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Music Therapy and Skill Development in Children with Autism Spectrum Disorder: A Systematic Review

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Abstract

Background: Autism Spectrum Disorder (ASD) affects one in 100 children worldwide, posing challenges in communication, social interaction, and behavior. While music therapy (MT) shows promise in improving these areas, its comprehensive impact remains underexplored. The study evaluates the research question of whether MT has effects on key developmental outcomes in children with ASD.

Method: This systematic review included randomized controlled and quasi-randomized trials published in English. Searches were conducted in PubMed and Cochrane databases. Participants were children with ASD. The intervention focused on music therapy, with control groups receiving standard therapy or placebo. Key outcomes included social interaction, communication, adaptive behavior, autism functioning, global improvement, and quality of life.

Results: 14 studies on MT for children with ASD showed varied results. Intervention periods varied between 5 days and 8 months, with frequencies ranging from twice daily to once weekly. Key effects included improvements in social interaction, verbal and nonverbal communication, global functioning, and quality of life at home and school.

Conclusions: Future research should focus on robust methodologies, larger samples, and longer follow-ups. Investigating the effectiveness of MT group versus individual interventions offers an important direction for future research.

Keywords: Autism Spectrum Disorder; Music Therapy; Children; Alternative Medicine; Non-Pharmacological Therapy

Introduction

Autism Spectrum Disorder (ASD) is a neurological condition influenced by genetic factors and is observed more commonly in males than in females, with a ratio of 4:1 [1]. According to the World Health Organization, approximately one in 100 children worldwide is affected by ASD, which is characterized by persistent difficulties in social communication and interaction, along with restricted and repetitive behaviors [2, 3]. Additionally, it often co-occurs with various comorbid conditions, such as attention deficit hyperactivity disorder, anxiety, or depression, which affect nearly 75% of children with ASD [4]. In the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), pervasive developmental disorders were divided into autistic disorder, Rett syndrome, childhood disintegrative disorder, Asperger disorder, and pervasive developmental disorder not otherwise specified [5]. In the DSM-V, these were consolidated under the umbrella term ASD, with

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Rett syndrome recognized as a separate condition [6], and childhood disintegrative disorder removed as an independent diagnosis [7].

Pharmacological treatments for ASD (e.g., psychostimulants, alpha-2 adrenergic receptor agonists, atypical antipsychotics) can involve side effects such as fatigue, irritability or social withdrawal, as well as high costs, prompting many families to explore non-pharmacological options [4,8]. Consequently, there is a growing need for research on non-pharmacological therapies [4]. Examples include acupuncture, massage, and music therapy (MT), the latter showing particular promise in ASD [9].

MT is described by the World Federation of Music Therapy as a professional practice that utilises music and its components to improve overall quality of life and support intellectual, physical, emotional, social, and spiritual well-being [10]. The American Music Therapy Association further describes MT activities such as singing, moving to music, creating, and listening [11]. MT can take active or receptive forms: in active MT, individuals use their voices or instruments, often through improvisation, whereas receptive MT focuses on listening for relaxation or other therapeutic goals [12, 13]. A recent study indicate that MT may positively influence communication abilities, social interaction, and behavioural development in children with ASD [14].

Children with ASD often experience communication impairments but retain relatively strong musical abilities. Music and language share structural and cognitive similarities, such as hierarchical organization, complex acoustic information, and reliance on attention and memory. These shared features facilitate the transfer of learning between the two domains. Musical activities, such as singing and playing instruments, inherently involve communication and interaction, making them valuable tools for enhancing language-related skills in children with ASD [15, 16]. Additionally, music-making and singing in small groups can foster social bonding and cooperation through synchronisation, shared purpose, and empathy. These activities help build key social skills, including imitation, turn-taking and joint attention, which are often impaired in children with ASD. Furthermore, children with ASD can recognize affective cues conveyed through musical elements even when they struggle to interpret emotional signals in speech, making group music-making a valuable avenue for enhancing social and emotional development [15].

Two systematic reviews on MT for ASD were published in 2022 and 2024, one focusing on individuals with ASD and the other on language and social skills in children, though limited to Chinese literature; neither comprehensively examined its impact on children across all relevant outcomes [13, 14].This study aims to fill this gap by focusing on seven key outcomes: social interaction, verbal communication, nonverbal communication, adaptive behavior, overall autism functioning profile, global improvement, and quality of life at home and at school.

Objectives

The study evaluates the research question of whether MT interventions have effects on key developmental outcomes in children with ASD. Specifically, it examines these effects when MT is conducted alone or in combination with standard therapies.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (see PRISMA checklist) [17].

Types of studies

Randomized controlled studies (RCT), quasi-randomized studies, and cluster-randomized controlled trials, all written in English, were included as types of studies in the analysis. Both single- and double-blind designs were considered. Single-blinding could be achieved by blinding participants to the study conditions. However, double-blinding could be challenging due to the involvement of music therapists conducting the interventions, who might have been aware of group allocation through their role in delivering the therapy. Crossover designs or designs with multi-armed trials were also included. Pilot studies were excluded. The reason for the latter was that they are studies conducted to identify potential problems or challenges for an upcoming large study, to be addressed or avoided later [18].

Search methods employed for the identification of studies

We performed database searches in PubMed and the Cochrane Central Register of Controlled Trials (detailed search strategy in Appendix 1.). There was no restriction on the time period for the selection of studies. The search query used was: music* AND autism AND child*. This was narrowed down by searching only for RCT. The filter “birth – 18 years” was applied in PubMed in order to exclude studies with older participants. Authors whose studies were included were contacted and asked to forward any existing studies. The literature search was initially conducted on 12 August 2023 and last updated on 21 March 2024.

Types of participants

This study includes children and adolescents diagnosed with ASD, covering an age span from birth to 18 years. The criteria outlined in the International Classification of Diseases (ICD-11) and the DSM-V form the basis for the definition of ASD. The study does also include earlier research that predates these versions, thus, utilizing ICD-10 and DSM-IV criteria. Exclusions from the study are cases of Rett’s disorder

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
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and childhood disintegrative disorder. Rett's disorder is categorized as a separate condition in both the ICD-11 and DSM-V, and, as such, is not included in this study. Similarly, instances of childhood disintegrative disorder are excluded due to their significantly different clinical progression compared to ASD [5].

