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REVIEW OPEN ACCESS

The Effect of Rhythmic Auditory Stimulation on Gait in Adults with Multiple Sclerosis: A Literature Review

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Abstract
Introduction: Multiple sclerosis (MS) is a neurodegenerative disease that attacks the central nervous system, leading to a buildup of sclerotic plaques, demyelination, and lesions. While the nature of the disease varies per individual, the most common symptom is impaired gait related to sensory deficits, fatigue, and muscle weakness. These deficits impact quality of life and the ability to complete activities of daily living. While current rehabilitative treatments help prevent further disability, they generally do not improve existing mobility. Rhythmic auditory stimulation (RAS) is a therapeutic approach to restoring mobility using metronomic and musical cues to improve gait parameters such as speed, distance, and double support time. While the positive effects of RAS have been well documented in other neurologic conditions, there is limited research regarding RAS and MS. This literature review aims to summarize the rehabilitative potential of RAS and how this impacts gait in adults with MS.
Methods: A literature search was performed using keywords including, but not limited to, multiple sclerosis, rhythmic auditory stabilization and cueing, gait, and ambulation. Databases included in the search were Web of Science, Ovid - Medline, PubMed, Google Scholar, and EBSCO. The search yielded six articles published in the English language between 2010 and 2021 that were included for review.
Results: RAS was found to significantly improve gait parameters including speed, distance, and double support time. RAS was both used alone and in combination with either motor imagery or verbal cueing. Aspects of quality of life including fatigue, mood and pain were also positively impacted for participants in some of the studies.
Discussion: Improvements in mobility correspond with increased ability to complete activities of daily living, ambulate in the community, and maintain social wellbeing. Despite promising results, several limitations were identified for the studies that may have impacted results. Furthermore, the therapeutic effect of RAS may vary depending on the auditory stimulus used.
Conclusion: RAS shows great potential as an accessible, cost-effective therapy that may help people with MS regain lost mobility, however further research with larger sample sizes and longer intervention timeframes is warranted to determine the rehabilitative use of RAS.

Keywords: rhythmic auditory stimulation (RAS); multiple sclerosis (MS); gait; ambulation; motor imagery (MI); verbal cueing (VC); neurological rehabilitation

Introduction

Multiple sclerosis (MS) is a chronic neurodegenerative autoimmune disease that attacks the central nervous system (CNS) [1-3]. Typical age of onset is between 20 to 40 years, with a prevalence ratio of 2.3-3.1:1 women to men [1,4]. The etiology of MS is not well understood, but likely includes genetic predisposition and environmental factors that trigger an autoimmune response [1]. There are three types of MS, including relapsing remitting MS (RRMS), primary progressive MS (PPMS), and secondary progressive MS (SPMS) [5,6]. While clinical progression varies per individual, typical prognosis involves an initial onset of RRMS, in which the disease fluctuates through periods of amplified symptoms and remittance [1,5]. Eventually, the disease progresses to SPMS, which is characterized by slow functional decline and increased disability [1,5]. PPMS, although less common, causes a steady disease progression without remittance [5].

Despite the variability in disease progression, the neurological changes involved in MS are similar for each type. Amplified immune responses lead to inflammation, causing neural damage such as demyelination, gliosis, and axonal injury [1,6]. Due to the accumulation of sclerotic plaques and lesions, symptoms are variable and may include sensory changes, weakness, cognitive changes, and ataxia [1,2,5]. Sensory loss impacting plantar sensation can lead to decreased balance and coordination and increase the risk of falls [7]. Fatigue and muscle weakness, for example in the dorsiflexors, can lead to foot drop and reduced mobility [8]. Impaired cognition has also been linked with slowed motor processing and ataxia, leading to reduced gait control [9]. Gait describes patterns of ambulation and involves balance, coordination, positioning, and posture [8]. Gait and mobility impairments have severe impacts on both activities of daily living (ADL) and quality of life (QOL) [3]. Fear of falls and embarrassment due to impaired mobility can increase reluctance to ambulate outside the home, leading to deconditioning and impacts on social wellbeing [8]. Additionally, impaired ambulation may impact the ability to work or perform ADLs, leading to both financial and caregiver burden [9]. As MS affects approximately two million people worldwide, it is essential that individuals with MS be able to access appropriate treatments that can increase QOL and prevent further decline [2].

