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Rhythmic Auditory Cueing for Gait Rehabilitation in Parkinson's Disease: An Evidence-Based Narrative Review

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Abstract:
Background: Parkinson's disease commonly disrupts gait automaticity, step scaling, rhythm, turning, and the capacity to adapt walking to environmental demands. Rhythmic auditory cueing provides an external temporal reference that may compensate for impaired internal movement timing. Objective: To critically synthesise evidence on the effects, mechanisms, and clinical relevance of rhythmic auditory cueing for gait rehabilitation in adults with Parkinson's disease. Methods: A structured narrative review was undertaken using peer-reviewed trials, systematic reviews, and clinically relevant mechanistic literature published through 31 December 2023. Evidence was organised by cue mechanism, immediate response, training effect, gait outcome, freezing, balance, functional mobility, and implementation. Results: The literature consistently supports short-term improvement in selected spatiotemporal gait variables, particularly gait speed and step or stride length, but the magnitude and durability of benefit vary. Outcomes depend on cue type, tempo, synchronisation ability, medication state, disease severity, task complexity, comparator intensity, and whether assessment occurs with or without the cue. Evidence for freezing, balance, falls, participation, and long-term retention is less uniform than evidence for straight-line gait. Conclusion: Rhythmic auditory cueing is best regarded as an individually titrated rehabilitation tool rather than a universal protocol. Clinical use should combine response testing, safety screening, task-specific training, periodic uncued assessment, and planned cue fading.

Keywords: Parkinson's disease; rhythmic auditory stimulation; auditory cueing; gait; freezing of gait; neurorehabilitation; physiotherapy

1. Introduction

Gait impairment in Parkinson's disease (PD) reflects interacting deficits in movement amplitude, timing, automaticity, postural control, cognition, and sensory integration. Reduced step length, slow walking, greater temporal variability, turning difficulty, festination, and freezing can restrict independence even when limb symptoms respond to medication. Because falls and activity restriction emerge from more than one impairment, rehabilitation must address both measurable gait parameters and the situations in which walking becomes unsafe (Balestrino & Schapira, 2020; Bloem et al., 2004).

External cueing is a long-established physiotherapy strategy for bypassing or supplementing impaired internal movement regulation (Morris, 2000; Keus et al., 2007). Rhythmic auditory cueing (RAC), often described as rhythmic auditory stimulation (RAS), uses a metronome beat, rhythmically accentuated music, ecological footstep sounds, or another predictable acoustic signal to structure step timing. Early experimental training showed that auditory rhythm can modify gait velocity, stride length, and cadence (Thaut et al., 1996), while subsequent trials extended investigation to home training, treadmill walking, freezing, balance, and falls.

The clinical question is no longer simply whether a beat can change walking. More useful questions concern who benefits, which outcomes change, whether change persists without the cue, and how cueing can be prescribed without increasing hurried gait, cognitive load, or environmental risk. This review therefore emphasises the distinction between immediate compensation and training-related learning, and between statistically detectable effects and functional change relevant to neurological physiotherapy.

2. Review approach

This evidence-based narrative review drew on peer-reviewed clinical trials, systematic reviews, meta-analyses, and mechanistic papers indexed in major health-science databases and published through 31 December 2023. Core concepts included Parkinson disease, rhythmic auditory stimulation, auditory cueing, metronome, music, gait, walking, cadence, step length, freezing, balance, and mobility. Greater interpretive weight was given to controlled studies, transparent intervention descriptions, validated outcomes, and syntheses that distinguished intervention and assessment conditions. Because a new systematic search with duplicate screening was not performed for this manuscript, no PRISMA flow counts or pooled effect estimates are claimed.

3. Why rhythm may influence Parkinsonian gait

Auditory rhythm has unusually strong temporal salience. Repeated beats can support prediction of when a movement should occur and provide immediate information about whether the step matches the target interval. Auditory–motor entrainment describes the coupling of movement timing to this regular sensory structure (Thaut et al., 2015). In PD, the cue may reduce reliance on impaired internally generated timing and recruit attention-dependent cortical and cerebellar networks that support externally guided action (Nombela et al., 2013; Koshimori & Thaut, 2018).

This explanation should not be reduced to a simple “replacement” of the basal ganglia. Cue response is shaped by beat perception, hearing, executive function, instruction, motivation, and motor capacity. Music may improve engagement, but musical complexity can obscure the beat; conversely, a metronome offers a clear interval but may be monotonous. Beat-perception ability and explicit synchronisation instructions alter gait response, illustrating that sound delivery alone does not guarantee entrainment (Ready et al., 2019).