Types of intervention

The intervention included MT. Clinical routine activities, if they had already been implemented beforehand, were also included. The control group continued to receive their standard therapy in addition to either a placebo therapy or no therapy at all.

Types of outcome measures

1. Social interaction
2. Verbal communication
3. Nonverbal communication
4. Adaptive behaviour
5. Overall autism functioning profile
6. Global improvement
7. Quality of life, at home and at school

Study selection

We carried out a detailed review of all titles and abstracts of studies identified by the specified search terms. Additionally, authors were contacted directly to inquire about other relevant studies they might have conducted. If a study did not meet the inclusion criteria, it was excluded from this review. For those that did, full texts were obtained and analysed meticulously. A decision was made subsequently regarding the suitability of each study for inclusion in the review.

Data extraction and management

We utilized Review Manager 5 to analyse and extract data. Information was gathered from each study using data collection forms, including details about the study design, participants, interventions, and outcomes. Study selection and bias assessments were carried out by a single author. Uncertainties were discussed collectively among the authors.

Synthesis of Findings

If the inclusion criteria were met, not all studies necessarily measured every outcome (see study characteristics in Appendix 2). All reported outcomes were identified and qualitatively compared across studies. If any data were missing, the corresponding authors were reached out to for clarification. If no response was received, this was documented in the bias assessment. Heterogeneity was addressed by highlighting differences and providing detailed explanations of the measurement instruments used.

Evaluation of bias potential

Studies were assessed for bias using the Risk of Bias 2 tool, categorized as low, high, or unclear risk (details in Appendix 3) [19]. The evaluation included seven criteria: random sequence generation, allocation concealment, blinding of participants, blinding of personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting.

Results

Search results

The electronic search for studies entailed searching through the Cochrane Central Register of Controlled Trials and the PubMed databases. The result was 130 titles as shown in Figure 1. All but two articles were written in English. In order to access any potential additional studies, we contacted the authors of studies. However, we received no positive responses, so the search for other resources remained unsuccessful. Out of 130 articles, 32 were identified as duplicates and removed. The titles and abstracts of the remaining 98 articles were assessed: 80 were excluded; 44 did not meet the methodology criteria; the study was still ongoing for 30; and 6 were pilot studies. Full texts of the

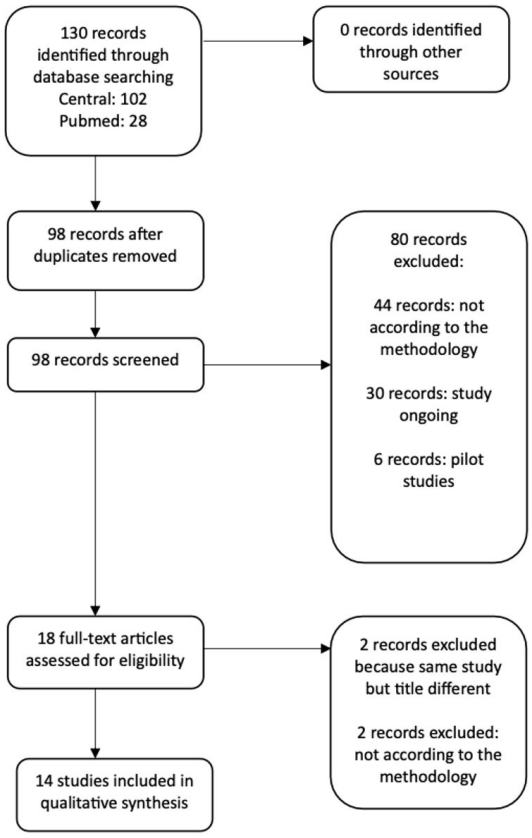

Figure 1: Review flow diagram illustrating the study selection process from initial screening to the final decision, including reasons for inclusion or exclusion of studies.

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

remaining 18 studies were reviewed. Two were excluded due to identical content, despite different titles, and another two for lacking MT intervention, leaving 14 studies for inclusion.

Studies included

This review included 14 RCTs (see study characteristics in Appendix 2), 5 with a crossover design [20-24]. Group interventions were described in several studies [28, 30]; one study hinted at group observations without explicit mention [25]. One study combined one-to-one and group settings [26]. The other studies were conducted as one-to-one interventions [20, 21, 22, 24, 27, 29, 31-33], with one study not clearly defined but likely also a one-to-one session [23].

Geographically, studies were conducted in the USA, South Korea, Canada, Australia, France, Brazil, India, and in one case, across nine countries [27]. Participant numbers ranged from 10 to 364, with children aged 3-12 years. All participants were diagnosed with autism or ASD based on different diagnostic standards, including DSM-IV, DSM-V, ICD-10, the Childhood Autism Rating Scale, or healthcare provider diagnoses. While one study specified ASD as the sole diagnostic criterion without detailing the diagnostic method [26], another provided only formal documentation of the diagnosis [28]. An additional study explained that the ASD definition was made both by healthcare providers and the Social Communication Questionnaire [24]. The shortest intervention duration was five days [26, 29], while the longest lasted eight months [21, 30]. Including the follow-up period, the longest study had a total duration of twelve months [27]. There was a follow-up in six studies, although no clear time point was specified in three studies [25, 27, 28, 31-33].

Intervention types included classical MT with activities such as singing and dancing, specialized approaches, for example, therapist-led sessions, bodywork, and tasks combined with music listening. Control groups varied, involving play, music listening, routine care, language training, or bodywork. Intervention frequencies ranged from twice daily to weekly, with durations from three to 45 minutes. Some studies did not specify either frequency or duration.

Risk of bias evaluation

Figure 2 shows possible risk of bias of each study.

Allocation

The analysis of 14 studies showed that all used randomization to allocate participants. Six studies employed methods like computer generation, random lists, or coin tossing, indicating low risk of bias [27, 28, 30-33]. Seven studies had unclear bias risk due to insufficient randomization details [20-22, 24, 26, 29] or reliance on a random number chart [23]. One study with quasi-random assignment was rated as high risk [25].

