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Role of Balinese Flute Playing in Enhancing Cognitive Function and Serum Brain-derived Neurotrophic Factor (BDNF) Levels in the Elderly

Anak Agung Ayu Putri Laksmidewi [1]*, Ni Putu Ayu Putri Mahadewi[1], Lasta Arshinta[1], Made Sebastian Dwi Putra Hardika[1], Christine Kathy Putri Sari[1]

[1]*Department of Neurology, Medical Faculty of Universitas Udayana, Ngoerah Hospital, Denpasar, Bali, Indonesia*

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*) Correspondence to:
putri_laksmidewi@unud.ac.id

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ABSTRACT

Background: Aging is associated with cognitive decline, yet the brain retains adaptive capacity with proper stimulation. Musical activities, including traditional Balinese flute playing, have shown potential in enhancing memory, concentration, and cognitive performance.
Objective: This study examined the effect of playing the Balinese flute piece *"Morning Happiness"* on cognitive improvement in the elderly, as indicated by changes in serum Brain-derived Neurotrophic Factor (BDNF) levels.
Methods: This experimental study was conducted from June to September 2024 among elderly participants (>60 years) with controlled risk factors. Subjects were randomized into an active musical engagement group (n=28) and passive music exposure group (n=14), with a male-to-female ratio of 3:4. The active musical engagement group played the Balinese flute for 20 minutes daily, while the passive group listened to the same Balinese flute composition for 10 minutes, three times weekly. Cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina), and serum BDNF levels were measured before and after the 90-day study period.
Results: The active musical engagement group showed a significant improvement in total MoCA-Ina scores (Z = -2.82, p = 0.005), particularly in abstraction (Z = -2.296, p = 0.022) and delayed recall (Z = -3.436, p = 0.026). Serum BDNF levels also increased significantly after the intervention (from 5.46 ± 6.16 to 7.63 ± 10.16; p = 0.033), while no significant changes were observed in the passive listening group.
Conclusion: Balinese flute playing enhances short-term cognitive improvement, especially abstraction and memory recall, and increases serum BDNF levels, may has role as a non-pharmacological strategy to promote cognitive health in the elderly.

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1. Introduction

Aging is a natural part of the human life cycle, characterized by a gradual decline in the body's ability to adapt to environmental stressors. This process involves anatomical, physiological, and biochemical changes, including reduced information processing speed, memory capacity, and cognitive flexibility.[1,2] Indonesia is among the countries with the largest elderly populations, comprising approximately 9.7% of the total population in 2019, with projections suggesting a twofold increase by 2035.[1,3,4]

Cognitive impairment is a common health issue in older adults and has a significant impact on their daily lives as well as on their families.[3,5,6] However, studies have shown that the adult brain, including in the elderly, retains considerable neuroplasticity, allowing it to adapt and restructure in response to new learning experiences. [6,7] Music, whether vocal or instrumental, is considered a recreational activity that may support cognitive preservation and enhance well-being in the elderly. Musical activity has been found to positively affect various cognitive domains, including executive function, memory, visuospatial ability, and perception.[2,6,8] Learning and playing music may influence brain function by activating subcortical circuits, the limbic system, and emotional centers. Long-term musical training is recognized as a strong stimulus for neuroplasticity.[6,9]

The Balinese flute is a traditional musical instrument known to have calming psychological effects by lowering heart rate, slowing respiratory rate, and modulating emotions through the limbic system.[5,7] Previous research has shown that listening to Balinese flute music can improve concentration and is comparable to Western classical music in its effects on cognitive function, especially memory.[10]

Various biomarkers have been developed to detect cognitive impairment caused by degenerative processes at an early stage, one of which is brain-derived neurotrophic factor (BDNF). BDNF plays a vital role in long-term potentiation, a form of synaptic plasticity that serves as a model for long-term memory. Pathological processes in the brain are often associated with impaired BDNF release. Since BDNF can cross the blood-brain barrier, its serum levels are considered a useful reflection of its concentration in the brain. High serum BDNF levels are believed to have a protective effect against the development of dementia.[4,11,12]

This study aims to determine the impact of a Balinese flute intervention using the song *"Morning Happiness"* on cognitive function improvement in the elderly, as indicated by an increase in serum BDNF levels.