4. Evidence by outcome

4.1 Gait speed, step length, and cadence

Across foundational trials and later quantitative syntheses, RAC is most consistently associated with improvement in gait speed and step or stride length (Thaut et al., 1996; Ghai et al., 2018; Wang et al., 2022; Ye et al., 2022). These variables, however, are mechanically interdependent. A faster pace is not automatically safer if it is produced by rapid short steps, and a change in cadence is not inherently therapeutic. Clinicians should therefore interpret speed together with step length, variability, turning control, and the ability to stop.

Tempo selection is a plausible effect modifier. A cue close to comfortable baseline cadence may stabilise timing, whereas a modest increase may encourage speed in a patient who can preserve step amplitude. A faster beat can be counterproductive when it provokes festination, reduced step length, or loss of balance. The evidence does not support a single tempo percentage for every patient and every goal; individual response testing is more defensible than rigid prescription.

4.2 Freezing, turning, and complex walking

Freezing of gait is episodic and context sensitive. Straight-line laboratory walking may not reproduce doorway hesitation, turning, dual-task interference, or destination-related freezing. Arias and Cudeiro (2010) demonstrated that response differs between participants with and without freezing, while broader physiotherapy evidence indicates that cueing can be useful but is not uniformly effective across freezing phenotypes (Rutz & Benninger, 2020). External rhythm may help initiate or continue stepping, yet constant stimulation can increase cognitive demand or fail when attention is divided.

The attentional cost of cueing becomes especially relevant during complex tasks (Rochester et al., 2007). Training should progress from predictable straight walking to starts, stops, turns, obstacles, narrow spaces, and carefully selected dual tasks. Outcome assessment should document the trigger context and separate freezing frequency or duration from general slowness.

4.3 Balance, falls, and functional mobility

Evidence for balance and falls is more heterogeneous than evidence for spatiotemporal gait. RAC may improve balance indirectly by increasing step amplitude and predictability, or directly when combined with treadmill, overground, and postural-challenge training. Controlled studies have reported favourable balance or fall-related findings in specific programmes (Harro et al., 2014; Thaut et al., 2019), but intervention packages and follow-up schedules differ. A reduction in falls cannot be inferred solely from faster gait.

Functional mobility depends on transfers, turning, endurance, attention, environment, and confidence. Home cueing in the RESCUE trial produced modest short-term gains and illustrated both the feasibility and limitations of domiciliary training (Nieuwboer et al., 2007). Treadmill plus music and ecological footstep sounds provide alternative delivery models that may enhance task practice or engagement (Calabrò et al., 2019; Murgia et al., 2018). These approaches should be interpreted as programme-specific evidence rather than interchangeable versions of one treatment.

Domain	Likely role of RAC	Interpretive caution
Straight-line gait	External timing may improve speed and step/stride length.	Assess quality, variability, stopping, and uncued carryover.
Freezing	May support initiation or rhythm in selected triggers.	Response varies by phenotype, context, attention, and tempo.
Balance	May assist indirectly within task-specific training.	Do not equate faster walking with lower fall risk.
Functional mobility	Home and technology delivery can increase practice.	Transfer to turns, community tasks, and participation is not assured.
Retention	Repeated practice may support learning.	Separate cue-present performance from cue-absent retention.

5. Immediate compensation versus motor learning

A cue-present improvement demonstrates that the patient can use external timing; it does not demonstrate independent motor learning. Training-related learning requires change that persists after the cue is removed or at a later follow-up. Studies and reviews often vary in whether outcomes were obtained during stimulation, immediately after a programme, or weeks later. Combining these time points risks overstating durability.

A clinically useful programme can deliberately use both functions. RAC may be retained as a compensatory strategy for specific tasks while practice also includes uncued trials to test transfer. Cue fading—reducing cue duration, using intermittent beats, or reserving the cue for difficult transitions—may limit dependence and reveal whether the patient has internalised the target rhythm. The decision should follow repeated objective measurement rather than an assumption that all cue use must be withdrawn.