Four studies, categorized as low risk of bias, described their participant allocation [27, 29, 31-33]. It was unclear in

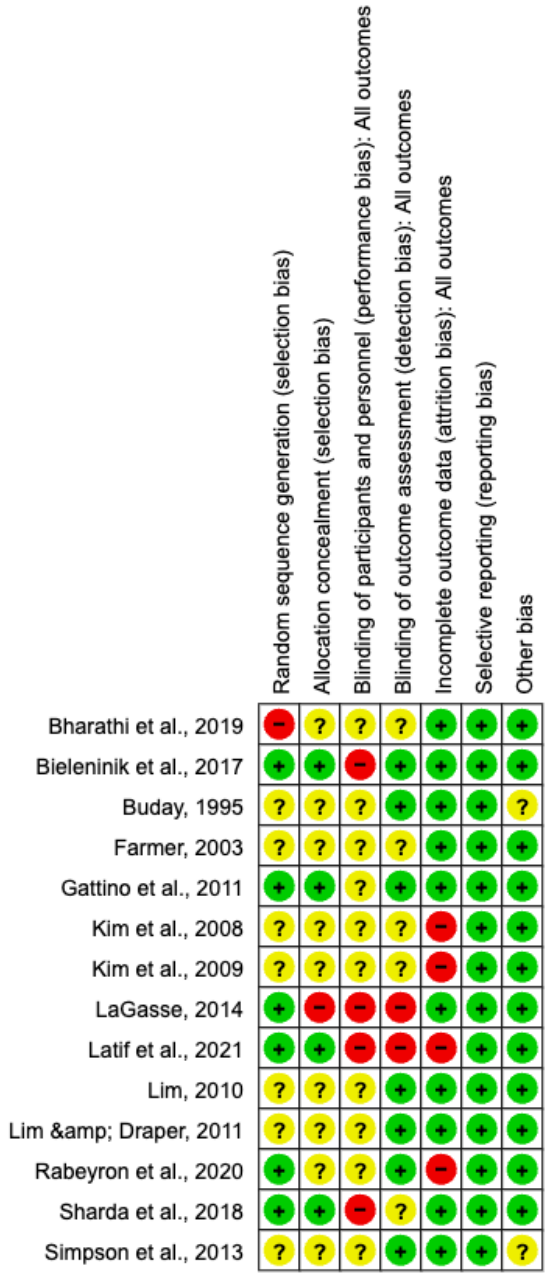

Figure 2: Risks of bias were assessed, examining the included studies for random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.

nine studies whether the secrecy and unpredictability of group allocation were ensured [20, 21-26, 29, 30]. One study was classified as having a high risk of bias due to its unblinded randomized control design [28].

Blinding

Because of how the intervention was designed, blinding of staff and participants was often not feasible, leading to ten studies being rated as having an unclear risk of bias. Specific cases included a study in which blinding was lifted because

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

parents or others mentioned the intervention [27], another where parents were informed [33], a non-blinded study [28], and a study where a therapist treated both groups [32]. These four studies were classified as having a high risk of bias.

Seven studies [20, 23, 24, 27, 29-31] with blinded assessors were assessed as having a low risk of bias. Two studies [21, 33] had blinded assessors but not legal guardians, resulting in an unclear classification. One study [28] involved parent and researcher evaluations, where coders identified sessions by children's clothing, also rated as unclear. Studies with unclear assessor blinding [25, 26] were similarly classified. Two studies [22, 32] reported partial blinding, leading to a high risk of bias classification.

Incomplete outcome data

Seven studies reported no dropouts or missing data and were therefore assessed as having a low risk of bias. Six studies reported dropouts, with two addressing missing data statistically [27, 33]. One study excluded two participants and had three withdrawals, but pretest results showed no significant differences between completers and non-completers [28]. Two studies with a 30% dropout rate were rated as high risk of bias [21, 22], as were two others with unclear handling of missing data or dropouts [30, 32].

Selective reporting

Selective reporting could not be demonstrated in any of the studies. Consequently, a low risk of bias can be concluded in all of them.

Other potential sources of bias

Professional music therapists were involved in the research in 12 out of 14 studies. No professional music therapist is mentioned in two studies [20, 24]. The latter were categorized as having an unclear risk of bias.

Results of outcome measures

Social interaction

Eight studies [21, 24, 25, 27, 28, 31-33] examined social interaction outcomes.

The Social Responsiveness Scale, designed for children aged 3-18, comes in 65-item and 30-item versions, both highly valid [34]. Three studies used the Social Responsiveness Scale [27, 28, 33]. Out of the three studies, two reported significant improvements in the MT group compared to the control group [27, 28] and one did not [33].

The Pervasive Developmental Disorder Behavior Inventory, completed by parents and teachers, assesses children with Pervasive Developmental Disorders, measuring maladaptive and adaptive behaviours and providing an overall "Autism Score" [35]. One study used the Pervasive Developmental Disorder Behavior Inventory and found no significant differences [21].

The TRIAD Social Skills Assessment serves as a tool crafted for the evaluation of social skills among children with ASD in settings of inclusive education. It includes four components: Initiating Interactions, Responding to Initiations, Affective Understanding/Perspective Taking, and Sustaining Interactions [36].

One study used the TRIAD Social Skills Assessment test showed the MT group significantly improved social skills [25].

One study analysed social interaction types. Significant differences were measured in supported joint engagement, triadic joint engagement and task-relevant objects. No significant differences were noted in co-ordinated joint engagement and other forms [32].

The Childhood Autism Rating Scale (CARS) serves as an instrument for clinicians to evaluate ASD, spanning domains like cognitive, adaptive, communicative, emotional, and social areas [37].

One study used the Brazilian edition of the CARS test (CARS-BR) but showed no significant difference between the two groups [31]. One study demonstrated a significant disparity in engagement between MT and the control, yet found no significant variation across the groups over time. Only a significant difference for behaviour was only found in the group [24].

Verbal communication

Verbal communication was examined in six studies [20, 23, 26, 29, 31, 33]. The Peabody Picture Vocabulary Test 4 involves selecting pictures matching words, suitable for those aged 2+ [38]. One study used it for verbal communication evaluation, but found no significant difference [33].

The Verbal Production Evaluation Scale, developed by the researcher, was applied in two studies to measure verbal responses [23, 29]. Both studies compared MT to two control groups: one with speech intervention and one without. While MT showed significant improvements compared to no-intervention, no notable differences were found between MT and speech intervention.

