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REVIEW ARTICLE

Effects of Rhythm Training on Open Skill Athletes' Performance: A Systematic Review

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ABSTRACT
Background. In open skill sports, rhythm serves as a critical performance component. Rhythm-based training has been proposed to enhance athletes' adaptability, refine timing, and optimize psychological readiness within unpredictable and dynamic environments. **Objectives.** This systematic review evaluated the effects of rhythm training on athletic performance across various open skill sports. **Methods.** A systematic search was conducted across four electronic databases (PubMed, EBSCO, Web of Science, and Scopus) from inception through January 3, 2026. The included studies employed physical or technical rhythm-based interventions, including interactive metronome training, music stimuli, tempo-regulated exercises with heart rate feedback, and rhythmic competence assessments. All included studies involved athletes participating in open skill sports. **Results.** Seven studies met the inclusion criteria. The findings indicate that rhythm training can positively influence both physiological and psychological outcomes, including improved heart rate regulation, reduced fatigue, enhanced emotional stability, and greater rhythmic competence. These adaptations were associated with better reaction time, increased movement accuracy, and improved technical consistency in sport-specific tasks. **Conclusion.** Rhythm training appears to be a promising approach for enhancing athletic performance in open skill sports. Further research should investigate its long-term effects and applicability across diverse athletic populations, integrating both physiological and psychological outcome measures.

INTRODUCTION

Sports performance emerges from the interaction of multiple interdependent factors. As noted by Eliakim Gemser et al., performance is determined by the integration of anthropometric, physiological, technical, tactical, and psychological characteristics across sport disciplines (1). A common framework for classifying sports based on these demands distinguishes between open skill and closed skill sports. Open skill sports (e.g., interceptive or strategic activities such as tennis and badminton) require athletes to adapt in real time to dynamic and unpredictable environments (2, 3). In contrast, closed skill sports such as swimming, track and field, and gymnastics are typically performed in stable, self-paced, and consistent settings (1).

Research indicates that athletes in open skill sports tend to outperform their closed skill counterparts in various cognitive tasks (4, 5). Meta-analytic evidence further supports these findings, demonstrating that open-skill athletes exhibit superior attentional flexibility, decision-making accuracy, and adaptability in motor execution (5, 6). A key factor underlying these advantages is motor timing, a critical component for both reactive and proactive behaviors on the field or court (7). The ability to accurately perceive timing, regulate spatial awareness, and execute precise movements is therefore essential for successful performance in tasks such as ball interception and tactical execution (8).

Recent literature underscores the importance of rhythm in regulating motor skills and promoting movement efficiency and coordination (9). One widely studied method is synchronized metronome training (SMT), in which athletes coordinate their movements with external rhythmic cues, such as auditory beats. Research indicates that SMT and similar timing-based interventions can enhance sport-specific performance across various disciplines (10, 11). By demanding precise temporal synchronization, SMT is thought to sharpen attentional focus, stabilize technical execution, and improve emotional regulation. For instance, in table tennis, sustained attention to ball rhythm has been linked to increased positive affect and greater stroke accuracy, thereby facilitating skill acquisition (12). Mechanistically, SMT may function as a neurocognitive intervention that strengthens sensorimotor networks and enhances motor synchronization (10, 13-16). Empirical studies support its utility, demonstrating improvements in areas such as cross-pass accuracy in soccer (17), shot precision in golf (10, 17), and stroke control in tennis (11, 15).

In elite training environments, particularly across European programs, rhythm training has been integrated to enhance sport-specific performance. For example, Zachopoulou et al. reported that such training improved rhythmic ability in tennis, basketball, and swimming, and specifically advocated for the inclusion of rhythmic stroke execution in tennis practice (11). Similarly, Crespo et al. emphasized the foundational role of rhythm in motor coordination (18). Further supporting its efficacy, a longitudinal study involving children demonstrated that music-based rhythm training improved both motor performance and rhythmic ability (19). Notably, the extent of improvement correlated with pretraining rhythmic perception, suggesting that individuals with a stronger initial rhythm predisposition achieved greater gains (18). Collectively, these findings suggest that rhythm-based interventions have been increasingly adopted in athletic training and are now widely regarded as essential components of performance development across sports (20-22).

Recent evidence from systematic reviews indicates that listening to music exerts significant positive effects on performance-related outcomes in team sports such as soccer, volleyball, and basketball (23). Benefits extend to psychological responses, ratings of perceived exertion (RPE), and markers of fatigue. Furthermore, pre-exercise music listening has been shown to enhance psychological readiness and mitigate exercise-induced fatigue, with more pronounced effects observed among trained athletes who are permitted to self-select their preferred music (24).

Although existing research supports the positive effects of rhythm training on athletic performance, especially among elite racket sport athletes, no systematic review has yet synthesized its impact specifically within open skill sports. This study, therefore, systematically reviews the literature to evaluate the effects of rhythm-based training on training and performance outcomes in open skill athletes, to advance theoretical understanding and guide future research and practice in this field.

