

Review Paper

Listening to Music, Biomechanics of Gait and Sports Performance: A Narrative Review



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Citation Zare Mojtahedi M, Fatahi A, Tabatabai Ghomsheh F, Amirali Jafarnezhadgero A. Listening to Music, Biomechanics of Gait and Sports Performance: A Narrative Review. *Physical Treatments*. 2025; 15(2):91-100. <http://dx.doi.org/10.32598/ptj.15.2.416.8>

<http://dx.doi.org/10.32598/ptj.15.2.416.8>

Article info:

Received: 16 Jul 2024

Accepted: 22 Oct 2024

Available Online: 01 Apr 2025

Keywords:

Music, Sports performance, Gait, Biomechanics

ABSTRACT

Purpose: Music is one of the most widely used artistic elements in different societies. Today, it has drawn much attention due to its extensive societal effects. Music stimuli can affect human sports performance and gait as important indicators of different health conditions. This review study investigates how listening to music affects sports performance and gait.

Methods: This systematic review based on a descriptive-analytical method was conducted to investigate the interaction of music with sports performance and gait. We searched in reliable citation databases based on the keywords “gait”, “music”, and “biomechanics” in articles published between 2003 and 2023. After the final screening, the full texts of 11 studies were extracted and analyzed.

Results: Based on the interpretation of the qualitative findings of the articles, it was observed that music can improve sports and gait performance. For example, changes in walking speed, step length, rhythm, and step time were significantly improved in the gait kinematic section.

Conclusion: Listening to music improves motor performance in clinical settings and functional environments. In addition, music can be used as a therapeutic agent or directly in treating people with movement disorders.

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Highlights

- Listening to music can improve sports processes and spend less energy to perform performance.
- Listening to music enhances athletic performance by optimizing processes and reducing the energy expended during the performance.
- In the field of gait biomechanics, music significantly affects various kinematic parameters of gait, including speed, step length, rhythm, and alterations in step time. These changes in step time can also have implications for specific kinetic parameters of gait.

Plain Language Summary

Music plays a crucial role in human culture and development, significantly influencing human locomotion, which can enhance motor skills in various contexts. Engaging with music has been shown to decrease tiredness during physical activities and elevate workout intensity. Moreover, music has been found to alter the biomechanical aspects of gait, affecting gait efficiency and performance.

Introduction

Music constitutes an artistic manifestation of sound within the temporal dimension and can convey emotions and conceptualizations via the fundamental components of rhythm, melody, harmony, and timbre [1]. Historically, music has achieved considerable attention due to its diverse impacts on human society [2]. Individuals across different cultures and traditions have engaged with music for sports, entertainment, and ceremonies [3]. A positive relationship was reported between music and physiological, psychological, and emotional responses during physical activity and work [4]. Music might play an important role in motor unit activation due to rhythms, muscle contraction, and synchronization of body locomotion with the beat [5]. The human body regulates performance according to song stimulation [1, 5]. These qualities present various possibilities for applications in exercise and, ultimately, in enhancing the quality of life. Nonetheless, specific outcomes of music's effects have been documented on physiological conditions, such as increased heart rate, respiration, blood pressure, endorphin levels, skin responses, brain activity, motor responses, flexibility, and motor coordination, as well as its impact on the limbic nervous system and the autonomic nervous system's control mechanisms [6, 7]. These effects also include reduced perception of pain in the body [8]. Engaging with auditory stimuli, such as music, prior to and throughout physical exertion has been empirically demonstrated to enhance motivational levels and exertional intensity, consequently resulting in superior performance metrics [9, 10].