Verbal communication evaluation during the intervention in one study showed a significant difference between the two groups [20]. One study also evaluated verbal communication during the intervention, noting an average 53 % increase in verbal response in the MT group [26]. One study used the CARS-BR to test verbal communication. No significant differences could be measured between the two groups [31].

Nonverbal communication

Six studies investigated nonverbal communication [20, 21, 26, 28, 31, 33]. Three studies utilised observation forms [20, 26, 28], where one observed a significant difference

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

in body language signs [20], another found no significant difference in gestural responses [26], and the third reported significant differences in joint attention with peers and eye gaze, but not in joint attention with adults, initiation or response to communication, or withdrawal/behaviours [28].

One study used the CARS-BR to measure nonverbal communication, finding no significant overall results. However, a significant positive change was noted in nonverbal communication among the MT group in the subgroup analysis [31].

The Children's Communication Checklist-2 is used for identifying pragmatic disorders and screening for language disorders and autism in children with communication deficits [39]. One study employed this checklist to evaluate pragmatic communication between the MT and control group, resulting in a significant difference [33].

The Early Social Communication Scales assesses nonverbal communication in young children, with an emphasis on joint attention, behavioural requests, and social interaction [40]. One study utilised the Early Social Communication Scales test for nonverbal communication, reporting significant results across all measured aspects [21].

Adaptive behaviour

The Vineland Adaptive Behavior Scales assess adaptive behaviour in daily living skills, communication, and socialization, with optional motor skills and maladaptive behaviour evaluations. [41]. The subdomain maladaptive behaviour was examined in one study and showed a significant improvement in both groups [33].

The Aberrant Behaviour Checklist is a widely used tool with five subscales assessing various behaviours [42]. One study utilised it and found no significant overall differences in adaptive behaviour, but significant differences were observed in the Lethargy and Stereotypy subcategories [30].

Overall autism functioning profile

Two studies utilised the CARS for autism assessment. One noted significant post-intervention improvements but no intergroup differences [30], while the other did not provide any details about outcomes [25]. The Autism Treatment Evaluation Checklist, completed by caregivers, assesses treatment responses in individuals with ASD and includes a total score alongside four subscales (Speech/Language, Sociability, Sensory/Cognitive, Health/Behaviour) [43]. One study utilised this tool and found significant improvement over time in the MT group, but no significant differences between the groups [28]. Another study found significant improvements in joy, emotional synchronicity, and engagement initiation [22].

One study observed a significant difference in behaviour between the groups. Regarding the level of engagement and correct responses, a significant difference was noted in both groups. However, no significant correlation was found between correct responses and the level of challenging behaviour [24]. The Autism Diagnostic Observation Schedule, a tool for assessing social interaction and communication in ASD [44], was used in one study, which found no significant differences among groups [27].

Global improvement

The Clinical Global Impression scales serve as straightforward assessment instruments, mirroring a clinician's holistic evaluation of a patient's condition [45]. One study used the Clinical Global Impression scales and found a significant difference between the groups [30].

Quality of life, at home and at school

Two studies focused on quality of life. One study observed a significant quality of life difference between the high-intensity group and the control group, but not in other comparisons [27]. The other study used the Family Quality of Life Questionnaire, which assesses a family's collective well-being, including interactions, parenting, emotional and physical health, and support aspects [46] and demonstrated a significant difference [33].

Discussion

This review aimed to determine, through existing studies, whether or not MT contributes to the improvement of skills in children from birth to 18 years with ASD. It focused on qualitative analysis and evaluated seven outcomes: social interaction, verbal communication, nonverbal communication, adaptive behaviour, overall autism functioning profile, global improvement, and quality of life at home and at school. 14 studies were analyzed in total. As mentioned in the introduction, musical activities such as singing and making music are described as effective tools for promoting social skills, particularly by enhancing imitation, turn-taking, and joint attention in group settings. Furthermore, MT not only supports language development but also has a positive impact on social and emotional development.

The findings of this review confirm this. Significant improvements were observed, particularly in the aspects of social interaction, communication, global improvement, and quality of life, at home and at school for children with ASD, areas where children with ASD often face challenges.

The analysis of three group intervention studies [25, 28, 30] highlights both the potential and limitations of MT for children with ASD, with mixed outcomes. Notably, two studies [25, 28] reported significant improvements in social interaction, emphasizing the effectiveness of group interventions in this area. The application of different assessment tools in these studies suggests that group dynamics may consistently enhance social interaction regardless of

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

the specific evaluation method. This indicates that MT in a group setting might address core challenges faced by children with ASD, such as initiating and maintaining social relationships, by providing a structured and supportive environment for practicing these skills. The interpretation of the findings remains uncertain due to the use of different evaluation methods. For instance, the Verbal Production Evaluation Scale focuses on verbal communication, whereas the more versatile CARS-BR covers broader contexts. Such methodological differences could account for the variations in results and call for a critical assessment of their significance.

Another intriguing result was observed in the area of verbal communication, where few significant differences were found. Two studies demonstrated that MT and speech intervention led to similar progress in verbal communication [23, 29]. These findings align with the theory that both approaches target comparable cognitive and social mechanisms. MT can thus serve as a valuable complement or alternative to speech therapy.

These findings highlight the potential effectiveness of MT in these domains.

Nevertheless, some uncertainties emerged, particularly concerning randomization. As noted in the Risk of Bias assessment, only six studies employed blinded randomization, which can be considered a strength of these studies. Interestingly, most of these studies reported non-significant results, in contrast to others. Proper randomization helps reduce selection and confounding [47].

Studies identified as having an “unclear risk of bias” or a “high risk of bias” demonstrated a limitation in randomization, as it remained unclear whether this may have introduced distortions in the results. Another reason for the limitation observed in these studies was the heterogeneous approach to blinding. A significant number of “unclear risk of bias” assessments were related to “blinding participants and personnel”. This could be explained by the fact that the personnel conducting the studies often consisted of music therapists who were aware of the group assignments. Additionally, four “high risk of bias” studies lacked proper blinding, with one study omitting it entirely. This lack of blinding likely introduced performance bias, which could have been avoided [48].

