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Music Therapy in Pediatric Asthma Improves Pulmonary Function while Reducing Hospitalizations

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Abstract

Objective. The aim of this study was to evaluate music therapy (MT), in conjunction with standard care, as a complementary option for asthma management in pediatric patients.

Methods. 173 children were randomly assigned to one of three groups: 1) Music: a single individualized MT session along with a recorder and journal with instructions for home use; 2) Music Plus: weekly group MT sessions along with a recorder and journal for home use; or 3) Control: standard of care. Primary endpoints included pulmonary function tests (FEV₁, FVC, FEF₂₅₋₇₅, PEF), hospitalizations, ER visits, missed school days, and quality of life (Juniper).

Results. Significant intergroup differences relative to Controls were observed for FEV₁/FVC (Music and Music Plus, $p < 0.05$) and FEF₂₅₋₇₅ (Music Plus; $p < 0.01$). Music Plus participants experienced fewer hospitalizations compared to Controls ($p < 0.001$), corresponding to 1.16 fewer hospitalizations per patient-year. Caregivers' perception of their children's QOL significantly increased in the Music ($p = 0.011$) and Music Plus ($p < 0.001$) groups compared to Controls.

Conclusion. These results reflect MT's potential to favorably impact pediatric asthma management as a child-friendly, low-risk intervention. Further research is needed to substantiate the possible benefits of incorporating MT into standard treatment regimens.

Keywords: asthma, music therapy, complementary medicine, pediatrics, hospitalizations, pulmonary function, quality of life, deep breathing relaxation

Introduction

Asthma has become the most common chronic illness of childhood in the United States. An average of 1 out of every 10 school aged children in the US have asthma with about 6 million children under the age of 18 affected (1). Increasingly viewed as an emergency room illness (2), asthma results in 1.78 million emergency room visits annually (1) as only 14.3% of patients with mild to moderate asthma using their preventer therapy report good control (3). Given that 54% of expenditure on childhood asthma is for inpatient services and that poor asthma control is correlated to hospital admission and readmission (4), there is an unmet need for an approach that complements regular therapy to prevent asthma exacerbations.

Music therapy (MT) may play a complementary role in the management of asthma. MT is the use of music-based interventions within a therapeutic relationship to accomplish individualized goals (5, 6). A common technique employed in MT is entrainment, a process whereby two oscillating systems assume the same periodicity (7-9). Entrainment utilizes musical vibrations, which when specified at variable pitch and tempo, have been shown to alter heart rate, blood pressure, respiratory rate, and brain activity (EEG), among other physiological variables (5, 10 - 13). Although apparent with recorded music, entrainment may be further enhanced when a music therapist matches a patient's physiological rhythm of respiration and gradually alters the pitch, tempo, dynamics, and tonality (14). Breathing, one of the few physiological processes that can be voluntarily controlled (15), is a prime candidate for such MT intervention (12, 13). Another technique employed in MT is guided visualization, an exercise in which a person's imagination is drawn upon to achieve a certain goal, usually relaxation (16). In MT, Remo ocean drums are often utilized in guided visualization to induce a relaxation response with the sound of ocean waves entrained to patients' respiratory rate. Guided visualization has been shown to reduce anxiety and nausea in patients receiving chemotherapy (16), but there is a paucity of research on its effects in children with asthma.

As it relates specifically to asthma, MT, especially when involving wind instruments, has shown mixed benefits. In children with asthma, consistent practice of a wind instrument as well as singing have been shown to significantly improve spirometry (17, 18, 19). Further, a 30-day wind playing intervention for adolescents with asthma led to improvement in "emotional response to asthma symptoms," based on standardized diary responses (20). In male patients aged 18 to 23, MT decreased bronchial resistance beyond the effects observed in a control group of traditional breathing exercises (21). This evidence can be considered hypothesis-generating and warrants critical examination of the impacts of music both passively (listening) and actively (wind playing and breathing-relaxation strategies) on asthma-related outcomes.

The present study complemented medical care for pediatric asthma with MT. Our hypothesis is that an MT-based intervention, in conjunction with standard care, can reduce primary endpoints of hospitalizations and ER visits in children 6 to 19 years old who suffer from asthma. Secondary endpoints include missed school days, quality of life, and change in pulmonary function as measured by spirometry. Our study outlines a concrete MT approach, designed by an experienced team, and instituted in 5 NYC public schools. Our school clinic-based preventative treatment plan combining traditional pharmacological methods with complementary breathing techniques builds on our former MT studies (5, 6). Such a program potentially provides the medical community with a safe and cost effective approach to utilize MT as a complementary and low risk option in managing pediatric asthma.

Methods

Sample and Control Groups

Our study investigated the use of MT in preventative asthma initiatives at several sites in the Mount Sinai Beth Israel (MSBI) Health Care System's primary care service areas that included residents of 5 inner-city neighborhoods in 4 NYC boroughs. The hospital's primary service areas comprise the Lower East Side/Union Square and Harlem in Manhattan, Melrose in the Bronx, and Greenpoint/Williamsburg and Bedford Stuyvesant/Crown Heights in Brooklyn. Approximately 3,000 pediatric visits at MSBI were asthma-related respiratory problems.

Music therapists worked with 5 NYC Board of Education school sites providing music therapy sessions throughout the school day. The participants were identified by the school nurse and assessed for severity according to past medical history, which included past hospitalizations, ER visits, quality of life, medication compliance, and missed days of school due to asthma exacerbations. All children identified were asked to be in the study. 204 children were randomized 1:1:2 by a blinded statistician between the Music, Music Plus, and Control groups. 173 children completed baseline testing and received one of three 6-month interventions: (1) Music: a single individualized music therapy session and a recorder and journal with instructions for home use (n = 54); (2) Music Plus: weekly group music therapy sessions and a recorder and journal for home use (n = 49); or (3) Control: the standard of care (n = 70). Informed consent was obtained from all participants' parents, and assent was obtained from all participants. This study was approved by the local Institutional Review Board.

