

PROTOCOL

Title. Study on the changes of physical reserve and training adaptability of speed skaters based on macro–microcycle structure: prospective longitudinal cohort study.

Design. Prospective observational cohort at a national training centre and university laboratory. All participants follow the same structured 24-week macro–microcycle program with standardized aerobic, resistance, and on-ice training. No randomisation or masking. Repeated measures are taken at baseline, mid-phase (week 12), and post-phase (week 24), with additional taper follow-up to week 32.

Objectives. The objectives are to: (i) quantify changes in physiological reserve (VO_2max , lactate threshold, Wingate power, countermovement jump, heart rate recovery, HRV) across macrocycle phases; (ii) evaluate microcycle-specific training adaptability using HRV, session-RPE, and performance load ratio (PLR); (iii) assess inter-individual variability in responses to reloading stressors; and (iv) develop a feedback-driven framework for adaptive training design in competitive speed skating.

Endpoints. The primary endpoints are changes from baseline to week 24 in VO_2max , lactate threshold, Wingate peak power, CMJ height, heart rate recovery (HRR-1), and HRV RMSSD. Key secondary endpoints include session-RPE, subjective readiness, PLR, training compliance and monotony, HRV suppression and lag coefficients, biomechanical asymmetry index (3D motion capture and IMU), and composite Performance Reserve Index (PRI) retention at week 32.

Population. Competitive male and female speed skaters aged 18–25 years, with ≥ 3 years of elite-level training, $\text{VO}_2\text{max} \geq 58$ mL/kg/min (males) or ≥ 52 mL/kg/min (females), and medical clearance for high-intensity sport. Key exclusions: medications affecting cardiovascular/endocrine/metabolic function; banned substances; diagnosed cardiovascular, pulmonary, or neuromuscular disorders; or acute illness, musculoskeletal injury (grade ≥ 2), or surgery within 3 months.

Exposure definitions. All athletes complete the same structured macro–microcycle program designed by team coaches: (a) aerobic–anaerobic conditioning phase (16 weeks, including Zone 2/3 running, resistance training, and on-ice intervals); (b) taper and neuromuscular consolidation phase (8 weeks, including reduced volume, ballistic lifting, and sprint sharpening). Internal and external loads are monitored via session-RPE, GPS/on-ice timing gates, and tethered sled measurements.

Procedures and assessments.

- **Baseline:** VO_2max (MetaMax 3B), lactate threshold (Biosen C-Line), Wingate test (Monark 894E), CMJ (OptoJump), HRR-1 (Polar H10), HRV (Polar H10 + Kubios), biomechanical asymmetry (Vicon Nexus + Xsens DOT).
- **Follow-up:** repeat at weeks 12, 24, and PRI retention at week 32.
- **Daily/weekly:** HRV RMSSD, sRPE, readiness scale (McLean 1–10), PLR, monotony index, and training compliance.
- **Adverse events:** injuries, illness, or training interruptions are recorded throughout.

Sample size. Eighteen athletes were recruited, exceeding the power analysis minimum of 16 to detect medium effect sizes ($\alpha = 0.05$, power = 0.80) in repeated-measures designs.

Safety monitoring. Risks are limited to exercise testing and training. Possible fatigue, soreness, or minor injury are managed by medical staff on site. Any acute adverse events are logged and reported per institutional protocol.

Ethics. Written informed consent obtained from all participants. Approved by the **Ethics Committee of Tianjin University of Sport** (Approval No. TJUS 2025-093). Conducted in accordance with the Declaration of Helsinki and institutional regulations.

Dissemination. Results will be published in a peer-reviewed journal and presented at conferences. Summaries will be shared in plain English on the registry and provided to participating athletes and coaches. De-identified individual data may be available on request after publication, subject to ethics approval