considered by the MA due to 1) the lack of standard deviation,[39] the lack of data after intervention,[56] and 3) the lack of data before intervention.[61] Moreover, five articles[54,55,58,59,62] assessed Anxiety but using different scales. Concerning HR, four articles,[53,57,60,62] were included in MA, as the remaining articles did not evaluate this parameter. The other parameters, namely, depression, satisfaction, pain, BP, DBP, LF, and HF, were evaluated in a few studies (one or two), not allowing their inclusion in the MA. Meta-analysis was performed to compare anxiety levels between the control (without music) and experimental (with music) groups before and after the procedure. Most articles did not provide the necessary information to compare before and after the procedure in both groups; only two articles,[53,63] provided this data. The variances were not considered equal for the MA models, so the fixed effects model was used. To assess heterogeneity, that is the variability or difference between studies in relation to the estimation of effects, the I^2 statistic and the Chi-Square (χ^2) test and respective p-value were used. The global effect test was performed using the Z statistic and its p-value. To assess the variability between studies, Tau^2 was used. A 5 % significance level was considered. The MA was performed in Comprehensive Meta Analysis, v4.

Results & discussion

Study selection

As previously described, the PRISMA framework was used, and the results are represented in the flow diagram PRISMA 2020 (Fig. 1).

Before the screening procedure, 952 articles (112 PubMed papers, 402 papers from Web of Science, and 438 papers from Scopus) were obtained, of which 175 were identified as duplicates and excluded. Under the screening procedure, 761 articles were excluded through the title and abstract due to the age of samples, samples with animals, reports written language, type of procedure (excluded non-diagnostic imaging procedures), and study design (excluded qualitative, reviews, and MA studies). Of the remaining 16 articles, it was not possible to obtain access to 1 article for reading and analysis and for this reason, it was excluded. The full text of the remaining 15 articles was analysed, and two were excluded, with the reported exclusion criteria: sample <18 years old.

Overall, thirteen studies were verified according to their study type, with ten articles[52–57,60–63] being considered randomized controlled trials and three articles[39,58,59] as a quasi-experimental study. The thirteen included studies scored between 23 and 68 in the JBI Checklist (See Supplementary Material, SM1 and SM2). More than 75 % of the results presented a low risk of bias (Figs. 2 and 3).

Table 2
PICO criteria for inclusion and exclusion in systematic review.

Parameters	Inclusion Criteria	Exclusion Criteria
P – Population	Adult patients (aged 18 years or older) who have had imaging procedures.	Pediatric patients and health professionals
I - Intervention	Music intervention before or during medical imaging procedures.	Music Intervention in Medical treatment
C – Comparison	Patients with department standard protocol.	Other non-pharmacological strategies
O – Outcomes	Patients' psychophysiological effects. Sound repertory and technical characteristics of music based intervention.	

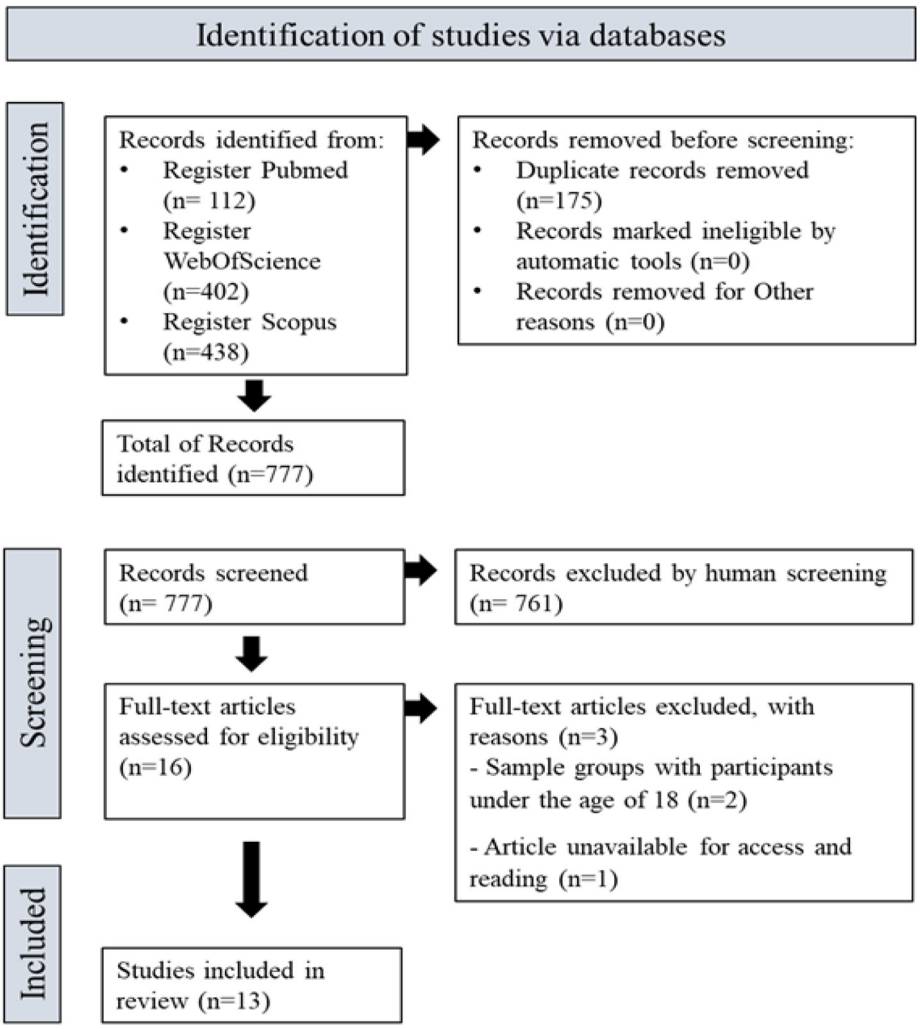

Figure 1. Search and study selection PRISMA flow diagram.

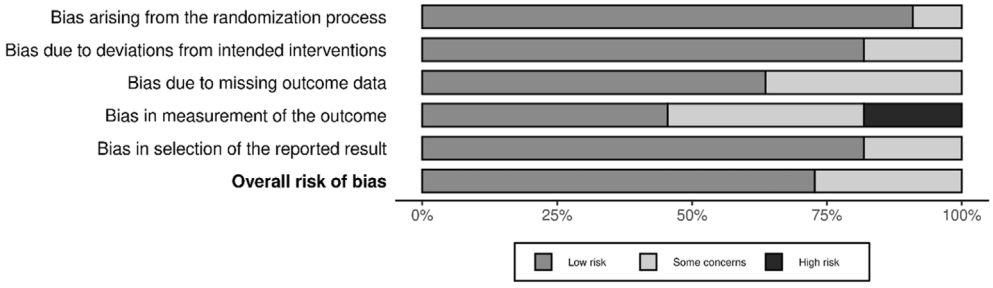

Figure 2. Risk of Bias domains with RoB2.0 dataset. Summary plot for randomized controlled trials reports.

Characteristics of included studies

The thirteen studies included in this systematic review were published between 2005 and 2022 and carried out in eight countries, USA,[52,53,56] UK,[39] France,[58,61] Ireland,[59] Iran,[54,62] China,[60,63] Sweden,[55] and Turkey[57](Fig. 4).

