Active production of music as distraction for venipuncture in children and adolescents: a randomized clinical trial

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Abstract

More than 50% of children report considerable pain during venipuncture or intravenous cannulation. Despite the tools and techniques may be employed to reduce pain and distress in everyday clinical practice, the care offered is frequently insufficient. Music's potential effect in healthcare settings has received increasing attention. This study aimed to verify if the active production of music with a Leap Motion Controller could help decreasing pain and distress during venipuncture in children and adolescents. We conducted an open-label randomized controlled clinical trial with parallel arms. Children aged 8 to 17 were enrolled at the blood-drawing center of the Institute for Maternal and Child Health IRCCS Burlo Garofolo of Trieste, Italy. We hypothesized that in order to demonstrate an adequate improvement in the pain score in the intervention group, at least 200 children, 100 in each group, were needed, with alpha 5% and 1-beta 80%. Differences between the groups were evaluated with the nonparametric Mann–Whitney U-test. The subjects were randomly assigned either to the active production of music group or to the standard of care group. The primary outcome was the median self-reported procedural pain score between experimental and standard of care group. Secondary outcomes were: the median pain and distress scores according to parental judgment and operators' judgment between the experimental and control group. Three hundred subjects entered the study and were randomized, 150 in the active production of music group and 150 in the standard of care group. Median self-reported pain scores were 1 (0–2) in the active production of music group and 2 (1–2) in the standard of care group and this difference was statistically significant ($p=0.0016$). Median procedural distress was 1 (0–3) in the active production of music group and 3 (1–6) in the standard of care group, according to parental judgment, and this difference was statistically significant ($p=0.0000016$).

Conclusion: This research showed that the active production of music is a valuable distraction technique to decrease venipuncture related pain and distress in children and adolescents.

Trial registration: The study protocol was registered with ClinicalTrial.gov (June 28[th] 2022, NCT05441241) before the start of the subjects' enrolment.

What is Known:

- *The benefits of music on pain and anxiety are well known and have been tested during different painful procedures.*
- *The effect of active production of music has never been tested in children during venipuncture.*

What is New:

- *In our study median self-reported pain scores and median procedural distress, according to parental judgment, were lower in the active production of music group than in the standard of care group and these differences were statistically significant.*

Keywords Pain · Venipuncture · Children · Distress · Music

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Introduction

Venipuncture and peripheral intravenous cannulation are the most frequent procedures carried out in children in daily practice, and they often result in significant pain and discomfort [1]. Unmanaged pain can have detrimental consequences

at every age during childhood [2, 3]. Despite the tools and simple actions that may be employed to reduce pain and distress in everyday clinical practice, the care offered during these procedures is frequently insufficient [4, 5].

Distraction, relaxation, suggestion, hypnosis, and cognitive behavioral therapy are psychological methods employed to reduce procedural distress and pain during needle procedures [1].

Distraction involves engaging children in cognitive or behavioral tasks to divert attention from painful stimuli. According to the attention-control mechanism, distraction is supposed to take advantage of the inability of the child to focus on more than one meaningful stimulus at the same time [6].

Distraction techniques include active and passive methods and may employ technological tools. Passive distraction methods use visual and or auditory stimulation, such as watching a video or listening to music. On the other hand, active distraction requires the subjects to be actively involved and use multisensory and motor responses. High-tech methods such as virtual reality or computer games are effective [7, 8], but there is no clear evidence that they are more efficacious than low-tech methods [9]. Music's potential effect in healthcare settings has received more and more attention in recent years [10]. Evidence suggests that music offers therapeutic benefits for pain, stress, and anxiety and may be more cost-effective than other conventional therapy from both a clinical and economic standpoint [11].

Music is one of the most immediate communication tools. Music activates the dopaminergic mesolimbic system, which regulates memory, attention, executive functions, motivation, mood, and pleasure. It can produce measurable cardiovascular and endocrine responses [12–15]. Several studies and reviews regarding music therapy and music medicine interventions for patients undergoing various procedures showed positive results for pain and distress reduction [12, 18–25]. In these studies, music was employed mainly as a passive tool with patients listening to pre-recorded music or following a music therapist. A review published in 2015 selected seven studies performed on children undergoing needle procedures such as venipuncture (one study), peripheral intravenous cannulation (two), vaccination (two), and lumbar puncture (one) [24]. In particular, Hartling et al. (2013) investigated pain and distress in intravenous cannulation in children 3–11 years old. They found a significantly smaller increase in pain in the group with an intervention with the listening of recorded music during procedures, selected by the researcher, compared to the group with standard of care.