Available treatments targeting gait and mobility include pharmacological therapy, occupational therapy, and physiotherapy [1,11]. Gait impairments can be difficult to treat due to disease variability, and while these treatments may be effective in preventing further disability, they are not often able to restore lost mobility or functional ability [12,13]. Rhythmic auditory stimulation (RAS) is a rehabilitative approach that involves rhythmic cueing to facilitate gait through the synchronization of participants' steps to musical or metronomic beats [13,14]. It has been found to improve auditory-motor synchronization and facilitate motor coordination, allowing for improved gait control, mobility, and neuroplasticity [13-15].

The rehabilitative potential of RAS has been studied in relation to multiple neurological conditions, such as stroke and Parkinson's disease, however, there has been minimal research studying the effects of RAS on individuals with MS [13,14,16]. Therefore, the purpose of this literature review is to summarize the rehabilitative use of RAS and how it impacts gait in adults with MS.

Methods

A literature search was conducted using the keywords "rhythmic auditory stimulation", "rhythmic auditory cueing", "multiple sclerosis", "MS", "gait", "gait training", "ambulation", and "walking". Databases included in the search were Web of Science, Ovid - Medline, PubMed, Google Scholar, and EBSCO. The inclusion criteria were peer-reviewed studies published in English that concerned the use of RAS and consisted of participants who were diagnosed with MS. There was no limitation to the date of publication due to the limited research available. Furthermore, the search was not limited to participants with any one type of MS. The exclusion criteria consisted of studies focusing on any neurological condition that was not MS, review articles and research protocols. Six articles were found following the search, and each one was read thoroughly to determine eligibility for this review. A summary of the search process is included in Table 1.

Table 1. Literature Search Strategy for Studies Investigating the Effect of Rhythmic Auditory Stimulation on Gait in Adults with Multiple Sclerosis

Search Date	Databases	Keywords & Boolean Operators	Search Results
24/09/2023	Medline Web of Science, Ovid - Medline, EBSCO, PubMed, Google Scholar	(rhythmic auditory stimulation OR rhythmic auditory cueing) AND (multiple sclerosis OR MS) AND (gait OR gait training OR ambulation OR walking) NOT (parkinson* OR huntington* OR cerebral palsy OR stroke)	11 articles reviewed. Removal of articles as per exclusion criteria. 6 articles to be included in the review.

Results

Six studies met the eligibility criteria and were included in the review. Publication dates ranged between 2010 and 2021. The measurement of gait parameters varied; gait speed was measured in all studies, whereas distance was measured in only three studies [17-19]. Double support time (DST) was measured by Shahraki et al. and Conklyn et al., and balance was measured by Maggio et al. [13,14,20]. Additional variables such as fatigue, QOL, and treatment usability were discussed by Seebacher et al. [17-19]. Pain and mood were measured by Conklyn et al. and Maggio et al. respectively [13,20]. Participant recruitment included all MS phenotypes apart from a study by Maggio et al. that required a diagnosis of SPMS [20]. Participant demographics are summarized in Table 2.

Table 2. Description of Studies Investigating the Effect of Rhythmic Auditory Stimulation on Gait in Adults with Multiple Sclerosis

Study	Sample Size	MS Phenotype	Severity of Disability*	Sex Ratio (women:men)	Mean Age (years)
Maggio et al., 2021 [20]	10	SPMS	Moderate	2.3:1	45.3
Seebacher et al., 2019 [19]	59	All	Mild to moderate	3.9:1	44.4
Seebacher et al., 2017 [18]	101	All	Mild to moderate	5.3:1	44.1
Shahraki et al., 2017 [14]	18	All	Moderate	3.5:1	40.33
Seebacher et al., 2015 [17]	30	All	Mild to moderate	2.8:1	45.06
Conklyn et al., 2010 [13]	10	All	Mild to moderate	2.3:1	48.65

Note: MS: multiple sclerosis; SPMS: secondary progressive multiple sclerosis
*Disability was measured using the Expanded Disability Status Scale in five of the six studies [13,16-19]. Conklyn et al. used the Ambulation Index to document participant disability [13].