Human gait analysis serves as a crucial indicator concerning various health metrics. Specifically, gait is recognized as the sixth vital sense due to its correlation with daily functionality, mobility in older age, well-being, and cognitive capacity [8, 11, 12]. The gait process involves a circular motion comprising repetitive sequences that persist until the individual halts [13, 14]. The gait cycle consists of two primary phases [15]: Stance and swing phases [16-18]. The foot is significant in the human body as it absorbs ground impact forces, maintains equilibrium, and transmits forward forces. Moreover, as the final component of the movement chain, it opposes applied forces [19, 20]. Gait represents a fundamental movement pattern employed throughout life, influenced by numerous factors and circumstances [21-23]. Researchers have endeavored to enhance gait performance through various means [24]. Walking analysis is a method utilized to unveil the complex mechanisms governing human locomotion by quantifying factors dictating the lower limbs' functional display [25, 26]. Technological advancements in motion capture equipment, research methodologies, and data analysis have spurred numerous investigations [27, 28]. Kinetic analysis, introducing and examining forces, influences gait performance by offering insights into movement production and body position maintenance [13, 29, 30]. Kinetic and kinematic analyses are crucial in enhancing gait performance, including utilizing music [24, 31]. Given the current lifestyle changes and decreased physical activities, alongside the paramount significance of gait, leveraging music to promote gait and sports performance and appreciating these fundamental activities emerge as potentially effective strategies. This review explores music and human biomechanics of gait and sports performance.

Materials and Methods

A review article offers a thorough examination of the literature about a specific field of study, and its methodology, similar to other scientific studies, is methodical and systematic to address the research problem unbiasedly [32]. The current investigation represents a descriptive-analytical inquiry focusing on music-biomechanics gait and sports performance, employing a review approach in its execution.

Eligibility criteria and search strategy

During this research, a comprehensive search was conducted across reputable internal and external databases using specific keywords such as “music”, “sports performance”, “gait”, “biomechanics”, and logical operators like AND and OR. Specifically, the inclusion criteria were studies on the intersection of music, gait, sports performance, biomechanics, kinematics, and kinetics published from 2003 to 2023. Initially, eligibility and exclusion criteria were established following standard screening protocols or the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline. Subsequently, a broad search was undertaken among research articles, drawing from [Scientific Information Database \(SID\)](#), [Science Net](#), and [Noor Mags](#) and external databases like [Google Scholar](#), [PubMed](#), [ScienceDirect](#), [Web of Science](#), and [Scopus](#). A large number of articles were obtained by searching keywords, but the purpose of the present study was only to review the research in which the effect of music on human performance was examined from a biomechanical point of view. Through a meticulous review process, 150 studies were selected based on judgmental criteria, with many articles being excluded due to reasons such as unavailability of full text, irrelevant findings, and preliminary reports. Only 33 complete articles were scrutinized, leading to biomechanical in-depth extraction and review, with 11 final articles for full-text evaluation, after additional scrutiny based on identified citations to eliminate erroneous entries, duplicates, and those not meeting entry and exit criteria. It is important to highlight that this study specifically focused on articles that comprehensively addressed the role of music in the biomechanics of human locomotion. However, it is acknowledged that some relevant articles from other databases may have been overlooked. Furthermore, the review was confined to articles in Persian and English, with no search conducted for articles in Spanish, French, Turkish, Chinese, or German.

Exclusion criteria

Papers outside the biomechanics field and articles related to this topic in English and Farsi were excluded from the study. In addition, the papers that used the data extraction form and formulated with the specific purpose of the study, do not match the desired criteria.

Study selection and bias

To alleviate possible biases or inaccuracies in the selection of studies, each of the four reviewers independently assessed the titles, abstracts, and full texts of the studies in strict accordance with the established inclusion criteria. Should any inconsistencies arise, a collaborative resolution was attained through a deliberative discussion among the four reviewers.

Data collection

A single author extracted information from the included articles.

Data extraction and assessment of methodological quality

Data about each study were systematically gathered and subsequently inputted into Excel: The identity of the researchers (year of publication), the study’s objectives, the sample population, the quality assessment, and the outcomes. The compilation and examination of articles about various domains, including music, gait, sports, biomechanics, kinematics, and kinetics, were conducted.