Balan et al. [16] investigated venipuncture for blood collection in children 5–12 years old, comparing a group with recorded music selected by the researcher, a group with local anesthetic and a group with placebo cream. They did not find significantly differences in self-reported pain in the three groups. However, they found a little reduction of pain rated by parents, by the investigator and by an independent observer in the music group.

A subsequent pediatric trial revealed that listening to music was as effective as distraction with cards during venipuncture [25].

Data regarding the impact of music on pain and distress during needle procedures in children are anyway limited [16–18, 26], and no studies investigated the role of active production of music in this clinical contest.

Therefore, we investigated if the active production of music with a Leap Motion Controller helps decreasing pain and distress during venipuncture in children.

Material and methods

Study design

This study was an open-label, randomized controlled clinical trial with parallel arms and was conducted from July to October 2022.

Participants and setting

Eligible subjects were children and adolescents from 8 to 17 years old who underwent venipuncture at the blood-drawing center of the tertiary-level, children's hospital Institute for Maternal and Child Health IRCCS Burlo Garofolo of Trieste, Italy.

Usually, general practitioners and family pediatricians refer subjects to the center to perform routine and non-urgent blood tests.

At the blood drawing center, local anesthetic cream is not routinary applied, but patients with chronic diseases, who need repeated tests, are invited to put the cream at home before going to the center.

The exclusion criteria were the presence of cognitive impairment or the inability to report pain verbally, a premedication with a local anesthetic cream, and a language barrier with parents unable to provide a written informed consent.

The study was conducted during the presence at the center of a specifically trained senior medical student who was responsible for the subjects' enrolment and who acted as an external operator during the procedures.

The purpose of this study was explained to the eligible subjects in agreement with their parents.

Written informed consent was collected for every subject prior to participation.

Randomization procedure

The enrolled subjects were randomly allocated to the experimental or control group.

The randomization list was electronically generated, with blocks of four. The sequence generated was concealed with opaque envelopes, sealed and enumerated in ascending order, in which the assigned treatment according to the randomization was indicated. Subjects could be enrolled only once.

Intervention and control intervention

In the experimental group, the external operator showed the subject how to use the Leap Motion Controller to create a melody.

The Leap Motion Controller (Ultraleap, Mountain View, California, USA) is an infrared device that, in real-time, digitalizes the movements of the hand above it, and it is connected with a software that converts this signal into a musical tone previously set. It was already used in a study focused on a stroke rehabilitation protocol [27]. We used the same device, developing a different software. In software programming, the vertical space above the Leap Motion Controller was divided into 8 equally spaced intervals and each of these intervals was assigned a musical note. A pentatonic scale with the notes C-D-F-G-A-C-D-F was selected. The sound was accurately created to be pleasant regardless of the child's musical skills; so, every melody created by the patient will sound consonant, and the timbre will be warm and in the human vocal range (like a baritone saxophone).

Once patients became comfortable with the device, after a limited time lapse (from 30 s to 3 min), while they are playing it with one hand, the venipuncture was performed on the other arm. Procedures were performed by pediatric residents or nurses.

In the control group, the standard of care was performed, mainly by verbal comfort or distraction techniques. Where a non-pharmacological analgesic technique was employed, it was registered in the data collection form. In the standard of care group, the external operator was not involved in the procedure nor in the distraction of subjects.

The parents of all patients were invited to provide verbal and physical comfort to their children during procedures, staying close to them.

Primary and secondary outcomes

The primary study outcome was the median self-reported procedural pain score between the experimental and control group.

Secondary outcomes were the median pain and distress scores according to parental judgment and operators' judgment between the experimental and control group.

The procedural pain was self-reported by patients and reported by parents and by the operator performing the venipuncture, immediately after the first attempt of venipuncture, and was measured through the Faces Pain Scale-Revised (FPS-R). The scale includes a numeral rating scale from zero (no pain) to 10 (maximum pain), and a series of faces with an expression changing from no pain to severe pain [28].

The procedural distress was measured immediately before the procedure and reported by parents through a visual scale named the "distress thermometer" [29], which uses a score from zero (no distress) to 10 (severe distress).