2. Methods

This experimental study was conducted from June to September 2024. Participants were recruited consecutively from Banjar Padang Indah, Padangsambian Klod, West Denpasar, an area with an active elderly community. The sample size of 42 participants was calculated using the Pocock formula, including $\alpha = 0.05$, power = 80%, and expected effect size, and variance assumptions based on previous music intervention studies. The 2:1 allocation ratio was justified on feasibility and exploratory grounds. Inclusion criteria included individuals aged over 60 years who were able to walk independently or with assistive devices (such as canes or walkers) and who provided informed consent. Exclusion criteria included severe visual or hearing impairments, illiteracy, and a history of neurological or systemic diseases such as stroke, brain tumors, brain infections, epilepsy, depression, and chronic kidney disease.

Participants were allocated into intervention (active musical engagement) and control (passive music exposure) groups. The active musical engagement group was instructed to play the Balinese flute performing the song "Morning Happiness" by Agus Teja Santosa, S.Sn, for 20 minutes daily. The passive group listened to the same song for 10 minutes, three times per week. All participants underwent an initial two-hour in-person training session and were provided with video tutorials and printed sheet music. Researchers supplied each participant with one Balinese flute, one music sheet, and a daily activity log. Caregivers were contacted regularly during the 90-day study period to ensure adherence and provide support.

Cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina), which evaluates multiple cognitive domains including visuospatial and executive function, naming, attention, language, abstraction, memory, and orientation. MoCA-Ina is a validated screening tool with performance characteristics dependent on population and cut-off values, with appropriate references, defined by a score of <26. Serum BDNF levels (ng/mL) were measured before and after the 90-day study period using venous blood samples. Samples were collected in the morning, processed to obtain serum, and stored at -80°C until analyzed with the BDNF Enzyme-Linked Immunosorbent Assay (ELISA) ELISA kit (BT LAB, Cat. No. E1302Hu, China).

Collected data were processed and analyzed using SPSS (Statistical Package for the Social Sciences) version 24.0. Descriptive statistics were used to summarize demographic characteristics of the intervention and control groups. Normality of the data distribution was assessed using the Shapiro-Wilk test. As MoCA-Ina domain scores and serum BDNF levels showed non-normal distribution, non-parametric tests were consistently applied. Within-group comparisons were analyzed using the Wilcoxon signed-rank test and between-group comparisons of change scores were analyzed using Mann-Whitney U test. Statistical significance was set at a p-value of <0.05, with a 95% confidence interval applied throughout the analyses.

3. Result

Out of 61 participants assessed for eligibility, 12 participants were excluded (7 did not meet inclusion criteria and 5 declined to participate), 7 were lost to follow-up, resulting in a total of 42 total participants who were divided into 28 participants in the intervention group and 14 in the control group. Both groups had an equal male-to-female ratio of 3:4. Participants in both groups were aged between 60 and 80 years. Table 1 presents the baseline characteristics of the study subjects, including age, gender, education level, and history of chronic diseases such as diabetes mellitus, hypertension, and dyslipidemia.

Table 1. Baseline Characteristics of Study Participants

Variable	Control (n=14)	Intervention (n=28)	p-value
Sex			
Male	6 (42.9)	12 (42.9)	1.000
Female	8 (57.1)	16 (57.1)	
Age			
Mean ± SD (years)	71.14 ± 6.21	67.57 ± 5.55	0.066
Education Level			
Low (< 12 years)	3 (21.4)	7 (25.0)	1.000
High	11 (78.6)	21 (75.0)	
Diabetes Mellitus			
Yes	2 (14.3)	4 (14.3)	1.000
No	12 (85.7)	24 (85.7)	
Hypertension			
Yes	6 (42.9)	14 (50.0)	0.913
No	8 (57.1)	14 (50.0)	
Dyslipidemia			
Yes	2 (14.3)	10 (35.7)	0.277
No	12 (85.7)	18 (64.3)	

The components of the MoCA-Ina domain scores and serum BDNF levels were tested for normality using the Shapiro-Wilk test, which indicated non-normal data distribution. Therefore, comparative analysis was conducted using the non-parametric Wilcoxon test. The table below illustrates the differences in MoCA-Ina scores and serum BDNF levels in both groups before and after the intervention.