Results

Figure 1 shows the screening process, divided into four sequential steps: Identification, screening, eligibility, and inclusion in the review plan. [Table 1](#) demonstrates the inclusion and exclusion criteria of the studies. [Table 2](#) expresses the included private investigations.

Of 11 articles included in the study ([Table 2](#)), 3 articles related to the study of the effect of music and sports performance [4, 33, 34], 6 articles dealt with the effect of song on walking kinetics [3, 35-39] and 2 articles on the study of the effect of songs on walking [40, 41].

Most studies showing the effect of music on gait have only investigated temporal and spatial characteristics, or the effect of music intervention on preventing gait in people with skeletal abnormalities and certain diseases, as well as the effect of music on specific exercise. Below is a review of articles investigating the relationship

Table 1. Search components

Search Component	Description
Document databases	Google Scholar, PubMed, Science Direct, Web of Science, Scopus, NoorMags, SID
Keywords	Music, sports performance, gait, biomechanics, kinematics, kinetics
Search Field in the library (Domestic and foreign)	Title, Abstract, Keywords
Type of documents	Journal articles and reviews
Period	2003-2023
Language	English and Persian

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between music and walking and analyzing motor performance.

Most studies showing the effect of song on walking have mainly investigated temporal and spatial characteristics or have focused on the effect of music intervention on walking disorders in people with skeletal abnormalities and specific diseases, as well as the effect of song on exercise. Below is a review of articles that have found a

connection between music and gait and analysis of motor performance based on their research.

Discussion

The purpose of the present paper is to investigate the effects of music on gait. This research is a systematic review, and the mentioned articles are searched using the principle of PRISM (Preferred Reporting Items for Systematic Reviews and Meta-analyses). After screen-