The sample size was variable among the various studies. The study with the smallest sample size included 35 patients,[58] and with the largest sample 267 patients.[62] The studies included in this systematic review evaluated the effects of music intervention in seven specific medical imaging procedures: MRI,[59,61,63] Coronary Angiography,[54,58] Vascular Angiography,[53] Positron Emission Tomography,[55,60] Myocardial Perfusion Scintigraphy,[57,62] Mammography,[52] and Cerebral Angiography.[56] It is noteworthy that an additional study in Radiological Interventional Procedures also did this evaluation.[39]

Sound repertoire and technical characteristics

In all studies, the MI was classified according to sound repertoire and technical characteristics (Table 3).

Regarding the sound repertoire the use of the term "sound repertoire" instead of "musical repertoire" is due to the use of

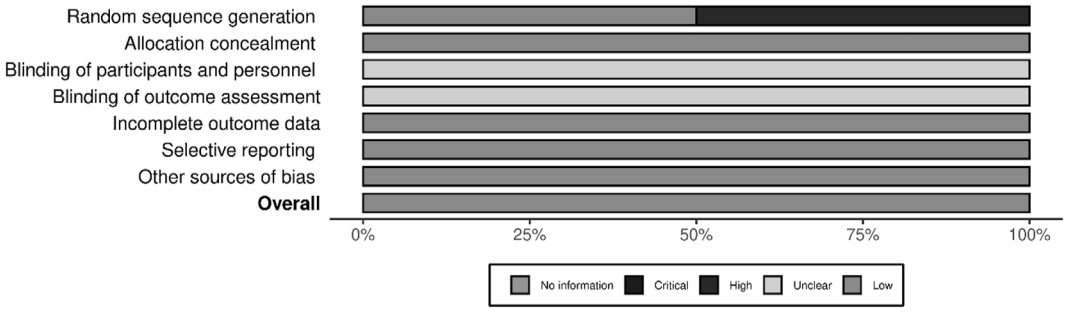

Figure 3. Risk of Bias domains with Generic dataset. Summary plot for quasi-experimental studies reports.

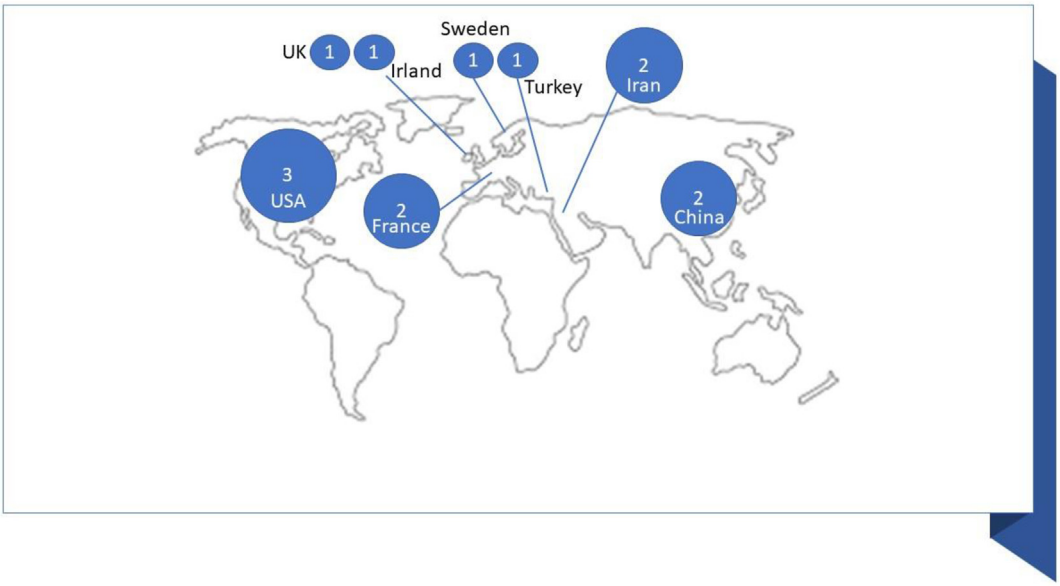

Figure 4. Number of articles published in different countries.

sound materials that are not considered music by their authors. Two studies used as sound repertoire sounds of nature,[59,62] six studies used specific musical themes,[39,54,55,60,61,63] and five musical genre.[52,53,56–58] To listen to the sound repertoire, the following media were used: CD in four studies,[39,53,57,60] cassette in two studies,[52,54] digital playlist in six studies,[55,56,59,61–63] and android application synthesized particular binaural beats frequency in two studies.[58,62] While in eight studies[39,52,54,55,60–63] the MI was an investigator-selected music, in five studies,[52,53,56–58] it was patients who chose between the possible options given by the technicians or any personal choice.[39] As for the technical characteristics, several sound equipment were used: Stereo System in five studies.[53,55,56,60,63] Headphones in seven studies[39,52,54,58,59,61,62] and an AudioPillow in one study.[55] For these devices, the authors defined: i) time length for eleven studies,[39,53–60,62,63] with 15 min being the shortest time,[53,57] and 60 min the longest time length[39]; ii) music volume for three studies,[55,57,60] with a mean value of 50–60 dB; and iii) musical frequency for four studies,[55,57,60,62] with a mean value of 60 and 80 beats per min.

In nine studies[39,53,56–59,61–63] present in this systematic review, MI is applied during the time of image acquisition, however, two studies[54,60] include intervention before the exam, two studies[54,55] after the exam and in one study the MI occurred before and during the imaging procedure.[52]

Psychophysiological measures

In this study, psychophysiological measures were selected to assess anxiety (Table 3). The psychological measures were collected using different measuring instruments: State-Trait Anxiety Inventory form- STAI in seven studies,[39,52,53,56,60,61,63] Depression Anxiety Stress Scales - DASS-21 in two studies,[54,62] Likert anxiety scale – LAS,[52] Self-Rating Anxiety Scale-SAS,[63] Kolcaba General Comfort Questionnaire – GCQ,[63] McGill Pain Questionnaire – MPQ,[52] Anxiety numeric rating scale – NRS,[55] Music Enjoyment Scale - MES,[53] Well-being questionnaire – WBQ,[55] each of them used in only one study.

Regarding the results of psychological parameters: i) four studies[55,59,61,63] showed that MI provides significant responses to improve exam experience and patients' comfort; ii) two studies[54,62] showed that MI provides significant responses to patients' stress reduction, and iii) nine studies[53–55,58–63] showed that MI provides significant responses to decrease anxiety levels. Additionally, in three studies,[61–63] the authors created specific situations that improved patients' psychological parameters: In the study, Santangeli et al., 2021,[61] luminous environment (with colour and intensity change) combined with slow-time music improves patients' satisfaction and decreases anxiety; In the study, Zahraei-Moghaddam et al. (2022),[62] experimental groups with particular

Table 3
Characteristics and results of the included studies.

