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MUSIC THERAPY IN THE REHABILITATION OF THE MOTOR FUNCTION OF UPPER LIMBS IN PATIENTS WITH MULTIPLE SCLEROSIS USING THE KEYBOARD

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Abstract
Background: Multiple sclerosis is a chronic, inflammatory, and disabling disease of the central nervous system. It affects any functional area, mainly people of productive age. Rehabilitation must be comprehensive and involve the different systems simultaneously. Neurological music therapy offers strategies in which several brain areas can be stimulated at once. Objective: To analyze the effects of keyboard music therapy applied to patients with multiple sclerosis with compromised short pathways. Methods: This work is a single case study, in which 22 music therapy sessions are offered to a right-handed patient with multiple sclerosis with compromised motor function of the right upper limb. Both hands were subjected to the same process. Results: The function of the left hand remained without relevant changes, while the right hand achieved significant and sustained changes in the 9-pin test, which remained constant from session 15 onwards. Similarly, the patient reports having regained the ability to perform a series of activities of daily living with her right hand. Conclusions: It is concluded that the process of musical interventions favored the functional recovery of the right extremity in this patient.

Keywords: multiple sclerosis, neurological music therapy, motor function, keyboard, 9-hole pin test

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BACKGROUND

Multiple sclerosis is a chronic, controllable, but not curable autoimmune disease that affects the central nervous system. Since its identification as a clinical entity, its incidence has been increasing due to multiple genetic and environmental factors, in addition to technological advances and greater knowledge of the disease that allow an earlier and more timely diagnosis. Its clinical manifestations are as many as the functions of the central nervous system, in such a way that the patient may present motor, sensory, visual, balance, bladder, and intestinal symptoms, among others. Its highest incidence is in the population of productive and economically active age, with a predominance in women. Multiple factors have been associated with predisposing agents, but there is no clear cause (Nourbakhsh & Mowry, 2019).

The symptoms are not limited to the neurological sphere, as there are a number of other conditions that compromise the quality of life of patients with multiple sclerosis, such as fatigue, depression, cognitive impairment, social and work performance, chronic pain, sexual dysfunction, among others (Lakin et al., 2021).

Multiple sclerosis is the leading cause of neurological – non-traumatic – disability affecting young adults. Its management represents high costs to the health and social economy, not only because of the patient's own needs but also because of the high investments involved in the use of disease-modifying pharmacological therapies. If we add to this the increase in

the incidence, the chronicity of the disease, and the age group most affected, the effect on the economy and productivity is even greater. At the individual level, patients' perception of quality of life and emotional state are seriously affected as a consequence of – and at the same time directly impacting – the degree of disability of the patient (Kobelt et al., 2017). Its management is multidisciplinary, involving specialties such as neurology, neuropsychiatry, mental health, physiatry, urology, social work, and psychology, among others.

Disease-modifying therapies are needed to control inflammatory activity, as well as to address all symptoms, neurological (such as spasticity, neuropathic pain, balance disorders, etc.), and non-neurological (depressive disorder, urological disorders, socio-familial situations, among others). Therefore, pharmacological and non-pharmacological therapies are required (Dobson & Giovannoni, 2019).

Of the main complications from the functional point of view, it is the physical sequelae that generate the greatest disability. Different mechanisms have been described by which the patient can acquire this dysfunction, either by a relapse without complete recovery or by the independent progression of relapses (Lublin et al., 2022).

There are different scales for an objective assessment of the patient's disability status, including Kurtzke's expanded disability status scale (EDSS), the 25-foot gait, and the 9-pin pin test (9HPT). 2003). They can also be used to evaluate the progression of the disease because even if the patient does not have new symptoms, i.e., a relapse, there may be a progression of the disability, as already noted, and this will be decisive in the therapeutic process, both pharmacological and non-pharmacological.

One of the most relevant non-pharmacological elements in the management of multiple sclerosis is physical therapy or rehabilitation. It is very important to establish the degree of disability in this group of patients, as the approach with disease-modifying therapies depends to a large extent on this. It is necessary to define if the physical limitation is real and irreversible or if it is a condition that has not received an adequate rehabilitation process. Physical and cognitive rehabilitation programs should ideally be individualized, structured, and multidisciplinary, according to the patient's needs, as Amatya, et al. (2019) conclude in their review study.