Description of the Music Therapy

An integrative music therapy-medical team was comprised of music therapists, pulmonologists, residents, and medical students. MT sessions took place at the schools for 30 minutes during the school day. Children in the Music Group received a single individualized session while those in the Music Plus group received MT each week in a group size of 2 to 6 participants. MT sessions were divided into 3 segments. First, participants completed a deep breathing relaxation warm-up with guided visualization imagery (participants imagined their favorite place) while listening to the therapist play entrained live music (wind, voice, or string instrument as well as ocean drum). During this time, the therapist made a qualitative assessment of how much difficulty the participant had with relaxation and breathing at rest. Through entrainment, the offered meter of the breath was expanded over time to deepen and enhance the participants' breath capacity. Second, the therapist used a piano or guitar to accompany the patient in a free wind or vocal improvisation. The child improvised a piece in a style of his or her choosing. Third, the music therapist engaged in structured play of simple tunes that included four to five note patterns on the recorder, slide whistle, or melodica. The child could choose to play the tunes that utilize simple note patterns with long-held tones such as Hot Cross Buns, Pachelbel Canon, or Jingle Bells (22). The Music and Music Plus group participants were given Yamaha recorders for home use, a music therapeutic orientation protocol, and a diary and asthma log for daily use. The logs were updated and evaluated at subsequent visits.

Data Collection

Enrollment occurred from September to January with follow-up at 6 months. Children and their caregivers were interviewed at school at month 1 (entry, pre-intervention) and month 6 (post-intervention). ER visits and hospitalizations within the prior 6 months preceding the intervention and prior 6 months preceding the conclusion of the intervention were tracked through these interviews. Missed days of school in the 1 month preceding the intervention and the 1 month preceding the conclusion of the intervention were tracked using school attendance records as well as through contacting parents, school nurses, and teachers. Participants and their

caregivers were also asked to maintain an asthma diary (all groups) and music chart (Music and Music Plus groups only) as part of their treatment record, which noted medications taken, side effects, symptoms, days missed from school, visits to their school nurse or doctor, hospitalizations, and ER visits. Spirometry results were measured by pulmonary function testing conducted at the school by a blinded research assistant at month 1 and month 6. To measure the children's quality of life, participants and their caregiver(s) were asked to complete the Pediatric Asthma Quality of Life Questionnaire (PAQLQ) and Pediatric Asthma Caregiver's Quality of Life Questionnaire (PACQLQ) surveys, respectively (23). These questionnaires were completed at month 1 (pre-intervention) and month 6 (post-intervention).

Data Analysis

Data were collected over the 6-month study period. To calculate the change in spirometry values, hospitalizations, ER visits, and missed school days after the 6-month study, the month 1 data was subtracted from the month 6 data. The median of the differences with respect to each group was found. The non-parametric Dunn's Test was used to compare the median difference of each group. The Bonferroni adjustment was used to account for multiple comparisons.

Due to the normal distribution of the PAQLQ and PACQLQ scores, parametric testing was used for QOL data analysis. The month 1 scores were subtracted from the month 6 scores. The mean of the differences with respect to each group was found. Parametric t-tests were used to compare the mean difference of each group.

An initial power analysis showed that 40 subjects in each comparison group allowed for detection of a medium-large effect size of 0.63 with $\geq 80\%$ power. The final samples of 47 and 48 subjects allowed for 86% power to detect an effect size as earlier specified.

All patient data were analyzed, except in cases where outcome data were unavailable due to patient dropout. The attrition rates were 33%, 4%, and 31% for the Music, Music Plus, and Control groups, respectively. An additional participant was lost to follow up in the Music Plus Group for PAQLQ measurement only, which corresponds to an attrition rate of 6% for Music Plus PAQLQ; however, their caregiver did complete the PACQLQ which was included in the study.

The analyzed group and excluded group did not differ significantly with respect to age, sex, race, BMI, income, baseline spirometry values, number of hospitalizations / ER visits within the 6 months preceding the study, number of missed school days in the 1 month preceding the study, or asthma severity ($p < 0.05$).

Results

173 asthmatic children participated in this study. 54 participants were randomly assigned to the Music group, 49 to the Music Plus group, and 70 to the Control group. The three groups did not significantly differ in BMI, initial spirometry values, number of hospitalizations / ER visits within the 6 months preceding the study, number of missed school days in the 1 month preceding the study, and PAQLQ / PACQLQ scores (Kruskal-Wallis rank sum, $p > .05$). The Music group significantly differed from the Control group in age and height (Dunn's test, $p < .05$). Table 1 summarizes all baseline data.

Spirometry

The respective -3.0 and -8.5 median decreases in FEV₁/FVC and Forced Expiratory Flow (FEF₂₅₋₇₅) observed in the Control group significantly differed from the +2.0 and +7.0 median increases observed in the Music Plus group (Dunn's Test, $p = 0.016$) (Dunn's Test, $p = 0.009$). The -3.0 median decrease in FEV₁/FVC observed in the Control group significantly differed from the +1.5 median increase observed in the Music Group (Dunn's Test, $p = .026$). Table 2 summarizes the spirometry data analysis. Figure 1 illustrates the intergroup differences in the change of spirometry values after 6 months.

Hospitalizations, Missed School Days, and ER Visits

The +0.13 mean increase in hospitalizations observed in the Control group significantly differed from the -0.45 mean decrease observed in the Music Plus group (Dunn's Test, $p = .0007$), corresponding to 1.16 fewer hospitalizations per patient-year. Compared to the month 1 baseline, the Music Plus group had significantly fewer hospitalizations (Dunn's test, $p = .0034$), missed school days (Dunn's test, $p = .022$), and ER visits (Dunn's test, $p = .027$) at month 6. Table 3 summarizes the means and analysis of hospitalizations, missed school days, and ER visits. Figure 2 illustrates the intergroup differences of the means of ER visits, hospitalizations, and missed school days.