Methodologies

Musical Intervention versus Metronomic Intervention

RAS was provided by either music or metronome with rhythms in 2/4 or 4/4 meter with strong on and off beats [17,18]. Conklyn et al. specified that music must be between 50-120 beats per minute [13]. While both musical and metronomic interventions were effective at improving gait parameters, Seebacher et al. found that music was more effective at increasing participant engagement and adherence to treatment [17]. Shahraki et al. only used metronomic beats, gradually increasing the speed to encourage participants to walk slightly faster than their preferred ambulatory speed [14].

Motor Imagery and Verbal Cueing

RAS can be used alone or alongside other therapies such as motor imagery (MI) or verbal cueing (VC). Seebacher et al. combined RAS with MI, having participants visualize their movements before completing the physical action [17-19]. VC was achieved by the researchers verbally reinforcing on and off beats of the music, using phrases to cue movement such as “toe-off” or “step-step” [18]. Significant improvements in gait speed, distance, and QOL were observed for participants who received this combination treatment [18].

Improvement in Gait Parameters

Gait Speed

A significant improvement in gait speed was observed in participants following RAS treatment for all six studies. Gait speed was typically measured using the Timed 25-Foot Walk Test, which has excellent test-retest reliability and construct validity [13,17-19,21]. Other gait measurement systems included the GT3 treadmill, the GAITRite system, and the Qualisys motion analysis device [13,14,20]. Use of ambulatory aides such as canes or walkers was permitted when assessing gait speed, however Seebacher et al. found that there was no improvement in gait speed for participants who used these assistive devices [13,17-19].

Distance

Distance was only discussed in studies by Seebacher et al. and was measured using the 6 Minute Walk Test, which has been recommended for use in MS populations by the Neurology Section of the American Physical Therapy Association’s Multiple Sclerosis Task Force [17-19,22]. Seebacher et al. found clinically significant improvements in ambulatory distance for participants who received treatment, and no improvement for the control group [17]. Distance was not measured in studies by Maggio et al., Shahraki et al. or Conklyn et al. [13,14,20].

Double Support Time, Balance and Falls

DST refers to the amount of time during the gait cycle where an individual has both feet contacting the ground [23]. A shorter DST is linked with faster gait speed, improved balance, and reduced risk for falls [24]. Conklyn et al. found that DST improved significantly on both left and right sides after two weeks of treatment [13]. DST was also found to improve significantly in a study by Shahraki et al. following three weeks of intervention using metronomically-cued RAS [14]. Static and dynamic balance were found to improve significantly in a study by Maggio et al. [20]. DST and balance were not measured in studies by Seebacher et al. [17-19]. While fall risk was not tested, Seebacher et al. reported that one participant fell during treatment due to reduced foot dorsiflexion, however this did not impact the participant’s ability to continue with treatment [18]. No other adverse outcomes were reported.

Impact on Quality of Life

The impacts of RAS on additional factors were considered in certain studies. Studies by Seebacher et al. measured impacts to QOL and fatigue [17-19]. Maggio et al. and Conklyn et al. measured mood and pain [13,20]. Shahraki et al. did not investigate issues pertaining to QOL [14].

Fatigue

Fatigue was measured pre and post-treatment using a Modified Fatigue Impact Scale. Seebacher et al. found that RAS had no impact on fatigue, whereas a follow-up study determined that musically cued RAS significantly reduced physical fatigue, however, it had no impact on psychosocial or cognitive fatigue [17,18]. Fatigue was not measured in studies by Shahraki et al., Conklyn et al., and Maggio et al. [13,14,20].

Mood and Pain

Maggio et al. found that participants' moods significantly improved following musically cued RAS due to personal enjoyment of the music, which increased the likelihood of continuing with treatment [20]. When considering potential treatment barriers, Conklyn et al. determined that RAS did not impact participants' pain level following multiple weeks of intervention [13]. Mood and pain were not evaluated in the other studies included in this review.

Discussion

Based on the reported findings, RAS positively influences gait parameters including speed, distance, DST, and balance, and may improve aspects of QOL including mood and fatigue with minimal risk for falls [13,17-20]. These results suggest that RAS may be an effective and accessible therapy for individuals with MS.

