TRANSACTIONS ON CYBERNETICS AND DIGITAL INNOVATION

S M Nazmuz Sakib Cardio-Optimized Rhythmic Exercise (SCORE): A Heartbeat-Harmonic Training Paradigm for Real-Time Skeletal–Cardiac Synchronization

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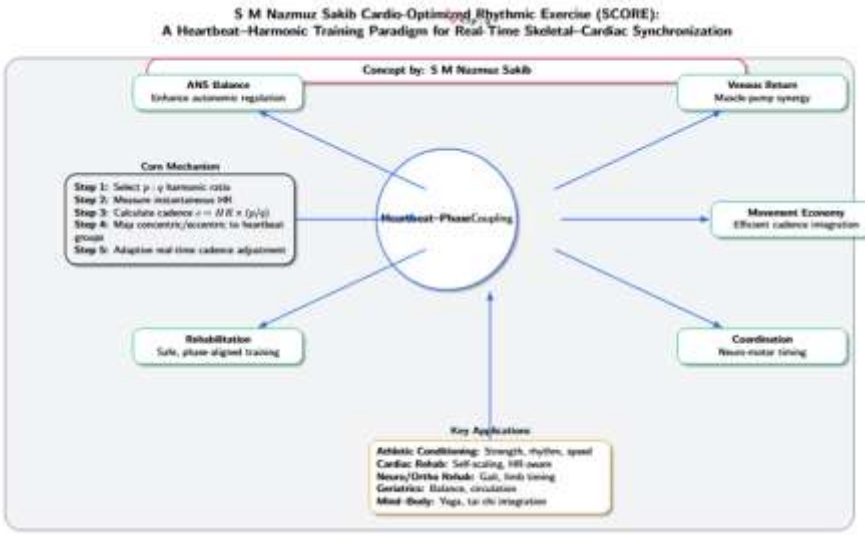
GRAPHICAL ABSTRACT



ABSTRACT

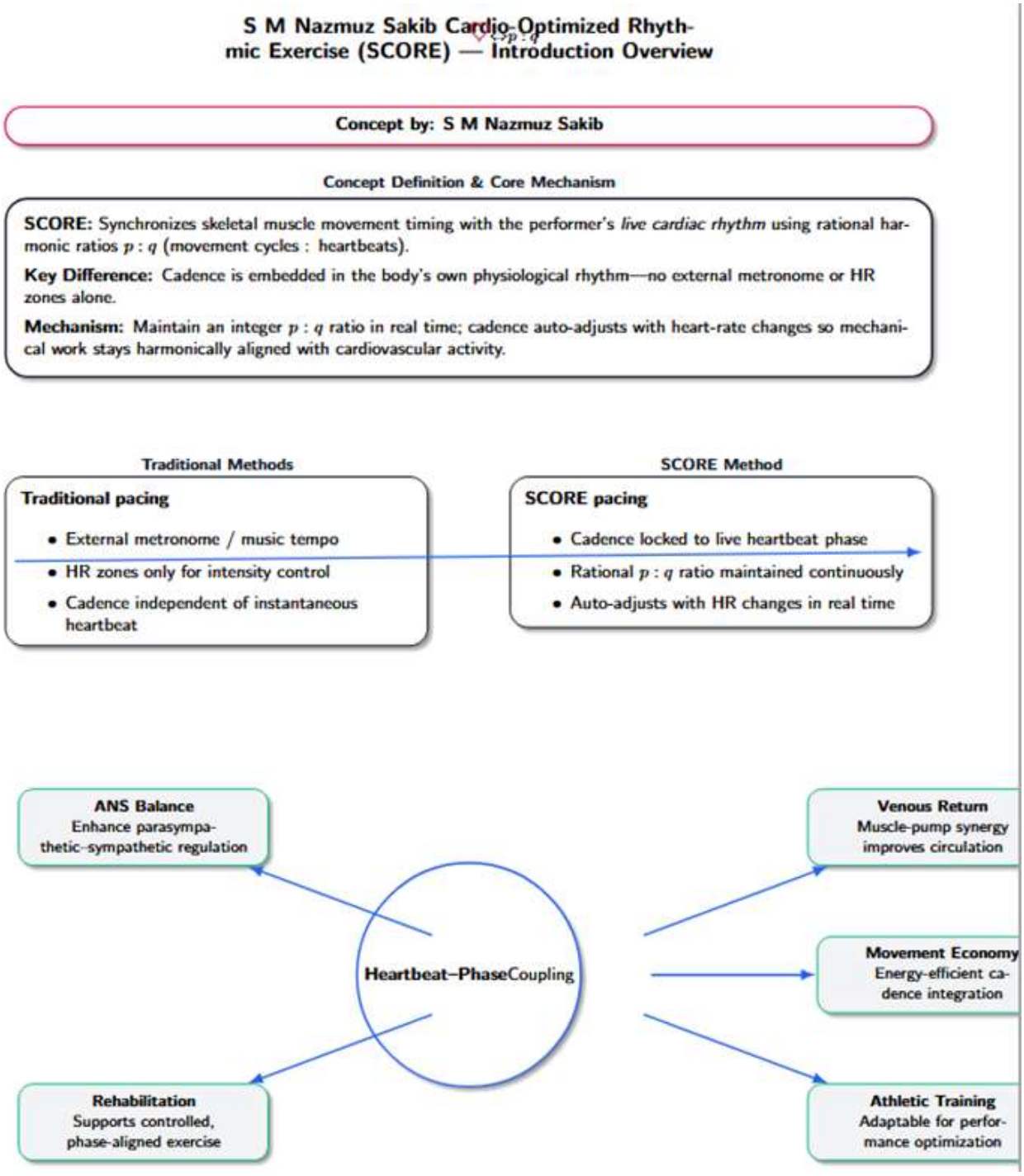
The S M Nazmuz Sakib Cardio-Optimized Rhythmic Exercise (SCORE) method introduces a novel paradigm in exercise science that synchronizes skeletal muscle movement cadence to the performer's real-time cardiac rhythm via rational p : q harmonic ratios. Unlike conventional tempo training driven by fixed external beats, or heart-rate zone methods that regulate intensity without temporal coupling, SCORE dynamically adjusts movement cadence in direct proportion to instantaneous heart rate, preserving the chosen harmonic ratio throughout a session. Each concentric and eccentric phase is intentionally aligned to grouped heartbeat cycles, enabling biofeedback-driven, adaptive training that can enhance autonomic regulation, optimize venous return through muscle-pump synergy, and improve movement economy. Different ratio configurations allow targeted outcomes: slower ratios ($p < q$) for strength and time-under-tension, near-equal ratios ($p \approx q$) for coordination and endurance, and faster ratios ($p > q$) for quickness and elasticity. SCORE requires only real-time heart rate monitoring and can be applied across a variety of movements without specialized equipment, making it accessible for athletes, rehabilitation settings, and general fitness. This approach establishes a distinct, testable organizing principle for synchronizing human movement with intrinsic cardiac timing.