Another explanation for the differences observed could be the wide range of the number of study participants. Studies with the smallest sample size (n = 10) showed statistically significant results [20-22, 26]. By contrast, the study with the largest number of participants (n = 364) found only small statistically significant differences in the subgroups and in a rating for the outcome “social interaction” [27]. Although small sample sizes can deliver results quickly, but are often too small for reliable conclusions [49].

Nonetheless, all studies share a notable strength: they exclusively involved children up to 18 years old. Research with children presents unique challenges, requiring stricter ethical standards and parental involvement due to concerns about potential harm to participants [50]. This could partly explain why some studies had relatively small sample sizes.

Another factor in the variability of results is the different interventions in the control groups, which ranged from routine care to language training as mentioned in the results. This diversity of control conditions may have influenced the results, making it difficult to draw firm conclusions.

Long-term studies face similar challenges as short-term studies but differ significantly in terms of costs as well as the temporal and spatial reproducibility of the results [51]. In this review, all 14 studies had to define methodological approaches. However, the limitation of comparability of results remains due to the range of intervention duration varying from five days to eight months in these studies.

Furthermore, the question of follow-ups arises. Six of the included studies conducted a follow-up, which is a strength of these studies. Follow-ups play an essential role as they illustrate progress and, consequently, the long-term effectiveness of the treatment [52]. One study that did not conduct a follow-up addressed this issue in its discussion, emphasizing that without a follow-up, the long-term effects of the therapy could not be assessed [30]. This recommendation applies not only to this study but to all studies that omitted a follow-up.

A strength of this review is its demonstration that MT is particularly effective for children with ASD, especially in improving social interaction, verbal and nonverbal communication, global improvement, and quality of life. A limitation is the methodological heterogeneity across studies, complicating comparability and general conclusions. Study selection and bias assessments were conducted by a single author, but uncertainties were discussed collectively, and standardized assessment tools were used to ensure reliability.

Conclusion

Future research should focus on rigorous methodologies, including better randomization, blinding, and standardized tools, alongside larger samples and longer follow-ups to ensure reliable and comparable results. Another potential research field could be the comparison of MT group interventions versus individual interventions for children with ASD.

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Statement of Ethics

An ethics statement is not applicable because this study is based exclusively on published literature.

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
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Conflict of Interests Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Tabea Frei: Conceptualization, investigation, methodology, project administration, visualization, writing – original draft, writing – review and editing.

Thomas Szucs: Conceptualization, methodology, supervision, writing – review and editing.

Both authors have approved the final version for publication and explicitly affirm their readiness to assume responsibility for all aspects of the work, ensuring that questions concerning the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
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Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

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Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Appendix 1

Detailed Search Strategy

PubMed

Search conducted: 30 August 2023 – 21 March 2024

Filter: birth – 18 years, RCT

Search: music* AND autism AND child*

"music*"[All Fields] AND ("autism s"[All Fields] OR "autisms"[All Fields] OR "autistic disorder"[MeSH Terms] OR ("autistic"[All Fields] AND "disorder"[All Fields]) OR "autistic disorder"[All Fields] OR "autism"[All Fields]) AND "child*"[All Fields]

Translations

autism: "autism's"[All Fields] OR "autisms"[All Fields] OR "autistic disorder"[MeSH Terms] OR ("autistic"[All Fields] AND "disorder"[All Fields]) OR "autistic disorder"[All Fields] OR "autism"[All Fields]

Cochrane Central Register of Controlled Trials

Search conducted: 12 August 2023 – 21 March 2024
Search: (music* AND autism AND child*):ti,ab,kw

Appendix 2

Study characteristics

Bharathi et al., 2019

Methods	RCT, quasi-experimental, group setting **Blindness:** No information **Duration:** Three months intervention, follow-up after three months
Participants	**Diagnosis:** ASD, (DSM-V criteria) **N:** 52 **Age range:** 72–144 months **Male:** 26 **Female:** 26 **Location:** India
Intervention	**1. MT (n = 26):** Singing, dancing, playing with musical instruments, 35 min session, three weekly sessions, **2. Control (n = 26):** Listening to music alone, 35 min session, three weekly sessions group sessions
Outcomes	**Social interaction:** Measured and recorded with the TRIAD Social Skills Assessment Significant increase in social skill in MT group compared to Control. **Overall Autism Functioning Profile:** Measured with Childhood Autism Rating Scale (CARS), pre- and post-test by researcher, but no information

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Bieleninik et al., 2017

Methods	RCT **Blindness:** Assessors were blinded **Duration:** 12 months (intervention 5 months), Follow-up between 2012 and 2016
Participants	**Diagnosis:** ASD (ICD-10 criteria) **N:** 364 **Age range:** 48–83 months **Male:** 302 **Female:** 62 **Location:** Nine countries (Australia, Austria, Brazil, Israel, Italy, Korea, Norway, UK and USA)
Intervention	**1. MT (n = 91):** Low-intensity (one weekly session) plus standard care, plus improvisational MT, duration 30 min, possibly joined by family members, singing, instrumental play, improvisation techniques **2. MT (n = 91):** High-intensity (three weekly sessions) plus standard care, plus improvisational MT, duration 30 min, possibly joined by family members, singing, instrumental play, improvisation techniques **3. Control (n = 182):** Enhanced standard care, routine care, three 60 min sessions of parent counsellingone-to-one sessions
Outcomes	**Social interaction:** Social Responsiveness Scale (rated by parents), small significant improvements between MT and Control in several Social Responsiveness Scale subscales: MT versus standard care: greater improvements in social motivation over 5 months, greater improvements in autistic mannerisms over 2 and 12 months Three-group comparison: low-intensity MT versus standard care: greater improvements in social awareness at two months. High-intensity MT versus standard care: greater improvements in autistic mannerisms over five months. **Overall Autism Functioning Profile:** Measured with the Autism Diagnostic Observation Schedule, MT versus standard care with no significant difference, MT with high- and low-intensity with no significant difference **Quality of life, at home and at school:** Rated by parents, high-intensity versus Control with a significant positive effect after five months, the other comparisons were non-significant