Quality of Life

No intergroup differences in the change of PAQLQ scores after 6 months were observed. The -0.10 mean decrease in total PACQLQ score of the Control group was significantly different than the respective +0.67 and +0.86 increases observed in the Music (Welch two sample t-test, $p = .011$) and Music Plus (Welch two sample t-test, $p = .0008$) groups. Table 4 summarizes the QOL data. Figure 3 illustrates the intergroup differences in change of PACQLQ over 6 months.

It is important to note that the minimum change in PAQLQ / PACQLQ score necessary for clinical significance is generally accepted to be ± 0.5 . Table 4 shows that changes > 0.5 were observed in both the Music and Music Plus groups for all domains of the PAQLQ and PACQLQ. No changes > 0.5 were observed in the Control group with the exception of the +0.54 increase of emotional function PAQLQ score (Table 4).

Discussion

This study investigated the complementary use of music therapy in the management of pediatric asthma. The study identified the impact of MT on spirometry, hospitalizations, ER visits, missed school days, and QOL. The hypothesis that a weekly MT intervention in conjunction with standard care would improve management of asthma relative to standard care, alone, was supported by this study. These results reflect MT's potential to have a favorable impact as an intervention in the management of pediatric asthma across multiple functional domains.

Spirometry

The MT intervention protected the Music and Music Plus participants from the worsening lung function observed in the Control group. While the FEV₁/FVC, FEF₂₅₋₇₅, and PEF of the Control group decreased over the 6 month course of the study, the FEV₁/FVC, FEF₂₅₋₇₅, and PEF of the Music and Music Plus groups stayed constant with significant intergroup differences relative to Controls observed for FEV₁/FVC (Music & Music Plus groups) and FEF₂₅₋₇₅ (Music Plus group). Since spirometry results have been shown to affect treatment decisions and predict disease severity in pediatric populations (24,25), our findings contribute to the literature showing the positive effect of MT interventions on pulmonary function and, consequently, the management of pediatric asthma.

Further research is needed to discern the mechanism by which lung function improved. It is possible that the act of routinely playing wind instruments and singing may have led to physiological adaptations that improved pulmonary function. Previous research has shown that professional wind players possess a greater baseline lung vital capacity (VC) than non-wind player matched controls (26). Children with asthma have shown an increase in FEV₁ and FVC after playing a wind instrument relative to asthmatic children who did not play wind instruments (27,28). Furthermore, singing has resulted in maintained or increased PEF in children with asthma (18) and improvements in spirometry have also been seen with music-assisted breathing exercises (21).

However, it is also possible that MT improved lung function through a behavioral mechanism in which medication adherence and proactive management of symptoms were encouraged. Positive reinforcement systems have been shown to motivate pediatric adherence to treatment regimens (29-31). Playing a musical wind instrument provides an inherently child-friendly and low risk option, though it has rarely been associated with risk of barotrauma (32). Musical exploration has been shown to elicit the potential for reward and motivation, especially through increasing activity in the paralimbic system (33, 34). Given that there is little incentive for children to continue monitoring their breathing once asthma symptoms have diminished (35,36), an intervention that encourages ongoing self-monitoring could be instrumental in exacerbation prevention (37).

Hospitalizations

The Music Plus group also experienced significantly fewer hospitalizations relative to the Control group. As asthma accounts for 439,000 hospitalizations annually in the US, interventions that can improve control may lead to a reduction in hospitalizations, missed school days, and ER visits. This MT intervention was able to accomplish this as participants in the Music Plus group had 1.16 fewer hospitalizations per patient-year compared to the Control group. Concordantly, a previous case-control study showed that playing a wind instrument decreased the number of ER visits in teenagers with asthma (20). Given that 54% of expenditures on childhood asthma are for inpatient services and poor asthma control is correlated to hospital admission and readmission (4), this sort of MT intervention has the potential for large-scale public health benefits.

Quality of Life

Additionally, caregivers in the Music and Music Plus groups reported significantly improved perceptions of their children's QOL compared to their counterparts in the Control group, though there were no significant intergroup differences in children's perceptions of their own QOL. QOL has a strong association with asthma control (38). Breathing retraining

programs have been shown to significantly improve quality of life in patients whose asthma was not adequately controlled by pharmacological methods, alone (39). Furthermore, Music assisted breathing exercises have been shown to improve psychological well-being (21). In addition, non-wind instrument playing controls reported more days of panic and fear in response to the physical symptoms of asthma as compared to wind playing counterparts (20). While little research exists showing the effects of MT on QOL, this study puts forth early evidence of its potential to improve QOL in a pediatric disease.

Limitations

While this MT intervention demonstrated success in many ways, there were limitations. Ideal assessment of hospitalizations and ER visits would be best achieved through medical chart review. Instead, this study relied on self-report through logs, interviews of parents and teachers, as well as diaries for data collection. Future MT research could utilize asthma logs to include data on adherence to asthma therapy to determine whether this may be a potential mechanism of improved outcomes. Though we demonstrated decreased hospitalization and ER visitation rates, further delineation of the severity of hospitalizations and ER visits may substantiate more fully the utility of MT. Further, these effect sizes are small, and this study does not account for other potential confounders, including pollution, socioeconomic status, sick contacts, and comorbidities.