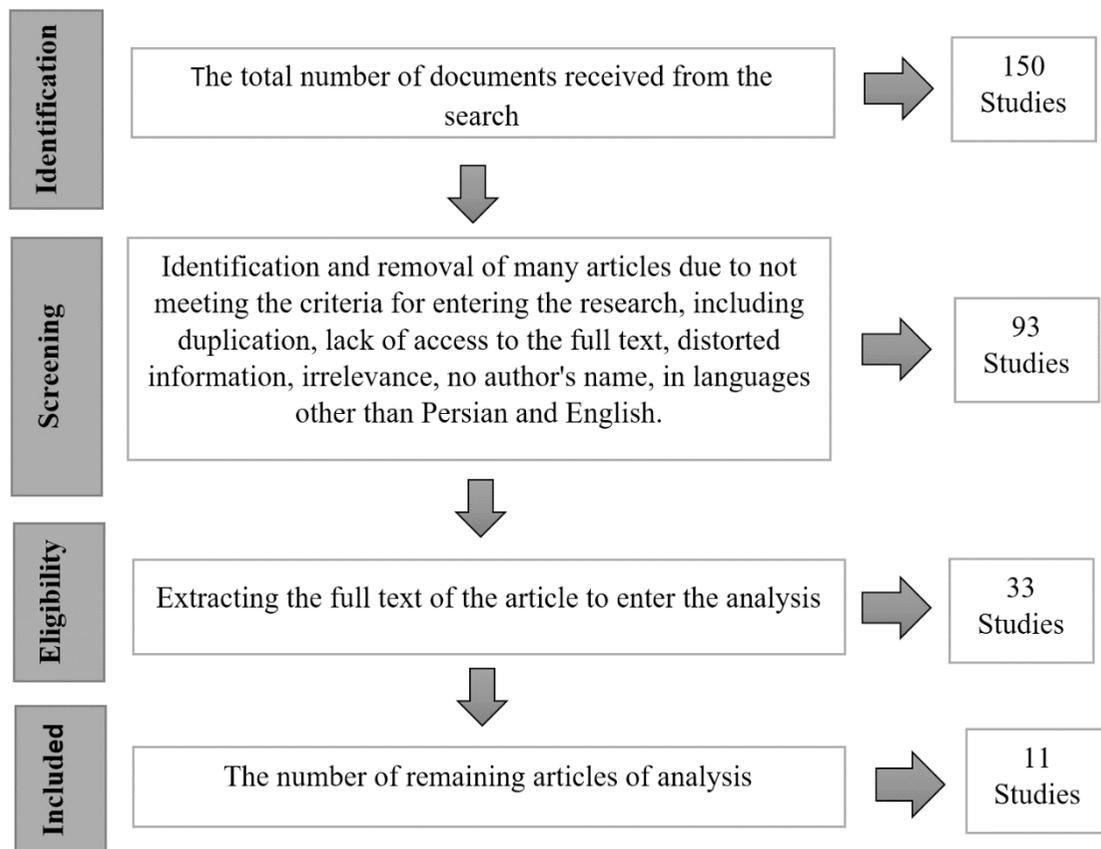


Figure 1. Extended design for searching protocol

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Table 2. Details of articles entered for analysis

No.	Author (Year) [Ref]	Title	Results
1	Sejdić et al. (2013) [36]	Listening to songs or watching television on human gait	All of the analyzed gait parameters (including statistical stability, dynamic stability, and gait diversity) did not show statistically significant differences when comparing experiments involving the presence or absence of music during gait analysis.
2	Torabi et al. (2013) [34]	Investigating the effect of music on the performance of physical fitness factors in adolescent boys	Engaging with music while engaging in endurance and power activities has enhanced performance.
3	de Bruin et al. (2015) [35]	Effects of the song on the walking performance	Listening to music is a pleasurable activity, and it affects gait.
4	Kazemi et al. (2017) [4]	Brain-waves stimulator music on improving athletic performance in adult women	Listening to all three types of music increases sports performance.
5	Park et al. (2019) [3]	Forward gait during music listening	Emotional states affect gait behavior while listening to music, and these effects change with familiarity with music.
6	Shahraki et al. (2019) [38]	The effect of rhythmic auditory stimulation during gait training on kinematic parameters of gait in patients with multiple sclerosis	Using rhythmic auditory stimulation in conjunction with walking exercises may be recommended as a supplementary approach to enhance the walking abilities of individuals with multiple sclerosis. The activities of Iran's junior judo team carry considerable weight.
7	Safaei et al. (2020) [33]	Effectiveness of energizing and relaxing music on performance of youth members of the Islamic Republic of Iran's national judo team	Exciting and relaxing music has a significant effect on the sports performance of the Iranian Judo team.
8	Roberts et al. (2021) [37]	Musical enjoyment does not enhance walking speed in healthy adults during music-based auditory cueing.	Music enjoyment had no significant effect on gait in young or old adults.
9	Derie et al. (2022) [40]	Biomechanical adaptations following a music-based biofeedback gait retraining program to reduce peak tibial accelerations	After completing a music-based biofeedback gait retraining program, runners can reduce impact when running over the ground in the laboratory.
10	Kong et al. (2023) [39]	Effects of music therapy intervention on gait disorders in persons with multiple sclerosis: A systematic review of clinical trials	Gait disorders of patients with multiple sclerosis were effectively improved by music therapy intervention.
11	Meinerz et al. (2023) [41]	Does listening to music affect running cadence and lower extremity biomechanics?	The auditory engagement with musical compositions characterized by elevated beats per minute did not demonstrate a significant enhancement in velocity nor a reduction in peak tibial acceleration during running.

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ing and extracting the articles from reliable databases of scientific documents, we translated them and examined them more closely. After obtaining the necessary information and analyzing the documents, it seems that these results can be presented in two categories based on the characteristics and content of the articles on these effects.

The first group of studies showed the effect of music and listening to music on sports performance. The second group of studies showed music's effects on gait biomechanics.