Evidence suggests that physical therapy can improve patients' motor performance and affect other aspects, such as the perception of quality of life, cognition, and fatigue (Amatya et al., 2019). Given the compromise of various functions of the central nervous system, therapies are required that manage to integrate the different tasks and have a pathophysiological impact on the rehabilitation process. One of the therapeutic modalities that has recently taken off in different neurological conditions is music therapy.

From a historical perspective, there are various definitions of the concept of music therapy. However, all of them have essential points of convergence, such as the use of music and its elements applied by a professional music therapist in various contexts for therapeutic purposes to improve conditions and meet the needs of patients (Pérez-Eizaguirre, 2021, pp. 32 - 39). Its use has spread to different areas, involving the social, educational, and health spheres.

One of the specialties that is beginning to make its way into the neurorehabilitation process is music therapy (Jurado-Noboa, 2018), and since MS is the neurological disease par excellence, it becomes an ideal pathology to influence through this specialty.

With technological advances, the options of functional studies in the central nervous system, and the progression of studies in music therapy, a new branch opened up from the 90s onwards, focused on neurological pathologies. "Neurological music therapy" was born, and with it, a series of therapeutic strategies focused on the different needs of these patients based on neurophysiological elements (Thaut & Hoemberg, 2014). Its therapeutic range ranges from stimulation in early childhood to patients with cognitive disorders, sequelae due to cerebrovascular disease, sequelae due to head trauma, and, in this specific case, patients with multiple sclerosis.

Multiple studies support the neuro-anatomical and functional bases by which the use of music in the rehabilitation process optimizes the patient's response to therapy (Soria-Urios et al., 2011), (Ruiz et al., 2019). In multiple sclerosis, being a pathology that affects various functional areas, music therapy can be used to improve motor, emotional, and cognitive aspects, among others.

Different musical strategies have been studied in patients with multiple sclerosis to optimize gait pattern (See-bacher et al., 2022), (Moumdjian et al., 2020), upper limb function (Lamers, 2016), and at least two studies in which the motor function of the upper body has been worked on through the use of the keyboard (Gatti et al., 2015).

Maintaining the functionality of the upper limbs is extremely important for patients who already have a greater commitment to their ability to walk: their hands represent their independence, their ability to carry out essential elements of daily life, such as personal hygiene, feeding, transfers – either with crutches or from a wheelchair to another place such as the bed -, etc.

Since music therapy is an accessible, low-cost alternative, without risks to the patient's physical integrity, without side effects, and that can also integrate other aspects such as cognitive function, emotional state, and the perception of quality of life (Lopes & Keppers, 2021), its implementation is justified in a

systematic and structured way for the rehabilitation of patients with multiple sclerosis.

The present work seeks to analyze the effects of keyboard music therapy applied to a patient with multiple sclerosis with short pathway involvement.

Materials and Methods

Participants

The music-therapeutic intervention was applied to a single patient (individual intervention) in her home. Given his limitations, this context was preferred to avoid the need for displacement. In addition, at home, she handles herself safely, which is very important to promote her performance and participation during activities.

All of their pharmacological and non-pharmacological therapies remained unchanged during the intervention period.

Stimuli and measures

A total of 22 music therapy sessions were carried out under a general structure, detailed in Table I.

The sessions were delivered in a staggered manner in relation to the objectives. We worked under a behaviorist model in which music was used as a stimulus and as a structure to improve the motor function of the upper limbs. The execution of the instrument served as a tool to work on the proprioceptive and motor factors (based on the dynamics, rhythm, and sonority of the piece), thus promoting rehabilitation under the concept of neuroplasticity.

A music therapist supervised all the sessions – supervisor, receiving the respective feedback for the optimization of the process.

Both subjective and objective parameters were assessed. Regarding the former, the evolution of the motor function of the upper limbs was subjectively evaluated according to the daily performance reported session after session by the patient in aspects of daily life (writing, use of crutches, eating, dressing, personal hygiene, brushing teeth, cooking, combing and applying makeup).

Regarding the objective parameters, we worked with the 9-pin test, quantifying the performance in the test prior to the start of the therapy and every two sessions until the end of the process and adjusting the therapies according to the objective progression in this test.

The interlay difference in the performance of the test prior to the start of therapy, every two sessions, and at the end of these sessions, was also assessed, with a view to achieving a significant - positive - difference in the execution of the 9HPT test in relation to the baseline.