Lastly, this study assessed the effects of the sum of the intervention rather than the relative contributions of its constituent parts. Based on the design of this study, it is unclear whether MT provides a benefit beyond the value of a weekly activity for children with asthma, but the Music group in this study and previous research illustrate its utility specific to pediatric asthma (17-21). Further, MT was administered using the “music as a group activity” technique, inclusive of entrained music listening along with active music participation to facilitate social interaction. Although the MT intervention was standardized in this study, the provision of MT is often specified to demographics, nature of illness, context of intervention, familiarity of MT, and relationship between music therapist and participant in a manner that other school-based activities are not. The individualized approach that MT follows in hospital and outpatient settings justified our multifaceted approach in this study for the purpose of external validity (40). This does, however, make it difficult to predict whether an MT approach with a different structure and constellation of activities would offer similarly positive outcomes.

Conclusion

In sum, this study adds supporting evidence that substantiates the role of MT as an indicated complementary treatment for pediatric asthma. In this randomized control trial, music therapy, administered in conjunction with standard care, significantly improved lung function, decreased hospitalizations, and elevated quality of life relative to standard care, alone. Complementary and alternative medicine has been increasing in utilization for asthma self-management (41). At the current time, there is evidence that MT can be used in conjunction with medication to improve outcomes. Future studies should investigate longer-term impacts of MT interventions on treatment adherence and disease progression to inform the potential for incorporation of MT into standard treatment regimens and current management guidelines.

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Declaration of Interests

No potential conflict of interest.

Citations

1. Center for Disease Control and Prevention. Most recent national asthma data https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm. Updated 2018. Accessed Aug 11, 2019.
2. Alpern ER, Clark AE, Alessandrini EA, et al. Recurrent and high-frequency use of the emergency department by pediatric patients. *Acad Emerg Med*. 2014;21(4):365-373. doi: 10.1111/acem.12347 [doi].
3. Colice GL, Ostrom NK, Geller DE, et al. The CHOICE survey: High rates of persistent and uncontrolled asthma in the united states. *Ann Allergy Asthma Immunol*. 2012;108(3):157-162. doi: 10.1016/j.anai.2011.12.017 [doi].
4. Visitsunthorn N, Lilitwat W, Jirapongsananuruk O, Vichyanond P. Factors affecting readmission for acute asthmatic attacks in children. *Asian Pac J Allergy Immunol*. 2013;31(2):138-141. doi: 10.12932/AP0247.31.2.2013 [doi].
5. Loewy J. Respiratory care for children. *Guidelines for music therapy practice in pediatric care*. 2013:403-441.
6. Canga B, Azoulay R, Raskin J, Loewy J. AIR: Advances in Respiration–Music therapy in the treatment of chronic pulmonary disease. *Respir Med*. 2015;109(12):1532-1539.
7. Manning FC, Harris J, Schutz M. Temporal prediction abilities are mediated by motor effector and rhythmic expertise. *Exp Brain Res*. 2017;235(3):861-871. doi: 10.1007/s00221-016-4845-8 [doi].

8. Lakatos P, Karmos G, Mehta AD, Ulbert I, Schroeder CE. Entrainment of neuronal oscillations as a mechanism of attentional selection. *Science*. 2008;320(5872):110-113. doi: 10.1126/science.1154735 [doi].
9. Ramirez JP, Olvera LA, Nijmeijer H, Alvarez J. The sympathy of two pendulum clocks: Beyond Huygens' observations. *Scientific reports*. 2016;6:23580.
10. Bernardi L, Porta C, Bernardi NF, Sleight P. S12. music and the autonomic nervous system: S12. 1 dynamic interactions between musical, cardiovascular and cerebral rhythms in man. *Autonomic Neuroscience: Basic and Clinical*. 2009;149(1):42-43.
11. Fachner JC, Maidhof C, Grocke D, et al. '... Telling me not to worry...'Hyperscanning and neural dynamics of emotion processing during guided imagery in music. *Frontiers in Psychology*. 2019;10:1561.
12. Laczika K, Graber OP, Tucek G, et al. "Il flauto magico" still works: Mozart's secret of ventilation. *Multidisciplinary respiratory medicine*. 2013;8(1):23.
13. Bernardi L, Porta C, Sleight P. Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: The importance of silence. *Heart*. 2006;92(4):445-452.
14. Thaut MH, McIntosh GC, Hoemberg V. Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. *Frontiers in psychology*. 2015;5:1185.
15. Luu BL, Saboisky JP, Taylor JL, Gandevia SC, Butler JE. TMS-evoked silent periods in scalene and parasternal intercostal muscles during voluntary breathing. *Respiratory physiology & neurobiology*. 2015;216:15-22.
- 16) Karagozoglu, Serife, Filiz Tekyasar, and Figen Alp Yilmaz. "Effects of music therapy and guided visual imagery on chemotherapy- induced anxiety and nausea–vomiting." *Journal of clinical nursing* 22.1-2 (2013): 39-50.
17. Marks MB. The 1974 bela schick memorial lecture. musical wind instruments in rehabilitation of asthmatic children. *Ann Allergy*. 1974;33(6):313-319.
18. Wade LM. A comparison of the effects of vocal exercises/singing versus music-assisted relaxation on peak expiratory flow rates of children with asthma. *Music therapy perspectives*. 2002;20(1):31-37.