Authors, Year and Country	Aim	Imaging procedure	Study design	Sample	Intervention		Measurement instruments	Main Results	
					Repertory/sounds:	Technical Characteristics		Physiological parameters	Psychological parameters
Domar et al., 2005, Boston, USA[52]	To determine whether listening to a relaxation audiotape before and during mammography decreases subjective reports of pain and anxiety.	Mammography	RCT	**N = 143** CG: (n = 46) EG1: (n = 47) − music without meditation - EG2: (n = 50) − music with meditation.	**M**: Cassete player; **MG**: - CG: Blank Audio Tape; - EG1: **ISM** - meditation tape with breath focus and body scan. - EG2: **PSM** - genre choice: classical, jazz or soft rock.	**SE**: headphones; **TL:** no information; **IA:** before and during the exam.	**1° Outcome:** - STAI: AS: 1−4 scale (“not at all” to “very much so”) AT: 1−4 scale (“never” to “almost always”) score: 20−80 **2° Outcome:** - MPQ: 3 classes (“sensory”, “affective”, “evaluative”) Evaluative: pain intensity 1−5 scale (“mild” to “excruciating”) score: 1−5 **3° Outcome:** - LAS: 1−10 scale (“not anxious to “very anxious”) score: 1−10		**Anxiety:** **STAI:** AT: Before CG (32.5 ± 8.6) EG1 (32.7 ± 8.7) EG2 (32.6 ± 8.3) AS: Before CG (33.2 ± 14.5) EG1 (33.6 ± 8.9) EG2 (34.8 ± 9.7) AS: After CG (33.2 ± 13.3) EG1 (30.9 ± 10.0) EG2 (30.4 ± 9.3) **LAS:** CG (2.8) vs EG1 (2.6) vs EG2 (3.2) - (p-value = 0.43) **Pain: MPQ:** CG (13.7) *vs* EG1 (11.8) *vs* EG2 (12.5), (p-value = 0.34)
Buffum et al., 2006, California, USA[53]	To evaluate whether music reduced patients' anxiety before their vascular angiography procedures	Vascular angiography procedures: abdominal lower extremities	RCT	**N = 170** - CG: (n = 81); - EG: (n = 89).	**M**: CD; **MG**: classical, jazz, rock, country, wester; − 5 selections/categories. **PSM.**	**SE**: Boom box: stereo system; **TL**: 15 min; **IA:** during the exam and option to listen music for the rest of exam.	**1° Outcome:** - STAI: AS: 1−4 scale (“not at all” to “very much so”) AT: 1−4 scale (“never” to “almost always”) score: 20−80 **2° Outcome:** - MES: 2 item scale (“yes” or “no”) **3° Outcome:** - HR - BP and RR	**HR (bpm):** Before CG 69.0 ± 12.5) EG (67.04 ± 11.11) After CG (68.9 ± 10.54) EG (65.24 ± 9.7) ΔHR: CG (−0.11) *vs* EG (−1.8), (p-value = 0.02) **BP (mmHg)** **SBP:** Before CG (137.8 ± 22.0) EG (142.5 ± 26.5), (p-value = 0.211) After CG (136.9 ± 21.0) EG (143.9 ± 26.2) **DBP:** Before CG (75.3 ± 9.9) EG (76.7 ± 14.2), (p-value = 0.458) After CG (75.1 ± 11.0) EG (75.2 ± 13.1) **RR** Before CG (16.3 ± 4.1) EG (16.8 ± 4.5) (p-value = 0.471) After CG (15.3 ± 3.3) EG (15.7 ± 4.1)	**Anxiety:** **STAI:** AT: Before CG (35.3 ± 8.5) EG (37.0 ± 9.6) AS: Before CG (36.2 ± 10.5) EG (38.6 ± 10.5) AS: After CG (35.1 ± 10.6) EG (35.2 ± 9.7) ΔSTAI: CG (1.1) *vs* EG (−3.37) - (p-value = 0.05) **MES:** EG enjoy exam (98 % felt relaxed). Significant reduction in anxiety to EG.
Moradipanah et al., 2009, Iran[54]	To examine the effect of music on the levels of anxiety, stress, and depression experienced by patients undergoing coronary angiography	Coronary angiography	RCT	**N = 74** - CG: (n = 37); - EG: (n = 37) − music therapy intervention.	**M**: Cassete player; **ST**: “Canon in D”, “Love story” and “Dance of the iguana”; **ISM.** .	**SE**: headphones; **TL**: 40 min; **IA:** 20 + 20: before and after the exam **MF**: 70−80 beats/min.	**1° Outcome:** - DASS-21: 0−3 scale (“did not apply to me” to “applied to me very much or most of time”) score: 0−21.		**Depression: DASS-21** Before CG (5.9 ± 4.2) EG (6.6 ± 4.6) After CG (5.0 ± 3.8) EG (4.4 ± 4.4) **Anxiety: DASS-21** Before CG (6.8 ± 4.3) EG (6.8 ± 4.1) After CG (6.1 ± 3.7) EG (4.1 ± 3.8) ΔAnxiety: CG vs EG (−2.00); (p-value = 0.006) **Stress: DASS-21** Before CG (11-0 ±4.9) EG (11.4 ± 4.3) After CG (5.9 ± 5.2) EG (3.9 ± 4.4) ΔStress: CG vs EG (−2.89); Significant reduction in anxiety and stress to EG Before Angiography.
Weeks et al., 2010, Sweden[55]	To test the effects of patient focused music versus loudspeaker music versus standard sound on patient's	Mammography	RCT	**N = 98** - CG: (n = 34); - EG1: (n = 30) −loudspeaker music;	**M**: Digital Playlist; **ST**: no specific gender, calming influence, different melodies;	**SE**: - EG1: stereo system; - EG2: audiopillow;	**1° Outcome:** - NRS: 0−10 scale (“no anxiety” to “worst possible anxiety”) score: 0−10;		**Anxiety: NRS:** CG (scale 1−10) vs EG1 (scale 1−9) vs EG2 (scale 1−8)