Data collection

Data were recorded in a standardize chart filled by the external operator. For each subject and procedure, the following variables were also collected in order to analyze their influence on the outcomes: age and gender, presence of a chronic disease, a declared extra-curricular musical activity such as playing an instrument or singing, the site of the procedure such as cubital fossa or hand, the number of similar procedures undergone in the last year, previous bad experiences during similar procedures, the number of similar procedures performed by the operator in the last month, and adverse events during the procedure.

Statistical analysis

Data available from a previous study performed in the same blood-drawing center allowed us to estimate that children receiving conventional measures to limit pain and distress during venipunctures reported a mean pain value of around 2.5, on a 0–10 scale, with a standard deviation ranging between 1.5 and 2 [9]. Based on this, we hypothesized that in order to demonstrate an improvement in the pain score of 0.8 in the intervention group, at least 200 children, 100 in each group, were needed, with alpha 5% and 1-beta 80%.

Analyses were carried out according to the intention-to-treat principle. Continuous variables were reported as means and standard deviations or medians and interquartile ranges (IQR) with categorical data reported as numbers and percentages. The two groups were confronted regarding their main features, in order to evaluate the effectiveness of the randomization. Differences between the groups were evaluated with the nonparametric Mann–Whitney U-test. Data were analyzed with SPSS software, version 21.0 (IBM Corp, Armonk, New York, USA). A P value of < 0.05 was considered statistically significant.

Results

Population characteristics

During the study period, 466 children and adolescents were accessed for eligibility. Of these, 31 refused to participate and 135 were excluded (Fig. 1). Three hundred subjects entered the study and were randomized, 150 in the active production of music group and 150 in the standard of care group.

Among the 150 subjects in the active production of music group, 144 (96%) were able to use the Leap Motion Controller autonomously, 3 (2%) were not interested in using it, 2 (1%) stopped playing before the end of the procedure, 1 (1%) played with the hand moved by the external operator.

Among the 150 subjects who received the standard of care, 141 (94%) received a verbal comfort from operators and/or parents, 8 (5%) were distracted looking at some predisposed pictures, and 1 (1%) was distracted watching a smartphone.

Table 1 shows the baseline features of the study population. Median age was 14 years (IQR 11–16) in the active production of music group and 13 years (IQR 11–15) in the standard of care group, respectively. No statistically significant differences were found between groups regarding age and sex of patients, presence of chronic diseases (mainly type 1 diabetes, autoimmune thyroiditis, celiac disease, hematological diseases, and epilepsy), presence of bad experiences during previous similar procedures, number of blood sampling performed in the previous year, declared extra-curricular musical activity, site of procedure, success of venipuncture at the first attempt, and experience of the operators who performed the procedure (Table 1).

Primary and secondary outcomes

Median self-reported pain scores were 1 (IQR 0–2) in the active production of music group and 2 (IQR 1–2) in the standard of care group and this difference was statistically significant ($p = 0.0016$) (Table 2). Figure 2 provides a visual picture of the distribution in percentiles of the self-reported pain scores in the two groups. A value of 4 was found at the 91st percentile in the active production of music group and at the 83rd percentile in the standard of care group. The maximum pain score was 6 in the active production of music group, experienced by 2 subjects (1.3%) and 9 in the standard of care group, experienced by 1 subject (0.7%).

The median pain scores reported by parents and by operators were statistically lower in the active production of music group as well, $p = 0.00018$ and $p = 0.003$, respectively (Table 2).

Median procedural distress was 1 (IQR 0–3) in the active production of music group and 3 (IQR 1–6) in the standard of care group, according to parental judgment, and this difference was statistically significant ($p = 0.0000016$) (Table 2). In the same way, procedural distress was lower in the active production of music group according to the operators performing the venipuncture, $p = 0.03$ (Table 2). Figure 3 shows the distribution in percentiles of distress