Buday, 1995

Methods	RCT, crossover design **Blindness:** The assessors were blinded, yet, the experimenter was present during the evaluation of the results to aid the scorer. **Duration:** Two weeks, no follow-up
Participants	**Diagnosis:** Autism (diagnosed by their own health care provider who was a paediatric psychiatrist in most cases) **N:** 10 **Age range:** 52–108 months **Male:** 8 **Female:** 2 **Location:** USA
Intervention	**1. MT (n = 10):** Five trials each day for four days; seven signed and spoken words presented together with music to encourage imitation of singing and speech **2. Control (n = 10):** Five trials each day for four days; words spoken rhythmically (not sung) to the rhythm and tempo of the original music to test the imitation of an additional seven words, one-to-one sessions Video recorded. Assessed by experimenter during intervention one-to-one sessions
Outcomes	**Verbal communication:** Production of words, MT versus control, significant main effect, $p < .02$ **Nonverbal communication:** Signs showed with body language, MT versus control, significant main effect, $p < .05$ Data collected with an observation form

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Farmer, 2003

Methods	RCT, one-on-one sessions and groups of n = 2 **Blindness:** No information **Duration:** Five days, no follow-up
Participants	**Diagnosis:** Autism **N:** 10 **Age range:** 24–60 months **Male:** 9 **Female:** 1 **Location:** USA
Intervention	**1. MT (n = 5):** Using guitar, drum and singing **2. Control (n = 5):** See below Activities in both groups: greeting, movement activities, touching different body parts, clapping, turning around, identifying mystery items, blowing and popping bubbles, walking like a dinosaur, making a noise like a cat/dog/dinosaur, 20 min, five activities. Under "Parental consent form", it is stated that the intervention took place twice a week for three consecutive weeks. All sessions were recorded on video. One-to-one sessions (at Walden School, two groups with two and two)
Outcomes	**Verbal communication:** The data indicated a rise (53 %) in verbal responses within the music group, while the control group displayed variable verbal responses. **Nonverbal communication:** Gestural responses: The gestural scores did not show an increase, yet, the music group outperformed the control group. Data collected with an observation form.

Gattino et al., 2011

Methods	RCT **Blindness:** Assessors were blinded **Duration:** seven months, follow-up mentioned, timing not specified
Participants	**Diagnosis:** ASD (DSM-IV criteria) **N:** 24 **Age range:** 84–144 months **Male:** 24 **Female:** 0 **Location:** Brazil
Intervention	**1. MT (n = 12):** three MT assessment sessions, 16 weekly interventions, one final MT assessment session. Clinical routine activities included. Each session was 30 min, one-to-one sessions **2. Control (n = 12):** only weekly routine clinical activities
Outcomes	**Social interaction:** Measured with CARS-BR, no significant difference **Verbal communication:** Measured with CARS-BR**,** no significant difference **Nonverbal communication:** Measured with CARS-BR, no significant difference Nonetheless, a significant positive difference was observed in the nonverbal communication of patients with autistic disorder in the subgroup analysis, with a p-value of .008

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DOI:10.26502/jppd.2572-519X0241

Kim et al., 2008

Methods	RCT, crossover **Blindness:** Assessors were blinded **Duration:** Seven to eight months because of holidays and sick leave, no follow-up
Participants	**Diagnosis:** Autism (DSM-IV criteria) **N:** At the beginning n = 15, at the end n = 10 **Age range:** 36–60 months **Male:** 13, 3 drop-outs **Female:** 2, 2 drop-outs **Location:** South Korea
Intervention	**1. (n = 10):** Improvisational MT sessions, 12 weekly 30 min sessions **2. Control (n = 10):** Play sessions with toys, 12 weekly 30 min sessions 12 weekly 30 min sessions Each session divided into 15 min child-led and 15 min directed parts and recorded on video. One-to-one sessions
Outcomes	**Social interaction:** Measured with Pervasive Developmental Disorder Behavior Inventory, not significantly higher between groups (rated by professionals and parents) Only time had a significant effect, $p < .0001$ **Nonverbal communication:** Measured with Early Social Communication Scales, significant interaction of time and group, $p = .01$ Eye contact duration: Significant effect, $p < .0001$ MT versus Control Turn-taking duration: Significant effect, $p < .0001$ MT versus Control

Kim et al., 2009

Methods	RCT, crossover **Blindness:** Assessors were not blinded **Duration:** 12 weeks, no follow-up
Participants	**Diagnosis:** ASD by DSM-IV-TR **N:** At the beginning 15, at the end 10 **Age range:** 36–60 months **Male:** Beginning of study unclear, at the end, all participants were male (n = 10) **Female:** Beginning of study unclear, at the end, no participants (n = 0) **Location:** South Korea
Intervention	**1. MT (n = 10):** Improvisational MT session, once a week for 30 min **2. Control (n = 10):** Toy play session, once a week for 30 min Sessions divided into undirected (child-led) and more directed (therapist-led) parts, each lasting 15 min. They were recorded on video. One-to-one sessions
Outcomes	**Overall Autism Functioning Profile:** Joy: $p < .001$ Emotional synchronicity: $p < .001$ Initiation of engagement: $p < .001$ $p < .001$ between the MT group and the control group for joy, emotional synchronicity and initiation of engagement. Significant improvement of the MT group in relation to the control group

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

LaGasse, 2014

Methods	Non-blinded RCT design, group setting (small groups with three to four children/group) **Blinding:** Non-blinded, participants and personnel knew about the randomization **Duration:** Five weeks, follow-up after three weeks for Autism Treatment Evaluation Checklist
Participants	**Diagnosis:** Formal documentation of ASD **N:** 17 **Age range:** 72–108 months **Male:** 13 **Female:** 4 **Location:** USA
Intervention	**1. MT (n = 9):** MT, twice a week, 50 min sessions, with a professional music therapist In the MT group, the Transformational Design Model was applied to craft musical activities that enhanced social skills using music cues and structures, while actively involving children in music-making and diverse forms of communication **2. Control (n = 8):** Social skills, twice a week, 50 min sessions, cooperative play Group sessions
Outcomes	**Social interaction:** Measured with the Social Responsiveness Scale, interaction of time and group, Social Responsiveness Scale scores, significant difference, $p < .05$ **Nonverbal communication:** Eye gaze: Third and tenth session recorded on video and analysed. Significant between-group differences Joint attention with peers: Third and tenth session recorded on video and analysed. Significant between-group differences, $p = .031$ Joint attention with adults: Third and tenth session recorded on video and analysed. No significant between-group differences, $p > .05$ Initiation of communication with peers or adult: Third and tenth session recorded on video and analysed. No significant between-group differences, $p > .05$ Response to communication: Third and tenth session recorded on video and analysed. No significant between-group differences, $p > .05$ Withdrawal/behaviours: Third and tenth session recorded on video and analysed. No significant between-group differences, $p > .05$ **Overall Autism Functioning Profile:** Progress of children with ASD measured with Autism Treatment Evaluation Checklist, $p = .8234$