Table I.

Structure of music therapy sessions.

Phases and timing	Activity	Objective
Welcome Song 5 min.	Improvised. Greeting. Musical dialogue about the week's activities, their functional progress, their emotions, among others.	Generate a musical dialogue with the patient. Encourage expressiveness and creativity.
Motivational Song 5 min.	The patient is presented with a song by her favorite performers. During this phase, the patient was free to just listen, sing the song, dance to it, keep the rhythm with an instrument or clapping hands, etc.	Generate an emotional-positive environment prior to the therapeutic intervention. Encourage attentive listening. Incorporate rhythmic elements. Promote freedom of expression.
Heating 5 min.	Prior to the start of the keyboard exercises, physical warm-up exercises are performed at the level of the fingers, wrists, elbows, shoulders and neck.	Prevent injuries in a patient who is not accustomed to playing the keyboard.
Setting with the piece	The patient is presented with the target piece in each session: the fourth movement of Beethoven's Ninth Symphony.	Familiarize the patient with the rhythm, sonority and lyrics of the song.
Musical Performance 30 min.	The patient is asked to perform different exercises to become familiar with the technique, posture, relaxation, the execution with separate hands and hands together (mirrored and superimposed), and then they began to advance with the piece itself. For these purposes, a simple tutorial was used in which the posture of the hand could be kept as anatomical and functional as possible. During the performance of the piece, the patient was asked to sing the notes at the same time as she played them.	Rehabilitate the motor and proprioceptive function of both hands. Stimulate lateralization at the brain level. Promote the process of neuroplasticity through the activation and integration of different functional systems at the brain level.
Stretch 5 min.	At the end of the keyboard activity, stretching exercises were performed with different relaxing songs – based on the patient's preferences.	Prevent post-practice injuries with the instrument.
Objective Assessment 5 min.	Every two sessions (odd sessions), the 9 hole pin test was performed.	To assess in a standardized and quantifiable way the progression of the motor function of both hands in the patient.
Farewell 5 min.	Each session ended with a farewell song that, like the opening song, was improvised, highlighting the patient's attitude and achievements.	Motivate the patient to continue with her work and performance in the sessions. Define the end of the session.

Procedure

The sessions were worked as follows:

Session 1: Application of scales – receptive period for familiarization with the piece to be used, given the clinical context and the patient's baseline musical skills.

Sessions 2 to 7: continued with familiarization with the keyboard, notes, finger position on the keyboard, muscle relaxation and other technical aspects. Both hands were worked on—only with the melody—and both hands received the same motor training, reinforced with melodic and rhythmic elements. Given the patient's affinity for singing, elements of melodic solfeggio were used to bolster the process. In session 6, he was asked to initiate a songwriting process in order to promote writing, motivation, creativity, and expressiveness.

Session 8 to 13: Once the patient was familiar with the technical elements, rhythmic elements were added to the metronome, through which parameters were adjusted according to the patient's musical advances and motor ability. The work was kept in separate hands. Rhythmic variants were added to consolidate the musical aspects and favor neuroplasticity, as well as offering conditions that made the dynamics more challenging and less monotonous.

Sessions 14 to 21 We began to work together to integrate motor function and laterality and promote neuroplasticity. Elements such as dynamics and loudness were associated with promoting greater motor and proprioceptive awareness to achieve rehabilitation with intention (not only did we seek to recover movement, but also to attain functional movements through intentionality, direction, strength and coordination of movement).

Session 22: Closing session of the program. Farewell.

For the proper development of the sessions, the following materials were used:

- Portable keyboard - digital - Casio brand - model CTK-4400.
- Base in¨X¨ for keyboard support.
- Wooden drum.
- Xylophone.
- Standard ukulele.
- Harmonica.
- Tripod.
- Digital camera to record the sessions.
- Stopwatch to measure the times when performing the 9-pin test.
- Equipment for the 9-pin test: wooden base, metal pins.
- Electronic tablet where the structure of each of the sessions is recorded, as well as the links to access the respective songs used in the different phases of the therapy.
- Wireless internet connection.
- Connection to electricity for the electric keyboard.
- Metronome (built-in electric keyboard).
- Sign-in sheet.