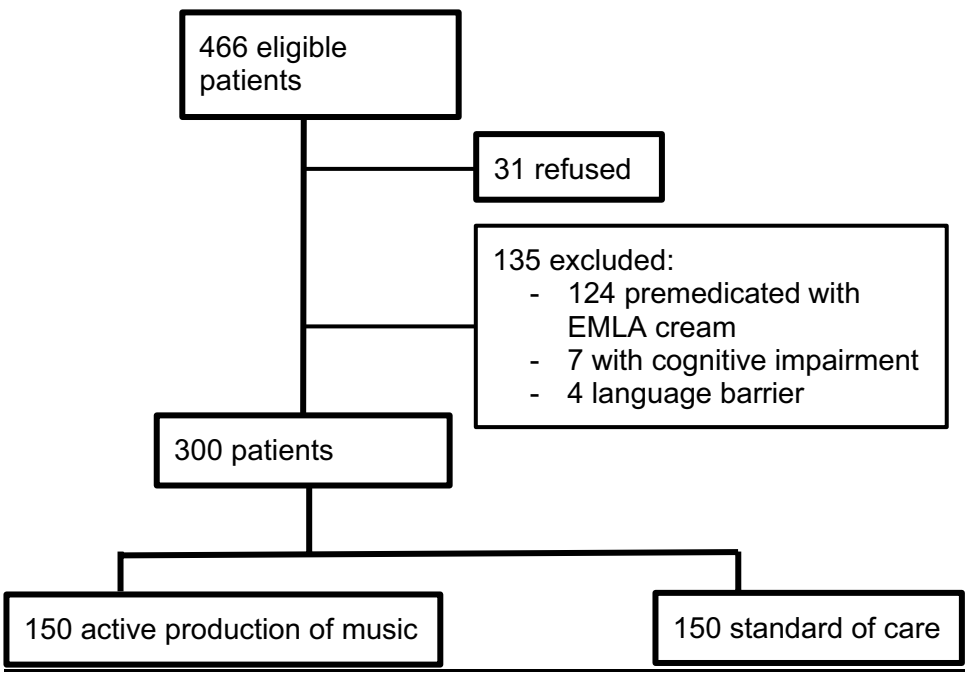

Fig. 1 Study algorithm

Table 1 Patients' and procedures' characteristics

	Active production of music group	Standard of care group	Total	*P* value
Age, median (IQR)	14 (11–16)	13 (11–15)	14 (11–15)	$p=0.57$
Age				$p=0.64$
• 8 to 12 years	56 (37.3%)	60 (40.0%)	116 (38.7%)	
• 13 to 17 years	94 (62.7%)	90 (60.0%)	184 (61.3%)	
Sex				$p=0.64$
• Male	68 (45.0%)	72 (48.0%)	140 (46.7%)	
• Female	82 (55.0%)	78 (52.0%)	160 (53.3%)	
Chronic diseases				$p=0.82$
• Yes	70 (46.7%)	68 (45.3%)	138 (46.0%)	
• No	80 (55.3%)	82 (54.7%)	162 (54.0%)	
Previous bad experiences				$p=0.11$
• Yes	44 (29.3%)	32 (21.3%)	76 (25.3%)	
• No	106 (70.7%)	118 (78.7%)	224 (74.7%)	
N° of blood sampling in the last year				$p=0.32$
• 0–1	97 (64.7%)	105 (70.0%)	202 (67.3%)	
• >1	53 (35.3%)	45 (30.0%)	98 (32.7%)	
Extracurricular musical activity				$p=0.10$
• Yes	40 (26.7%)	28 (18.7%)	68 (22.7%)	
• No	110 (73.3%)	122 (81.3%)	232 (77.3%)	
Professional who made the sampling				$p=0.69$
• Pediatric residents	111 (74.0%)	114 (76.0%)	225 (75.0%)	
• Nurse	39 (26.0%)	36 (24.0%)	75 (25.0%)	
Number of procedures performed in the previous months by operators:				$p=0.63$
<10	8 (5.3%)	10 (6.7%)	18 (6%)	
>10	142 (94.7%)	140 (93.3%)	282 (94%)	
Site of venipuncture:				–
- Cubital fossa	150 (100%)	149 (99.3%)	299 (99.6%)	
- Hand	0 (0%)	1 (0.7%)	1 (0.4%)	
Success of venipuncture at the first attempt:				$p=0.36$
- Yes	143 (95.3%)	146 (97.3%)	289 (96.3%)	
- No	7 (4.7%)	4 (2.7%)	11 (3.7%)	

scores in the two groups according to parental judgment. A value of 4 was found at the 78th percentile in the active production of music group and at the 55th percentile in the standard of care group.

Considering the different features of the subjects enrolled in this study, we found that the active production of music was more effective than the standard of care in pain and distress reduction both in children and adolescents (Table 3).