4. Discussion

The aging process is accompanied by various anatomical and structural changes in the brain. Brain volume may decline with age, with changes occurring at the molecular to morphological levels, which can in turn contribute to cognitive decline. In older adults, homeostatic reserves begin to deteriorate, reducing glucose and oxygen supply—essential substrates for brain metabolism.[1,4,13] Cognitive impairment arises from structural alterations in the frontal cortex and hippocampus, with reported gray matter volume reductions of 6.14% and white matter reductions of 16–20% by the age of 60.[3,4]

Dementia is characterized by progressive deterioration in cognitive functions such as memory and language, often accompanied by behavioral changes.[6] Cognitive impairment is influenced by various factors, including age, sex, education level, sociocultural status, psychosocial condition, genetic predisposition, history of head trauma, cardiovascular diseases, and environmental exposures.[1,4] Cognitive abilities generally decline with advancing age, affecting the capacity to learn, follow instructions, and coordinate attentional and motor responses.[1,3] Women are at higher risk of cognitive decline, likely due to the role of endogenous sex hormones. Estrogen receptors are found in brain regions responsible for memory and learning, such as the hippocampus. Estradiol is considered neuroprotective and has antioxidant properties. Low estradiol levels have been associated with general and verbal memory decline. Educational attainment, as a proxy for lifelong intellectual stimulation, plays an important role in cognitive health; lower education levels correlate with reduced mental stimulation and poorer cognitive function.[4] In this study, both groups showed similar distributions of educational level, generally skewed toward higher education, which may explain the relatively higher average MoCA-Ina scores in both groups.

Variable	Control (n = 14)				Intervention (n = 28)			
	Median (IQR)		Z-score	p-value	Median (IQR)		Z-score	p-value
	Pre	Post			Pre	Post		
MoCA-Ina	25 (4.75)	22.5 (4.5)	-0.750	0.453	24 (5)	27 (4)	-2.820	0.005*
- Visuospatial	4 (2.25)	4 (2.25)	-1.342	0.180	4 (2)	4 (1.75)	-0.104	0.917
- Naming	3 (1)	3 (1)	-0.577	0.564	3 (1)	3 (0)	-1.387	0.166
- Attention	6 (0.5)	5.5 (1.25)	-0.343	0.732	6 (2)	5.5 (2)	-0.143	0.887
- Language	3 (1)	2 (1)	-0.333	0.739	2 (1)	3 (1)	-1.641	0.101
- Abstraction	2 (0.25)	1.5 (2)	-1.857	0.063	1 (1)	2 (1)	-2.296	0.022*
- Delayed recall	2 (3)	2 (4)	-0.659	0.510	1.5 (3)	4 (2)	-3.436	0.001*
- Orientation	6 (0)	6 (0.25)	0.000	1.000	6 (0)	6 (0)	-0.513	0.608
Serum BDNF level (ng/mL)	2.49 (0.96)	2.09 (0.54)	-0.534	0.594	2.19 (5.36)	2.3 (6.9)	-2.129	0.033*

Figure 1. Comparison of MoCA-Ina Scores and Serum BDNF Levels Before and After Intervention

Cognitive components decline at different ages. Attention, defined as the ability to focus on specific stimuli, begins to decline as early as age 20. Executive function, which enables complex motor planning, typically declines by age 70, affecting mobility in the elderly. Poor mobility leads to increased dependency and reduced quality of life. Memory decline becomes apparent around age 80, while visuospatial function often deteriorates by age 60.[3]

Music-based interventions for the elderly are well-tolerated and can be implemented individually or in group settings. These interventions involve elements such as melody, rhythm, harmony, and sound, through active participation (e.g., singing, dancing, playing instruments) or passive listening. Group music training may enhance communication and social interaction among older adults and caregivers.[5,8] Listening to music involves sound perception, rhythm processing, and lyric interpretation, engaging widespread cortical activation. Music may reduce neurodegeneration by enhancing brain plasticity and promoting new neural connections via mesolimbic pathways, including the nucleus accumbens, ventral tegmental area, hypothalamus, and insula.[5,6] It also affects the immune response, influencing lymphocyte production, T cells, interferon-gamma, and interleukin-6.[5]

Cross-sectional studies have found superior cognitive performance—especially in working memory, executive function, language, and visuospatial skills—among older adults who have played musical instruments throughout life. Even individuals without prior musical experience can benefit cognitively from music training, as shown by increased neuronal activity in the fusiform gyrus and superior parietal lobule.[2,13]