	experiences of anxiety and well-being during coronary angiographic procedures.			- EG2: (n = 34) – patient-focused.	**ISM:** MusicCure, composed by Niels Eije according to the classical composing technique;	**TL**: 51 min; **IA**: during the exam; **MV**: EG1 – 60 dB; **MF**: 60–80 beats/min.	**2° Outcome:** - WBQ: 1–5 scale ("very positive" to "don't know") score: 1–5; **3° Outcome:** - SEQ: 1–5 scale ("very pleasant" to "don't know") score: 1–5.		**Well-being:** **WBQ:** scale 1–2: CG (38 %) vs EG1 (83 %*) vs EG2 (79 %*) **SEQ:** - scale 1–2: CG (88 %) vs EG1 (90 %*) vs EG2 (97 %*); - Significant reduction in anxiety and well-being increased to EG1 and EG2 compared to CG
Kulkarni et al., 2012, UK[39]	To assess the effects of playing patient-selected music during interventional procedures on the doses of sedation and analgesia and anxiety levels	Radiological interventional procedures	QE	**N = 100** - CG: (n = 50); - EG: (n = 50).	**M**: CD; **ST;** **PSM:** CD from home, any music. For enables CD, department's made the choice.	**SE**: headphones; **TL**: 60 min; **IA:** during the exam; - Patient selected a comfortable volume.	**1° Outcome:** - STAI (AS): 1–4 scale ("nothing at all" to "very obvious") score: 20–80 **2° Outcome:** - HR and BP **3° Outcome:** - Sedation and analgesia	**HR (bpm) and BP (mmHg):** No significative differences to HR and SBP (p-value>0.05) **Sedation, midazolam (mg):** Midazolam dose: CG (2.1) vs EG (1.3 mg) Requirement: CG (60 %) vs EG (42 %) **Analgesia (fentanyl):** - Fentanyl dose: CG (29) vs EG (18) - Requirement: CG (52 %) vs EG (36 %)	**Anxiety: STAI:** AS: Before CG (±46) EG (±47) AS: After CG (±42) EG (±45)
Vanderboom et al., 2012, Massachussetts, USA[56]	To test the effect of a music intervention on procedural anxiety, stress response and medication requirements in participants with a cerebral aneurysm or AVM undergoing cerebral angiography	Cerebral angiography	RCT	**N = 48** - CG: (n = 24); - EG: (n = 24).	**M**: Digital Playlist; **MG**: classical, jazz, new, age, country, pop, rock, folk, acoustic and mediative trance; **PSM.**	**SE**: stereo system; **TL**: 30 min; **IA:** during the exam.	**1° Outcome:** - STAI: AS: 1–4 scale ("not at all" to "very much so") AT: 1–4 scale ("never" to "almost always") score: 20–80 **2° Outcome:** - HR **3° Outcome:** - SBP	- **HR (bpm) and SBP (mmHg):** No significative differences to HR and SBP (p = 0.270, p = 0.570, respectively).	**Anxiety: STAI:** AT: Before CG (34.7 ± 7.8) EG (40.3 ± 9.0) AS: Before CG (41.6 ± 11.6) EG (44.7 ± 10.1)
Tan et al., 2015, Turkey[57]	To research if exist a significant effect on heart rate and heart rate variability due to listening to relaxing music during ECG GATED MPS imaging under gamma camera.	Gated-MPS	RCT	**N = 100** - CG: (n = 50); - EG: (n = 50).	**M**: CD; **MG**: 15 pieces of instrumental folk music; **PSM.**	**SE**: headphones; **TL**: 15 min; **IA:** during the exam; **MV**: 50–55 dB; **MF**: 60–80 beats/min.	**1° Outcome:** - BP **2° Outcome:** - HR	**HR (bpm):** Before CG (82.9 ± 17.0) EG (78.5 ± 11.7) After CG (89.0 ± 17.8) EG (72.70 ± 11.2) p-value CG = 0.339 p-value EG < 0.001 **BP (mmHg)** **SBP:** Before CG (128.5 ± 13.0) EG (128.7 ± 12.1) After CG (129.0 ± 12.5) EG (126.7 ± 10.5) p-value CG = 0.816 p-value EG = 0.810 **DBP:** Before CG (80.7 ± 17.9) EG (79.5 ± 11.6) (p-value = 0.458) After CG (82.0 ± 14.0) EG (80.0 ± 12.0) p-value CG = 0.782 p-value EG = 0.866 **BP (mmHg):** no significative differences in SBP and DBP HR: Significant reduction in EG	
Guétin et al., 2016, France[58]	To perform an initial evaluation of the application for use with patients undergoing a coronarography.	Coronary angiographic	QE	**N = 35** - EG1: (n = 17) music intervention with women; - EG2: (n = 18) music intervention with men.	**M**: Android - MusiCare application; **MG**: 20 musical styles (classical, jazz, world music: India, Andes, Africa, etc) **PSM:** offered a choice of pieces recorded in high quality	**SE**: headphones; **TL**: 20 min; **IA:** during the exam; - Standardized musical sequence of adjustable length.	**1° Outcome:** - Pain intensity scale: 0–10 scale ("no pain" to "most intense pain") score: 0-10 **2° Outcome:** - Anxiety scale: 0–10 scale ("no anxiety" to "most intense anxiety") score: 0–10		**Pain intensity scale:** Before: Total Sample (0.11 ± 0.53) EG1 (0.24 ± 0.8) EG2 (0.0 ± 0.0) After: Total Sample

(*continued on next page*)

Table 3 (*continued*)

Authors, Year and Country	Aim	Imaging procedure	Study design	Sample	Intervention		Measurement instruments	Main Results	
					Repertory/sounds:	Technical Characteristics		Physiological parameters	Psychological parameters
					recording studios with musicians.		3° **Outcome:** - Satisfaction scale: 1–4 scale ("very satisfied" to "very unsatisfied" score: 1–4		(0.30 ± 1.70) EG1 (0.06 ± 0.2) EG2 (0.0 ± 0.0) p-value for Total = 1.00 p-value EG1 = 1.00 p-value EG2 = n.a. **Anxiety scale:** Before: Total Sample (2.63 ± 2.67) EG1 (3.1 ± 2.9) EG2 (2.1 ± 2.5); After: Total Sample (1.7 ± 2.2) EG1 (2.2 ± 2.5) EG2 (1.3 ± 1.9); p-value for Total<0.0001 p-value EG1 = 0.018 p-value EG2 = 0.004 Significant reduction in anxiety **Satisfaction scale**: Scale 1–2: Majority of participants was satisfied or very satisfied (97 %)
Stanley et al., 2016, Ireland[59]	To assess the effect of sensory stimulation on patient MRI experience and to assess whether sensory stimulation has a significant effect on MR image quality.	MRI	QE	**N = 106** - CG: (n = 42); - EG1: (n = 51) scent and sound intervention; - EG2: (n = 13) sound intervention.	**M**: Digital Playlist; **SN**: designed to evoke open spaces like "Birdsong"; **ISM:** design natural sounds.	**SE**: non-metallic headphones; **TL**: ±30 min **IA:** during the exam.	Questionnaire with 3 parts: - 1° **Outcome:** - Terms of anxiety preceding exam: 1–4 scale ("relaxing" to "intolerable") score: 1–4 - 2° Outcome: - Patient experience: 1–5 scale ("very positive experience" to "very negative experience") score: 1–5 - 3° **Outcome:** - Sound experience: 1–5 scale ("very positive experience" to "very negative experience") score: 1–5		**Terms of anxiety preceding exam:** CG (38 % reported anxiety) EG1 (39 % reported anxiety) EG2 (39 % reported anxiety); **Patient experience:** CG (2.8 ± 0.7) EG1 (2.5 ± 0.9) EG2 (2.4 ± 1.0); **Sound experience:** CG (1.8 ± 0.68) EG1 and EG2 (1.58 ± 0.65); p-value = 0.327
Lee et al., 2017, Taiwan, China[60]	To examine the effects of listening to meditative music on state anxiety and HRV of patients during the uptake phase before PET scans	PET	RCT	**N = 72** - CG: (n = 37); - EG: (n = 35).	**M**: CD; **ST**: relaxing music without lyrics; **ISM:** produced by music composers and a Taiwanese physician.	**SE**: stereo system; **TL**: 30 min; **IA:** before the exam; **MV**: 50–60 dB; **MF**: 60–80 beats/min.	1° **Outcome:** - STAI (AS): 1–4 scale ("nothing at all" to "very obvious") score: 20–80; 2° **Outcome:** - HR; 3° **Outcome:** - LF/HF ratio.	**HR (bpm):** Before CG (59.7 ± 10.7) EG (59.5 ± 10.1) p-value = 0.94 After CG (58.8 ± 11.1) EG (54.8 ± 9.4) p-value = 0.10 **LF/HF ratio (n.u):** Before CG (1.5 ± 1.3) EG (1.6 ± 1.7) p-value = 0.78 After CG (1.2 ± 0.9) EG (1.3 ± 1.3) p-value = 0.59	**Anxiety: STAI:** AS: Before CG (37.73 ± 5.07) EG (40.26 ± 5.68) p-value = 0.50 AS: After CG (38.38 ± 5.66) EG (34.97 ± 6.73) p-value = 0.02 - Significant reduction in anxiety to EG
Santangeli et al., 2021, France[61]	To compare the patient's anxiety that performs MRI	MRI	RCT	**N = 208** - CG: (n = 27) without luminous environment, without music; - EG1: (n = 60) luminous environment, without screen, music with fast time; - EG2: (n = 60) luminous environment, with screen, music with slow time; - EG3: (n = 61) without luminous environment, music with fast time.	**M**: Digital Playlist **ST**: playlist themes (no information); **ISM:** created by radiologic technologists' team.	**SE**: headphones; - Music theme changes as the light in the room changes color and intensity **TL:** Dependent of participants **IA:** during the exam.	Questionnaire with 3 parts: - Sociodemographic data; - 1° **Outcome**: Qualitative data: open-ended questions subject: positive points during the exam - 2° **Outcome**: STAI: AS: 1–4 scale ("not at all" to "very much so") AT: 1–4 scale ("never" to "almost always") score: 20–80		Experience of the exam (most chosen answers) - CG (7 %): "would like auditory stimulation" - EG1 (29.9 %) and EG2 (58.3 %): "relaxing music, video and atmosphere"; **Anxiety: STAI:** AT:CG (46.00 ± 14.63) > EG1 (42.95 ± 9.59) > EG2 (41.83 ± 12.63) > EG3 (39.85 ± 10.07) AS: CG (43.22 ± 16.79) > EG1 (38.22 ± 11.32) > EG3 (34.90 ± 11.31) > EG2 (32.17 ± 11.65) p-value = 0.001