19. Eley R, Gorman D. Didgeridoo playing and singing to support asthma management in aboriginal australians. *The Journal of Rural Health*. 2010;26(1):100-104.
20. Lucia R. Effects of playing a musical wind instrument in asthmatic teenagers. *Journal of Asthma*. 1994;31(5):375-385.
21. Janiszewski M, Kronenberger M, Drozd B. Studies on the use of music therapy as a form of breathing exercise in bronchial asthma. *Polski merkuriusz lekarski: organ Polskiego Towarzystwa Lekarskiego*. 1996;1(1):32-33.
22. Fried R. Integrating music in breathing training and relaxation: II. applications. *Biofeedback Self*. 1990;15(2):171-177.
23. Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in the parents of children with asthma. *Quality of Life Research*. 1996;5(1):27-34.
24. Nair SJ, Daigle KL, DeCuir P, Lapin CD, Schramm CM. The influence of pulmonary function testing on the management of asthma in children. *J Pediatr*. 2005;147(6):797-801.
25. Ramsey CD, Celedón JC. The hygiene hypothesis and asthma. *Curr Opin Pulm Med*. 2005;11(1):14-20.
26. Bouhuys A. Lung volumes and breathing patterns in wind-instrument players. *J Appl Physiol*. 1964;19(5):967-975.
27. Andrew W. Bronchial boogie. *Community practitioner*. 2006;79(3):78.
28. Eley R, Gorman D. Didgeridoo playing and singing to support asthma management in aboriginal australians. *The Journal of Rural Health*. 2010;26(1):100-104.
29. Rapoff MA, Lindsley CB, Christophersen ER. Improving compliance with medical regimens: Case study with juvenile rheumatoid arthritis. *Arch Phys Med Rehabil*. 1984;65(5):267-269.
30. Greenan-Fowler E, Powell C, Varni JW. Behavioral treatment of adherence to therapeutic exercise by children with hemophilia. *Arch Phys Med Rehabil*. 1987;68(12):846-849.
31. Magrab PR, Papadopoulou ZL. The effect of a token economy on dietary compliance for children on hemodialysis. *J Appl Behav Anal*. 1977;10(4):573-578. doi: 10.1901/jaba.1977.10-573 [doi].

32. Kyung SK, Heurtebise F, Godon A, Rivière M, Coatrieux A. Head-neck and mediastinal emphysema caused by playing a wind instrument. *European annals of otorhinolaryngology, head and neck diseases*. 2010;127(6):221-223.
33. Blood AJ, Zatorre RJ. Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Sciences*. 2001;98(20):11818-11823.
34. Blood AJ, Zatorre RJ, Bermudez P, Evans AC. Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions. *Nat Neurosci*. 1999;2(4):382.
35. Penza-Clyve SM, Mansell C, McQuaid EL. Why don't children take their asthma medications? A qualitative analysis of children's perspectives on adherence. *J Asthma*. 2004;41(2):189-197.
36. Rhee H, Belyea MJ, Ciurzynski S, Brasch J. Barriers to asthma self-management in adolescents: Relationships to psychosocial factors. *Pediatr Pulmonol*. 2009;44(2):183-191. doi: 10.1002/ppul.20972 [doi].
37. Modi AC, Pai AL, Hommel KA, et al. Pediatric self-management: A framework for research, practice, and policy. *Pediatrics*. 2012;129(2):473. doi: 10.1542/peds.2011-1635 [doi].
38. Vollmer WM, Markson LE, O'CONNOR E, et al. Association of asthma control with health care utilization and quality of life. *American Journal of Respiratory and Critical Care Medicine*. 1999;160(5):1647-1652.
39. Bruton A, Lee A, Yardley L, et al. Physiotherapy breathing retraining for asthma: A randomised controlled trial. *The Lancet Respiratory Medicine*. 2018;6(1):19-28.
40. Preti, Costanza, and Graham F. Welch. "Music in a hospital setting: a multifaceted experience." *British Journal of Music Education* 21.3 (2004): 329-345.
41. George M, Topaz M. A systematic review of complementary and alternative medicine for asthma self-management. *Nursing Clinics*. 2013;48(1):53-149.

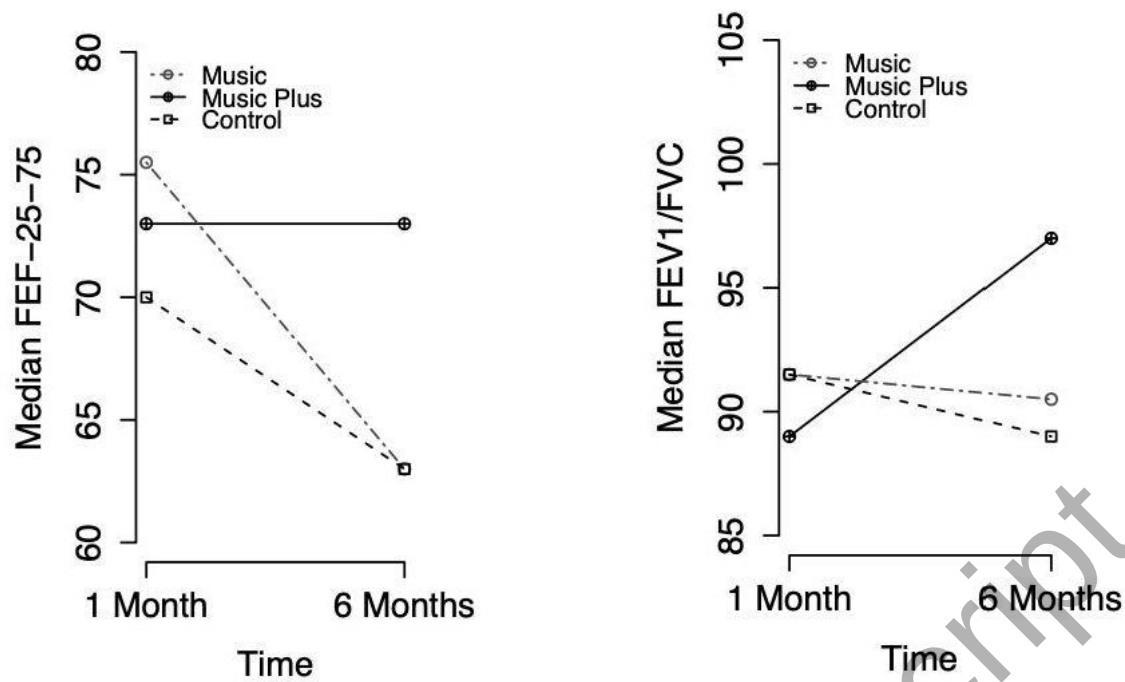


Figure 1. Median spirometry values at month one and month six for the Music, Music Plus, and Control groups.

