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The Effect of Makassar Folk Music on Cerebral Hemodynamics Measured by Transcranial Doppler

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Abstract
This study aimed to evaluate the effect of Makassar folk music on cerebral hemodynamics using transcranial doppler (TCD). This was an experimental study with a pre- and post-test design. The study was conducted on 30 subjects at the Sonology clinic of Wahidin Sudirohusodo Hospital, Makassar from August to September 2019. The subjects listened to either rock, classical, or Makassar folk music and cerebral hemodynamic parameters before and after listening were assessed using TCD. The results of the study show that there were significant changes in both the left and the right middle cerebral artery (MCA) mean flow velocity (MFV) after listening to three genres, with a p-value < 0.0001 for each genre. There was no significant difference between the changes observed in left MFV MCA compared to the one on the right side. The value of MFV change was not significantly different across genres. The results indicate that Makassar folk music has the same effect on increasing cerebral hemodynamics as classical music and rock music.

Keywords: Cerebral Hemodynamics, Mean Flow Velocity, Music, Transcranial Doppler

1. Introduction

The relationship between music and brain function is increasingly investigated in modern neuroscience. More evidence points to a close relationship between brain activity, cerebral blood flow, and metabolism, implying that tasks requiring cognitive activation, such as listening to music will affect the blood flow velocity of cerebral arteries, particularly within regions involved in musical perception. Increased cerebral blood flow rate reflects higher brain metabolism activated by cognitive, motor, and sensory tasks. Music is known to induce and modify cognitive, mental, and emotional states. The act of listening to music results in the extensive activation of neural networks in the human brain, and has been regarded as a potential treatment option for psychological and neurological diseases (Antić et al., 2012; Hsu & Lai, 2004; Osuch et al., 2009).

In the past decade, a growing body of evidence on the use of music interventions in clinical practice has emerged, through singing, listening to music, music improvisation, and structured music therapies. Given that music involves multiple brain regions that regulate emotion, motivation, cognition, and motor function, musical interventions have been proposed with the aim of improving socialization, cognitive and motoric function, and emotional state (Chanda & Levitin, 2013; Koelsch, 2010; Raglio et al., 2015). Clinical investigations into the effect of music on the recovery process have shown a clear relationship between music and improved post-stroke recovery. Benefits that have been reported are in terms of muscle or movement control, speech, cognition and mood recovery. Music listening stimulates multiple brain structures and improves brain circulation. For this reason, it is a potentially useful tool in the neurological rehabilitation of post-stroke patients (Antić et al., 2012).

Cognitive activities such as listening to music can impose metabolic alterations in specific cortical centers, that lead to changes in the velocity of blood flow in the large cerebral arteries, which is considered as a manifestation of cognitive activity. Therefore, the increase of cerebral blood flow rate is a reflection of an upregulated brain metabolism triggered by motor, sensory, or cognitive function activities such as listening to music (Antić et al., 2012; Vingerhoets & Stroobant, 1999).

Changes in the velocity of cerebral blood flow during and following cognitive activity can be assessed by transcranial doppler (TCD). For more than two decades, TCD has been used as an assessment method for characterization of cerebral hemodynamics. Commonly evaluated parameters include mean flow velocity (MFV) due to cognitive activation. In addition to being non-invasive, the advantages of functional TCD are that they are inexpensive, do not require special preparation, accurate, specific and sensitive for direct evaluation of cerebral blood flow dynamics and are easy to carry (for portable TCDs) (Antić et al., 2006).

Cerebrovascular hemodynamics refers to the relationship between blood flow, perfusion pressure, and resistance. The main principle of cerebrovascular hemodynamics is based on Ohm's law, where cerebral blood flow is defined as cerebral perfusion pressure (CPP) divided by cerebrovascular resistance (CVRes). Factors that influence cerebral perfusion include cerebral perfusion pressure, arterial blood pressure (ABP), intracranial pressure (ICP) and cerebrovascular resistance, all of which are determined by the functional status of arteriolar blood vessels within the cerebral microcirculation. Hence, the analysis of cerebral blood flow is considered as one of the most effective cerebral perfusion assessment methods (Schöning et al., 2005; Valdueza, 2017).

Previous studies have shown that in healthy individuals, music perception and processing requires bilateral activation of the cerebral hemispheres (Antić et al., 2006), as evidenced by the increase in cerebral blood flow during music listening in both sides of the brain. However, most studies that assessed music-related cerebral hemodynamic changes only used classical music as the research material (Carod Artal et al., 2004; Marinoni et al., 2000; Vollmer-Haase et al., 1998). Although folk music is not as widely studied, folk music in many communities can have different emotional and social implications that may affect cerebral blood flow. Hence in this study, we aimed to determine whether there is an influence of Makassar folk music on changes in cerebral hemodynamics measured by TCD, on subjects of the local Makassar area. The changes imposed by the folk music were compared with other genres such as rock and classical music.