Latif et al., 2021

Methods	RCT **Blindness:** Assessors were not blind **Duration:** 8–12 weeks, follow-up mentioned, timing not specified
Participants	**Diagnosis:** DSM-IV **N:** 51 **Age range:** 72–144 months **Male:** 43 **Female:** 8 **Location:** Canada
Intervention	**1. (n = 26):** Music-based intervention, child-centric approach using musical instruments, songs and rhythmic cues **2. Control (n = 25):** Without music-based intervention, structurally matched, play-based activities Once a week for 45 min One-to-one sessions
Outcomes	**Social interaction:** Joint engagement, measured with percent time per activity, joint engagement (macro categories: Coordinated Joint/Supported Joint/Object/Other) Supported Joint Engagement: MI group spent significantly more time than control group, $p = .0040$ Object Engagement: MI group spent significantly less time with task-relevant objects than control group, $p < .001$ Coordinated Joint: No significant difference between the groups, $p = .19$ Other Engagement: No significant difference between the groups, $p = .41$ Triadic Joint Engagement: Significantly higher in MI group, $p < .001$ **Nonverbal communication:** Movement elicited by music-making, significantly higher in MI group, $p = .035$
Notes	

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Lim, 2010

Methods	RCT **Blindness:** Speech/language pathologists were blinded, rest of personnel or participants is unclear **Duration:** Five days, no follow-up
Participants	**Diagnosis:** Childhood Autism Rating Scale or the Autism Diagnostic Interview Revised **N:** 50 **Age range:** 36–60 months **Male:** No information **Female:** No information **Location:** USA
Intervention	**1. MT (n = 18):** Music, Participants watched a music video (9 min), twice a day, three days **2. Control (n = 18):** Speech: Participants watched a speech video (5 min 40 s), twice a day, three days **3. Control (n = 14):** No training One-to-one sessions
Outcomes	**Verbal communication:** Production of target words: measured with VPES MT and Speech training showed no significant difference, but compared to the No training group, there was a significance of p = 0.001 Four components: semantics, phonology, pragmatics, and prosody No statistically significant differences between music and speech conditions on the various aspects of speech production: semantics (p = .709), phonology (p = .995), pragmatics (p = .709) and prosody (p = .768).

Lim & Draper, 2011

Methods	RCT, crossover study with participants randomly assigned in which order to receive training **Blindness:** Assessors were blinded **Duration:** Two weeks, no follow-up
Participants	**Diagnosis:** ASD, diagnostic criteria set by their respective healthcare providers, such as paediatric psychologists or neurologists **N:** 22 **Age range:** 36–60 months **Male:** 17 **Female:** 5 **Location:** USA
Intervention	**1. MT (n = 22):** Music Applied Behavior Analysis Verbal Behavior (ABA VB) training, three periods of training per week, five trials for each assigned verbal operant, professional music therapist, songs composed by the researchers were used in the music condition. These songs included a total of 30 target words (6 pairs of target words for mand and 18 target words for tact, echoic and intraverbal). Songs were presented in singing. Pictures were presented. Training in Music ABA VB involved the vocal rendition of verbal directives. **2. Control (n = 22):** Speech (ABA VB) training, three periods of training per week, five trials for each verbal operant assigned, the same music therapist who was active in the music condition spoke the sentences in the speech training. The same texts for sentences and instructions used in the music training were also utilzed for the speech training and were spoken. **3. Control (n = 22):** No training Unclear if one-to-one or group sessions but likely one-to-one given individual assignment and structured sequence
Outcomes	**Verbal communication**: Measured with VPES MT versus speech: no significant difference (MT even though better progress) MT versus no training: significant difference (the same for speech and no training)

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Rabeyron et al., 2020

Methods	RCT **Blindness:** The study was designed as a "single-blind" study, whereby the assessors (the clinical psychologists) who evaluated the participants were blinded to the children's group affiliations (MT or music listening). **Duration:** Eight months, no follow-up
Participants	**Diagnosis:** Diagnosis of ASD based on the Childhood Autism Rating Scale **N:** 37, one mother withdrew agreement after allocation (N = 36) **Age range:** 36–84 months **Male:** 31 **Female:** 5 **Location:** France
Intervention	**1. MT (n = 19):** MT, 25 interventions every week for 30 min (except holidays) with a professional music therapist Opening ritual: 5 min of instrumental music listening Improvisation: 20 min of instrumental and vocal improvisation with access to instruments Closing ritual: 5 min of vocal music listening **2. Control (n = 18):** Music listening, 25 interventions every week for 30 min (except holidays) Listening to commercial music (French and foreign songs) chosen before the study by the therapist. Group sessions
Outcomes	**Adaptive behaviour:** Measured with Aberrant Behavior Checklist; Aberrant Behavior Checklist total scores showed no significant difference between groups, except for Lethargy p = 0.01 and Stereotypy p = 0.03. **Overall Autism Functioning Profile:** Measured with CARS; CARS scores improved significantly, but in both groups. No significant improvement between the groups. **Global improvement:** Measured with Clinical Global Impression, post-test: p = 0.005 between groups