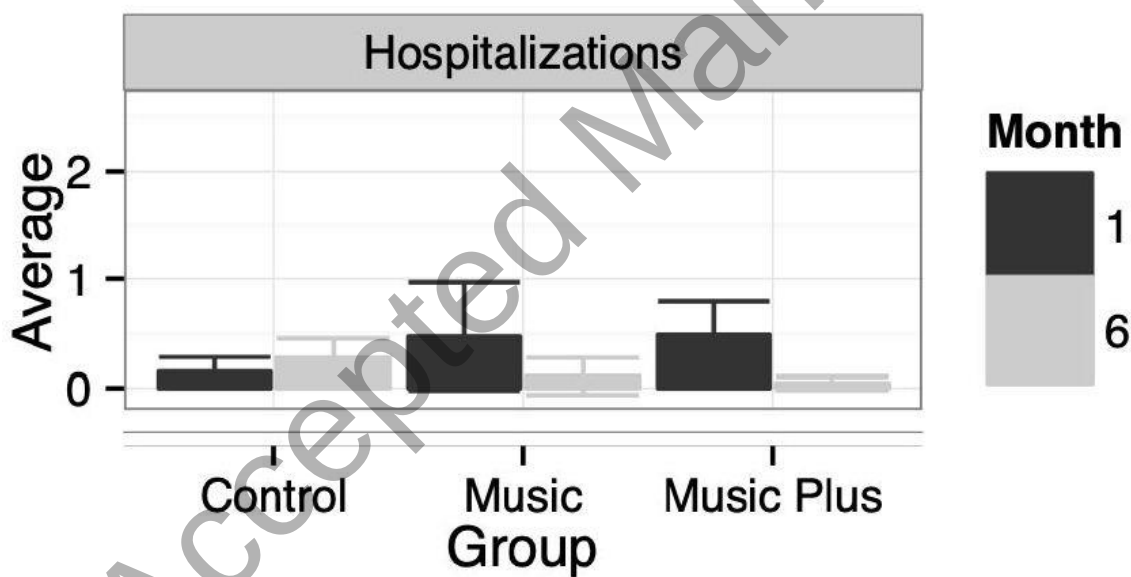


Figure 2. Means and error bar charts for hospitalizations that occurred in the six months preceding month one and month six.

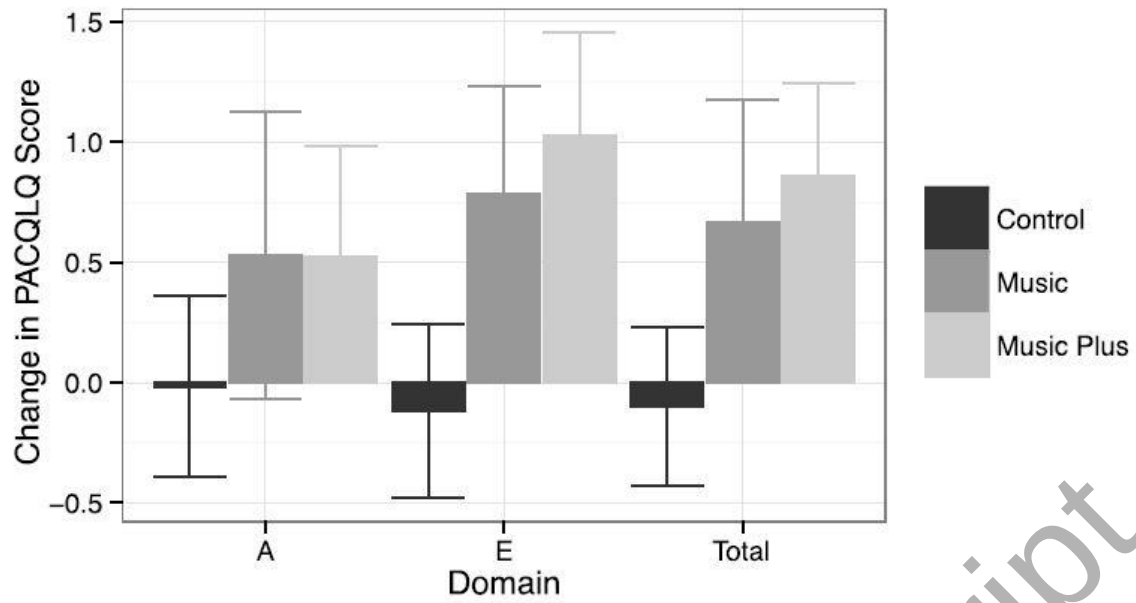


Figure 3. Mean and error bar charts of the change in PACQLQ scores after six months.

Table 1. Participant characteristics at enrollment.