MATERIALS AND METHODS

Study design. This study systematically reviewed the existing evidence based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (25). The protocol was registered in the PROSPERO registry (CRD42024572995).

Search strategy and Study selection. All search results were initially imported into EndNote 21 for automatic duplicate removal, after which any remaining duplicates were identified and removed manually. Study selection was conducted using a three-step process. First, the deduplicated records were randomly allocated to two independent reviewers, who screened titles and abstracts to determine potential relevance. Studies deemed irrelevant were excluded at this stage. In cases of uncertainty or disagreement, the corresponding full-text articles were retrieved and independently assessed, with discrepancies resolved through discussion and adjudication by a third reviewer until consensus was achieved.

Subsequently, titles, abstracts, and full-text articles were systematically evaluated by an independent reviewer according to the PICOS criteria outlined in Table 1.

The search strategy employed Boolean operators ("AND", "OR") to systematically combine keywords relevant to targeting rhythm-based training and open skill sports. The following search string was applied across all databases: ("rhythm train*" OR "rhythmic train*" OR "tempo train*" OR "timing train*" OR "metronome train*" OR "sensorimotor training") AND ("open skill sports" OR "table tennis" OR "tennis" OR "badminton" OR "basketball" OR "soccer" OR "handball") AND (athlete* OR player*) AND ("performance" OR "enhancement" OR "sports ability" OR "training effect*").

Inclusion was restricted to peer-reviewed articles available in full text and published in English. Additionally, the reference lists of all included articles and relevant reviews were manually screened to identify potentially eligible studies not captured by the database search.

Eligibility criteria. Study eligibility was determined using the PICOS (participants, intervention, comparators, outcomes, and study design) framework. The specific inclusion and exclusion criteria are presented in Table 1.

Table 1. PICOS Eligibility Criteria

Category	Inclusion criteria	Exclusion criteria
Participants	Healthy athletes participating in open skill sports, with no restrictions on competitive level, sex, or age	Athletes with health problems (e.g., injuries, recent surgery, or illness) that preclude participation in a rhythm-based training
Intervention	Rhythm-based training or rhythm-related exercises (e.g., synchronized metronome training, interactive metronome training, tempo-based or music-based interventions)	Exercise or training interventions not involving rhythmic or tempo-based components.
Comparators	Rhythm-based training compared with another rhythm condition or combined with standard sport-specific training.	Training program without rhythmic components or non-exercise control conditions
Outcomes	At least one pre- and post-intervention outcome related to sport-specific skill performance and/or training performance	Studies lacking pre- and post-intervention outcome measures, or reporting only follow-up data without baseline comparison.
Study design	Controlled intervention studies including at least one comparator group (e.g., different rhythm-training protocols or control groups receiving neutral or no specific instruction)	Systematic reviews, observational studies, case reports, or case series

Only full-text, peer-reviewed original studies published in English were considered eligible for inclusion in this systematic review.

Data Extractions. Data extraction was conducted independently by two reviewers using a standardized extraction form. Each reviewer examined the full-text articles and recorded relevant details, including: participant characteristics (sport type, competitive level, sample size, age, gender, height, weight); study characteristics (type of rhythm-training intervention, specific training components, session frequency, session duration, and total intervention period); outcome measures (methods used to assess reaction time, technical accuracy, and other performance-related indicators). Following independent extraction, the reviewers cross-checked their entries for consistency and accuracy. Discrepancies were discussed and resolved through consensus; if agreement could not be reached, a third reviewer was consulted for arbitration. The extracted data are summarized in Table 3.

Study Quality and Assessment of the Risk of Bias. The risk of bias in the included studies was independently assessed by one review author using the Physiotherapy Evidence Database (PEDro) scale (26). The PEDro scale, whose validity and reliability are well-established (26-28) consists of 11 items, 7 of which contribute to the total score. Item 1 (external validity) is not scored. In exercise-based interventions, blinding of participants and therapists (Items 5 and 6) is often impractical, and blinding of therapists (Item 7) is considered nearly impossible. Therefore, the maximum possible score in this review was 7, with one point awarded per satisfied criterion. Studies were subsequently categorized as "excellent" (≥6 points), "good" (≥5 points), "moderate" (≥4 points), and "low" (0–3 points) based on their total score. Any uncertainty in scoring was resolved through discussion with a third reviewer (Linghong Liu) until consensus was reached.

RESULTS

Study selection. The study selection process is presented in the PRISMA flow diagram (Figure 1). As of January 3, 2026, a total of 76 records were identified through electronic database searches, including 7 from PubMed, 49 from EBSCOhost, 13 from Web of Science, and 7 from Scopus. Three additional articles were identified through manual searching of reference lists. After duplicate removal, 33 unique records remained. Screening of titles and abstracts excluded 27 records that did not meet the inclusion criteria. The remaining 9 articles underwent full-text eligibility assessment, of which two were excluded: one was not a research article, and the other did not meet the language criterion. Ultimately, 7 studies were included in the qualitative synthesis, three from manual searches and four from the database searches.