Quality of Life and Activities of Daily Living

Gait Speed

Impaired gait is one of the most common disabilities associated with MS and has significant impacts on QOL [25]. Safe and efficient ambulation directly relates to the ability to complete ADLs, such as eating, bathing, toileting, and dressing [26]. Gait speed, a parameter found to improve significantly following RAS, is connected to both QOL and ADLs. A gait speed of $\leq$ 0.8 m/s is associated with reduced ambulation in the community, increased mortality, disability, and cognitive decline [27]. Shahraki et al. reported baseline gait speeds for individuals with MS of 0.38 m/s, far below the threshold for community ambulation [14,27]. Shahraki et al. set the metronomic rate at a speed 10% higher than each participant's baseline speed to encourage faster ambulation. Following three weeks of RAS treatment, average gait speeds increased to 0.9 m/s. Seebacher et al. reported baseline gait speeds between 1.25 m/s and 1.41 m/s, with post-intervention speeds increasing to between 1.44 m/s and 1.69 m/s [17-19]. Speed improvements correspond with the ability to cross roads safely, complete self-care tasks, and reduce the risk of hospitalizations [27]. This improvement will allow participants more safety and freedom when ambulating in the community, will facilitate ADL completion, and will allow greater social participation.

Distance and DST

MS-related disability can lead to difficulty ambulating for longer distances, due factors such as muscle weakness, fatigue, or reduced balance [25]. Furthermore, people with MS spend more of their gait cycles in DST compared to individuals without disability [25]. As gait speed decreases, DST increases, thereby increasing risk for falls [13,24]. The ability to ambulate for longer distances without significant risk of falling is an important factor in completing ADLs and ambulating in the community. Additionally, improving these gait parameters may facilitate participation in social activities that were enjoyed prior to the onset of disability. These findings suggest that RAS may not only have the potential to improve gait parameters but also help make these activities more accessible, thereby impacting social and physical wellbeing.

Musical Enjoyment and Adherence to Treatment

Enjoyment of the music selected for RAS may influence patients' perception of treatment and increase adherence to therapy. Seebacher et al. noted that 8 out of 10 participants who received musically cued RAS reported their experience to be pleasurable, whereas only 4 out of 10 participants who received metronomically cued RAS enjoyed the treatment [17]. Conklyn et al. noted that having participants walk to their favourite music increased motivation and adherence to treatment [13]. To maintain interest, Seebacher et al. changed the provided audio weekly, and selected music with enjoyable melodies [18]. These findings are in line with literature discussing the relationship between music and exercise. Including music with physical activity increases entertainment and distraction from physical exertion [28]. Furthermore, the genre of music may impact the effect of RAS on various gait parameters. A systematic review discussing the effects of RAS on various neurological conditions found that rock and heavy metal genres increased gait speed, stride duration, and range of motion [29]. Familiarity with the music also has been found to improve gait parameters as individuals synchronize their steps through an internal timing process [29]. Despite these promising results, some studies have found that enjoyment of the music selected for RAS therapy had no effect on gait, rather individual beat perception and participant age were more indicative of RAS effectiveness [30].

Motor Imagery, Verbal Cueing, Dopamine and Neuroplasticity

Studies by Seebacher et al. investigated the effect of RAS when coupled with MI or VC [17-19]. Seebacher et al. found that using both music and verbal cues alongside MI led to greater improvements in gait parameters than MI alone [19]. Imagining physical movements is believed to activate sensorimotor areas in the brain including the cerebellum, basal ganglia, and prefrontal cortex, thus increasing synaptic connectivity, and strengthening the connections involved in producing movement [31]. Pleasurable activities, such as listening to music, facilitate the release of the neurotransmitter dopamine, which is involved in movement control, synaptic modification, and learning [32,33]. Dopamine agonists, including levodopa, are often taken by individuals with MS to reduce tremor which can impact mobility [34]. In a study on the use of RAS for people with Parkinson's Disease, researchers speculate that changes in sensorimotor rhythms following treatment may be related to dopamine release triggered by music [35]. Further studies ought to be conducted to determine if dopamine release may influence the effectiveness of RAS in people with MS. Strengthening motor pathways through the combination of therapeutic techniques is linked with increased neuroplasticity. Neuroplasticity, or the ability of the brain to reorganize and change its activity following injury, is a key part of neurological rehabilitation in disorders such as MS [36]. As there are limited studies investigating the combination of RAS, MI and VC, further research may uncover more definitive links between these therapies and neuroplasticity.