KEYWORDS: S M Nazmuz Sakib, SCORE, Cardio-Optimized Rhythmic Exercise, heartbeat harmonic training, p : q ratio exercise.

INTRODUCTION

The S M Nazmuz Sakib Cardio-Optimized Rhythmic Exercise (SCORE) method represents a novel, science-backed approach to exercise that directly synchronizes skeletal muscle movement timing with the performer's live cardiac rhythm through rational harmonic ratios (p : q). Unlike traditional methods where movement is paced by an external metronome or constrained within heart rate zones for intensity control, SCORE embeds the exercise cadence within the user's intrinsic physiological rhythm, the heartbeat and maintains a fixed integer ratio between movement cycles and heartbeats in real time (Hauser et al., 2025; Vauthier et al., 2025).

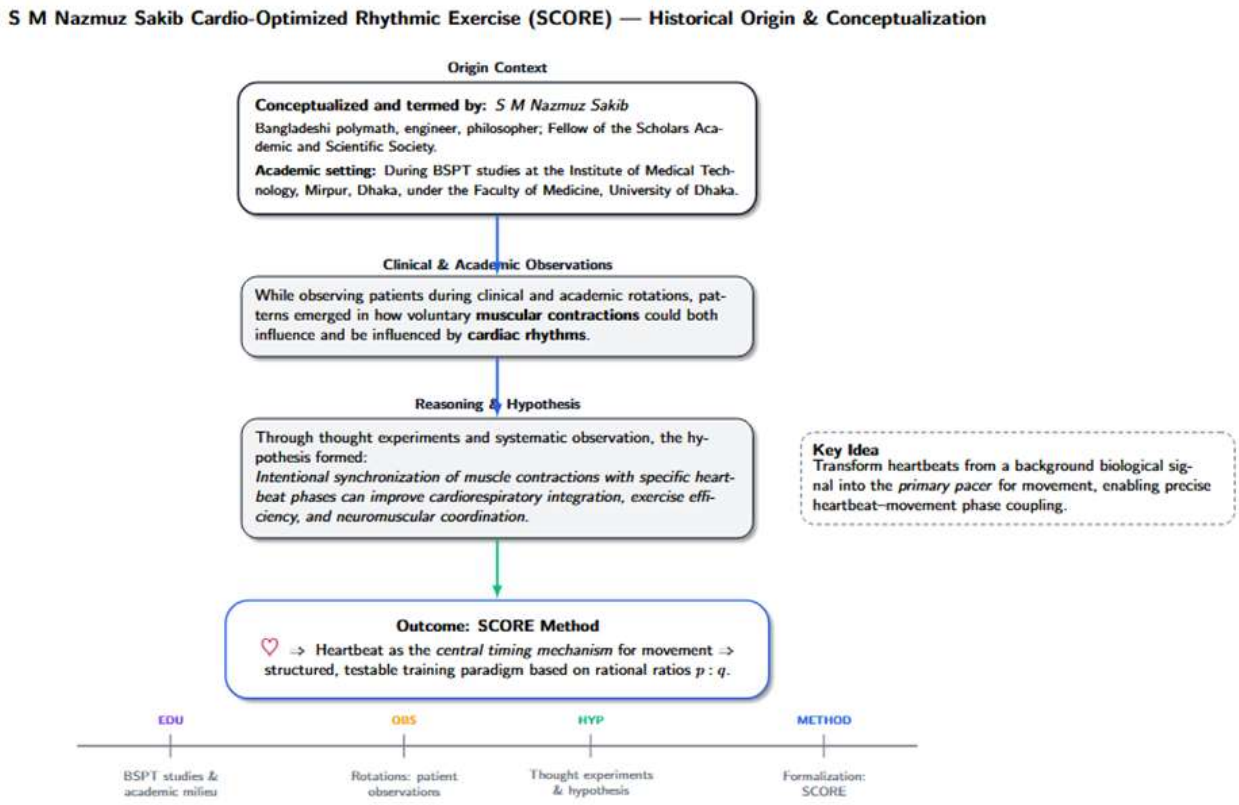
Figure



This heartbeat-phase coupling allows for continuous auto-adjustment of cadence as the heart rate naturally fluctuates, ensuring that the mechanical work of muscles is always harmonically aligned with cardiovascular activity. Such coordination can enhance autonomic nervous system balance, improve venous return through muscle-pump synergy, and support movement economy, making SCORE potentially beneficial in athletic training, rehabilitation, and general fitness (Engelen et al., 2024; Florindi et al., 2025; Jan & Cheung, 2025; Le, 2025; Manning et al., 2025; Marchand et al., 2025; Xu & Wang, 2025).

2. HISTORICAL ORIGIN

Figure



SCORE was conceptualized and coined/termed by Prof. (H.C.) Engr. Dr. S M Nazmuz Sakib, CMSA®, FPWMP®, FTIP®, BIDA®, FMVA®, CBCA®, a Bangladeshi polymath, engineer, philosopher, and Fellow of the Scholars Academic and Scientific Society, during his studies in the Bachelor of Science in Physiotherapy (BSPT) program at the Institute of Medical Technology, Mirpur, Dhaka, under the Faculty of Medicine, University of Dhaka (Amazon.com: SPROUTING FASCISM OR NATIONALISM IN INDIA: 9798899660757: Nazmuz Sakib, Prof (H.C.) Engr. Dr. S M: Books, n.d.; Amin, 2025; SPROUTING FASCISM OR NATIONALISM IN INDIA, n.d.).

While observing patients during clinical and academic rotations, Engr. Sakib noticed patterns in how voluntary muscular contractions could influence, and be influenced by, cardiac rhythms. Through thought experiments and systematic observation, he hypothesized that intentional synchronization of muscle contractions with specific heartbeat phases could yield measurable benefits in cardiorespiratory integration, exercise efficiency, and neuromuscular coordination (Amin et al., 2024; Rimban, Dr. Erwin and Tanvir Mahtab Faysal, Mirza MD. and Islam, Md. Ahsanul and Sonda, Israth Jahan and Tamanna, Lubbabah Sugra Siddiqi and Hasan, Mehedi and TALUKDAR, NUR- E- IMAN NASIM and Mia, Liton and Hossain, Md Nazmul and Hasan, Ejaz and Rayna, Nazifa Thasin and Amin, PT, PhD, Dr. Md. Ruhul, n.d.).