String and percussion instruments were used to encourage rhythmic activities with motivational songs. They were also used for the improvisation process in the welcome and farewell songs.

Data analysis

The data were taken from the record sheet and prepared to make the respective annotations for each session. Both qualitative and quantitative data were typed and processed for tabulation and analysis in Microsoft Excel 365, version 2.73, of Microsoft Corporation.

RESULTS

We worked with a 47-year-old right-handed patient with multiple sclerosis with an EDSS of 6.5 (moderate disability) and recurrent metastatic thyroid cancer.

A total of 22 music therapy sessions were carried out under a behaviorist model. In general, the patient's disposition for the sessions was always positive, with a fair to good physical condition within her context. During the period in which the music intervention therapies were offered, the patient had a stable underlying disease, with no relapses or need for adjustment in her treatments.

Due to the time of year when the therapies were carried out, work was carried out under very high temperatures, reaching up to 34° Celsius in some sessions.

The subjective parameters assessed are summarized in Table II. The following activities were covered: brushing teeth, brushing hair, putting on makeup, dressing, personal hygiene, writing, cooking skills, eating, use of crutches and personal hygiene. At the beginning of the process, the patient could not perform any of the evaluated activities with her right hand, but she could perform them with her left. From the third session on, she reports trying to brush her teeth, get dressed, help herself with personal hygiene, eat and use crutches with her right hand, but she still couldn't try to comb her hair, put on makeup, write or do kitchen chores. In session number 7, the patient reported that she was able to write with her right hand. By session eight, he indicated that he had managed to eat with his right hand and make proper use of the crutches while the other functions were still in process. In session number 12, the patient says that she is already able to use her right hand to dress herself and for her hygiene, in addition to maintaining the other functions that she has already achieved. Finally, in session number 13, he

reports that he can perform all the tasks evaluated and maintains the faculties during the subsequent sessions until the end of the intervention program.

Table 2.

Achievements achieved after the sessions

Parameter	Basal	Session 7	Session 8	Session 12	Session 13
To write	NO	YES	YES	YES	YES
Use of crutches	NO	NO	YES	YES	YES
Eat	NO	NO	YES	YES	YES
Dress	NO	NO	NO	YES	YES
Grooming	NO	NO	NO	YES	YES
Brushing your teeth	NO	NO	NO	NO	YES
Cook	NO	NO	NO	NO	YES
Comb	NO	NO	NO	NO	YES
Makeup	NO	NO	NO	NO	YES

Note: Summary of the achievements in functional capacity for activities of daily living with the right hand from baseline and in the different sessions.

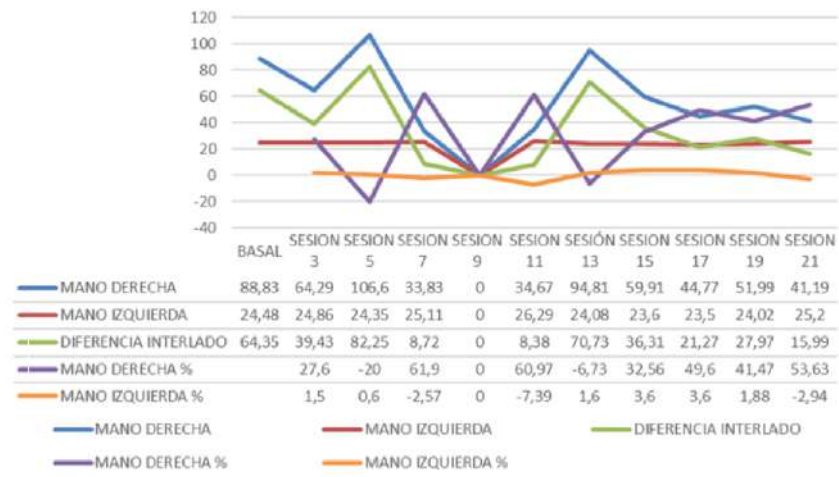
Regarding the objective parameters, assessed with the 9-pin test, a basal time of 88.83 seconds was recorded with the right hand and 24.48 seconds with the left. Figure 6 summarizes the clinical evolution documented with this standardized test session after session. There are three key points in the graphic representation regarding the evolution of the right hand: session 5, in which the percentage difference did not exceed 20%; session 9, in which the test could not be performed, as it was necessary to end the session earlier than expected, since the patient mistakenly took a medication that she was supposed to take at night, and began to have side effects that prevented her from continuing; and session 13, in which the patient was convalescing from the flu and even that day in the morning she had been suffering from a fever.