Sharda et al., 2018

Methods	RCT **Allocation:** coin toss and computer software **Blindness:** Some parents knew about the randomization, raters were blinded **Duration:** 8–12 weeks, follow-up mentioned, timing not specified **Design:** RCT
Participants	**Diagnosis:** DSM-IV criteria for ASD **N:** 51 **Age range:** 6–12 years **Male:** 43 **Female:** 8 **Location:** Canada
Intervention	**1. MT (n = 26):** Weekly 45 min sessions by an accredited music therapist, MT: musical instruments, songs and rhythmic cues while targeting communication, turn-taking, sensorimotor integration, social appropriateness and musical interaction **2. Control (n = 25):** Weekly 45 min sessions, play-based intervention One-to-one sessions
Outcomes	**Social interaction:** Social Responsiveness Scale-II for symptom severity in social skills, group x timepoint interaction, no significance **Verbal communication:** Measured with Peabody Picture Vocabulary Test-4, group x timepoint interaction, no significance **Nonverbal communication:** Measured with Children's Communication Checklist-2 for pragmatic communication, post-test: significant group x timepoint interaction, p = .01 **Adaptive behaviour:** Measured with Vineland Adaptive Behavior Scales, significant improvement in both groups, p = .01 (no information concerning group x timepoint interaction) **Quality of life, at home and at school:** Measured with Family Quality of Life, group x timepoint interaction, significant improvement in family quality of life for MT

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Simpson et al., 2013

Methods	RCT, crossover design **Blindness:** Assessors were blinded **Duration:** Unclear, intervention – wash-out phase (one month) – intervention, no follow-up
Participants	**Diagnosis:** ASD, (paediatrician's diagnosis plus Social Communication Questionnaire) **N:** 22 **Age range:** 42–108 months **Male:** No information **Female:** No information **Location:** Australia
Intervention	**1. MT (n = 22):** The recordings described, each lasting 10 s, employed a straightforward quadruple metre and exhibited a melodic contour characterized by a distinct rise and fall in intervals. The melody was "Twinkle Twinkle". **2. Control (n = 22):** The spoken recordings lacked a defined metre and were delivered more rapidly, each lasting only 7 s, while exhibiting a smooth, flowing contour. Two sets of comparable materials were developed, based on a garden theme and consisting of a contextual sentence, a prompt to touch a picture, and four creatures. In case of an incorrect or no response within 10 s, a gradual error correction approach was used. Correctly touching the picture led to the display of the creature's image and its pre-recorded name. The intervention consisted of 15 teaching sessions, where children were required to label garden creatures. Each creature was named three times per session, with the audio file accompanying the picture presentation. Correct and incorrect responses were recorded, with error correction applied as needed. Duration for each session between 3 and 6 min, depending on the reaction time of participants. One-to-one sessions
Outcomes	**Social interaction:** Engagement and behaviour, measured in percentages of time Engagement: Condition: p = .04 Group: p = .19 Time: p = 0.09 **Overall Autism Functioning Profile:** Correct responses in the picture-labelling task Behaviour: Condition: p = .065 Group: p < .01 Time: p = .36 Challenging engagement, behaviour and learning: Level of engagement and correct responses: MT (p < .01), Control (p < .01), significant Level of challenging behaviour and correct responses: MT (p = .06), Control (p = 16), non-significant

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

Appendix 3

Criteria for determining risk of bias

Bias arising from the randomization process:

- Low risk of bias: table of random numbers, computer-generated random numbers, coin toss.
- High risk of bias: physician assignment, patient preference, test result or availability of the intervention, quasi randomization, for example, date of birth, day of the week, file number
- Unclear risk of bias: It was unclear how randomization was achieved.

Selection bias:

- Low risk of bias: If the covert allocation was sufficient and both participants and researchers were unclear about the future group allocation until eligibility was clarified and informed consent obtained, the risk of bias was rated as low.
- High risk of bias: If the concealed allocation was inadequate, that is, if allocation was apparent to participants prior to informed consent or to researchers prior to the decision to enrol, the risk of bias was considered high. This is always true for quasi-randomized studies.
- Unclear bias: If the method of concealed allocation was not described in detail, the risk of bias was judged to be unclear.

Performance bias:

- Low risk of bias: Secure blinding with no opportunity for circumvention ensures that the endpoint is not affected. Instances of absent, partial or disrupted blinding are present; however, the impact on the endpoint due to inadequate blinding is considered a risk of bias.
- High risk of bias: There is either no blinding, or incomplete or interrupted blinding; however, it is unlikely that this lack of blinding will affect the study's endpoint significantly.
- Efforts were made to blind study participants and personnel, yet, there is a high likelihood of this blinding being compromised; the absence of effective blinding is likely to influence the study's endpoint.
- Unclear risk of bias: Information to assess whether the risk of bias is high or low is missing.

Detection bias:

- Low risk of bias: guaranteed blinding during the assessment of endpoints with a low risk of bias of unblinding occurring. No blinding implemented during the assessment of endpoints; however, the impact of this absence of blinding on the endpoints is deemed unlikely.
- High risk of bias: There is no blinding in place during the assessment of endpoints, and it is likely that this absence of blinding will affect the outcomes. There was an attempt to implement blinding at the endpoint assessment, yet, there is a high chance that the blinding was compromised; it is risk of bias that this deficiency in blinding will impact the outcomes.
- Unclear risk of bias: Information to assess whether the risk of bias is high or low is missing.

Attrition bias:

- Low risk of bias: There are no missing data in the endpoint survey. It is likely that the reasons for any missing data are not associated with the intervention/exposure or the results. The amount of missing data is evenly distributed across the treatment groups, and the reasons for the missing data are similar between the groups.
- High risk of bias: The missing data in the study are probably related to the interventions or outcomes, and show an imbalance between groups.
- Unclear risk of bias: There is too little information to assess whether low or high risk of bias is present.

Reporting bias:

- Low risk of bias: The study protocol is either available and all relevant pre-specified endpoints have been reported in the publication, or the protocol is not available but the publication obviously contains all of the endpoints expected. In the latter case, such convincing publications are rare.
- High risk of bias: Not all of the prespecified primary endpoints were reported in the study. Some of these endpoints were analysed using either analysis methods which were not pre-specified or subsets of data, such as subgroups. In addition, some endpoints were not pre-specified. Key endpoints for the review were not fully reported and are, therefore, unusable. In addition, the results ofa critical endpoint for the study question were not published.

Freia T and Szucsb T., J Psychiatry Psychiatric Disord 2025
DOI:10.26502/jppd.2572-519X0241

- Unclear risk of bias: There was too little information to assess whether low or high risk of bias was present.

Other forms of bias:

Other forms of bias are the performance of MT by a non-professional music therapist, the performance of MT and supervision by the same person, and MT not performed according to the definition of MT.