This insight led to the formulation of SCORE as a structured, testable training paradigm: a method that transforms heartbeats from a background biological signal into the central timing mechanism for physical performance.

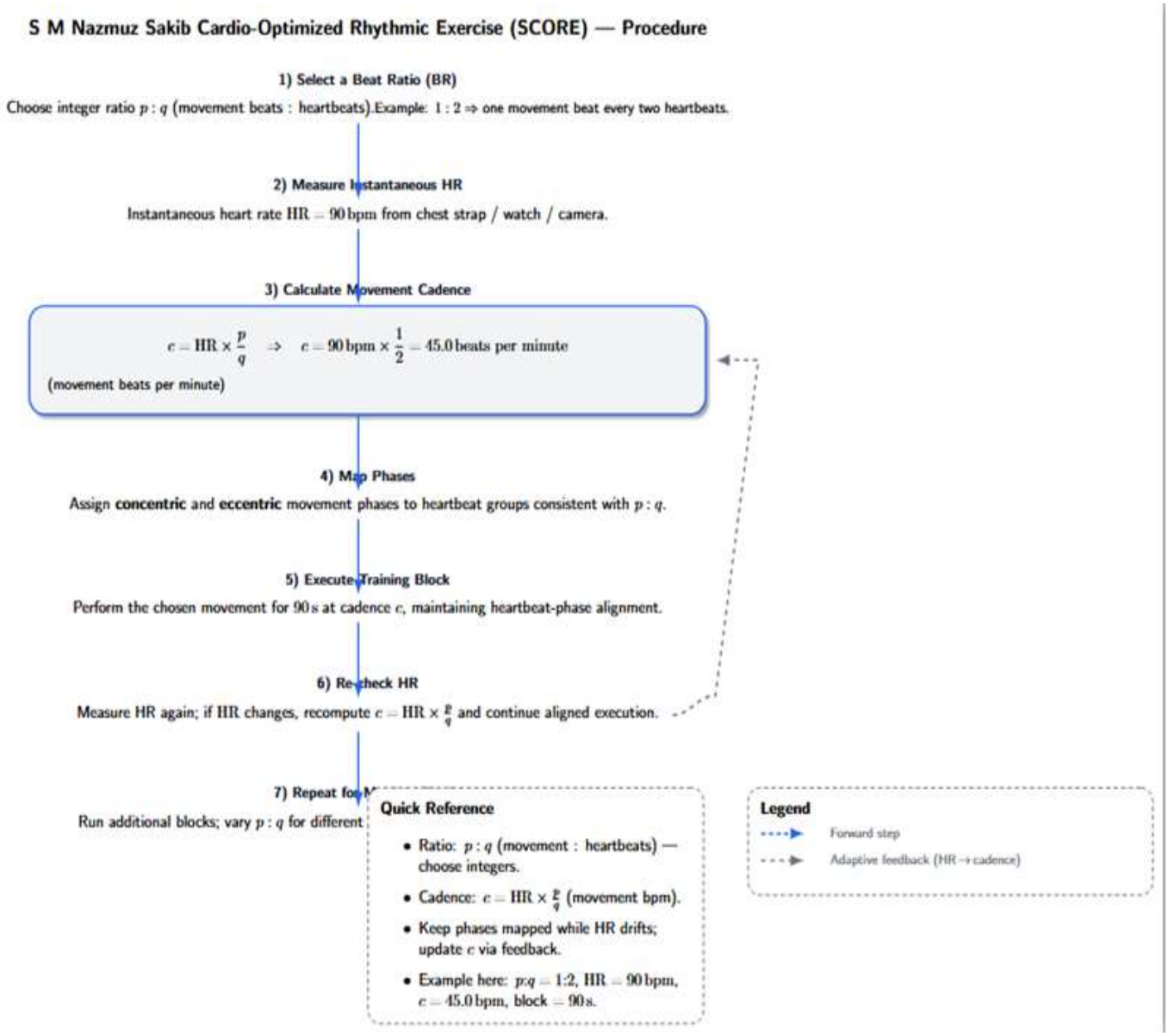
3. PROCEDURE

Equipment Needed:

- Heart rate detection method (manual pulse palpation, smartwatch, chest strap, or camera-based HR app)
- Simple movement (e.g., micro-squat, wall push, marching in place, farmer carry)
- Optional: metronome app that can be programmed to cadence c

STEPS:

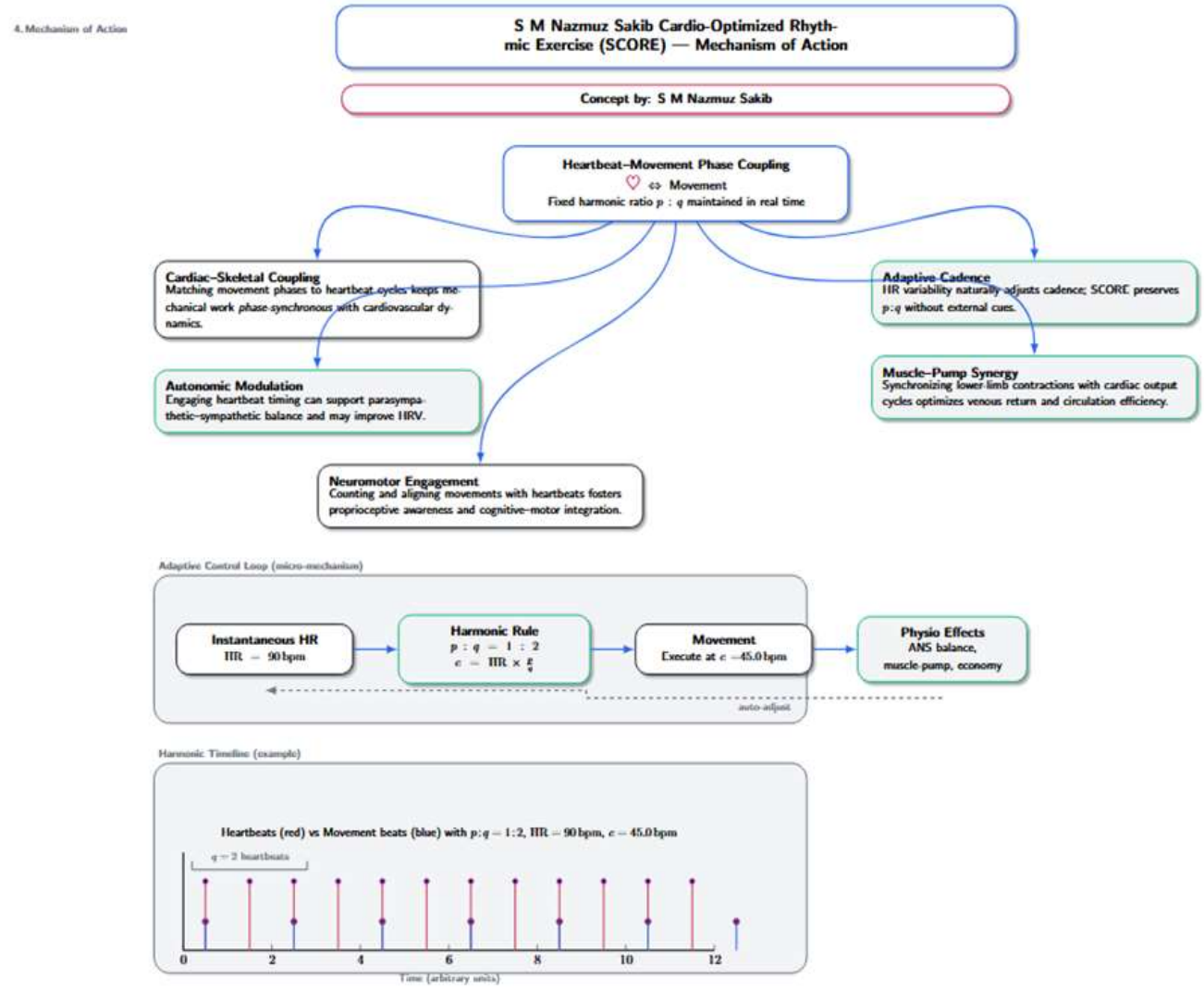
Figure



1. Select a Beat Ratio (BR): Choose a p: q ratio (movement beats : heartbeats).
   Example: 1:2 = 1 movement beat every 2 heartbeats.
2. Measure Instantaneous Heart Rate (HR): In beats per minute (bpm).
3. Calculate Movement Cadence (c): c=HR×(p/q)(movement beats per minute)
4. Map Phases: Assign concentric and eccentric phases to heartbeat groups.
5. Execute Training Block: Perform movement for 90 seconds at calculated cadence, maintaining phase alignment.
6. Re-check HR: Adjust cadence for next block as HR changes.
7. Repeat for Multiple Blocks: Use different ratios for varied training effects (strength, rhythm, quickness).

4. MECHANISM OF ACTION

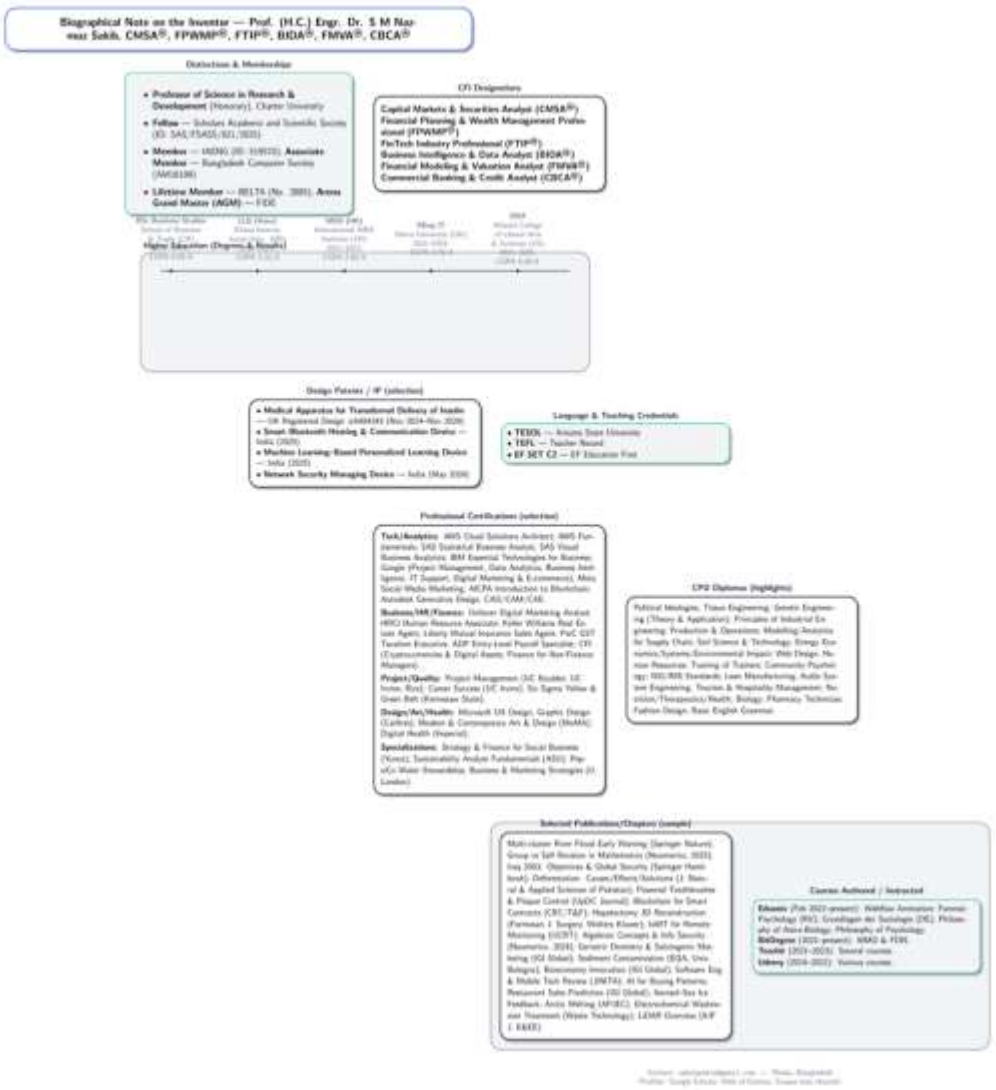
Figure



- **Cardiac–Skeletal Coupling:** By matching movement phases to heartbeat cycles, SCORE ensures mechanical work is phase-synchronous with cardiovascular dynamics.
- **Adaptive Cadence:** HR variability during exercise naturally adjusts movement speed without external cues.
- **Autonomic Modulation:** Engaging with heartbeat timing enhances parasympathetic–sympathetic balance and may improve heart rate variability (HRV).
- **Muscle-Pump Synergy:** Synchronizing lower limb contractions with cardiac output cycles optimizes venous return and circulation efficiency.
- **Neuromotor Engagement:** Counting and aligning movements with heartbeat fosters proprioceptive awareness and cognitive–motor integration.