Table 2 Main study outcomes: the primary outcome is the median self-reported procedural pain score, secondary outcomes are the median pain and distress scores according to parental judgment and operators' judgment

	Active production of music group ($n=150$)	Standard of care group ($n=150$)	*P* value
Pain score, median (IQR)			
Self-reported	1 (0–2)	2 (1–2)	0.0016
Reported by parents	1 (0–2)	2 (1–3)	0.00018
Reported by health operators	1 (0–2)	1 (1–2)	0.003
Distress score, median (IQR)			
Reported by parents	1 (0–3)	3 (1–6)	0.0000016
Reported by health operators	1 (0–3)	2 (0–4)	0.03

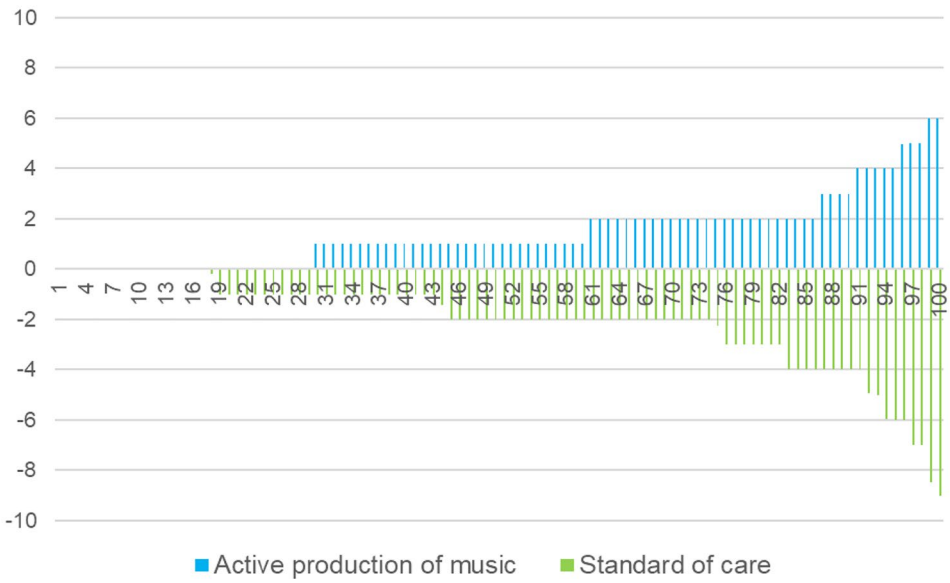

Fig. 2 This graph shows the distribution in percentiles of self-reported pain scores. Blue values above describe the distribution in the active production of music group, green values below in the standard of care group

Other results

The difference in distress scores was more pronounced in children than in adolescents, $p = 0.000067$ and $p = 0.0071$, respectively. The effect of the active production of music was statistically different in distress reduction in both females and males ($p = 0.0068$ and $p = 0.000068$, respectively). It was statistically different in pain reduction only in males, $p = 0.0034$. Moreover, the effect of the active production of music was statistically different in pain reduction both in subjects with chronic diseases and with declared previous bad experiences during venipunctures, but not in subjects who performed two or more venipunctures in the previous year. On the other hand, it was statistically effective in distress decrease in all these three latter categories of subjects. Notably, the effect of the active production of music was not statistically different in pain and distress decrease in subjects who practice music activities. On the contrary, in subjects who do not practice music activities the effect was statistically significant both for pain and distress reduction (Table 3).

Regarding adverse events, one subject in the active production of music group vomited at the end of the procedures. Two subjects reported dizziness after the venipuncture, one in the active production of music group and one in