2. Material and Method

2.1. Time and location

The study was carried out from August 2019 to September 2019 at the Sonology Outpatient Clinic, Dr. Wahidin Sudirohusodo Hospital Makassar Indonesia. Consecutive sampling was performed on subjects that consisted of local medical students and residents at the Faculty of Medicine Hasanuddin University who have consented to participate in the study.

2.2. Data Collection

This is an experimental research with a pre-test and post-test design. The cerebral hemodynamics were assessed before and after listening to three different genres. The cerebral hemodynamic parameters include MFV and middle cerebral artery (MCA). The three genres consisted of classical music (*Canon in D*), folk music (*Turiolo Jenetallasa* local orchestra), and rock music (*We will rock you*).

Cerebral blood flow parameters were measured using the Transcranial Doppler DWL Digital Multi-Dop® X-type, and the music was administered using the Huawei Honor 8x Cellphone and HTC earbud type headset. Other collected data include patient characteristics obtained from the medical status and respondent form. All participants provided their informed consent prior to the data collection. Prior to commencement, the study has obtained ethical approval from the Ethics Board at the Faculty of Medicine, Hasanuddin University (Ethics Number: 584/UN4.6.4.5.31/PP36/2019).

2.3. Data Analysis

The collected data were processed through statistical analysis using SPSS version 22. In order to see the comparison between the two groups, paired T-test and students T-test was used to measure differences between the means of two groups of paired and unpaired data. One-way ANOVA was used to determine the difference between the means of 3 groups or more. A threshold of $p < 0.05$ was considered significant.

3. Results

A total of 30 subjects were included in this study, and consisted of 14 males (46.7%) and 16 females (53.3%). The subjects were randomly divided into 3 groups consisting of 10 subjects per group in the classical music, folk music and rock music groups**.** Tabel 1 presents the age characteristics of the 30 subjects, showing similar age ranges across groups.

Table 1: Characteristic of the study subject

Age characteristics of subjects in each group		
Treatment group	N (%)	Mean age (SD)
Classical music group	10 (33.3%)	30.30 (5.67)
Folk music group	10 (33.3%)	28.30 (3.19)
Rock music group	10 (33.3%)	29.00 (6.16)

The average left MCA MFV value before listening to music was 63.90 ± 10.025 cm/s and 64.97 ± 9.023 cm/s for the right MCA MFV. Table 2 shows changes in the left MCA MFV of the classical music group before and after listening to music. Prior to the classical music treatment, subjects showed a mean MFV of 67.7 ± 11.18 in the left MCA, which increased into an MFV of 81.70 ± 11.66 after listening to classical music. In the right MCA, the subjects yielded an average MFV of 68.7 ± 10.10 before the music treatment and 81.10 ± 12.76 after the classical music treatment. The changes in both the left and right MCA before and after the classical music treatment was statistically significant ($p<0.0001$, paired t-test), with a mean ΔMFV of 14 ± 4.19 and 12.4 ± 3.37 in the left and right and MCA correspondingly.

Similar results were observed in the folk music group. Prior to the folk music treatment, subjects showed a mean MFV of 62.9 ± 10.19 in the left MCA, which increased into an MFV of 75.9 ± 10.96 after listening to folk music. In the right MCA, the subjects yielded an average MFV of 62.6 ± 8.51 before the music treatment and 76.00 ± 10.89 after the folk music treatment. The ΔMFV in the left MCA was 13 ± 2.35, and 13.40 ± 3.40 in the right MCA. In the rock music group, subjects showed a mean baseline MFV of 61.1 ± 8.30 in the left MCA, which increased into an MFV of 73.30 ± 8.94 after listening to rock music. In the right MCA, the subjects yielded an average MFV of 63.60 ± 8.00 before the music treatment and 76.90 ± 9.50 after the rock music treatment. The ΔMFV was similar ($p <0.442$, students T-test) in the left MCA (12.20 ± 2.89) and the right MCA (13.30 ± 3.36).