5. BIOGRAPHICAL NOTE ON THE INVENTOR

Figure



Prof. (H.C.) Engr. Dr. S M Nazmuz Sakib, CMSA®, FPWMP®, FTIP®, BIDA®, FMVA®, CBCA® is a multidisciplinary scholar and innovator with expertise spanning engineering, business, law, and medical sciences. He is a Fellow of the Scholars Academic and Scientific Society, a Member of the International Association of Engineers (IAENG), a Bangladeshi Arena Grand Master (AGM) in the International Chess Federation (FIDE), and a lifetime member of the Bangladesh English Language Teachers Association (BELTA) (Pt et al., 2024; Rimban, Dr. Erwin and Shikdar, Sabbir and Ali, Romjan and Rahaman, Md. Arafat Ur, Sakibism, 2025; Sakib, n.d.).

His diverse educational background from primary studies in Sreepur and Jashore to advanced degrees in business, law, and engineering from institutions reflects a lifelong pursuit of interdisciplinary mastery. Engr. Sakib's professional certifications cover digital marketing, cloud architecture, UX design, insurance, human resources, data analytics, project management, engineering design, and healthcare-related disciplines (Sakib, 2023; Sakib, 2024; Sakib, S M Nazmuz FIDE Chess Profile, n.d.).

With a prolific publication record across Springer Nature, IGI Global, CRC Press, Taylor & Francis, Wolters Kluwer, and other academic outlets, Dr. Sakib has contributed to fields as varied as flood warning systems, AI, blockchain, environmental science, psychology, and medical engineering. The creation of SCORE is a natural extension of his commitment to innovative, cross-domain solutions that integrate human physiology, engineering precision, and practical application (Sakib, S M Nazmuz FIDE Chess Profile, n.d.; Sakib, 2023a).

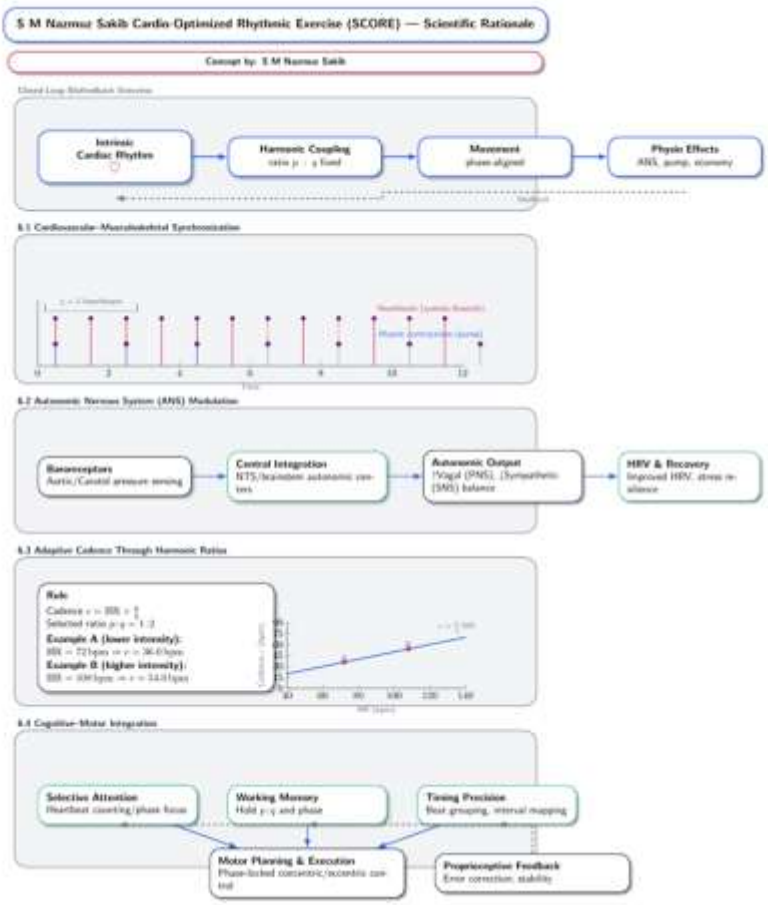
6. SCIENTIFIC RATIONALE

The scientific basis for SCORE lies in the integration of cardiac physiology, exercise science, and neuro-motor coordination. The method leverages the body's intrinsic cardiovascular rhythm as the primary pacing mechanism for movement, creating a closed-loop biofeedback system.

6.1 CARDIOVASCULAR–MUSCULOSKELETAL SYNCHRONIZATION

The human heart operates in rhythmic cycles of systole (contraction) and diastole (relaxation), producing predictable pulses of blood flow and arterial pressure waves. Skeletal muscles, especially in the lower limbs, also serve as auxiliary pumps, aiding venous return through rhythmic contractions. SCORE aligns muscle contractions with specific phases of cardiac output, maximizing the muscle-pump synergy for optimal circulation efficiency (Pierce, 2025; Rosenfeld et al., 2025; You et al., 2025).

Figure



6.2 AUTONOMIC NERVOUS SYSTEM (ANS) MODULATION

By intentionally attending to heartbeat timing, participants engage baroreceptor reflex pathways and central autonomic circuits, potentially improving heart rate variability (HRV): a marker of autonomic balance. This rhythmic entrainment could enhance parasympathetic tone, aiding recovery and stress resilience (Ciesielski et al., 2025; Jalandhra et al., 2025).