Limitations and Implications for Further Research

Despite promising results, there were several limitations to the studies. Three studies were conducted by the same research team, thus limiting the diversity of results, and increasing risk for bias. Several of the studies had relatively small sample sizes; Maggio et al. had a sample of 10 participants, Shahraki et al. had a sample of 18, and Conklyn et al. had a sample of 10 [13,14,20]. As the Conklyn et al. and Maggio et al. studies were feasibility studies, the small sample sizes are less generalizable to a larger population [37]. Furthermore, blinding was not used in any of the studies, which may have impacted results. Homogeneity was limited as three of the six studies included interventions such as MI or VC in combination with RAS; while these studies provided new insights, it points to a lack of studies focusing on the impact of RAS alone. Finally, the lengths of the studies were short, lasting between two to four weeks. Longitudinal studies would facilitate insights into the long-term effects of RAS and feasibility of treatment. Further studies ought to be conducted with larger sample sizes and longer intervention timeframes, and investigation into the effects of different musical genres or familiarity of music may lead to new implications for treatment.

Conclusion

This review explored the impacts of RAS on gait in adults with MS. RAS was found to significantly improve gait parameters including speed, distance, balance, and DST. Furthermore, RAS may positively impact various aspects of QOL including mood, pain, fatigue, and ability to complete ADLs. RAS may be used alone or in conjunction with other approaches including MI or VC and may involve either metronomic or musical cues. Due to the prevalence of MS globally and the severity of disability that can occur due to this disease, it is essential that new rehabilitative treatments are identified and implemented to prevent further decline. RAS shows promising potential as a therapy to improve gait for individuals with MS; however, further research is warranted to investigate the long-term potential of RAS therapy for broader populations.

List of Abbreviations Used

ADL: activities of daily living
CNS: central nervous system
DST: double support time
MI: motor imagery
MS: multiple sclerosis
PPMS: primary progressive multiple sclerosis
QOL: quality of life
RAS: rhythmic auditory stimulation
RRMS: relapsing remitting multiple sclerosis
SPMS: secondary progressive multiple sclerosis
VC: verbal cueing

Conflicts of Interest

The author declares that they have no conflicts of interest.

Ethics Approval and/or Participant Consent

Ethics approval and participant consent was not required due to the nature of this review.

Authors' Contributions

KN: Designed and planned the review; collected, analyzed, and interpreted data; drafted the manuscript and gave final approval of the version to be published. KN is to be held accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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References

[1] Huang WJ, Chen WW, Zhang X. Multiple sclerosis: pathology, diagnosis and treatments. Exp Ther Med. 2017 Apr 28;13(6):3163-3166. https://doi.org/10.3892/etm.2017.4410

[2] World Health Organization [Internet]. Multiple sclerosis; 2023 [cited 16 Nov 2023]. Available from: https://www.who.int/news-room/fact-sheets/detail/multiple-sclerosis#:~:text=It%20is%20estimated%20that%20over,young%20adults%20and%20in%20females

[3] Walton C, King R, Rechtman L, Kaye W, Leray E, Marrie RA, et al. Rising prevalence of multiple sclerosis worldwide: insights from the atlas of MS, third edition. Mult Scler J. 2020 Nov 11;26(14):1816-1821. https://doi.org/10.1177/1352458520970841

[4] Harbo HF, Gold R, Tintore M. Sex and gender issues in multiple sclerosis. Ther Adv Neurol Disord. 2013 Jul;6(4):237-248. https://doi.org/10.1177/1756285613488434

[5] Wilkins A. Cerebellar dysfunction in multiple sclerosis. Front Neurol. 2017 Jun 28;8. https://doi.org/10.3389/fneur.2017.00312

[6] Zephir H. Progress in understanding the pathophysiology of multiple sclerosis. Rev Neurol. 2018 Jun;174(6):358-363. https://doi.org/10.1016/j.neurol.2018.03.006

[7] Kelleher KJ, Spence WD, Solomonidis SE, Apatsidis DP. The effect of impaired plantar sensation on gait in people with multiple sclerosis. Int J MS Care. 2009 Jan 1;11(1):25-31. https://doi.org/10.7224/1537-2073-11.1.25