Table 2: Changes in the MFV values of the left and right MCA before and after listening to classical music

MFV MCA Changes in Classical Music		
Parameter	**Mean (SD) of MFV (cm/s)**	**P-value**
Left MFV MCA (n = 10)		
Before	67.70 (11.18)	< 0.0001#
After	81.70 (11.66)	
Right MFV MCA (n = 10)		
Before	68.70 (10.10)	< 0.0001#
After	81.10 (12.76)	
ΔMFV MCA (n = 10)		
Left	14.00 (4.19)	0.355*
Right	12.40 (3.37)	
# indicates p-values calculated with the paired T-test, * indicates p-values calculated with the student's T-test, MFV = mean flow velocity, MCA = middle cerebral artery		

Table 3: Changes in the MFV values of the left and right MCA before and after listening to folk music

MFV MCA Changes in Folk Music		
Parameter	**Mean (SD) of MFV (cm/s)**	**P-value**
Left MFV MCA (n = 10)		
Before	62.90 (10.19)	< 0.0001#
After	75.90 (10.96)	
Right MFV MCA (n = 10)		
Before	62.60 (8.51)	< 0.0001#
After	76.00 (10.89)	
ΔMFV MCA (n = 10)		
Left	13.00 (2.35)	0.7631*
Right	13.40 (3.40)	
# indicates p-values calculated with the paired T-test, * indicates p-values calculated with the student's T-test, MFV = mean flow velocity, MCA = middle cerebral artery		

Table 4: Changes in the MFV values of the left and right MCA before and after listening to rock music

MFV MCA Changes in Rock Music		
Parameter	**Mean (SD) of MFV (cm/s)**	**P-value**
Left MFV MCA (n = 10)		
Before	61.10 (8.30)	< 0.0001#
After	73.30 (8.94)	
Right MFV MCA (n = 10)		
Before	63.60 (8.00)	< 0.0001#
After	76.90 (9.50)	
ΔMFV MCA (n = 10)		
Left	12.20 (2.89)	0.442*
Right	13.30 (3.36)	
# indicates p-values calculated with the paired T-test, * indicates p-values calculated with the student's T-test, MFV = mean flow velocity, MCA = middle cerebral artery		

The differences in ΔMFV between the 3 groups were further analyzed, and Table 3 shows that there was no significant difference in the ΔMFV between all three music genres, in both the left ($p = 0.471$, one-way ANOVA) and the right MCA ($p = 0.769$, one-way ANOVA).

Table 5: Comparison between the ΔMFV in classical, folk, and rock music groups.

Music group	ΔMFV of the left MCA		p-value	ΔMFV of the right MCA		p-value
	Mean	SD		Mean	SD	
Classical music	14.00	4.19	0.471	12.40	3.37	0.769
Folk music	13.00	2.35		13.40	3.406	
Rock music	12.20	2.89		13.30	3.368	

P-values calculated with one-way ANOVA. MFV = mean flow velocity, MCA = middle cerebral artery

4. Discussion

This study was conducted to compare the effect of Makassar folk music with classical and rock music towards cerebral hemodynamics measured using transcranial doppler. The 3 types of music were chosen because rock music represents diatonic music, while classical and folk music represent pentatonic music. The average age of the subjects were 29.20 years, in line with previous observations by Antić et al (Antić et al., 2006) that looked at changes in cerebral hemodynamics during music perception in 61 subjects with an average age of around 30.8 years, and by Artal et al (Carod Artal et al., 2004) with an average age of 31.7 years. The average left and right MCA MFV value before listening to music was 63.90 ± 10.025 cm/s and 64.97 ± 9.023 cm/s, respectively. These results indicate that the MCA MFV value in our study subjects before listening to music was comparable to the normal value of MCA MFV of the 10-29 and and 30-49 year age group which are 70 ± 16.4 cm/s and 57 ± 11.2 cm/s, respectively (Csiba & Baracchini, 2016).

The changes in the MCA MFV before and after listening to music in all three music groups were statistically significant ($p < 0.0001$) in both the left and right MCA. Matteis et al (Matteis et al., 1997) reported the same observation, where there was a significant increase in MFV during listening to music compared to before listening to music. In line with the finding, Artal et al reported that sound stimulation stimulated a significant increase in MFV in the ipsilateral MCA compared to MFV at rest. This is consistent with previous theories which highlight that cognitively stimulating activities such as listening to music will induce metabolic changes in the form of increased CO_2 within specific cortical centers, leading to changes in blood flow velocity in the large cerebral arteries. In other words, the increase in cerebral blood flow velocity is a reflection of upregulated brain metabolism triggered by motor, sensory or cognitive function activities such as listening to music (Antić et al., 2012; Vingerhoets & Stroobant, 1999).