6.3 ADAPTIVE CADENCE THROUGH HARMONIC RATIOS

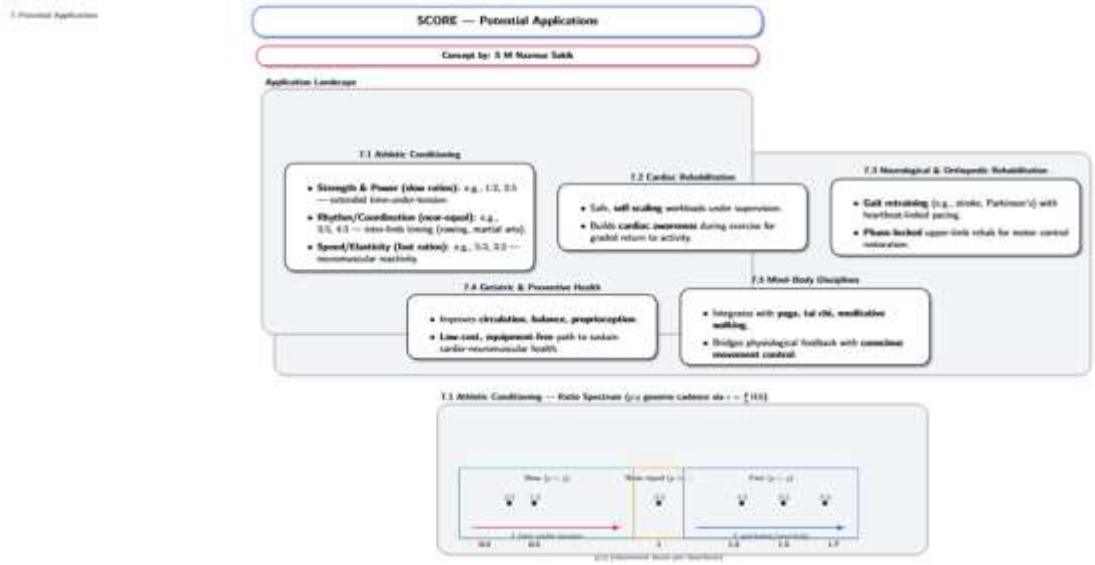
Unlike fixed-tempo exercise, SCORE's cadence changes automatically with heart rate. As intensity increases and HR rises, cadence scales proportionally to maintain the selected p : q harmonic ratio. This ensures that the neuromotor demand remains synchronized with cardiovascular load, minimizing overexertion or mismatch between muscular work and cardiac output (Bučík et al., 2025; Jia et al., 2024; Turc et al., 2025).

6.4 COGNITIVE–MOTOR INTEGRATION

The method requires counting and phase-matching movements to heartbeat cycles, stimulating prefrontal–motor network integration and fostering selective attention, working memory, and timing precision. Such dual-tasking may have neuroprotective benefits and applications in neurological rehabilitation (Birinci et al., 2025; Khan et al., 2025; Schnakers & Laureys, 2023).

7. POTENTIAL APPLICATIONS

Figure



7.1 ATHLETIC CONDITIONING

- Strength and Power Development: Slow ratios (e.g., 1:2, 2:5) provide extended time-under-tension without external pacing devices.
- Rhythm and Coordination Training: Near-equal ratios (e.g., 3:3, 4:3) enhance inter-limb timing for sports requiring rhythm (e.g., rowing, martial arts).
- Speed and Elasticity: Fast ratios (e.g., 5:3, 3:2) challenge neuromuscular reactivity.

7.2 CARDIAC REHABILITATION

- Safe, self-scaling workloads for post-cardiac event patients under medical supervision.
- Encourages awareness of cardiac function while exercising, aiding in gradual return to physical activity.

7.3 NEUROLOGICAL & ORTHOPEDIC REHABILITATION

- Gait retraining in stroke or Parkinson’s patients using heartbeat-linked pacing.
- Phase-locked upper limb rehabilitation for post-injury motor control restoration.

7.4 GERIATRIC & PREVENTIVE HEALTH

- Improves circulation, balance, and proprioception in older adults.
- Provides a low-cost, equipment-free method for maintaining cardiovascular and neuromuscular health.

7.5 MIND–BODY DISCIPLINES

- Integrates with yoga, tai chi, or meditative walking for enhanced mind–body coherence.
- Bridges physiological feedback with conscious movement control.

8. ADVANTAGES OVER EXISTING METHODS

1. Intrinsic Biofeedback: Uses the participant's own heart rhythm as the timing signal — no need for music or external metronomes.
2. Automatic Load Scaling: Cadence adjusts instantly to changes in HR.
3. Versatility: Works with a wide range of movements, from strength to mobility drills.
4. Low Barrier to Entry: Minimal or no equipment needed.
5. Scientific Testability: Outcomes can be measured via HRV, harmonic adherence, recovery metrics, and functional performance (Botonis et al., 2024; Fisher, 1922; Khan et al., 2025).

9. METHODS & IMPLEMENTATION PROTOCOL

This section outlines how SCORE can be implemented in a controlled, replicable manner for research, clinical, or training purposes. It covers participant preparation, calculation methods, session structure, safety measures, and performance tracking.

9.1 PARTICIPANT PREPARATION

- **ELIGIBILITY:**
  - Adults with no contraindicating cardiovascular or musculoskeletal conditions.
  - Clearance from a physician if there is a history of arrhythmia, uncontrolled hypertension, or recent cardiac events.
- **EQUIPMENT REQUIRED:**
  - Heart Rate Monitoring: Manual radial pulse, smartwatch, chest strap, or validated HR app.
  - Timing Support (optional): Metronome app capable of custom BPM setting to calculated cadence c.
  - Comfortable exercise clothing and stable footwear.

9.2 CORE CALCULATION FORMULA

$c = HR \times pqc$

Where:

- HR = Instantaneous heart rate (beats per minute)
- p : q = Movement beats per heartbeats ratio
- c = Movement beats per minute (cadence)

EXAMPLE:

- HR = 72 bpm, BR = 1:2
- $c = 72 \times (1/2) = 36$ movement beats per minute
- One movement beat every 1.67 seconds; full rep (two beats) = ~3.3 seconds

9.3 SESSION STRUCTURE

PHASE 1 – WARM-UP (3–5 MINUTES)

- Low-intensity movement (march in place, slow arm swings) without ratio coupling to gradually raise HR.