The Balinese flute, made from bamboo, produces harmonious, low-pitched, and slow-tempo music (60–80 bpm). Previous research has shown that listening to Balinese flute music improves cognitive function—particularly memory—comparable to Western classical music.[5,7] In this study, the Balinese flute was used as the sole intervention medium. The intervention group played the song "Morning Happiness" for 20 minutes daily, while the control group played it for 10 minutes three times per week. Intensive, repetitive exposure to music may induce bilateral cortical reorganization involving attention, memory storage, and sensorimotor integration.[5]

The duration of musical intervention is a critical factor in its effectiveness for cognitive function. Interventions lasting less than 20 weeks appear more beneficial in individuals with dementia than longer durations. The number of sessions per week may be less impactful than the total exposure time, which should be at least 8 hours over a minimum of 16 sessions. Music stimulates neurotransmitters such as endorphins, endocannabinoids, dopamine, and nitric oxide.[6] Active musical therapy is more effective than passive listening in stimulating the prefrontal cortex, which plays a central role in cognition.[8,14]

In this study, abstraction and delayed recall domains showed significant improvement in the intervention group, with Z scores of -2.296 ($p = 0.022$) and -3.436 ($p = 0.026$), respectively. We propose that playing the Balinese flute engages new learning processes—encoding, storage, and retrieval—supported by non-declarative memory networks involving the striatum, neocortex, amygdala, and reflex circuits.[5,8]

Serum BDNF levels significantly increased post-intervention (7.63 ± 10.16 ng/mL), compared to pre-intervention levels (5.46 ± 6.16 ng/mL; $p = 0.033$). Patahang et al. also reported a significant correlation between serum BDNF levels and MoCA-Ina scores. A BDNF threshold

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<1.99 ng/mL demonstrated 82.9% sensitivity and 85.7% specificity for cognitive impairment.[4] Higher BDNF levels are associated with better cognitive function in healthy adults. BDNF is widely expressed in highly plastic brain areas, including the hippocampus, hypothalamus, and cortex, and can also be found in peripheral organs such as the heart, gut, thymus, and spleen. Approximately 90% of serum BDNF is stored in platelets, with serum levels being over 100 times higher than plasma levels due to platelet degranulation during coagulation.[11,12] BDNF supports synaptic transmission, neuronal activity regulation, long-term memory, neurogenesis, synaptogenesis, and neural stem cell protection. BDNF expression is influenced by seizures, stress, ischemia, and hypoglycemia.[4,11,12] In patients with Alzheimer's disease, higher serum BDNF levels are associated with slower cognitive decline, especially in advanced stages, suggesting its potential as a predictor of disease progression.[11]

BDNF levels are modifiable through behavioral and environmental stimulation. Physical activity and cognitive engagement enhance BDNF expression, whereas sedentary behavior and high-fat, high-glucose diets suppress it.[11] Regular physical exercise has been shown to improve both cognitive function and serum BDNF levels.[11,15] The rise in BDNF following aerobic exercise may be due to increased cellular metabolism, though the mechanisms remain unclear.[15] Conversely, low BDNF levels have been reported in individuals with poor dietary patterns.[11]

This study has several limitations. Some elderly participants may have had difficulty comprehending the interview questions. Additionally, potential confounding factors that may affect BDNF levels—such as mood, diet, sleep, immune status, smoking habits, and daily physical activity-were not assessed in this study.

5. Conclusion

Playing the Balinese flute was significantly associated with short-term improvement in cognitive function, as indicated by increased MoCA-Ina scores—particularly in the domains of abstraction and delayed recall—along with a corresponding rise in serum BDNF levels. These results should be interpreted cautiously and considered hypothesis-generating for future controlled trials.

Ethical Approval

This study was approved by the Ethics Committee of the Faculty of Medicine, Udayana University (Approval No. 1997/UN14.2.2.VII.14/LT/2024).

Conflicts of Interest

The authors declare no conflict of interest.

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Author Contributions

Conceptualization, A.A.A.P.L.; methodology, A.A.A.P.L. and N.P.A.P.M.; software, L.A. and M.S.D.P.H.; validation, A.A.A.P.L. and N.P.A.P.M.; formal analysis, L.A. and M.S.D.P.H.; investigation, A.A.A.P.L.; resources, A.A.A.P.L.; data curation, N.P.A.P.M.; writing—original draft preparation, A.A.A.P.L. and N.P.A.P.M.; visualization, writing—review and editing, A.A.A.P.L., N.P.A.P.M., L.A., M.S.D.P.H.; supervision, A.A.A.P.L. All authors have read and agreed to the final version of the manuscript.

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