Activities that require neural activation such as listening to music demands an increase in cerebral blood flow which subsequently leads to cerebral arteriolar vasodilation and decreased vascular resistance to ensure adequate perfusion, a phenomenon known as cerebral vasomotor reactivity (CVR). A lack or significantly decreased CVR reflects impaired ability of cerebral vessels to adjust its caliber to vasodilator stimuli, and abnormal CVR has shown a high risk of stroke occurrence and recurrence (Rossini et al., 2004). Causative factors may include barotrauma from systolic pressure waves, low cerebral blood flow that leads to hypoperfusion, or impaired cerebrovascular capacity to adapt to sustained changes in blood pressure. Some vasodilator agents such as calcium channel blockers can enhance dynamic cerebrovascular function without affecting resting blood flow (Webb, 2019).

No significant difference was observed between changes in the left and right MCA MFV of the folk music group, similar to the classical and rock music groups. This is in line with the findings of Matteis et al (Matteis et al., 1997) who reported that during melody perception, a bilateral increase in MFV in the middle cerebral arteries was seen. Similar findings were reported by Artal et al (Carod Artal et al., 2004) who found that auditory stimulation in the form of instrumental music significantly stimulated blood flow velocity in the ipsilateral middle cerebral artery compared with the absence of auditory stimulation. It is suspected that a musical perception requires bilateral cerebral hemisphere activation. Vollmer-Haase et al (Vollmer-Haase et al., 1998) suggested that subjects who did no other task than passively listening to music exhibited a symmetrical increase in blood flow velocity, indicating balanced cerebral activation hemispheric activation bilaterally. This was also reported in the study by Antić et al (Antić et al., 2006) who observed that music perception requires bilateral cerebral hemisphere activation. Current studies have shown the activation of Broca's area during tasks other than language production. Many other studies report the involvement of these areas in the comprehension process of languages, action execution, as well as music perception and execution (Wang & Agius, 2018), where those statements further confirm the results of our study which showed that listening to music involves both hemispheres of the brain.

There was no statistically significant difference in both the right ($p = 0.769$) and left ($p = 0.471$) MCA MFV changes between the three study groups. The act of listening to music is a complex process, and requires multi-aspect involvement of psychological, emotional, and neurological systems. It can also lead to cardiovascular changes and modification of respiratory behavior. Whilst non-musicians typically utilize the non-dominant hemisphere of the brain, musicians use the dominant hemisphere and are typically more attentive when listening to music. This response influenced by the type of music (e.g., classical versus rock), and the melodic composition of the musical piece, in addition to the harmony, tempo, and rhythm. It is also highly influenced by verbal content wherein there appears to be asymmetry of brain activity shown for perception of language and melody but not found in perception of rhythm (Bernardi et al., 2006). The results obtained in our study suggest that the music we use has almost similar characteristics so that the differences in left and right MCA MFV changes between the three musical groups are not significant.

Music as a form of neurological rehabilitation is increasing. It has been shown that music training may lead to changes in brain structure and function, because the act of listening or performing music is known to activate not only cognitive but also motor function in healthy individuals. This may trigger neuroplasticity and promote cognitive as well as motor recovery after brain injury or disease. Actively playing and passively litening to music is known to influence rehabilitation and lead to neuroplasticity changes (Merrett & Wilson, 2012).

Listening to music improves post-stroke cognition and mood, and improve early sensory processing. In post-stroke patients who listened to music daily for two months, the amplitude of auditory mismatch negativity (MMN) for sound frequency changes was greater than the control group who did not listen to music. And although passive music listening itself is beneficial, active music execution and practice is an even more effective rehabilitation tool, particularly when targeting the motor domain. In a study on patients with movement deficits, the use of MIDI-tuned drums and keyboards to train gross and fine motor movements of the upper limbs have led to increased movement scores and changes in oscillatory neural activity related to stroke incidence compared to controls (Altenmuller et al., 2009). There are several mechanisms that have been proposed to explain this effect, and one of the most prominent is that music provides auditory feedback on motor movement and promotes audio-motor coupling (Rickard & McFerran, 2012).

The findings discussed in this study provides an interesting addition to the current body of knowledge on music-induced plasticity. The experience of listening to or playing music is typicaly perceived as pleasant and interesting for patients with neurological disorders. With these experimential findings, in combination with the known capacity of music to induce neuroplasticity, further exploration is warranted for the use of music therapy as a highly potential treatment option for neurological disorders. In conclusion, the results of this study indicates that Makassar folk music has the same effect on increasing cerebral hemodynamics as classical music and rock music.

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