DISCUSSION

To analyze the data presented, it is essential to understand the context of the results. Several relevant elements are highlighted: first of all, it is important to highlight the patient's health condition prior to each session: as noted, the patient was stable. That is to say; he did not have clinical relapses of his disease that affected his performance during the program: this element was fundamental and decisive for the continuity and development of the musical interventions. There was only one moment – in session 13 – postponed for eight days, as the patient suffered an

Figure 1.

Results of the 9-pin test.



Note: absolute and percentage numbers according to evolution with respect to baseline and interlay difference

upper respiratory infection and was very symptomatic. Still, on the day of the session, he had a fever in the morning, which explains the decrease in the 9-pin test. It is important to remember Uthoff's phenomenon, which implies a deterioration of functions in the patient with multiple sclerosis due to an increase in body temperature, so this was to be expected.

On the other hand, the patient's mood was also relevant in the process: she was always motivated, proactive and creative: she contributed her musical proposals in all the sessions, especially for the welcome song and the motivational song.

Finally, in relation to the general aspects in the context of the interventions, it is worth noting the climatic conditions: as already mentioned, the ambient temperature can decrease the performance of people with multiple sclerosis. The music therapy program was offered to this patient just in the hottest months.

When analyzing the performance in relation to the planning of the different blocks of sessions, it is observed how the patient was achieving the objectives in accordance with what was proposed: the achievement of the technical goals, then the gradual learning of the musical notes with separate hands, then the execution with joined hands, all this accompanied by a process of melodic solfeggio. Initially, a method was worked on that favored proprioception and motor awareness of the right hand by working on the function of each finger individually to achieve the functional recognition of each of them, initially managing to consciously dissociate the movement of each finger until reaching an

integration at a central level that favored the automatic execution of the movement.

This initial process favored joint work, which later led to the definition of laterality. The work was done with the melody: it was not possible to incorporate the harmony with the left hand due to difficulties in coordination, attributable to various factors in the neurological context and musical background of the patient. However, this made it possible to offer the same musical stimulus for both hands, favoring the interpretation of the final functional results.

As for other musical elements, such as rhythm and dynamics, resources were used beyond the use of the keyboard, always within the framework of the proposed activities. Thus, for example, percussion instruments were used with the motivational songs to carry the rhythm of the pieces, which the patient was achieving unconsciously in the course of the sessions, observing the phenomenon of¨entrainment¨: both the patient and the therapist played the xylophone or the wooden drum simultaneously carrying the rhythm of the songs offered; However, in the first session, the patient's performance did not have any agreement with the rhythms offered, and as the interventions progressed, the time came when – without her planning it – she managed to incorporate the rhythmic element and manifest it in the percussion instrument.

Once this was observed, warm-up exercises were incorporated at the keyboard level using the metronome, achieving an early incorporation of the rhythmic factor in the musical performance. The concept of dynamics was also applied in the warm-up exercises, both physical and keyboard, but not with the target piece, as it was difficult for him to process all the components when playing the song. The process of how the patient expressed her need to control the intention of movement was interesting: the incorporation of exercises with dynamics allowed her to understand the mechanism to achieve this goal.

Going into more tangible results, such as performance in activities of daily living, it is important to highlight that the patient was unable to perform absolutely any function with her right hand. She had different verb forms to describe her disability: 'my hand is dead,' 'for me, this side doesn't exist,' 'I had to learn to do everything with my left because this hand doesn't help me'...

During the therapeutic process, anatomical-physiological neurological concepts were explained to him so that he could understand the different mechanisms through which therapies would favor the reactivation of motor functions. Understanding this, the patient tried to reincorporate her right hand into her daily life activities, with important limitations at the beginning. However, maintaining the motivation not to fall into frustration, understanding that the achievements would be seen over time, as this was a process. The first function recovered was writing: within the therapeutic process, the technique of "songwriting" was incorporated to promote their creativity, reinforce their motivation, and achieve greater expressiveness. The proposed theme for the song was his feelings in relation to the music therapy process he was experiencing. He was made a requirement that the song should be written by hand, with his right hand, regardless of handwriting and spelling. The patient achieves this challenge within a week, and her handwriting does not denote fine motor failures.