Zahraei-Moghaddam et al., 2022, Iran[62]	To assess the effect of plain music and special binaural beat frequency embedded music on anxiety in patients undergoing myocardial perfusion imaging MPI	MPS	RCT	**N = 267** - CG: (n = 89); - EG1: (n = 89) streaming simple music; - EG2: (n = 89) streaming music with a special binaural beat frequency.	**M**: - EG1: Digital Playlist; - EG2: Android application synthesized special binaural beats frequency; **SN**: waterfall, rain, and birds; **ISM:** prearranged by researchers.	**SE**: headphones; **TL**: 30 min; **IA:** during the exam; **MF**: EG1 – 1.º - 15Hz – 3min; – 2.º - decline gradually to 7Hz–24 min.	**1° Outcome:** - DASS-21: 0–3 scale ("did not apply to me" to "applied to me very much or most of time") score: 0–21 **2° Outcome:** - HR	**HR (bpm):** Before CG (81.9 ± 12.6) EG1 (85.0 ± 11.0) EG2 (86.1 ± 12.6) p-value = 0.049 After CG (81.3 ± 11.9) EG1 (81.5 ± 10.2) EG2 (76.3 ± 11.9) p-value = 0.010 ΔHR after *vs* before: CG (−0.67) vs EG1 (−3.50) vs EG2 (−9.81*) CG and EG1 vs EG2: -7,59 * p-value<0.0001 - -Significant reduction in heart rate to EG2 compared to CG and EG1	- EG2 reported more satisfaction and less anxiety **Depression: DASS-21** Before CG (2.3 ± 2.4) EG1 (2.5 ± 1.9) EG2 (2.1 ± 1.6) p-value = 0.169 After CG (1.0.±1.2) EG1 (1.1 ± 1.2) EG2 (0.7 ± 1.1) p-value = 0.009 ΔDepression after *vs* before: CG (−1.4 ± 2.7) EG1 (−1.4 ± 1.6) EG2 (−1.4 ± 1.4) p-value = 0.150 **Anxiety: DASS-21** Before CG (3.5 ± 3.1) EG1 (2.6 ± 1.8) EG2 (2.4 ± 2.0) p-value = 0.246 After CG (2.0 ± 1.5) EG1 (1.6 ± 1.2) EG2 (1.0 ± 1.2) p-value = 0.0001 ΔAnxiety after *vs* before: CG (−1.5 ± 3.2) EG1 (−1.0 ± 1.8) EG2 (−1.5 ± 1.8) p-value = 0.225 **Stress: DASS-21** Before CG (3.9 ± 3.2) EG1 (4.1 ± 2.6) EG2 (4.5 ± 2.2) p-value = 0.047 After CG (1.1 ± 1.5) EG1 (1.3 ± 1.4) EG2 (0.3 ± 0.8) p-value<0.0001 - Δstress after *vs* before: CG (−2.3 ± 3.3) EG1 (−2.8 ± 2.1) EG2 (−4.2 ± 2.1) p-value<0.0001 - Significant reduction in anxiety and stress to EG2 compared to CG and EG1
Wen et al., 2022, China[63]	To investigate the effects of aromatherapy and music therapy on alleviating anxiety during MRI examinations	MRI	RCT	**N = 150** Imaging Procedures in Patients: CG-(n = 50); EG1-(n = 50) – music therapy EG2-(n = 50) – aromatherapy combined with music therapy;	**M**: Digital Playlist; **ST**: Pachelbel's Canon in D major **ISM:** selected after consultation with a licensed music expert.	**SE**: stereo system; **TL**: 20 min; - Repeated 3 times (6 min 40 s per time); **IA:** during the exam	**1° Outcome:** - STAI (AS): 0–4 scale ("nothing at all" to "very obvious") score: 20–80 - SAS: 1–4-scale ("no or little time" to "most or all of the time") score: 20–80 - ΔSTAI(AS) and ΔSAS: Before and after the exam **2° Outcome:** - GCQ: 1–4-scale ("strongly disagree" to "strongly agree") score: 28–112		**Anxiety:** **STAI:** AS: Before CG (48.1 ± 6.0) EG1 (47.6 ± 6.1) EG2 (48.4 ± 6.8) AS: After CG (46.2 ± 5.5) EG1 (44.9 ± 4.7) EG2 (41.9 ± 3.3) **ΔSTAI** after *vs* before**:** CG (1.9 ± 1.9) vs EG1 (2.7 ± 2.5) vs EG2 (6.5 ± 5.4); **SAS:** Before CG (55.50 ± 3.6) EG1 (55.0 ± 2.6) EG2 (54.7 ± 3.2) After CG (54.9 ± 3.6) EG1 (53.3 ± 2.6) EG2 (50.7 ± 3.3) **ΔSAS** after *vs* before**:** CG (0.6 ± 0.5) vs EG1 (1.7 ± 0.5) vs EG2 (4.0 ± 1.0) **Comfort:** **GCQ:** After CG (89.2 ± 8.5) EG1 (91.2 ± 6.3)

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Table 3 (*continued*)

Authors, Year and Country	Aim	Imaging procedure	Study design	Sample	Intervention		Measurement instruments	Main Results	
					Repertory/sounds:	Technical Characteristics		Physiological parameters	Psychological parameters
								EG2 (98.0 ± 6.9)	- Significant reduction in anxiety and comfort improve to EG2 compared to CG and EG1

Legenda: **AS**, anxiety-state; **AT**, anxiety-trait; **AVM**, arteriovenous malformation; **BP**, blood pressure; **bpm**, beats per minute; **CG**, control group; **DASS-21**, 21-item Depression Anxiety Stress Scales; **DBP**, diastolic blood pressure; **ECG**, electrocardiography; **EG**, experimental group; **GATED-MPS**, myocardial perfusion scintigraphy is synchronized with ECG; **GCQ**, Kolcaba's General Comfort Questionnaire; **HF**, high frequency; **HR**, heart rate; **HRV**, heart rate variability; **IA**, intervention acquisition; **ISM**, investigator-selected music; **LAS**, Likert anxiety scale; **LF**, low frequency; **M**, media; **MES**, Music Enjoyment Scale; **MF**, musical frequency; **MPQ**, McGill Pain Questionnaire; **MPS**, Myocardial perfusion scintigraphy; **MG**, musical genre; **MRI**, Magnetic resonance imaging; **MV**, music volume; **NRS**, anxiety numeric rating scale; **n.u**, normalised unit; **PET**, Positron emission tomography; **PSM**, patient-selected music; **RCT**, randomized control trial **RR**, respirations rate; **SAS**, Self-Rating Anxiety Scale; **SBP**, systolic blood pressure; **SE**, sound equipments AND **SEQ**, sound environment questionnaire; **SN**, sounds of nature; **ST**, specific themes; **STAI**, Spielberger's State Trait Anxiety Inventory; **STAI-S**, Spielberger Anxiety Inventory–State scale; **TL**, time length; **WBQ**, Well-being questionnaire.
Note: In psychological parameters column, continuous variables were presented as mean values, and categorical variables were presented as number (%).

binaural beats frequency had significantly lower anxiety and stress levels than the control group or other experimental group without this condition; In the study, Wen et al. (2021),[63] aromatherapy combined with music therapy showed better results in reducing patients' anxiety and improving patients' comfort. Two articles,[52,56] were unable to show significant psychological values and demonstrate an effect of the MI in reducing anxiety levels.