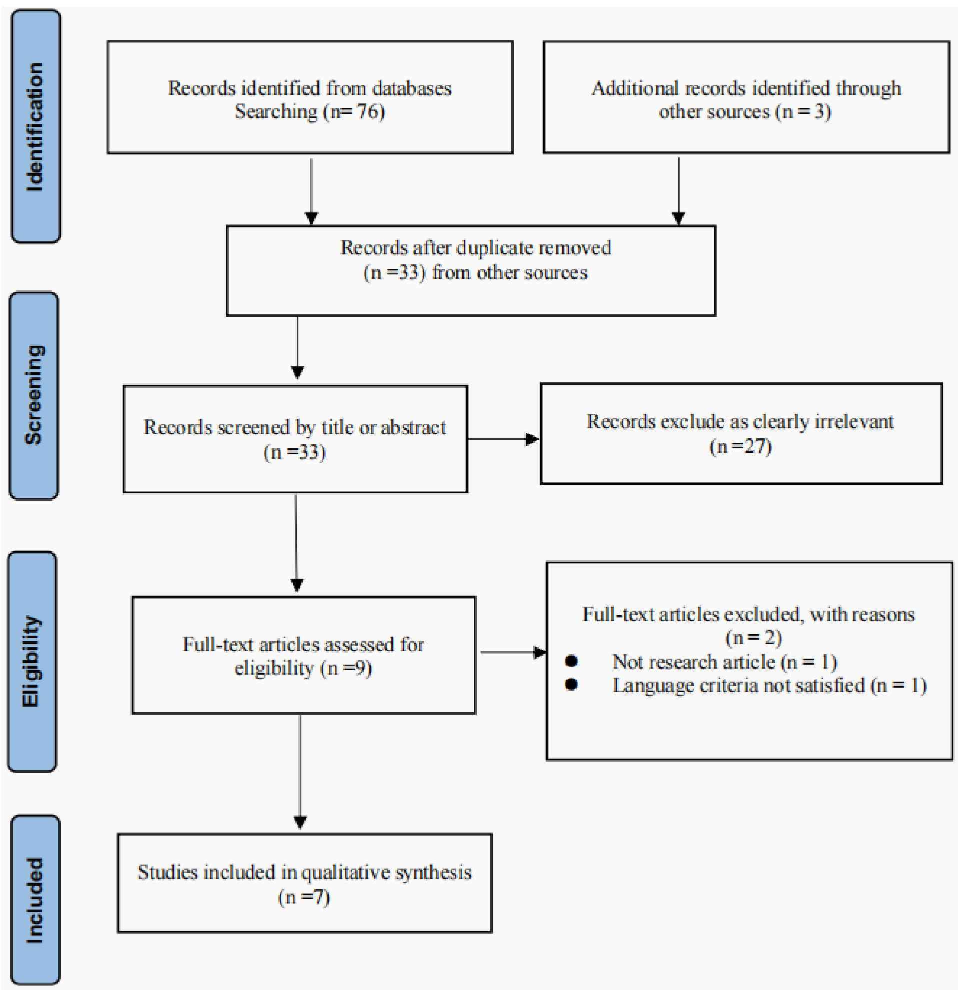

Figure 1. Flow diagram adapted from Preferred Reporting Items for systematic review and meta-analyses: the PRISMA statement (29).

Descriptive synthesis. Given the substantial heterogeneity in study designs, outcome measures, and data reporting among the included studies, quantitative meta-analysis was not feasible. Accordingly, the intervention characteristics and key findings of the seven included studies were systematically summarized, and the main effects of rhythm-based training interventions were compared. A structured narrative synthesis approach was adopted, with outcomes grouped into core domains of sports training science, namely physiological, psychological, and technical effects, to provide a comprehensive overview of the available evidence.

Methodological Quality. The results of the methodological quality assessment are summarized in Table 2. According to the PEDro scale, all seven included studies demonstrated moderate to good methodological quality, with total scores ranging from 4 to 5 and a mean score of 4.1 ± 0.3. One study (14) achieved a score of 5 and was classified as good quality, whereas the remaining six studies received scores of 4 and were rated as moderate quality. None of the included studies reported blinding of participants, therapists, or outcome assessors, which is consistent with the recognized challenges of implementing blinding procedures in exercise-based interventions. In addition, concealed allocation was not reported in any of the studies.

All studies reported random allocation and provided point estimates with measures of variability. Only three studies, however, described baseline comparability between groups (30-32). None met the criteria for Items 8 or 9, which require obtaining key outcome measures from more than 85% of initially allocated participants. Overall, the included studies exhibited a moderate risk of bias, with consistent methodological limitations related to blinding and participant retention.