6. Clinical prescription framework

Step	Clinical action	Minimum documentation
1. Screen	Review hearing, cognition, falls, orthostatic symptoms, medication state, pain, footwear, device, and goals.	Risks, medication condition, assistive device, baseline task.
2. Measure	Record comfortable gait and the target task without cueing.	Speed, cadence, step quality, freezing/turning observations.
3. Test	Compare metronome or music tempos while preserving safety.	Cue source, tempo, volume, instruction, synchronisation.
4. Train	Practise meaningful tasks; progress one demand at a time.	Walking exposure, task content, rests, assistance, adverse response.
5. Reassess	Repeat cued and uncued measures under comparable conditions.	Immediate response, carryover, falls/near-falls, patient preference.
6. Maintain/ fade	Specify independent-use limits, caregiver role, and review date.	Home route, stopping rules, progression or withdrawal criteria.

The initial dose should be limited by walking quality, fatigue, and safety rather than by a universal session duration. Training should stop or be modified when the patient chases the beat, shortens steps, develops marked instability, experiences dizziness or pain, or shows increased freezing. Earphones must not mask traffic, alarms, or verbal warnings. Community use should follow supervised testing, especially when cognitive impairment, recent falls, or a complex assistive device is present.

7. Sources of heterogeneity and evidence limitations

Cueing studies vary in disease stage, freezing status, medication timing, cue modality, tempo, instruction, training exposure, comparator, and outcome timing. Small samples and incomplete intervention reporting reduce precision and reproducibility. Meta-analyses support benefit in selected domains but necessarily pool studies that are not identical (Ghai et al., 2018; Spaulding et al., 2013; Wang et al., 2022; Ye et al., 2022). Review-level agreement should therefore not be mistaken for certainty about the best protocol.

Future trials should preregister primary outcomes, report baseline cadence and actual delivered tempo, quantify walking exposure, document synchronisation, distinguish cue-present from uncued testing, and record adverse events. Patient-important outcomes—falls, community mobility, confidence, adherence, and participation—deserve longer follow-up. Adaptive and on-demand systems should be compared with simpler low-cost cues, including economic and usability outcomes.

8. Implications for outcome measurement

Outcome selection materially shapes the apparent effectiveness of RAC. Gait speed is attractive because it is objective, responsive, and easy to reproduce, but it cannot represent the full mobility problem. A patient can increase speed by increasing cadence without restoring step amplitude, or can walk faster in a quiet corridor while remaining unable to turn safely. Trials and clinical services should pair speed with at least one measure of step scaling or gait quality and one measure that captures the patient's priority activity. Where freezing is relevant, the provoking context and medication condition must be recorded rather than treating all slow trials as freezing episodes.

Cadence deserves particularly careful interpretation. Synchronisation to an imposed tempo makes cadence partly a manipulation check: it indicates that the patient followed the beat, not necessarily that gait improved. Step or stride length, variability, symmetry, turning performance, and stability help determine whether the cadence response was useful. Instrumented walkways and wearable sensors provide detailed spatiotemporal data, but simple timed walks, observed step counts, and standardised video can still support rigorous clinical comparison when the protocol, walkway, acceleration zones, and assistive-device condition are held constant.

Balance and functional-mobility measures should be chosen according to the hypothesised pathway of benefit. If RAC is delivered only during straight walking, a broad balance scale may be insensitive to a short intervention. Conversely, a programme combining cued walking, turning, obstacle negotiation, and treadmill practice may reasonably influence functional mobility. Falls require prospective recording with a defined observation period and clear distinction between falls and near-falls. Retrospective recall over long periods is vulnerable to error, while short follow-up may miss clinically important events.

9. Patient selection and response variability

The average effect reported by a trial does not establish that every person with PD should receive the same cue. Candidate selection begins with a modifiable gait target and the capacity to perceive and use rhythmic information. Hearing impairment does not automatically preclude cueing, but audibility, comfort, and beat discrimination should be tested. Cognitive impairment, anxiety, and dual-task difficulty may increase the attentional cost of synchronisation. These factors call for simpler instructions, shorter trials, additional supervision, or an alternative cue rather than automatic exclusion.

Disease stage and medication state also influence response. In an optimally medicated state, a patient may have sufficient step amplitude and postural control to use an external rhythm effectively. During an "off" period, the same tempo may be unattainable or unsafe. Research reports should identify the time since medication and whether repeated assessments occurred in comparable states. Clinicians should interpret day-to-day variation before concluding that a programme failed or succeeded, especially when motor fluctuations are prominent.

Freezing phenotype, baseline cadence, musical familiarity, and personal preference further contribute to heterogeneity. A highly salient metronome may be helpful for one patient but stressful for another;

preferred music may enhance effort yet provide an ambiguous beat. Short response tests across cue formats can identify a workable option. A non-responder to one tempo or sound should not be labelled a non-responder to all external cueing, but repeated absence of meaningful benefit should prompt a different rehabilitation strategy rather than escalating complexity indefinitely.