Physiological measurements,[39,53,56,57,60,62] consisted in recording HR in six studies,[39,53,56,57,60,62] blood pressure in four studies,[39,53,56,57] and respiration rate in two studies.[39,53] In Kulkarni et al. (2012) study[39] the authors also analysed the effect of drug doses to sedation (midazolam) and analgesia (fentanyl). Regarding HR, for four studies,[53,57,60,62] it is found that for both the experimental group and the control group, HR was always lower after the imaging procedures; however, in the experimental groups, the decrease in HR was significantly higher. Concerning blood pressure and breaths per minute, no significant results were presented in none of the studies included in the review. In the Kulkarni et al. (2019)[39] study there was a significantly decrease in sedation and analgesia doses after the imaging procedure and lower results to the experimental group compared with the control group. Additionally, Vanderboom et al. (2012)[56] found no significant differences in HR for the different groups (*cf.* Table 3).

Meta-analysis

Before the procedure

From the analysis of the results in Fig. 5, there is no significant heterogeneity between the studies ($I^2 = 18.931$; $\chi^2_3 = 3.701$, $p = 0.296$; $z = -1.571$, $p = 0.116$; $Tau^2 = 0.009$). The difference in mean anxiety levels between the control and experimental groups is negative and significant, meaning that the control group had significantly lower mean anxiety levels in one study.[60] There were no statistically significant differences in mean anxiety levels between the two groups for the remaining studies,[52,53,63] which means that the groups were identical in terms of anxiety levels before the procedure. From the Forest Plot analysis (Fig. 5), there is no overlap in the results of the studies. However, they show the same trend, i.e., the experimental group shows higher anxiety levels than the control group. Overall, this trend is not statistically significant.

There is no significant heterogeneity among the studies ($I^2 = 53.201$; $\chi^2_3 = 6.410$, $p = 0.093$; $z = 0.284$, $p = 0.776$; $Tau^2 = 0{,}037$) (Fig. 6). Before the procedure, the differences in mean HR between the control and experimental groups were positive and no significant in three studies,[53,57,60] meaning that the experimental group had lower HR. Although the differences are not statistically significant in the remaining study[62] the differences are negative, revealing that the experimental group has higher HR after the procedure. From the Forest plot analysis (Fig. 6), there is no overlap between the results of the studies. However, they show the same trend, i.e., the experimental group shows lower anxiety levels than the control group. Globally, this trend is not significant (p-value = 0.776).

After the procedure

From the analysis of the results in Fig. 7, there is no significant heterogeneity among the studies ($I^2 = 25.694$; $\chi^2_3 = 4.037$, $p = 0.257$; $z = 1.922$, $p = 0.055$; $Tau^2 = 0{,}013$). After the procedure, the differences in mean anxiety levels between the control and experimental groups were positive and significant in one study[60] meaning that the experimental group had significantly lower anxiety levels. Although the differences are not statistically significant in the remaining three studies,[53,57,63] they are positive, revealing that the experimental group has lower anxiety levels

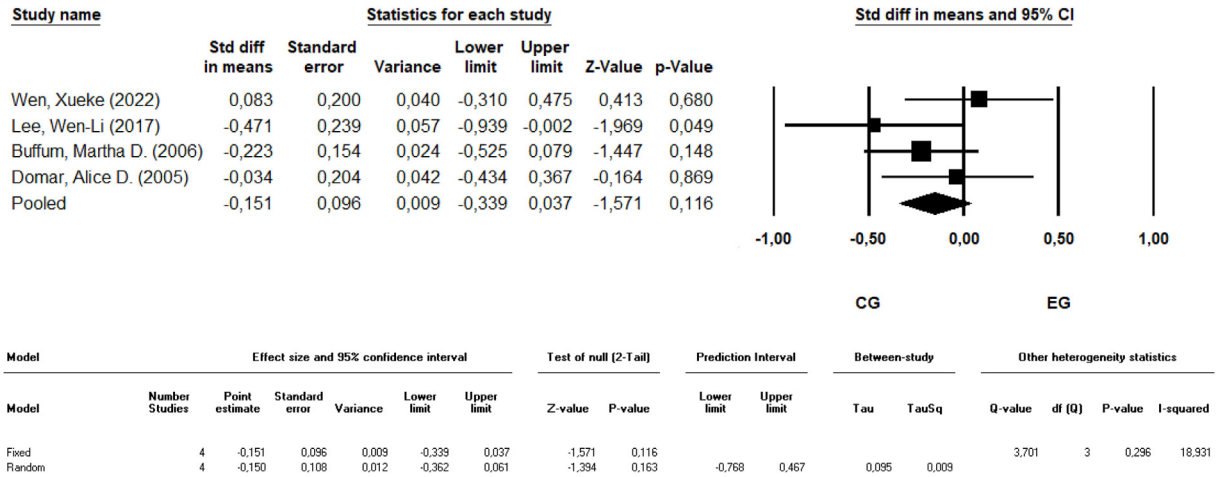

Figure 5. Forest Plot compares anxiety levels before the procedure, between the control and experimental groups, and model statistics.

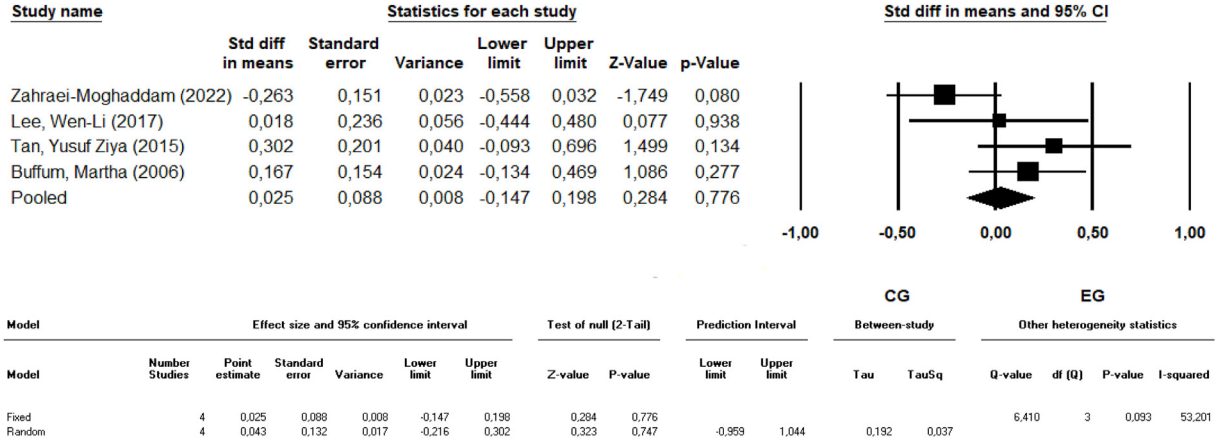

Figure 6. Forest Plot compares HR before the procedure, between the control and experimental groups, and model statistics.