[8] National Multiple Sclerosis Society. Gait or walking problems: the basic facts [Internet]; 2010 [cited 2023 Nov 16]. Available from: https://www.nationalmssociety.org/nationalmssociety/media/msnationalfiles/brochures/brochure-gait-or-walking-problems.pdf

[9] Hsieh KL, Sun R, Sosnoff JJ. Cognition is associated with gait variability in individuals with multiple sclerosis. J Neural Transm. 2017 Oct 25;124:1503-1508. https://doi.org/10.1007/s00702-017-1801-0

[10] Maguire R, Maguire P. Caregiver burden in multiple sclerosis: recent trends and future directions. Curr Neurol Neurosci Rep. 2020 May 22;20(7):18. https://doi.org/10.1007/s11910-020-01043-5

[11] National Multiple Sclerosis Society. Walking (gait) difficulties [Internet]; [date unknown] [cited 2023 Nov 16]. Available from: https://www.nationalmssociety.org/Symptoms-Diagnosis/MS-Symptoms/Walking-Gait-Balance-Coordination

[12] Mills R. Treating tremor and ataxia. In: Uccelli Messmer M, Summers L, Traversa S, editors. Tremor and ataxia in MS [Internet]. Cambridge: Cambridge Publishers; 2009 [cited 2023 Nov 21]. Available from: https://www.msif.org/wp-content/uploads/2014/09/MS-in-focus-13-Tremor-and-ataxia-English.pdf

[13] Conklyn D, Stough D, Novak E, Paczak S, Chemali K, Bethoux, F. A home-based walking program using rhythmic auditory stimulation improves gait performance in patients with multiple sclerosis: A pilot study. Neurorehabil Neural Repair. 2010 Jul 19;24(9):835-842. http://dx.doi.org/10.1177/1545968310372139

[14] Shahraki M, Sohrabi M, Taheri Torbati HR, Nikkhah K, Naeimikia M. Effect of rhythmic auditory stimulation on gait kinematic parameters of patients with multiple sclerosis. J Med Life. 2017;10(1):33-37. https://doi.org/10.22089/mbj.2018.1434

[15] Chatterjee D, Hedge S, Thaut M. Neural plasticity: The substratum of music-based interventions in neurorehabilitation. NeuroRehabilitation. 2021 Jan 1;48(2):155-166. https://doi.org/10.3233/NRE-208011

[16] Lindaman K, Abiru M. The use of rhythmic auditory stimulation for gait disturbance in patients with neurologic disorders. Music Ther Perspect. 2013 May 1;31(1):35-39. https://doi.org/10.1093/mtp/31.1.35

[17] Seebacher B, Kuisma R, Glynn A, Berger T. Rhythmic cued motor imagery and walking in people with multiple sclerosis: A randomised controlled feasibility study. Pilot Feasibility Stud. 2015 Jul 11;1(25). https://doi.org/10.1186/s40814-015-0021-3

[18] Seebacher B, Kuisma R, Glynn A, Berger T. The effect of rhythmic-cued motor imagery and walking in people with multiple sclerosis: A randomised controlled trial. Mult Scler J. 2017 Feb;23(2):286-296. https://doi.org/10.1177/1352458516644058

[19] Seebacher B, Kuisma R, Glynn A, Berger T. Effects and mechanisms of differently cued and non-cued motor imagery in people with multiple sclerosis: A randomised controlled trial. Mult Scle J. 2019 Oct;25(12):1593-1604. https://doi.org/10.1177/1352458518795332

[20] Maggio GM, Tripoli D, Porcari B, Manuli A, Filoni S, Naro A, et al. How many patients with MS benefit from using music assisted therapy? A case-control feasibility study investigating motor outcomes and beyond. Mult Scler Relat Disord. 2021 Feb;48. https://doi.org/10.1016/j.msard.2020.102713

[21] Phan-Ba R, Pace A, Calay P, Grodent P, Douchamps F, Hyde R, et al. Comparison of the timed 25-foot and the 100-meter walk as performance measures in multiple sclerosis. Neurorehabil Neural Repair. 2011 Sep 25;25(7):672-679. https://doi.org/10.1177/1545968310397204

[22] Potter K, Allen DD, Bennett SE, Brandfass K, Cohen E, Widener GL, et al. Neurology section of the American physical therapy association's multiple sclerosis task force [Internet] 2012 Feb [cited 2023 Nov 22]. Available from: https://www.neuropt.org/docs/ms-edge-documents/final-ms-edge-document.pdf?sfvrsn=913a970b_4