10. Integration within comprehensive rehabilitation

RAC addresses timing and can support step scaling, but it does not directly correct every contributor to impaired mobility. Lower-limb weakness, reduced aerobic capacity, axial rigidity, pain, postural instability, fear of falling, and environmental barriers may require strength, endurance, amplitude, balance, transfer, education, or home-modification interventions. The cue should therefore be linked to a broader problem list. If limited endurance is the main barrier, repeated short bouts with appropriate rest may be more valuable than pursuing a faster tempo. If turning instability predominates, the programme should emphasise turn strategy and postural control rather than straight-line cadence alone.

Combining RAC with treadmill training can increase stepping repetition and regulate speed, while overground training allows practice of initiation, turning, obstacle negotiation, and destination tasks. Music-based programmes may support motivation and sustained participation. These combinations make it difficult to isolate the effect of sound, but they may better reflect clinical care. Comparative studies should match practice time and therapist contact so that any advantage is not merely the result of a larger training dose.

Education is an active component of treatment. Patients should understand that the beat is a timing aid, not a cure, and that faster is not always better. Caregivers need a consistent role: prepare the device or environment when required, observe agreed safety signs, and avoid pulling or issuing competing commands during freezing. Clear explanation can improve adherence while preventing unplanned tempo increases or unsafe community experimentation.

The emphasis on translating physical gains into independence and participation is consistent with broader rehabilitation scholarship that links mobility-focused physiotherapy to social inclusion and community functioning (Katasani et al., 2021a, 2021b). These publications address community and paediatric rehabilitation rather than PD-specific auditory cueing; they are therefore used here only to support the participation-oriented rehabilitation framework, not as evidence that RAC improves Parkinsonian gait.

11. Methodological considerations for interpreting the literature

Narrative synthesis is appropriate when interventions and outcomes are diverse, but it requires explicit boundaries. Immediate crossover experiments answer a different question from multiweek parallel-group training trials. Review-level evidence may include the same primary trials, so several meta-analyses reaching similar conclusions should not be counted as independent replication. Likewise, a favourable within-group change does not demonstrate superiority when the comparator also improves. The most clinically informative comparisons match walking practice and differ mainly in the auditory component.

Blinding participants and therapists is difficult in cueing research, increasing the importance of standardised instructions, blinded outcome assessment where feasible, and transparent protocol registration. Small studies can produce unstable estimates and selective emphasis on favourable outcomes. Complete reporting of all prespecified variables, missing data, adherence, deviations, and harms would improve confidence. Evidence tables should separate statistical significance from clinical importance and should not imply long-term benefit when follow-up was absent.

The present review is limited by its narrative design and by reliance on published reports through the specified cutoff. It did not undertake a new duplicate systematic search, risk-of-bias adjudication, or quantitative pooling. Its contribution is therefore interpretive: it integrates established trials and reviews around questions faced by physiotherapists. Conclusions about effect magnitude should be taken from formal meta-analyses, whereas recommendations about assessment and prescription should be tested prospectively rather than treated as a validated universal protocol.

12. Research priorities

A first priority is to identify clinically meaningful responder profiles. Trials commonly estimate an average treatment effect, yet clinical decisions concern individuals whose gait phenotypes differ. Prospective studies should examine whether baseline step length, cadence variability, freezing status, beat-perception ability, cognition, hearing, disease stage, and medication responsiveness modify benefit. Prediction models require samples large enough for validation and should report calibration as well as discrimination. Until such models exist, response testing remains necessary and subgroup claims should be considered exploratory rather than used as firm exclusion rules.

Dose also needs clearer investigation. Scheduled session duration is an incomplete measure because rest periods, instruction, and non-walking activities vary. Researchers should report actual minutes or steps practised with the cue, frequency per week, total programme exposure, adherence, and progression. Factorial or adaptive designs could compare tempo strategies and intermittent versus continuous delivery while controlling practice volume. Follow-up should extend beyond the immediate post-training period to determine whether any uncued benefit is retained and whether patients continue using the cue appropriately.

Variation in rehabilitation timing, intensity, content, and outcome reporting is not unique to neurological cueing. Protocol diversity has also been mapped in postoperative physiotherapy, reinforcing the need to describe intervention components and progression rules explicitly (Katasani et al., 2023). This cross-condition citation supports a methodological point about protocol transparency; it does not imply that total-knee-replacement findings can be transferred directly to PD.