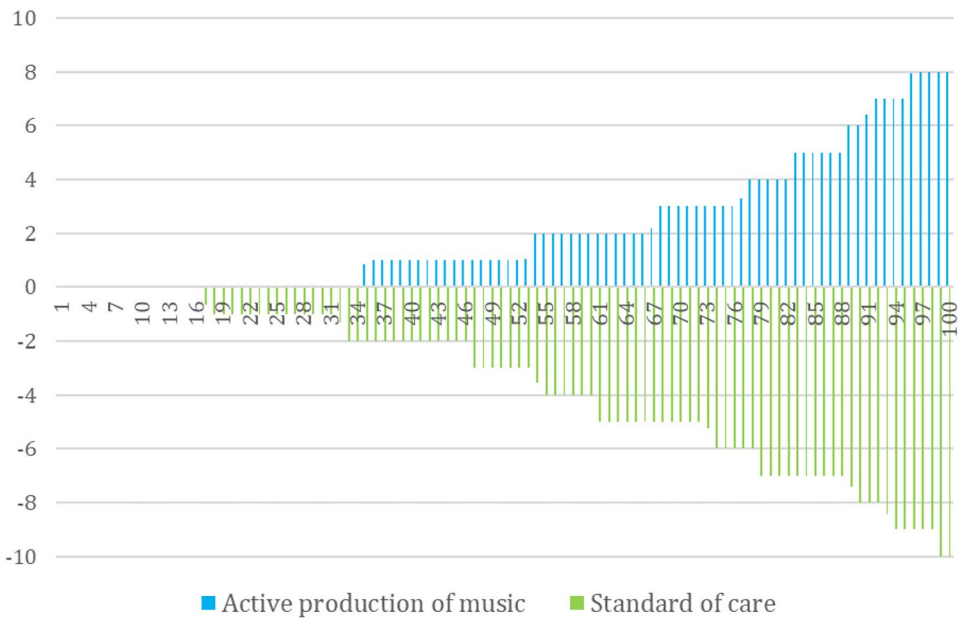

Fig. 3 Distress reported by parents. This graph shows the distribution in percentiles of distress scores reported by parents. Blue values above describe the distribution in the active production of music group, green values below in the standard of care group

Table 3 Main study outcomes in subgroups of subjects

	Active production of music group	Standard of care group	*P* value
Self-reported pain score, median (IQR):			
Children (8–12 yrs), $n=116$	2 (1–2)	2 (1–4)	0.028
Adolescents (13–17 yrs), $n=184$	1 (0–2)	2 (1–2)	0.021
Females, $n=160$	1 (0–2)	2 (1–2)	0.08
Males, $n=140$	1 (0–2)	2 (1–3)	0.0034
Subjects with chronic diseases, $n=138$	1 (0–2)	2 (1–2)	0.0035
Subjects without chronic diseases, $n=162$	1 (1–2)	2 (1–3)	0.085
Subjects with bad previous experiences, $n=76$	1 (0–2)	2 (1–2)	0.011
Subjects without bad previous experiences, $n=224$	1 (1–2)	2 (1–2)	0.0061
<2 venipuncture in the previous year, $n=202$	1 (0–2)	2 (1–3)	0.0018
2 or >2 venipunctures in the previous year, $n=98$	1 (0–2)	1 (1–2)	0.24
Subjects who practice music activities, $n=68$	1 (0–2)	2 (1–2)	0.32
Subjects who don't practice music activities, $n=232$	1 (0–2)	2 (1–3)	0.0031
Distress score according to parents, median (IQR):			
Children (8–12 yrs), $n=116$	1.5 (0–4)	4 (2–7)	0.000067
Adolescents (13–17 yrs), $n=184$	1 (0–3)	2 (1–5)	0.0071
Females, $n=160$	1 (0–2)	2 (1–2)	0.0068
Males, $n=140$	1 (0–2)	2 (1–3)	0.000068
Subjects with chronic diseases, $n=138$	1 (0–3)	2 (1–6)	0.0023
Subjects without chronic diseases, $n=162$	2 (0–3)	3.5 (1–6)	0.00047
Subjects with bad previous experiences, $n=76$	3 (1–5)	6.5 (3–7)	0.0069
Subjects without bad previous experiences, $n=224$	1 (0–2)	2 (1–5)	0.0000093
<2 venipuncture in the previous year, $n=202$	2 (0–3)	4 (1–6)	0.000037
2 or >2 venipunctures in the previous year, $n=98$	1 (0–3)	2 (1–5)	0.047
Subjects who practice music activities, $n=68$	2 (0–4)	2 (1–4)	0.55
Subjects who don't practice music activities, $n = 232$	1 (0-3)	4 (1-6)	0.00000096

the standard of care group. Physical restrain was necessary for one subject in the standard of care group.

Discussion

This randomized controlled trial showed that the active production of music is a useful distraction technique to decrease venipuncture related pain and distress in children and adolescents. In our population, this technique was more effective than the standard of care both in children and in adolescents, with a higher degree in children. As expected, the effect on distress was more substantial than on pain.