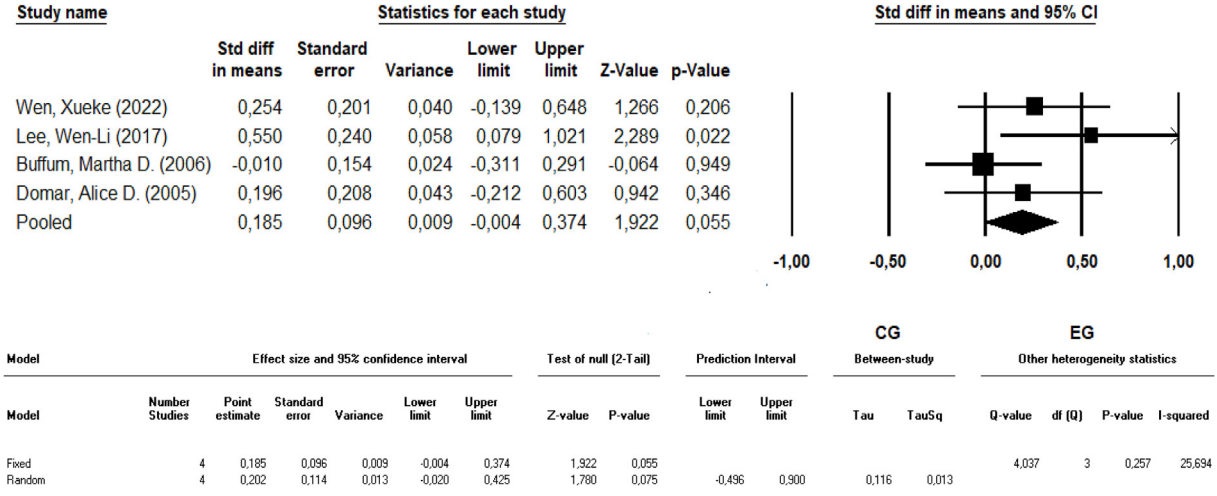

Figure 7. Forest Plot compares anxiety levels after the procedure, between the control and experimental groups, and model statistics.

after the procedure. From the Forest plot analysis (Fig. 7), there is no overlap between the results of the studies. However, they show the same trend, i.e., the experimental group shows lower anxiety levels than the control group. Globally, this trend is marginally significant (p-value = 0.055).

There is significant heterogeneity among the studies (I^2 = 81.526; χ^2_3 = 16.239, p = 0.001; z = 3.913, p = 0.000; Tau^2 = 0,147) (Fig. 8). After the procedure, the differences in mean HR between the control and experimental groups were positive and significant in two studies[53,57] meaning that the experimental group

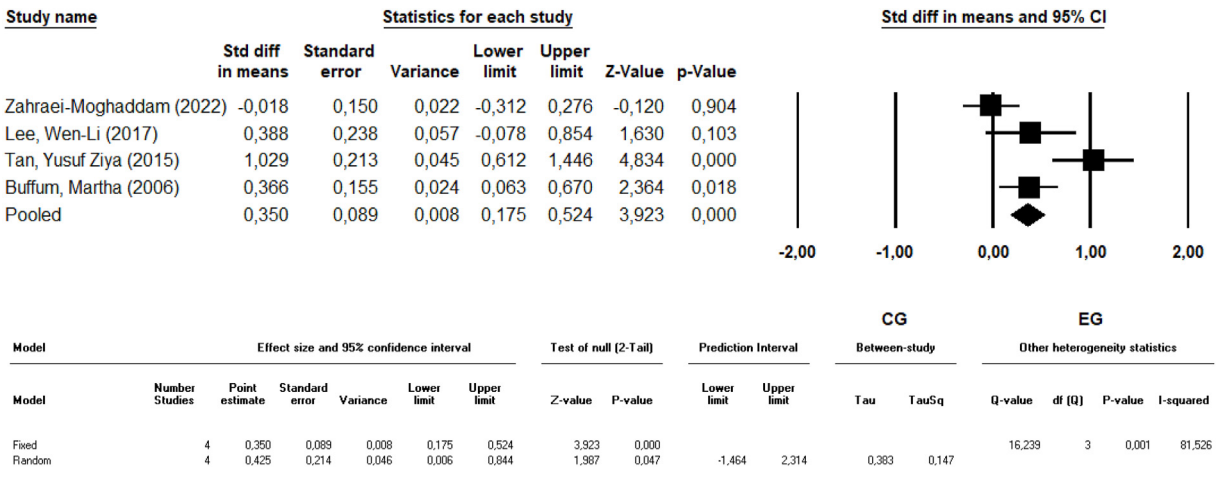

Figure 8. Forest Plot compares HR after the procedure, between the control and experimental groups, and model statistics.

had significantly lower HR. Although the differences are not statistically significant in the remaining two studies, in one of them[60] they are positive, revealing that the experimental group has lower HR after the procedure, but in another one[62] they are negative. From the Forest plot analysis (Fig. 8), there is some overlap between the results of the studies. However, they show the same trend, i.e., the experimental group shows lower anxiety levels than the control group. Globally, this trend is statistically significant (p-value = 0.000), revealing that the experimental group has significantly lower HR after the procedure.

Discussion

The purpose of this study was to update previously conducted research on the psychological and physiological effects of music intervention in adult patients undergoing medical imaging procedures. It was also expected to describe the sound repertoire and technical characteristics of MI and evaluate their effectiveness on patients' outcomes.

After a comprehensive thorough literature research based on PRISMA framework, thirteen articles were included under this review, all using music as a non-pharmacological intervention. In these studies, several different approaches were found, mainly in terms of the sound repertoire (sounds of nature or specific musical themes or musical genre), its media (CD, cassette, digital playlist, and android application), and the technical characteristics used for the music (sound equipment: stereo system, headphones, and AudioPillow; volume, time length, and musical frequency). Our findings are in line with the results of the systematic review developed by Yinger et al.[40] when they examined the application of musical interventions in different clinical environments and with different demographic groups. In short, the authors used different media for listening to music, however, digital playlists prevailed.[55,56,59,61–63]

Regarding the sound repertoire, most studies used a preselected musical genre,[52,53,56–58] with classical and jazz being the main choices, or chose a specific musical theme.[39,54,55,61,61] Concerning the specific music themes, there were different approaches; however, in studies Moradipanah et al.[54] and Wen et al.[63] the song "Canon in D major" composed by Johann Pachelbel was selected. This piece was previously associated by Knight et al.[64] with less stress levels, blood pressure, pulse, and body temperature. However, the diversity of studies in this systematic review did not allow for determining the most effective repertoire regarding psychophysiological outcomes of patients undergoing medical imaging procedures. These results align with the MA of Kuhlmann et al.[34] performed on surgical patients undergoing MI before surgery. The authors noted that the effect of musical disciplines appears to be more related to the use of slow, soft, relaxing music rather than a specific type of music. Siragusa et al.[65] developed a study with 25 volunteers, analysing the biomechanical configurations of the brain of those who listen to emotional and relaxing musical excerpts interspersed with periods of silence. The results demonstrated that relaxing classical music protects the amplitude of pulsating movements in the brain compared to silence. In agreement, Tan et al.[30] also emphasized the role of brain biomechanics in emotional regulation.

In six studies[39,52,53,56–58] the patient could choose the sound repertoire. Çift et al.[32] observed that listening to the patient's preferred music type during extracorporeal shock wave lithotripsy provided greater satisfaction. However, a recent systematic review and MA, developed by Nguyen et al.[66] related to the effects of music intervention on anxiety, depression, and quality of life of cancer patients receiving chemotherapy, found no significant difference between patient-selected music and researcher-selected music, recorded music, and live music.