Table 2. Methodological quality assessment of the included studies using the PEDro scale

Study	1	2	3	4	5	6	7	8	9	10	11	Score	Quality
(14)	1	1	0	1	0	0	0	0	0	1	1	5	Good
(31)	1	0	0	1	0	0	0	0	0	1	1	4	Moderate
(33)	1	1	0	0	0	0	0	0	0	1	1	4	Moderate
(34)	1	1	0	0	0	0	0	0	0	1	1	4	Moderate
(21)	1	1	0	0	0	0	0	0	0	1	1	4	Moderate
(35)	1	1	0	0	0	0	0	0	0	1	1	4	Moderate
(32)	1	0	0	1	0	0	0	0	0	1	1	4	Moderate

PEDro rating criteria (1) eligibility criteria specified; (2) randomly allocation; (3) concealed allocation; (4) baseline comparability; (5) blinding of participants; (6) blinding of therapists; (7) blinding of outcome assessors; (8) outcome measures obtained from >85% of participants; (9) intention-to-treat analysis; (10) between-group statistical comparisons reported; (11) point estimates and measures of variability reported.

Study Characteristics. Table 3 summarizes the key characteristics of the seven studies included in this review. Two studies investigated basketball players (32, 33), one focused on soccer (34), and one examined handball athletes (35), while the remaining three studies involved racket sports, including tennis, table tennis, and badminton (22, 30, 36). Across all studies, rhythm-based training was incorporated into the intervention protocols, typically integrated with sport-specific tasks. Considerable variation was observed in intervention frequency, duration, and rhythmic modality, including metronome pacing, music-based tempo, or coordination drills. Most studies employed pre–post experimental designs to evaluate the effects of rhythmic training on physical, technical, or cognitive performance outcomes.

All studies assessed timing-related motor performance, such as coincidence-anticipation timing, dribbling accuracy, or jump height consistency. Four studies (14, 22, 34, 35) incorporated sport-specific skill performance and physical fitness indicators, including agility, balance, sprint ability, and jump performance. Psychological and perceptual outcomes, such as mood states, anxiety, and ratings of perceived exertion, were evaluated in four studies using validated assessment tools (e.g., the RPE scale, Profile of Mood States (POMS), and feeling states scale). Two studies focused specifically on reaction time and anticipation accuracy under different stimulus conditions (30, 36).

Moreover, while not all studies directly assessed "rhythmic competence" with standardized instruments such as an interactive metronome (IM) or synchronized metronome training (SMT), every study included performance tasks that were intrinsically tied to motor timing and rhythmic synchronization.

Participant Characteristics. The seven included studies involved 396 participants, with sample sizes per study ranging from 20 to 90. Participants' ages spanned approximately 9 to 26 years, encompassing both adolescent and adult populations. Regarding sex distribution, four studies included both male and female athletes, one enrolled only female participants, another only male participants, and one did not report sex. Athletic experience varied from novice to school-level athletes to semi-professional and professional competitors. Anthropometric data (e.g., height, weight) were not consistently reported. Some investigations, such as Foo et al., provided detailed anthropometric data, whereas others did not report these measures (37). Athletes were recruited from a range of open skill sports, including basketball, soccer, handball, tennis, table tennis, and badminton (30, 36). Notably, two studies employed comparative designs involving multiple racket sports to examine differences in timing accuracy and reaction performance under varying stimulus conditions (30, 36).

Intervention characteristics. Most included studies employed randomized controlled trial (RCT) designs, in which experimental groups received interventions based on rhythmic training, music tempo modulation, or tempo-controlled motor exercises. Control groups either continued with standard sport-specific training routines or received no rhythmic intervention. Notably, three studies featured three-group designs, enabling more detailed comparisons across different rhythm-based protocols or training intensities (22, 30, 34).

All studies utilized a pre–post design, with outcome measures before and after the intervention. The intervention periods ranged from 4 to 10 weeks, except for one study that did not specify its duration (14). Two studies described the interventions solely by the total number of trials (six and thirty trials, respectively), without reporting session frequency or weekly duration (22, 36).

Training frequency varied across the included studies. Most interventions were administered two to three times per week. Session duration typically ranged from 15 to 90 minutes, with total intervention periods spanning 4 to 10 weeks. Specific protocols included a high-frequency schedule of five sessions weekly (14), a design with three weekly sessions distributed across 30 total trials (30), and a regimen comparing morning versus evening sessions to assess circadian effects (34). One study implemented two distinct rhythm-based programs (GRTG and TRTG), each involving two 15-minute sessions per week over 8 weeks (22).

The rhythmic training protocols exhibited substantial methodological diversity across studies. One study implemented an interactive metronome system (14), two studies employed music tempo training with varying tempos (34, 35), while one study incorporated metronome tempo dribbling tasks (32). Three studies focused on coordination and anticipation training, including sport-specific skill tasks and coincidence–anticipation exercises performed under different stimulus velocities (22, 30, 36).

Control conditions also varied considerably. In two studies, control groups received no rhythmic input (14, 36), whereas in two others, participants continued with regular sport-specific training routines (34, 36). These contrasting conditions facilitated the examination of the specific effects of rhythmic interventions on motor performance, perceptual outcomes, and psychophysiological responses.