The effect of music on sports performance

The sports domain has grown substantially in the last 20 years, becoming a crucial catalyst for numerous economies and significantly influencing our social and cultural structures. The intricacies involved in forecasting and improving athletic performance present considerable challenges that have historically been tackled

by specialists in the field, including coaches, managers, scouts, and professionals in sports health.

Ghorbanekjad and Safaei (2018) stated that athletes with exciting and relaxing music traveled a longer distance than those without music. They ran and showed better performance. It can also be said that people felt more positive after listening to soothing music than the other two groups. Listening to music by athletes before training improves motivation and reduces the perception of pain related to training, and as a result, they are allowed to show more effort [33]. Barzegar et al. (2013) presented an article that stated that motivational music increases and improves sports processes [42]. Torabi et al. (2013) found that exciting music leads to the highest sports scores in people, and in another investigation [34], English et al. (2019) revealed that the audition of motivational music during physical training improves performance by 10% [43]. In this way, listening to music reduces negative emotions in athletes and improves sports performance. Therefore, music can help the athlete in-

crease training and its intensity [43]. Also, Barel (2018) showed that listening to music at high speed helped the runners to run for a longer period than without music, and it also gave the runners constant speed and made the exercise easier for them. In addition, when the rhythm of the music is equal to the exercise, athletes consume less energy than when the music is quieter [44].

By examining these results, it can be said that stimulating music with its motivational effects causes a sustainable improvement in sports performance in training and competitions [33]. Listening to motivational music during exercise limits the reception and processing of fatigue-related neural messages. This condition causes the person to increase training intensity at higher levels [45] consciously.

A thorough examination of a substantial body of literature concerning elements such as music that may affect athletic performance holds considerable promise for advancing coaches, scholars, and competitors. By meticulously investigating the complexities and subtleties of this subject, a more profound comprehension of its ramifications on athletic results can be found. This augmented understanding can subsequently facilitate the formulation of more efficacious training regimens, performance evaluations, and holistic exercise methodologies. Consequently, allocating resources towards performance analysis and factors influencing outcomes such as music can confer substantial advantages in athletic achievement and development.

The effect of music on gait biomechanics

Research concerning the locomotion of humans is designated as gait analysis. The methodology employed in gait analysis entails the systematic quantification of factors that regulate the functionality of the lower extremities, thereby elucidating the fundamental mechanisms underlying human movement. The examination and evaluation of human locomotion, commonly called gait analysis, encompass various applications across diverse disciplines, including medical diagnosis, safety assessment, virtual reality, commerce, and enhancing physical activity knowledge [25, 46]. Dysfunctional ambulation may arise due to either acute or chronic injury or as a result of maladaptive biomechanics. Healthcare professionals can derive substantial benefits from various types of research in analyzing gait variability, employing kinematic and kinetic parameters to predict potential complications, and monitoring patients' recovery trajectories within clinical contexts [47].

Gait kinematics

Natalie de Bruin et al. (2015) reported that walking while listening to music was a pleasurable experience that influenced walking patterns. The selection of music types varies based on the music index or tempo, with music index choice impacting song parameters, tempo, and stride length. Conversely, the walking pace remains unaffected when non-indicative music is played. The tempo of the music did not show any distinct effect on walking performance (such as walking speed, step length, music, and changes in step time) among the participants [35]. Sejdíć et al. (2013) explored the impact of listening to music while watching television on human walking patterns, presenting a two-part study on different gait conditions. Although no statistically significant difference was observed when comparing music and no-music trials, changes in stride intervals and dynamics are notably greater during TV viewing with sound than watching with subtitles [36]. Parka et al. (2019) studied emotional responses based on familiarity with music choices while walking forward and listening to music. They showed that music can elicit various human emotions that influence movement. Moreover, familiarity with the music interacted with emotional reactions to affect walking kinematics, resulting in faster gait speed in the presence of familiar-pleasant music due to longer stride length [3]. Roberts et al. (2021) conducted a study on music enjoyment and its impact on gait speed in healthy adults using music-based cues, concluding that music enjoyment did not significantly affect walking patterns in younger and older adults. Specifically, younger adults walked faster (taking longer strides) in response to music compared to a metronome. Young adults with poor beat perception tend to take shorter and slower steps while listening to music, whereas older adults with poor beat perception display slower walking speeds in response to music [37].