In fact, although systematic reviews[34,40] state that MI should be chosen by patients so that it can be adapted to their musical preferences and can increase the satisfaction of patients undergoing medical imaging procedures, other studies[32,46] revealed non-significant decreases in pain and anxiety when the music was chosen by the patient (from personal choice or a playlist). This finding highlights the fact that the use of patient-selected music may not always be ideal and, in some situations, it may be more beneficial to use music chosen by healthcare professionals/investigators based on specific musical parameters, with which the patient may not be familiar (e.g. music volume, music frequency, and music duration). However, new studies comparing the effect on patients when they choose the musical repertoire themselves versus the musical repertoire selected by the health team are suggested.

Observing the technical characteristics of music intervention, headphones were the most used as sound equipment.[39,52,54,57–59,61,62] Although the study by Weeks et al.[55] did not show significant results between the experimental groups with loudspeakers and an AudioPillow, other studies[39,67] demonstrated that the use of equipment such as headphones compared to loudspeakers is easily used, may upgrade a quiet and private exam experience and may improve sound environment's effect such as acoustic noise reduction.

Three studies,[55,57,60] pointed to mean values of 50–60 dB to music volume. As for the musical frequency, four interventions,[55,57,60,62]

used an average value of 60–80 beats per min. This value is within the resting state of the HR of an adult (indicated as 60–100 beats per minute).[68] Thus, current findings indicate that music around 60–80 beats per minute can cause synchronization between the brain and the breath, causing alpha brainwaves, which are present when we are relaxed and conscious.[69] Additionally,[58,62] an android application synthesized with particular binaural beats frequency considering previous papers that established significant anxiety reduction, HR, and systolic blood pressure due to these applications.[62,70–72]

Moreover, this systematic review highlights that there is no consensus on the terms used to refer to MI, which several authors corroborate,[25,53,55,58,73,74] and reinforces the need for further reflection to define the most appropriate terms. A recent scoping review[47] related to characteristics of music intervention to reduce anxiety in patients undergoing cardiac catheterization also emphasized the heterogeneity of interventions and incompleteness of information in the studies. In this sense, Robb et al.[75] recommend that in addition to the use of the global term - music intervention, the use of terms that describe the intervention content (e.g., "recorded music listening program) and the details of the professional background of the intervention team (e.g., psychologist, music therapist).

Focusing now on the reports with psychological parameters, first, the patient's comfort and exams experience improves with the MI,[55,59,61,63] since the patients' attention on aspects such as procedure time or symptoms can be diverted as they focus on the music (increased feelings of well-being),[30] increasing compliance and improve outcome, as proven by other previous studies.[76–78] Second, significantly lower stress responses were observed due to MI[54,62] in agreement with previous studies.[64,79] Other systematic reviews and meta-analysis related to MI with patients undergoing percutaneous coronary procedures,[45] cancer patients receiving chemotherapy,[66] adult surgical patients,[34] children and adults undergoing medical procedures,[40] perioperative pediatric surgery,[42] and medical and dental procedures with children[43] also show decreased in anxiety levels. Third, regarding anxiety assessment, different instruments were used to measure anxiety, making comparing studies difficult. However, the STAI is the most standardised psychological instrument in this SR. In other scoping review[47] and SR[40] and meta-analyses[34,44] concerning MI in diverse medical settings, the STAI was also the most common instrument to assess patients' anxiety levels. Although the STAI was developed at an early stage to assess anxiety in healthy adults, it is increasingly becoming an anxiety measurement tool that can be used in a medical setting and by patients undergoing imaging procedures.[34,80–82]

In this SR, among the 13 articles[39,52–63] incorporated, twelve[39,52–56,58–63] addressed the assessment of anxiety. However, the diversity in the scales used makes comparisons between studies difficult. The analysis revealed that, in eight studies,[53–55,58–60,62,63] anxiety levels in the experimental group were lower compared to the control group at the end of the exam. However, the MA covering four studies revealed marginally significant differences (p-value = 0.055). It is important to highlight that, in the nine studies[53–55,58–63] that observed lower anxiety levels in patients, two were related to MRI,[59,63] and two to coronary angiography.[54,58] These imaging procedures (MRI and coronary angiography) are increasingly used for diagnosis and defining the treatment method, but both are associated with high anxiety levels. 37 % of patients undergoing MRI experience moderate to high levels of anxiety[83,84] that may require early interruption of the procedure and/or creation of motion artifacts.[83,84] The performance of this examination is also associated with a claustrophobia reaction that also led to the interruption of the scan.[85] Regarding coronary angiography, 82 % of patients experience anxiety before the procedure.[86,87] Additionally, some of these patients experience chest pain,[88] and collaborate less with health professionals during the procedure.[89] Delewi et al.[90] observed that younger patients, female gender, and lower level of education experience higher levels of anxiety just before angiography. Therefore, this review points out that using music-based interventions in these two imaging procedures can be very beneficial for the patients' scan experience and the quality of the procedure.

Of the six articles[39,53,56,57,60,62] that addressed HR as a physiological parameter in this SR, only four were considered in the Meta-Analysis.[53,57,60,62] These studies suggest that HR is influenced by MI, demonstrating a significant reduction during the final phase of the exam. These results are corroborated by other studies,[26,31] and SR and meta-analyses with burn patients during treatment procedures[41] and stress-related outcomes.[29] Regarding respiratory rate and blood pressure, no significant differences were identified in the presence of MI and, consequently, in the influence on anxiety. Some previous studies[40,91] support this finding but contradict other research already developed.[26,31,32,92]

As noted by Yinger et al.,[40] the evaluation of physiological measures must be carried out with extreme attention, since many studies in this systematic review do not consider whether patients used analgesic and anxiolytic medication, which could alter physiological signs. Furthermore, it is essential to highlight that music can affect vital signs without necessarily reflecting changes in anxiety. It should also be noted that the sample size and sampling methodology are also important factors in evaluating these parameters. Some articles[52,56] have not obtained significant correlations between anxiety levels and MI. The authors justify that this may be due to biased samples,[52] sample size or professional fellows in various stages of their training.[56]

Strengths and limitations

In agreement with the PRISMA guideline, the strengths of the present systematic review are the rigorous methods employed to find and choose all studies pertinent to the review's purpose, independent reviewers to upsurge validity and reduce the risk of bias, and the assessment of the study quality with the most used tool. However, it is essential to note some of the study's limitations. The search criteria method regarding article language could limit access to some articles. Moreover, the authors decided to exclude the qualitative articles to be able to perform a MA. Although we believe the most pertinent literature regarding MI for patients undergoing imaging procedures was included in the analyses, the number of articles was only 13. The studies also present several heterogeneities regarding sample size, patient outcomes, and music intervention, inhibiting intervention comparation. Therefore, more studies comparing different music interventions and studies that include the effect of these interventions on image quality are needed. Nevertheless, the present review highlights the music interventions as low-cost and do not require significant adjustments in the workflow strategies that can increase comfort and reduce anxiety and stress in patients undergoing imaging procedures.

Conclusions

The effects of the MI on the psychological outcomes of patients undergoing imaging procedures allowed patients to reduce anxiety, not only at the beginning of the imaging procedure but throughout the study. Regarding the physiological results of patients undergoing imaging procedures, there was a decrease in HR after MI; however, no significant results were presented concerning blood pressure and breaths per minute. Concerning the sound repertoire, although it was not possible to identify the most influential musical

genre, specific theme or sounds of nature, it seems clear that MI with slow, soft, and relaxing music, with a volume between 60 and 80 beats per minute and a frequency between 60 and 80 dB, proves appropriate.

Conflict of interest statement

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.radi.2024.01.014.

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