Physiological effects of rhythm training on athletes. Rhythm-based training interventions demonstrated consistent physiological benefits across the included studies. Interventions incorporating interactive metronome (IM) systems or music tempo exercises were associated with improved cardiovascular responses, including increases in heart rate and mean heart rate during exertion, alongside enhancing arousal and reducing fatigue and ratings of perceived exertion

(14, 34). Music tempo warm-up protocols, particularly at moderate (60 bpm) and high (120–140 bpm) tempos, were effective in enhancing jump performance and elevating core body temperature, with more pronounced effects observed during morning sessions, suggesting improved neuromuscular readiness and circadian alignment (34). In female athletes, rhythm-based training administered across different menstrual cycle phases, especially during the menstrual phase, was associated with improvements in lower-limb explosive performance (SJ, CMJ, and RSA) and agility, indicating *p* favorable modulation of physiological stress responses (35).

Table 3. Summary of interventional trials examining the impact of rhythm-based training on open skill athletes' performance (n = 7)

Study	Type of athletes	Participant characteristics	Intervention	Type of rhythm training
(14)	Professional and school-level basketball players	Sex: M=13, F=10, Age(y): 20.4± 4.32 EG=11, CG=12 WT (kg)=No reported reported, HT (cm)=176.22	Fre.: 5 times/week, Time: 1.5 h Length: No reported	EG: IM-(SIM) and (AIM) CG: NM
(32)	Experienced players with 10 years and novice collegiate basketball players	Sex: No reported Age(y): 23.12-26.57 EG=8, CG=8 WT (kg)=75.21-78.43, HT (cm)= 175.57-180.62, novice: 75.9 ± 4.6, expert: 74 ± 3.0	Fre.: No reported Time: No reported Length: 1 month	NT: 20s dribbling MT: 40% between the preferred and the fastest tempo FT: 80% Experience group (≥10 years) Novice group
(34)	Semi-professional soccer players	Sex: M=15 Age(y): 21.02±1.52 WT (kg)= No reported HT (cm)=No reported	Fre.: 6 test sessions Time: three times at 7 a.m. and three times at 5 p.m. Length: 4 weeks	Warm-up conditions and TOD: G1: NO-M G2: LOW-M G3: HIGH-M
(35)	Handball players	Sex: F=14, Age(y): 21-24 WT (kg)= 56.72 ± 8.67, HT (cm)= 161± 7	Fre.: 2 times/week, Time: 1h Length: 6 sessions (26-34 days)	Condition: different MCP (i.e., MP, LP, FP). Phase 1: Music (fast tempo-140 bpm) Phase 2: No-Music
(22)	Tennis players with 12.8 ± 12.3 months of training experience	Sex: M=15, F=15 EG=No reported, CG=No reported Age(y): 23.2 WT (kg)=No, HT (cm)=No	Fre.: 2 times/week, Time: 15 min Length: 8 weeks	EG1: GRTG EG2: TRTG CG: TG
(36)	Athletes with 3.5 years of tennis and table tennis experience	Sex: M=111（T 52, TT 59), F=97 (T 55, TT 42), Age(y): 12.2-12.4 T=107, TT= 101 WT(kg)=38.7-40.2, HT(cm)=146-149	Fre.: No reported Time: No reported Length: 6 trials	Tennis (T) Table tennis (TT) coincidence-anticipation timing, reaction time test,
(30)	Athletes with 3 years of experience in tennis, table tennis, and badminton	Sex: M=45, F=45 Age(y): 12.4-12.5 T=30, TT=30, B=30 WT (kg)=No reported, HT (cm)=No reported	Fre.: 3 days/week, Time: 30 trials at each stimulus velocity Length: 30 trials	The Bassin anticipation timer was set at stimulus velocities of 2, 4, and 6 m/s.

Table 3. (continue)

Study	Measure index	Outcomes
(14)	Resting heart rate response, exercise performance (shuttle run and shooting task), RPE scale	EG: HR, average HR, and RPE↑, arousal↑ , and fatigue↓, SIM: arousal↑, RPE↓ AMI and NM: RPE↑
(32)	Force plate (angular data of the right arm's fingers, wrist, and elbow), dribbling tempo metronome condition: normal, medium, and fast.	EG and CG dribbling accuracy↑, EG: accuracy and in the AP direction↑, consistency↑, in-phase structure CG: anti-phase structure
(34)	Warm-up, FS scale, CJ30: Hmax, Hmean, and FI% measure body temperature.	Hmax, Hmean, and body temperature at 5 p.m.↑ than 7 a.m.; LOW-M and HIGH-M: Hmax and Hmean, and FS↑ at 7 a.m.↑; HIGH-M: Hmax, Hmean, and FS↑ at 7 a.m.↑.
(35)	SJ, CMJ, TT, RSA test POMS questionnaires, RPE.	SJ, CMJ, TT, and RSA↑ in MCP; anxiety, anger, and confusion↑ in MP>LP and FP; Music: SJ↑ following warm-up in MCP, CMJ, TT, and RSA↑.
(22)	ITN, RCAT, UCRT.	EG1 and EG2: tennis level↑, forehand consistency performance↑, rhythmic competence↑ CG: tennis level↑, forehand consistency performance↔, rhythmic competence↔
(36)	RT and coincidence-anticipation timing accuracy to analyze the differences by sport and sex	T: error in the coincidence-anticipation timing ↓, TT: RT mean↓, M: errors in the coincidence-anticipation timing↓.
(30)	Coincidence-anticipation timing	T: accuracy↑ in low stimulus velocity, B: accuracy↑ in moderate speed, TT: accuracy↑ in high stimulus