In summary, the review of these studies demonstrates the potential influence of music on walking performance. Kong et al. (2023) reported that the decrease in lower limb function in the early stages of this disease usually leads to gait disorders, including slower speed and shorter steps than in healthy people. According to this research, music can influence the spatiotemporal parameters of gait [39, 48]. Shahraki et al. (2019) showed significant positive effects of auditory rhythmic stimulation on some kinematic parameters, including step length, step time, speed, and gait rhythm of patients with multiple sclerosis. However, the recovery time in these patients did not show a significant change; the findings of this study show that auditory rhythmic stimulation during gait exercise significantly affects the improvement

of the step length and the duration of the stance. Also, gait training with an auditory rhythmic stimulus leads to a 27% improvement in step time and 10% in swing time. However, these changes are not statistically significant [38]. These researchers used the fact that music helps to modify step frequency and improve gait patterns, mainly through auditory-motor feedback, to reduce motor and psychological stress. Leuk et al. (2023) also conducted a short review. They studied the mechanisms underlying the role of interventions based on acoustic and rhythmic auditory stimulation (RAS) and vibration therapy (VAT) for older people with gait disorders and tremors (motor deficits) [49]. They expressed two hypotheses: RAS may recruit alternative motor networks, which can bypass the defective spatiotemporal movement in Parkinson disease patients, and the use of RAS improves basal ganglia function through the bubble of beta oscillatory activity [32].

Gait kinetics

Dari et al. (2022), through the utilization of real-time musical biofeedback on peak tibial axial acceleration to mitigate impact measures and identify related adaptations, the researchers determined that participants were able to engage in overground running in the laboratory after completing the music-based gait retraining program, thereby diminishing the impact [40]. Miners et al. demonstrated that listening to music with faster beats per minute increased speed or reduced maximal tibial acceleration during running [41].

According to the studies that were conducted, a significant group of researchers are looking for different methods to analyze walking and ways to improve this fundamental movement, such as the effect of music as a standard clinical practice to assess the condition, recovery, and progress of patients with neurological disorders and use complex musculoskeletal systems and ultimately reduce potential emissions.

Conclusion

This article evaluates the questions that arise from applying music in the context of walking and exercise. The study tries to develop a methodological framework that can be used for future research. Our analysis has determined several critical research areas that provide a broad outline of current research and indicate unexplored areas for future research.

Subsequently, the prospect of using performance improvement methods such as music to improve the mentioned procedures was investigated.

In conclusion, music can significantly help in movement and sports performance by increasing motivation and reducing the perception of pain related to exercise, increasing the total volume of exercise and intensity, performing the function for a longer time, and limiting the reception and processing of nerve messages related to fatigue. It can help develop more beneficial exercise plans, functional evaluations, and overall sports techniques.

Also, music can increase walking variables, such as speed, step length, and step time, but no significant studies show that music can affect walking kinetics and reduce the risk of injury. Therefore, multicenter clinical studies with larger sample sizes should further investigate these effects.

In addition, music can directly be used as a therapeutic agent in treating people with movement disorders. For example, it can improve the mental health of patients with Parkinson disease, and it is suggested that this therapeutic approach be included in the holistic management of Parkinson disease as an adjunctive treatment to traditional drug treatment. However, research to design standard music protocols appropriate to the nature or stages of treatment must be developed together with current cognitive-behavioral and pharmacological treatments to increase effectiveness.

Ethical Considerations

Compliance with ethical guidelines

This article is a Narrative Review with no human or animal sample.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interception of the results, and manuscript drafting. Each author approved the submission of the final version of the manuscript.

Conflict of interest

The authors declared no conflict of interest.

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