		Music	Music Plus	Control	$P^{M,MP,C}$
<i>n</i> (%)		54 (31.2%)	49 (28.3%)	70 (40.5%)	
Male/Female (<i>n</i>)		25/29	35/14	44/26	
Age (years); mean (SD)		10.90 (2.84)	9.87 (2.62)	9.20 (2.22)	.002
Height (cm); mean (SD)		144.93 (16.17)	140.04 (12.06)	136.69 (13.31)	.012
BMI (kg/m ²); mean (SD)		23.50 (7.07)	20.93 (6.25)	21.58 (6.51)	.10
Income Level (<i>n</i>)	< \$19,000	12	11	14	
	\$20 – 49,000	21	11	23	
	> \$50, 000	8	13	17	
	Not Reported	13	14	13	
Race/Ethnicity (<i>n</i>) *	Black	24	15	22	
	Hispanic	26	28	40	
	White	5	9	13	
	Other	6	1	6	
Asthma Severity (<i>n</i>)	Intermittent	31	25	43	
	Mild Per.	6	7	11	
	Moderate Per.	8	13	14	
	Severe Per.	9	4	2	
Hospitalizations; mean (SD)		0.47 (1.50)	0.49 (1.04)	0.15 (0.46)	.14
Missed School Days; mean (SD)		1.05 (1.43)	1.26 (2.10)	1.43 (2.55)	.42
ER Visits; mean (SD)		1.13 (2.03)	0.63 (0.88)	0.50 (0.90)	.99
PAQLQ score; mean (SD)	Total	4.13 (1.18)	4.45 (1.13)	4.18 (1.17)	.32
	Activity	3.98 (1.27)	4.09 (1.06)	3.98 (1.20)	.83
	Symptom	4.16 (1.20)	4.48 (1.28)	4.30 (1.35)	.36
	Emotion	4.18 (1.55)	4.61 (1.32)	4.28 (1.43)	.24
PACQLQ score; mean (SD)	Total	4.83 (1.43)	4.77 (1.38)	5.18 (1.37)	.28
	Activity	4.88 (1.57)	4.85 (1.67)	5.26 (1.71)	.38
	Emotion	4.75 (1.53)	4.70 (1.42)	5.09 (1.35)	.34
Spirometry values (%);	FVC	86.5 (80.7, 92.3)	91.0 (86.74, 95.3)	94.0 (88.9, 99.1)	.33
median (95% CI)	FEV ₁	82.0 (74.2, 89.8)	81.0 (75.8, 86.2)	85.5 (80.4, 90.6)	.54

	FEV ₁ /FVC	91.5 (85.9, 97.1)	89.0 (84.5, 93.5)	91.5 (88.3, 94.7)	.98
	FEF ₂₅₋₇₅	75.5 (63.1, 87.9)	73.0 (65.6, 80.4)	70.0 (63.2, 76.8)	.87
	PEF	70.5 (59.2, 81.8)	61.0 (54.3, 67.7)	69.5 (63.9, 75.1)	.49

Notes: p = p value, n = sample size, $p^{M,MP,C}$ = difference between music, music plus, and control groups. “BMI” =

Body mass index, “CI” = confidence interval, “SD” = standard deviation, “FVC” = forced vital capacity, “FEV₁” =

forced expiratory volume, “FEV₁/FVC” = FEV₁ FVC ratio, “FEF₂₅₋₇₅” = forced expiratory flow from 25% to 75% of

FVC, “PEF” = peak expiratory flow, “ER” = emergency room, . “PAQLQ” = Pediatric Asthma Quality of Life

Questionnaire, “PACQLQ” = Pediatric Asthma Caregiver Quality of Life Questionnaire. Spirometry values represent

percentages of expected values given age, height, and sex. *Those who identify as both hispanic and

black/white/other are double counted.

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Table 2. Comparison of spirometry values for Music, Music Plus, and Control Groups.

		Music	Music Plus	Control	p^M	p^{MP}	p^C
		$n = 36$	$n = 47$	$n = 48$			
Spirometry values (%)	FVC	86.5 (80.7, 92.3)	91.0 (86.74, 95.3)	94.0 (88.9, 99.1)	-	-	-
at month 1	FEV ₁	82.0 (74.2, 89.8)	81.0 (75.8, 86.2)	85.5 (80.4, 90.6)	-	-	-
median (95% CI)	FEV ₁ /FVC	91.5 (85.9, 97.1)	89.0 (84.5, 93.5)	91.5 (88.3, 94.7)	-	-	-
	FEF ₂₅₋₇₅	75.5 (63.1, 87.9)	73.0 (65.6, 80.4)	70.0 (63.2, 76.8)	-	-	-
	PEF	70.5 (59.2, 81.8)	61.0 (54.3, 67.7)	69.5 (63.9, 75.1)	-	-	-
Spirometry values (%)	FVC	87.0 (81.9, 92.1)	91.0 (85.8, 96.2)	95.5 (91.9, 99.2)	.64	.74	.62
at month 6	FEV ₁	81.5 (75.8, 87.2)	85.0 (79.6, 90.4)	78.5 (73.9, 83.1)	.52	.83	.06
median (95% CI)	FEV ₁ /FVC	90.5 (87.3, 93.7)	97.0 (93.7, 100.3)	89.0 (86.4, 91.6)	.26	.10	.043
	FEF ₂₅₋₇₅	63.0 (54.1, 71.9)	73.0 (64.0, 82.0)	63.0 (56.2, 69.8)	.94	.31	.0004
	PEF	64.0 (58.1, 69.9)	66.0 (61.2, 70.8)	61.0 (55.6, 66.4)	.91	.44	.035
					p^1	p^2	p^3
Change in	FVC	5.0 (-1.4, 11.4)	3.0 (-2.9, 8.9)	2.5 (-0.9, 5.9)	.63	.97	1.0
spirometry values (%)	FEV ₁	1.5 (-6.0, 9.0)	1.0 (-4.0, 6.0)	0.0 (-3.6, 3.6)	.94	.23	.47
median (95% CI)	FEV ₁ /FVC	1.5 (-3.9, 6.9)	2.0 (-0.8, 4.8)	-3.0 (-5.1, -1.0)	1.0	.026	.016
	FEF ₂₅₋₇₅	0.5 (-11.8, 12.8)	7.0 (-1.2, 15.2)	-8.5 (-13.1, -2.9)	.76	.088	.009

	PEF	0.0 (-8.2, 8.2)	2.0 (-3.7, 7.7)	-4.0 (-8.9, 1.0)	0.28	.10
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Notes: p = p value, n = sample size, p^M = difference between month six and month one for music, p^{MP} = difference between month six and month one for music plus, p^C = difference between month six and month one for control, p^1 = difference between music and music plus, p^2 = difference between music and control, p^3 = difference between music plus and control. “CI” = confidence interval, “FVC” = forced vital capacity, “FEV₁” = forced expiratory volume, “FEV₁/FVC” = FEV₁ FVC ratio, “FEF₂₅₋₇₅” = forced expiratory flow from 25% to 75% of FVC, “PEF” = peak expiratory flow. Spirometry values represent percentages of expected values given age, height, and sex.