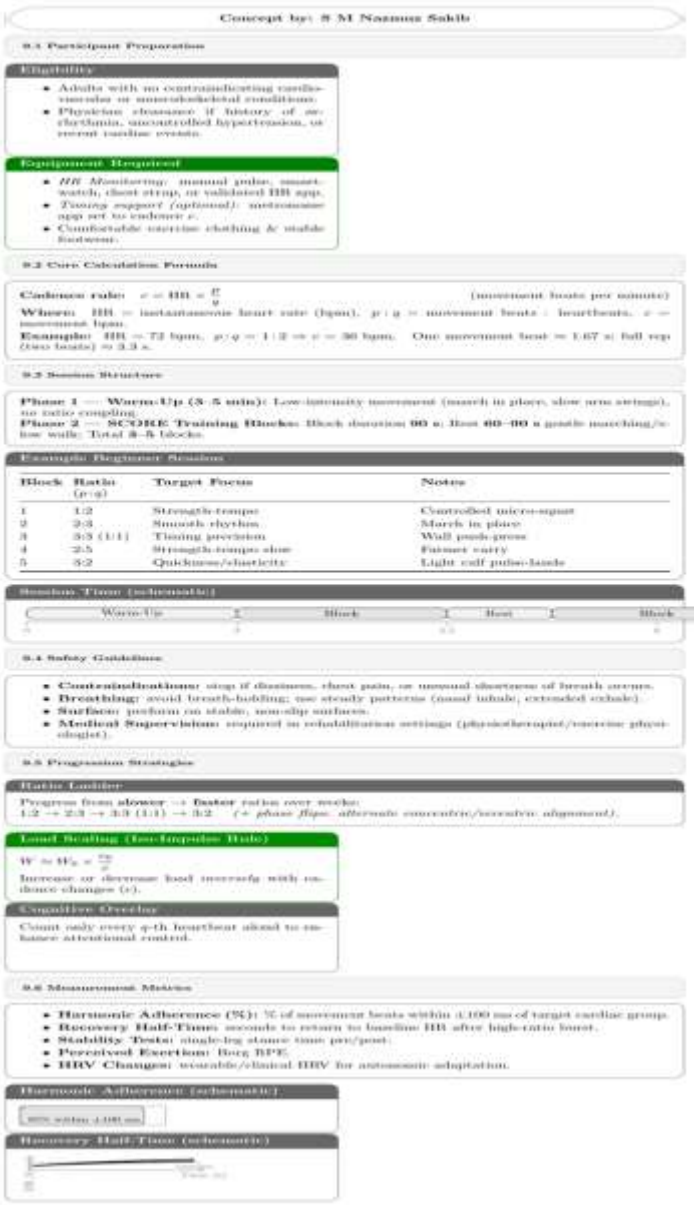
PHASE 2 – SCORE TRAINING BLOCKS

- Block Duration: 90 seconds per ratio.
- Rest Interval: 60–90 seconds of gentle marching or slow walking.
- Total Blocks: 3–5 blocks per session.

EXAMPLE BEGINNER SESSION:

Block	Ratio (p : q)	Target Focus	Notes
1	1:02	Strength-tempo	Controlled micro-squat
2	2:03	Smooth rhythm	March in place
3	3:3 (1:1)	Timing precision	Wall push-press
4	2:05	Strength-tempo slow	Farmer carry
5	3:02	Quickness/elasticity	Light calf pulse-lands

Figure



9.4 SAFETY GUIDELINES

- **Contraindications**: Skip SCORE if experiencing dizziness, chest pain, or shortness of breath outside normal exercise tolerance.
- **Breathing:** Avoid breath-holding; encourage steady breathing patterns (nasal inhale, extended exhale).
- **Surface:** Use stable, non-slip surfaces for all standing exercises.
- **Medical Supervision:** For rehab settings, sessions should be supervised by a physiotherapist or exercise physiologist.

9.5 PROGRESSION STRATEGIES

1. **Ratio Ladder:** Progress from slower (1:2) to faster (3:2) ratios over weeks.
2. **Phase Flips:** Alternate concentric/eccentric alignment with heartbeat groups.
3. **Load Scaling (Iso-Impulse Rule):**
   $W \approx W_0 \times (c_0/c)$
   Increase/decrease load in inverse proportion to cadence changes.
4. **Cognitive Overlay:** Counting only every q-th heartbeat aloud to enhance attentional control.

9.6 MEASUREMENT METRICS

- **Harmonic Adherence (%):** % of movement beats within ±100 ms of intended cardiac group.
- **Recovery Half-Time:** Time (seconds) to return to baseline HR post high-ratio burst.
- **Stability Tests:** Single-leg stance time pre/post intervention.
- **Perceived Exertion:** Using Borg RPE scale for subjective load tracking.
- **HRV Changes:** Evaluated through wearable or clinical monitoring for autonomic adaptation.

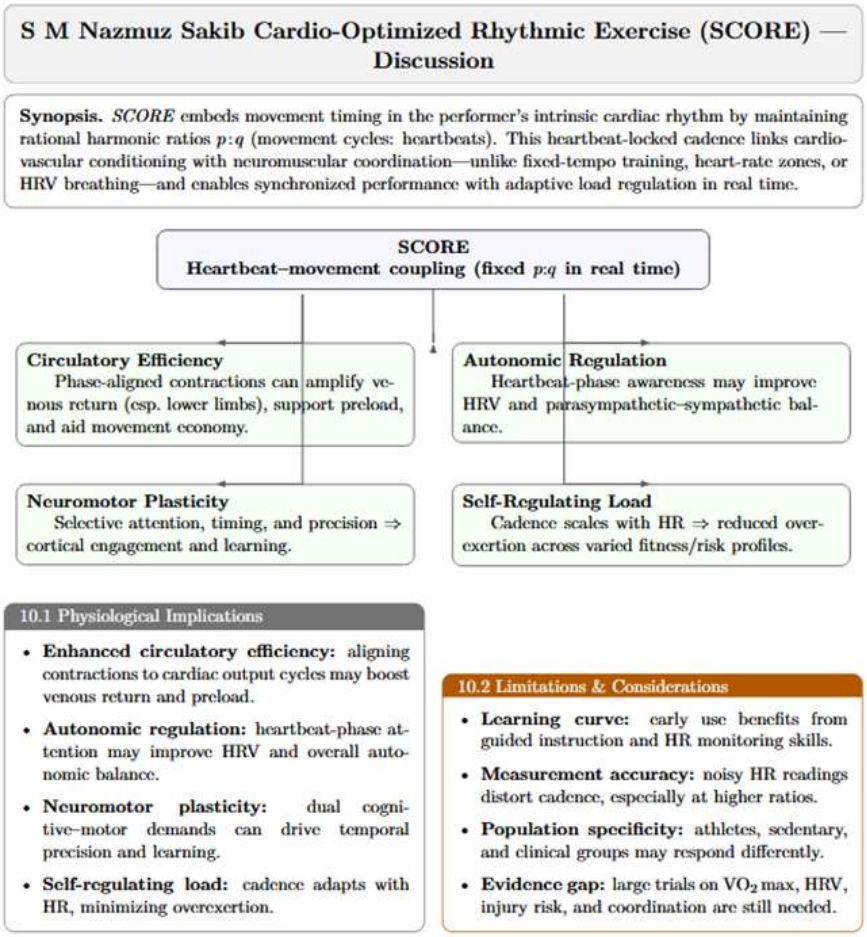
10. DISCUSSION

The S M Nazmuz Sakib Cardio-Optimized Rhythmic Exercise (SCORE) method offers a novel exercise framework that could shift how skeletal muscle and cardiovascular performance are trained in synchrony. By embedding movement timing within the performer's intrinsic cardiac rhythm via rational harmonic ratios, SCORE bridges the gap between cardiovascular conditioning and neuromuscular coordination in ways that traditional tempo training, heart-rate zone exercise, and HRV breathing do not.