Abbreviations: NM, no music; *IM,* interactive music; *HR,* heart rates; *RPE,* Rating of Perceived Exertion; *NT,* Normal Tempo; *MT,* Medium Tempo; *FT,* Fast Tempo; *AP,* anterior-posterior; *TOD,* times of day; *NO-M,* without music; *LOW-M,* with music at 60 bpm; *HIGH-M,* with music at 120-140 bpm; *FS,* feeling states; *Hmax,* maximal jump height; *Hmean,* mean jump height of all jumps; *FI%,* fatigue index; *CJ30,* 30-s continuous jump test. *MCP,* menstrual cycle phase; *MP,* menstrual phase; *LP,* luteal phase; *FP,* follicular phase; SJ, Squat Jump; *CMJ,* Countermovement Jump; *TT,* Agility T-test; *RSA,* Repeated Sprint Ability; *POMS,* Profile of Mood States; *GRTG,* General Rhythm Training Group; *TRTG,* Tennis-Specific Rhythm Training Group; *TG,* Tennis Group; *ITN,* International Tennis Number; *RCAT,* Rhythmic Competence Analysis Test; *UCRT,* Untimed Consecutive Rally Test; *RT,* reaction time;
EG, experimental group; *CG,* control group; *WT,* weight; *HT,* height; Freq, frequency; *Dur,* duration; *M,* Male; *F,* Female; *y,* year; ↑, significant within-group improvement from pre-to post-test; ↓, significant within-group decrease from pre-to post-test; ↔, no-significant within-group change.

Psychological effects of rhythm training on athletes. Several studies reported psychological benefits associated with rhythm-based training. Participation in rhythmic protocols, particularly those incorporating Interactive Metronome systems or music (tempo elements), was associated with increased perceived arousal and more favorable emotional states, including reductions in anxiety, confusion, and anger during training periods (14, 34). These effects were especially evident among female athletes, or whom rhythm-based training implemented during hormonally sensitive phases of the menstrual cycle was linked to improvements in mood states when rhythm was integrated with sport-specific exercises (35). In addition, rhythm synchronization positively influenced subjective ratings of perceived exertion, which may facilitate greater engagement during training and potentially support training adherence (14, 34).

Technical effects of rhythm training on athletes. Technical performance was consistently enhanced by rhythm training across the included studies. Interventions improved precision, stability, and timing in sport-specific skills tasks. For instance, basketball players exhibited increased dribbling accuracy and more in-phase movement coordination under tempo-regulated metronome conditions (32). Similarly, tennis players who completed general or tennis-specific rhythm training (GRTG/TRTG) demonstrated greater gains in forehand stroke performance and achieved higher scores in the slow tempo rhythm test compared to those receiving traditional tennis training (TG) (22). Moreover, racket-sport athletes improved in anticipation timing and reaction accuracy through rhythm-based drills using varied stimulus velocities: table tennis players responded more quickly and accurately to high-speed stimuli. In contrast, tennis and badminton athletes showed superior performance at moderate or low speeds (30, 36). Together, these results indicate that rhythm training supports motor planning, perceptual sharpness, and technical precision in open-skill sports where precise timing and coordination are essential.

DISCUSSION

This systematic review examined the effects of rhythm-based training on performance outcomes in open skill sports by synthesizing evidence from seven studies involving basketball, soccer, handball, tennis, table tennis, and badminton. Across these diverse sporting contexts, the findings were organized into three primary outcome domains: physiological, psychological, and technical, highlighting the versatility of rhythm-based training as an approach for enhancing athletic performance in open skill environments.

Physiological effects. The present findings indicate that rhythm-based interventions, particularly those incorporating fast-tempo music or Interactive Metronome systems, can yield measurable benefits for heart rate regulation, neuromuscular activation, and fatigue modulation during athletic training. This observation is consistent with growing evidence from medical and exercise science research demonstrating the positive effects of music on fatigue and sport performance (38-40). For instance, Szabo et al. reported that fast-to-slow music (FSM) improved cycling workload without a concomitant increase in heart rate (40), while Centala et al. found that fast-tempo music enhanced exercise tolerance and elevated the neuromuscular fatigue threshold. Such effects have been attributed, in part, to attentional distraction mechanisms, whereby rhythmic stimuli reduce perceived fatigue depending on the task-specific cognitive demands and stimulus intensity (38). Extending these findings to sport-specific contexts. The present review indicates that rhythm-based training can elevate heart rate and arousal while attenuating fatigue during high-intensity shuttle running and shooting drills (33, 34). Nevertheless, the magnitude and nature of physiological responses varied across sports, suggesting that the effects of rhythmic interventions may be modulated by task characteristics, movement complexity, and performance demands (41).