Distraction is a commonly employed psychological intervention to reduce distress during needle procedures [6, 30] and the most studied in children [6]. Distraction techniques are based on the attention-control mechanism. Promoting thoughts and focusing attention away from negative feelings may interfere with the neuronal activity associated with the processing of afferent pain stimuli and cognitive pain perception [31].

Our study was the first to employ the active production of music as an active distraction technique. Active production of music stimulates primary and secondary auditory cerebral areas, bilaterally, and also motor and premotor areas, language and cognitive areas. At the same time, it activates reward and gratification circuits with stimulation of the limbic system, neuro vegetative system, and endorphin release.

We decided to use a Leap Motion Controller. The value of this tool is that it allows children to create a melody just by moving their hand, without technical difficulties. This was confirmed by our experience in which 94% of subjects were able to play autonomously after a minimal training. Compared to other high-tech techniques such as virtual reality, it seems an easily implementable tool with the need of a laptop computer connected by a cable to the device and to a speaker located on the armrest of the subjects' chair. Moreover, its use does imply only a minimal training for operators performing procedures. Finally, a Leap Motion Controller device is not bulky, easy to carry and a little time-consuming in its use.

Besides the solid methodological design of this study, its results were strengthened by the deep characterization of the population enrolled. We described the distribution of subjects in the two groups with features, such as the number of recent previous procedures or previous bad experiences or the presence of chronic diseases, that could have influence distress and pain scores, and this distribution was similar. Moreover, we also considered a population of adolescents. In pediatric contexts, adolescents are the older patients. Compared to younger patients, they may demonstrate fewer verbal and behavioral signs of distress, possibly leading the operators to underestimate their suffering and to use less pain and distress relieving techniques. However, a recent study showed that adolescents experience similar pain and pre-procedural distress during intravenous cannulation compared to younger children [32]. Beside the novelty of the technique employed, to the best of our knowledge, this study had the largest sample size among trials which tested music as a distraction tool for needle procedures in children.

On the other hand, this trial had some limitations. First, it was not blinded, but considering the features of the technique employed, blindness was not possible. Second, pre-procedural distress scores were not self-reported, but reported by parents and operators. Measuring self-reported pre-procedural distress was not possible to not interrupt subjects while they were playing. Third, we could not exclude that the presence of the external operator and being part of a study may have influenced the behavior and judgment of the subjects involved. Fourth, the sample size was estimated for the entire population so that the results suggested by the subgroup analyses may not be confirmed with a larger sample size. Therefore, even if the number of enrolled subjects involved in music activities was limited, we did not find a higher effectiveness of this technique than the standard of care in this specific population, suggesting that the tool and the software could be perceived as too simple and they could be improved by trying to engage these subjects more. Furthermore, we did not do a cost analysis.

In conclusion, this was the first trial investigating the usefulness of an active production of music as a distraction tool for venipuncture in children and adolescents. It showed that this technique was feasible, and more effective in pain and distress relief than the standard of care. It is also easy to implement, and future studies will be used to evaluate this method against other methods of active distraction.

Acknowledgements The authors thank Alberto Muscherà, who developed the software and synthesized the tone used in this research. Owner of the software. Contact: alberto.muschera@icloud.com. They thank Martina Bradaschia for the English revision of the manuscript.

Authors' contributions Investigation: MO, BN, EC and PR Conceptualization: MO, GC and EB Methodology: MO, EB and GC First draft: BN, EC Supervision: GC and EB Data curation: LT, SS and SB Formal analysis: LT Resources: MO All authors reviewed and approved the manuscript All authors have no conflicts of interest to declare.

Funding This work was supported by the Italian Ministry of Health, through the contribution given to the Institute for Maternal and Child Health IRCCS Burlo Garofolo, Trieste, Italy.

Data availability The data that support the findings of this study are available on request from the corresponding author, EC.

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. All data were collected, stored, analyzed and reported anonymously. The study protocol received approval from the Institutional Review Board of the Institute for Maternal and Child Health IRCCS Burlo Garofolo of Trieste (RC 51/2022; IRB-BURLO 03/2022) and from the Independent Bioethics Committee of the Friuli Venezia Giulia (CEUR-2022-Sper-87).

Competing interests The authors declare no competing interests.

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