Since the patient also has functional limitation in the right lower limb, it was of utmost importance that she be facilitated in the use and mastery of Canadian crutches, which she achieved at week 8. In the same way, in this session, he indicated that he was already able to eat with his right hand without dropping the food or without staining his clothes, and more importantly, he recovered the ability to bring the food to his mouth without failing in the directionality and intentionality of the movement conditioned by his cerebellar problem.

This important function could be mediated by the process of awareness that was carried out in the individual work of the fingers, in addition to the visuospatial coordination favored by direct work with the keyboard.

Finally, the patient was able to resume tasks that involved not only the use of the hand but also more proximal motor functions, such as elbow flexion and the different arcs of movement of the shoulder. The patient also had limitations in her proximal mobility as a result of chronic tendinitis and bursitis in the right shoulder, which limited active movements involving this joint.

During the process, in the different warm-up activities, this joint was also worked, and once on the keyboard, the importance of relaxing the entire limb was reinforced. Indirectly, this motor breakthrough was achieved, and these functional limitations were overcome, conditioned more by pain than by real weakness. As he began to use his limb more and increased, this symptom improved, significantly facilitating his daily performance, reflected in his ability to comb his hair and put on makeup.
In relation to the results of the 9-pin test, the documented improvement is highly significant. Here are several interesting facts that should be highlighted:

- The execution of the test with the right hand prior to the start of the therapies lasts more than three times the time that the left-hand lasts, a reflection of the functional condition of this limb. This difference between the two decreases by more than 50%

during the therapeutic process, with the initial difference being 64.35 seconds and the average difference taking into account the totality of sessions in which the test was controlled at 28.6 seconds (55.54% difference).

- The percentage of variability of the left-handed test did not show significant changes, with the understanding that, for the differences to be representative, a difference +/- 20% of the baseline value of the test would have been required.
- In the representation of the right hand, three registers that could be considered "outliers" can be observed:
    - Session 5: The percentage difference was 20%. On this particular day, the ambient temperature was 32°C, and the humidity percentage was close to 90%.
    - Session 13: the patient was convalescing from an infectious process, and on the morning of the day of the session, she had a last feverish peak. Both moments (session 5 and 13) reflect Uthoff's phenomenon.
    - Session 9: The patient took a medication that she should have taken at night, and it caused extreme drowsiness as a side effect, so it was necessary to finish the intervention earlier than stipulated, and the test was not performed.
    - From session 15 onwards, the percentage difference in the execution of the test with the right hand in relation to the baseline remains persistently above 20%, which denotes a significant improvement, and this improvement was sustained during the following therapy sessions.

Although the observed improvement is sustained, there are fluctuations in performance for both hands, reflecting the variability induced by factors such as weather conditions and the degree of muscle fatigue.

As a result, it could vary depending on the test during the day or evening, for example, added to the level of activity performed during the day and the patient's state of mind, among others. Due to the study design, these variables were not directly controlled, but their effect has already been widely reported in the medical literature.

The main limitation of the study is the design, as it is a unique case: under this modality, the conclusions will be specific to the case. They cannot be extrapolated to the population from which the patient comes. It should be noted that musical intervention takes place in an academic context as part of a curriculum; Therefore, the experience of those who offer the therapeutic process is totally limited. Supervision mitigated this factor, which was fundamental to the development of the program.

It should be noted, however, that this intervention addresses an area that has been little explored in terms of clinical and scientific work.

In a musical intervention, the effects of music therapy applied to a patient with multiple sclerosis with compromised motor function in the upper limbs using the keyboard were analyzed, evidencing a positive and sustained response in the standardized 9-pin test and the subjective report of functional improvement in daily activities. Both hands were exposed to the same stimulus, keeping the function of the left-hand stable, with a marked improvement in their performance with the right hand. There was a significant reduction in the functional difference between the sides, narrowing the gap in test performance between the right hand and the left hand.

This case opens up multiple questions and serves as a basis for future research in relation to the role of neurological music therapy in patients with multiple sclerosis. The findings are considered highly significant and justify the need to continue exploring musical interventions in this group of patients.

There is a question that stands out: is it necessary to rethink the paradigm of rehabilitation in patients with multiple sclerosis?

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