Table 3. Comparison of hospitalizations, missed school days, and ER visits between groups.

		Music	Music Plus	Control	p^M	p^{MP}	p^C
		$n = 38$	$n = 47$	$n = 48$			
Month 1 total;	Hospitalizations	0.47 (1.50)	0.49 (1.04)	0.15 (0.46)	-	-	-
Mean (SD)	Missed School Days	1.05 (1.43)	1.26 (2.10)	1.43 (2.55)	-	-	-
	ER Visits	1.13 (2.03)	0.63 (0.88)	0.50 (0.90)	-	-	-
Month 6 total;	Hospitalizations	0.11 (0.51)	0.04 (0.20)	0.27 (0.64)	.10	.0034	.14
Mean (SD)	Missed School Days	1.27 (2.65)	0.51 (1.21)	1.74 (2.99)	.58	.022	.71
	ER Visits	0.55 (1.20)	0.28 (0.62)	0.50 (0.90)	.06	.027	1.0
					p^1	p^2	p^3
Change;	Hospitalizations	-0.37 (1.44)	-0.45 (1.02)	0.13 (0.57)	.26	.08	.0007
Mean (SD)	Missed School Days	0.22 (2.87)	-0.74 (2.30)	0.32 (2.32)	.34	1.0	.17
	ER Visits	-0.58 (1.88)	-0.35 (0.92)	0 (1.03)	1.0	.24	.09

Notes: p = p value, n = sample size, p^M = difference between month six and month one for music, p^{MP} = difference between month six and month one for music plus, p^C = difference between month six and month one for control, p^1 = difference between music and music plus, p^2 = difference between music and control, p^3 = difference between music plus and control. “ER” = Emergency Room. All hospitalizations and ER visits occurred within the prior six months to completing the survey. All missed school days occurred within the prior one month to completing the survey.

Table 4. Comparison of quality of life scores by group.

		Music	Music Plus	Control	p^M	p^{MP}	p^C
<i>Child</i>		$n = 38$	$n = 46$	$n = 47$			
PAQLQ score	Total	4.13 (1.18)	4.45 (1.13)	4.18 (1.17)	-	-	-
at month 1	Activity	3.98 (1.27)	4.09 (1.06)	3.98 (1.20)	-	-	-
mean (SD)	Symptom	4.16 (1.20)	4.48 (1.28)	4.30 (1.35)	-	-	-
	Emotion	4.18 (1.55)	4.61 (1.32)	4.28 (1.43)	-	-	-
PAQLQ score	Total	4.97 (1.23)	5.09 (1.25)	4.59 (1.15)	.0001	< .0001	.002
at month 6	Activity	4.67 (1.34)	4.72 (1.31)	4.36 (1.26)	.0087	.0008	.034
mean (SD)	Symptom	5.00 (1.36)	5.13 (1.29)	4.62 (1.42)	.0002	.0002	.055
	Emotion	5.23 (1.64)	5.37 (1.48)	4.82 (1.37)	.0002	< .0001	.0012
<i>Caregiver</i>		$n = 38$	$n = 47$	$n = 46$			
PACQLQ score	Total	4.83 (1.43)	4.77 (1.38)	5.18 (1.37)	-	-	-
at month 1	Activity	4.88 (1.57)	4.85 (1.67)	5.26 (1.71)	-	-	-
mean (SD)	Emotion	4.75 (1.53)	4.70 (1.42)	5.09 (1.35)	-	-	-
PACQLQ score	Total	5.50 (1.54)	5.63 (1.27)	5.08 (1.60)	.012	< .0001	.54
at month 6	Activity	5.41 (1.65)	5.37 (1.73)	5.24 (1.76)	.08	.026	.93
mean (SD)	Emotion	5.53 (1.57)	5.72 (1.14)	4.97 (1.66)	.0011	< .0001	.52
					p^1	p^2	p^3
Change in	Total	0.83 (1.20)	0.63 (0.98)	0.42 (0.88)	1.00	.23	.69
PAQLQ score	Activity	0.69 (1.53)	0.60 (1.18)	0.38 (1.20)	1.00	.95	.96
mean (SD)	Symptom	0.85 (1.25)	0.64 (1.08)	0.34 (1.19)	1.00	.19	.62
	Emotion	1.05 (1.58)	0.72 (1.20)	0.54 (1.07)	1.00	.27	1.00
Change in	Total	0.67 (1.55)	0.86 (1.32)	-0.10 (1.11)	1.00	.011	.0008
PACQLQ score	Activity	0.53 (1.81)	0.53 (1.57)	-0.02 (1.27)	1.00	.37	.21
mean (SD)	Emotion	0.78 (1.37)	1.03 (1.48)	-0.12 (1.22)	1.00	.006	.0003

Notes: p = p value, n = sample size, p^M = difference between month six and month one for music, p^{MP} =

difference between month six and month one for music plus, p^C = difference between month six and month one for

control, p^1 = difference between music and music plus, p^2 = difference between music and control, p^3 = difference

between music plus and control. "PAQLQ" = Pediatric Asthma Quality of Life Questionnaire, "PACQLQ" =

Pediatric Asthma Caregiver Quality of Life Questionnaire, "SD" = standard deviation.