In racket sports such as tennis and table tennis, where prolonged rallies impose sustained cardiovascular demands, rhythmic regulation may contribute to improved energy efficiency and a delayed onset of fatigue (22, 30, 36). Additionally, Belkhir et al. (26) demonstrated that warm-up protocols incorporating moderate- to high-tempo music (60–140 bpm) improved jump performance and elevated body temperature, with particularly pronounced effects during morning sessions. These findings suggest that rhythm-based warm-up strategies may enhance neuromuscular readiness and facilitate circadian alignment, thereby optimizing performance under time-of-day–specific constraints (34, 42).

Moreover, Chapados and Levitin reported that fast and loud music increases heart rate, blood pressure, core body temperature, skin conductance, and muscle tension, whereas soft and slow music elicits the opposite effect by reducing sympathetic arousal (43). This observation is consistent with the present findings showing that warm-up sessions incorporating moderate- to high-tempo music (60–140 bpm) improved jump performance and elevated core body temperature, particularly during early training sessions, suggesting enhanced neuromuscular readiness and improved alignment with circadian rhythms (34). Furthermore, Ghazel et al. demonstrated that rhythm-based interventions administered during specific phases of the menstrual cycle significantly enhanced lower-limb explosive power and agility in female athletes, indicating a potential interaction between rhythmic stimuli and hormonal regulation (35). Taken together, evidence from several well-controlled studies suggests that appropriately selected music may confer modest improvements in physiological efficiency, which could translate into meaningful performance gains in endurance-oriented activities (44, 45).

Psychological Effects. Psychological benefits of rhythm-based training were evident across several studies, particularly with respect to improvements in athletes' emotional states and subjective training experiences. A growing body of evidence indicates that music elicits multiple interrelated benefits in exercise-and sport-related contacts. For example, pre-task music tempo has been effectively used to stimulate arousal (33) or to facilitate relaxation (30). When applied during physical activity, music can promote positive affective responses (46) and divert attention away from sensations of physical discomfort and fatigue (47). Collectively, these psychological effects may contribute to the ergogenic benefits reported in empirical studies.

Consistent with these findings, interventions incorporating interactive metronome systems or music-paced training were associated with increased perceived arousal and reductions in anxiety, confusion, and anger, particularly among female athletes during hormonally sensitive periods (14, 35). Furthermore, rhythm-based interventions were linked to lower ratings of perceived exertion and improved engagement during training, which may, in turn, enhance motivation and support training adherence (14, 34).

Interestingly, contrary to theoretical predictions, music tempo did not significantly moderate affective responses in the included studies, thereby challenging findings from investigations into music-tempo preferences during exercise-related tasks (48, 49). One possible explanation is the widespread use of inspirational, energizing, or rhythmically complex music selections, even at a tempo below 120 bpm, which may attenuate or mask tempo-specific effects (50, 51). Alternatively, slow-to moderate-tempo music may exert a calming influence during high-intensity exercise, leading to favorable affective responses despite lower tempos (34, 41).

Overall, the available evidence suggests that rhythmic auditory stimulation, particularly when delivered through motivational music, can consistently enhance emotional regulation, support psychological self-regulation, and improve affective experience during physical activity. These effects appear to be robust across a range of individual, situational, and musical characteristics. In team sports settings, rhythm-based training may additionally facilitate interpersonal synchronization and group cohesion, whereas in individual sports, it may assist athletes in self-regulating under pressure and maintaining optimal performance states.

Technical Effects. Technical performance improvements emerged as one of the most robust outcomes associated with rhythm-based training. Rhythm-enhanced protocols were linked to improvements in accuracy, temporal control, and coordination during sport-specific motor tasks. In basketball, metronome-paced dribbling drills improved movement precision and promoted more stable in-phase motor control patterns (32). In racket sports, tennis players who participated in structured rhythm training programs (GRTG and TRTG) demonstrated superior forehand consistency, higher tennis skill levels, and enhanced rhythmic competence compared with control groups (22). These findings align with prior research indicating that synchronized metronome training (SMT) can facilitate motor performance in sports contexts. Although SMT is widely adopted in applied coaching practice, systematic scientific evaluation remains limited. Available empirical evidence suggests that SMT delivered via interactive metronome (IM) training can enhance golf shot accuracy and reduce performance variability (10, 17). Moreover, SMT has been shown to influence coordinative structures and improve the temporal synchronization of upper-limb movements during complex motor tasks, such as the golf swing (52).

Our review further revealed that rhythm-based music interventions can enhance lower-limb explosive performance in handball athletes, including squat jump, countermovement jump, and agility performance (35). These findings are consistent with those of Biagini et al. who reported improvements in bench press and squat jump performance following exposure to self-selected music compared with no-music conditions (53). Similarly, Eliakim et al. employed the Wingate Anaerobic Test to assess power output in elite adolescent volleyball players (1). They found that exposure to arousing, predetermined music (140 beats·min^{-1} for 10 min) prior to testing significantly increased peak anaerobic power during the initial 5 s of performance (1). Collectively, these findings suggest that listening to self-selected or tempo-appropriate music may facilitate acute enhancements in power-related performance.