[23] North American Society for Gait and Human Movement, American Academy of Orthotists and Prosthetists Gait Society. Terminology of human walking [Internet]. 1993, 1994 [cited 2023 Nov 22]. Available from: https://www.bostonoandp.com/Customer-Content/www/CMS/files/GaitTerminology.pdf

[24] Williams DS, Martin AE. Gait modification when decreasing double support percentage. J Biomech. 2019 May 20;92:76-83. https://doi.org/10.1016/j.jbiomech.2019.05.028

[25] Socie MJ, Sosnoff JJ. Gait variability and multiple sclerosis. Mult Scler Int. 2013 Mar 3;2013. https://doi.org/10.1155/2013/645197

[26] Edemekong PF, Bomgaars DL, Sukumaran S, Schoo C. Activities of daily living. In: StatPearls [Internet]. Treasure Island: StatPearls Publishing; 2023 Jun 26 [cited 2023 Nov 22]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470404/

[27] Middleton A, Fritz SL, Lusardi M. Walking speed: The functional vital sign. J Aging Phys Act. 2016 Apr 1;23(2):314-322. https://doi.org/10.1123/japa.2013-0236

[28] Park KS, Williams DM, Etnier JL. Exploring the use of music to promote physical activity: From the viewpoint of psychological hedonism. Front Psychol. 2023 Jan 25;14. https://doi.org/10.3389/fpsyg.2023.1021825

[29] Scataglini S, Van Dyck Z, Declercq V, Van Cleemput G, Struyf N, Truijen S. Effect of music based therapy rhythmic auditory stimulation (RAS) using wearable device in rehabilitation of neurological patients: A systematic review. Sensors (Basel). 2023 Jun 26;23(13): 5933. https://doi.org/10.3390/s23135933

[30] Roberts BS, Ready EA, Grahn JA. Musical enjoyment does not enhance walking speed in healthy adults during music-based auditory cueing. Gait Posture. 2021 Sept;89:132-138. https://doi.org/10.1016/j.gaitpost.2021.04.008

[31] Hanson M, Concialdi M. Motor imagery in multiple sclerosis: Exploring applications in therapeutic treatment. J Neurophysiol. 2019 Jan 25;121(2):347-349. https://doi.org/10.1152/jn.00291.2018

[32] Ferreri L, Mas-Herrero E, Zatorre R J, Ripolles P, Gomez-Andres A, Alicart H, et al. Dopamine modulates the reward experiences elicited by music. Proc Natl Acad Sci U S A. 2019 Feb 26;116(9):3793-3798. https://doi.org/10.1073/pnas.1811878116

[33] Gepshtein S, Li X, Snider J, Plank M, Lee D, Poizner H. Dopamine function and the efficiency of human movement. J Cogn Neurosci. 2016 Mar 23;26(3):645-657. https://doi.org/10.1162/jocn_a_00503

[34] Ghosh R, Roy D, Dubey S, Das S, Benito-Leon J. Movement disorders in multiple sclerosis: An update. Tremor Other Hyperkinet Mov (N Y). 2022;12:14. https://doi.org/10.5334/tohm.671

[35] Calabro R S, Naro A, Filoni S, Pullia M, Billeri L, Tomasello P, et al. Walking to your right music: A randomized controlled trial on the novel use of treadmill plus music in Parkinson's disease. J Neuroeng Rehabil. 2019 Jun 7;16:68. https://doi.org/10.1186/s12984-019-0533-9

[36] Kumar J, Patel T, Sugandh F, Dev J, Kumar U, Adeeb M, et al. Innovative approaches and therapies to enhance neuroplasticity and promote recovery in patients with neurological disorders: A narrative review. Cureus. 2023 Jul;15(7):e41914. https://doi.org/10.7759/cureus.41914

[37] Chan YH. Randomised controlled trials (RCTs) - sample size: The magic number? Singapore Med J [Internet]. 2003 [cited 2023 Nov 22];44(4):172-174. Available from: ResearchGate: https://www.researchgate.net/publication/10586056_Randomised_Controlled_Trials_RCTs-Sample_Size_The_Magic_Number

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