10.1 PHYSIOLOGICAL IMPLICATIONS

- Enhanced Circulatory Efficiency: Aligning muscle contractions with cardiac output cycles could amplify venous return, particularly in the lower limbs, thus improving preload and potentially aiding stroke volume efficiency.
- Autonomic Regulation: SCORE's focus on heartbeat-phase awareness may help improve heart rate variability (HRV) and overall autonomic balance, relevant for both athletic recovery and clinical rehabilitation.
- Neuromotor Plasticity: The method's cognitive–motor coupling demands selective attention, temporal processing, and motor precision, potentially stimulating neuroplastic changes in motor and prefrontal cortical circuits.
- Self-Regulating Load: SCORE's built-in cadence adaptation reduces the risk of overexertion, making it safer for populations with variable fitness or cardiovascular risk profiles.

Figure



10.2 LIMITATIONS AND CONSIDERATIONS

- **Learning Curve:** Initial application may require focused attention and HR monitoring skills, possibly limiting uptake without guided instruction.
- **Measurement Accuracy:** Inaccurate heart rate readings can compromise cadence calculations, especially at higher ratios.
- **Population-Specific Effects:** Responses to SCORE may differ between trained athletes, sedentary individuals, and clinical populations; tailored guidelines are necessary.
- **Absence of Large-Scale Validation:** While theoretically robust, SCORE currently lacks large-scale clinical or athletic trial data to confirm efficacy across outcomes such as VO_2 max, HRV, injury prevention, and coordination measures.

11. FUTURE RESEARCH DIRECTIONS

To establish SCORE's role in exercise science, targeted research is needed across several domains:

11.1 PILOT FEASIBILITY STUDIES

- Test protocol adherence and participant comfort in small, diverse groups (athletes, patients, elderly).
- Measure short-term improvements in harmonic adherence, perceived exertion, and balance stability.

11.2 CONTROLLED TRIALS

- **Athletic Performance:** Compare SCORE with traditional tempo and heart-rate zone training for endurance, speed, and coordination gains.
- **Rehabilitation:** Assess SCORE's impact on gait mechanics, circulation, and motor control in post-stroke and cardiac rehab populations.

11.3 PHYSIOLOGICAL MECHANISM STUDIES

- Investigate hemodynamic changes via echocardiography or Doppler during phase-locked movement.
- Study neurocognitive effects using EEG or fNIRS to track brain engagement during heartbeat-coupled exercise.

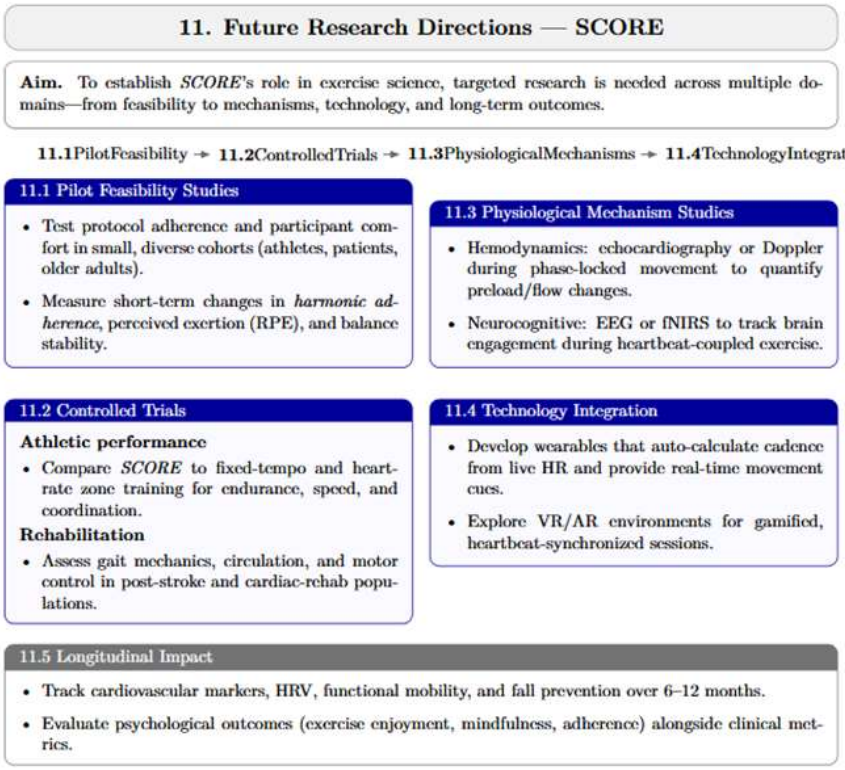
11.4 TECHNOLOGY INTEGRATION

- Development of wearable systems that auto-calculate cadence from live HR and deliver real-time movement cues.
- Explore integration with VR/AR training environments for gamified SCORE sessions.

11.5 LONGITUDINAL IMPACT

- Assess SCORE's influence on cardiovascular health markers, HRV, functional mobility, and fall prevention over 6–12 months.
- Examine potential psychological benefits, such as increased exercise enjoyment, mindfulness, and adherence.

Figure



12. CONCLUSION

SCORE introduces a new organizing principle for exercise by transforming the human heartbeat into the primary pacing mechanism for movement. This intrinsic, adaptive coupling has the potential to enhance performance, support rehabilitation, and promote overall health while requiring minimal equipment. While rooted in robust physiological rationale, SCORE now requires systematic scientific validation to establish its efficacy and optimize its application across populations. Given its adaptability, safety, and low barrier to entry, SCORE may become a transformative tool in both sports science and clinical exercise physiology.

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