However, not all studies have reported positive effects of music on athletic outcomes. For example, Dorney et al. compared two types of music with a no-music condition and observed no significant differences in dart-throwing performance (54). Other investigations have similarly demonstrated that music does not necessarily enhance performance and may even exert detrimental effects under specific task conditions (55). Therefore, the available evidence indicates that the ergogenic effects of music are task dependent; rhythm-based or tempo-appropriate music appears more likely to enhance acute power and explosive performance, whereas its influence on precision-based or highly constrained tasks may be limited or, in some cases, negative.

In fast-paced open skill sports such as table tennis, badminton, and tennis, rhythm-based training was associated with improvements in reaction time and coincidence-anticipation accuracy across a range of stimulus velocities (30, 36). These enhancements suggest that rhythmic interventions may facilitate temporal precision, perceptual-motor integration, and sensorimotor synchronization, core components of high-level performance in dynamic and time-constrained sporting environments.

Although this review systematically evaluated the effects of rhythm-based training on performance outcomes in open skill athletes from the physiology, psychology, and technique perspectives, several limitations should be acknowledged (37). First, existing literature is concentrated on a relatively narrow range of sports, including football, basketball, table tennis, tennis, badminton, and handball. Consequently, evidence regarding the effectiveness of rhythm-based training in other open skill sports remains limited. Future research should therefore extend the application of rhythm-based interventions to a broader spectrum of sports and further examine their sport-specific benefits and underlying mechanisms across diverse performance contexts. Moreover, the exclusion of studies published in languages other than English represents a minor limitation and may have resulted in the omission of relevant findings. Finally, because participants cannot be blinded to the presence or absence of rhythmic interventions, double-blind, placebo-controlled designs are not feasible in this area of research. This constraint constitutes an inherent methodological limitation of rhythm-based intervention studies, as well as of many investigations within the broader field of sport and exercise psychology (10).

CONCLUSION

Overall, the synthesized evidence supports the conclusion that rhythm-based training can produce significant positive effects for athletes participating in open skill sports. These benefits include improvements in heart rate regulation, reductions in fatigue, enhanced emotional stability, and increased rhythmic competence. Such physiological and psychological adaptations are frequently reflected in better reaction time, greater movement accuracy, and improved technical consistency during sport-specific tasks. However, these effects are not uniform across all contexts. The magnitude and nature of the benefits appear to depend on sport-specific demands, the characteristics of the rhythm-based training protocols, and individual athlete differences. Moreover, the current evidence base is constrained by the relatively small number of sport-specific studies, underscoring the need for further high-quality research.

APPLICABLE REMARKS

- This review highlights the practical potential of rhythm-based training for enhancing athletic performance in open-skill sports through integrated physiological, psychological, and technical benefits.
- The synthesized evidence provides practitioners with evidence-informed guidance for optimizing rhythm-based training interventions within sport-specific contexts.
- Based on the available findings, music tempos ranging from approximately 100–140 BPM appear to be suitable for rhythm-based training applications. Lower tempos (approximately 100–110 BPM) may be particularly appropriate for tasks emphasizing coordination, movement control, and fine motor skills.
- Moderate tempos (approximately 120–130 BPM) are commonly associated with improvements in explosive power, agility, and general movement efficiency. Higher tempos (approximately 135–140 BPM) may be beneficial for fast-paced, high-intensity open skill sports, as they are linked to increased neuromuscular activation, enhanced attentional focus, and improved temporal precision.
- Practitioners are encouraged to tailor tempo selection according to sport-specific demands, task characteristics, and individual athlete responses.

AUTHORS' CONTRIBUTIONS

Study concept and design: Linghong Liu, Garry Kuan. Acquisition of data: Linghong Liu, Junjian Xiao, Bustang Bustang. Analysis and interpretation of data: Linghong Liu, Garry Kuan, Yee Cheng Kueh. Drafting of the manuscript: Linghong Liu. Critical revision of the manuscript for important

intellectual content: Linghong Liu, Garry Kuan, Bustang Bustang, Yee Cheng Kueh. Statistical analysis: Linghong Liu, Yee Cheng Kueh. Study supervision: Yee Cheng Kueh, Garry Kuan.

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CONFLICT OF INTEREST

The authors state that they have no conflicts of interest that could have influenced the work reported in this paper.

FINANCIAL DISCLOSURE

The authors declare that there are no conflicts of interest.

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ETHICAL CONSIDERATION

Ethical approval was not required for this study, as it is a systematic review and did not involve direct participation of human or animal subjects.

ROLE OF THE SPONSOR

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ARTIFICIAL INTELLIGENCE (AI) USE

We confirm that no artificial intelligence (AI) tools were used in the writing, data analysis, or preparation of this manuscript.

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