Comparator design is equally important. Comparing RAC plus substantial gait practice with no intervention cannot isolate the contribution of rhythm. Matched comparators should receive the same walking tasks, therapist contact, feedback, and approximate dose without the rhythmic element. A pragmatic usual-care arm can still answer a service question, but the interpretation differs. Trials should state which causal question the comparator addresses and avoid attributing the whole programme effect to auditory stimulation when other components were not controlled.

Outcome sets should include both mechanistic and patient-important domains. Spatiotemporal gait variables clarify how walking changes, while falls, near-falls, freezing in relevant contexts, community mobility, confidence, fatigue, participation, and quality of life determine whether the change matters. Core outcome development involving people with PD, caregivers, physiotherapists, neurologists, and measurement experts could reduce selective reporting and improve comparison across trials. Outcomes should be assessed at prespecified time points and under clearly labelled cue-present and cue-absent conditions.

Safety reporting must become more systematic. Absence of a reported adverse event is not evidence that no event occurred. Studies should define falls, near-falls, musculoskeletal symptoms, dizziness, excessive fatigue, anxiety, device problems, and gait deterioration; specify how these were collected; and report denominators and exposure. Community studies should describe environmental-audibility precautions. Safety outcomes may be uncommon, but consistent reporting is essential before recommending unsupervised use to patients with substantial postural instability or cognitive impairment.

Technology research should demonstrate added value over simple cues. Adaptive systems that detect gait phase or freezing are attractive, yet algorithm accuracy in a laboratory does not ensure usability at home. Evaluations should include false alarms, missed episodes, setup burden, battery life, comfort, privacy, cost, caregiver workload, and the consequences of delayed or inappropriate cues. Head-to-head comparisons with metronome, music, and therapist-delivered strategies can determine whether sophistication produces meaningful clinical gain.

Finally, implementation studies should examine how RAC is adopted in routine physiotherapy. Relevant questions include training requirements, documentation fidelity, equipment access, cultural and musical preferences, tele-rehabilitation delivery, and maintenance after discharge. Hybrid effectiveness-implementation designs can test both outcomes and service feasibility. Transparent publication of neutral and unfavourable findings is necessary to counter selective enthusiasm and to establish when a different gait strategy is the better choice.

Economic evaluation is another neglected area. RAC can appear inexpensive when delivered through an existing telephone or metronome, but programme cost also includes assessment, therapist training, supervision, device setup, follow-up, and management of technical problems. Cost-effectiveness studies should compare complete care pathways rather than device prices alone and should include consequences for falls, caregiver time, and service utilisation. Low-cost delivery may be a major strength, but it should be demonstrated under realistic clinical conditions.

Cultural context may influence both cue selection and adherence. Familiar rhythmic music can support engagement, yet preference, language, religious context, and public acceptability differ across communities. Studies should describe how music was selected and whether participants could choose or change tracks. Cross-cultural validation is especially relevant when rhythm-based programmes developed in specialised centres are transferred to rural or resource-limited rehabilitation settings with different equipment and follow-up capacity.

Reporting negative response is clinically valuable. A trial average can conceal participants whose freezing, fatigue, or instability worsened. Individual response distributions, responder definitions specified before analysis, and reasons for withdrawal can help clinicians counsel patients realistically. Such reporting also prevents the mistaken conclusion that lack of benefit reflects inadequate effort. RAC should be discontinued when repeated, well-conducted testing shows no meaningful advantage or when safer alternatives better address the patient’s goals.

Publication practice should preserve the distinction between hypothesis-generating interpretation and confirmed effect modification. Post hoc observations about preferred music, freezing status, or disease severity can inform later trials but should not be presented as established selection rules. Journals and reviewers can strengthen the field by requesting complete intervention descriptions, protocol access, and cautious conclusions that match the design. This discipline will make positive findings more credible and clinically transferable.

13. Conclusion

Rhythmic auditory cueing has a credible neurophysiological rationale and a supportive evidence base for improving selected gait parameters in PD. Its benefits are neither universal nor fully represented by cadence or laboratory speed. The most defensible clinical approach is individualised, goal-directed, and safety monitored: establish baseline performance, test the patient’s response, select a tolerable cue, practise relevant tasks, compare cued and uncued outcomes, and plan maintenance or fading. This positions RAC as a flexible component of neurological physiotherapy rather than a stand-alone cure or fixed protocol.

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