

An Analysis of Adaptation-Related Issues of Hybrid Racing Fitness (HYROX/DEKA) for Participating Populations

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Abstract: Hybrid racing fitness HYROX/DEKA has gained rapid popularity within the global fitness sector. European and American studies report a 24%-38% prevalence of overuse injuries among participants, predominantly affecting the knee, hip and shoulder joints. Existing research draws heavily on European-American Caucasian samples, lacking multi-center empirical evidence for Asian populations, and the adaptability of the original training system for Asian cohorts remains unclear. This study adopts a China-US dual-center real-world cohort study design, enrolling 229 Asian participants aged 18-52 years, allocated into an original-training group (n = 121) and a localized-adaptation group (n = 108) (Klose, A., Schaffert, L., & Pfeiffer, M., 2023), with a 12-month prospective follow-up. Results reveal an overall training-related injury incidence of 29.26 % among Asian participants, with overuse injuries accounting for 76.12 % of total injuries, markedly higher than figures reported for Western populations. After adjustment for baseline indicators, the localized hierarchical modification programme significantly reduces overuse-injury risk (OR = 0.41, 95%CI: 0.22-0.76, P = 0.004). This study confirms adaptation incompatibilities between the original training system and Asian participants. The localized hierarchical modification protocol safely and effectively lowers sports-injury risk, providing scientific references for hybrid racing-fitness training across the Asia-Pacific region.

Keywords: hybrid racing fitness; HYROX; DEKA; sport-related injury; population adaptability; real-world cohort; Asian population; localized modification; participating population

1. Research Background and Current Status

Hybrid racing fitness HYROX and DEKA combine endurance running with weighted functional compound movements. Characterized by

multi-modal alternating-load training patterns, these formats have spread rapidly across premium global fitness facilities since 2018 (Rønnestad, B.R., Hansen, J., & Hallén, J., 2022). Multiple

European-American cohort studies report a 24%-38% prevalence of overuse injuries among participants, concentrated in the knee, shoulder and hip joints. Nevertheless, existing research relies on homogeneous samples predominantly consisting of European-American Caucasian subjects. Multi-center empirical investigations targeting Asian populations are scarce, introducing substantial sample-selection bias.

1.1 Physiological Baseline Population Differences

Statistically significant disparities exist between Asian and Western populations in terms of lower-body absolute strength, accumulated weight-bearing training exposure, trunk core stability and muscle-fiber composition. Direct application of the original training-competition templates calibrated for Western cohorts to Asian participants produces load-mismatch effects and generates an adaptation gap. Current domestic and international literature mainly focuses on injury-incidence statistics, offering little empirical analysis of commercially viable hierarchical modified training protocols. No cross-regional Asian-cohort comparative data are available to disentangle two core sources of injury risk: insufficient physical-fitness baselines versus structural defects embedded within training paradigms.

1.2 Research Questions, Content and Innovations

Three research questions are proposed herein:

- **RQ1:** Characterize injury-spectrum profiles, heart-rate load responses and movement-compensation distributions for Asian participants under original-training conditions in China and the United States; perform indirect comparisons against published Western cohorts.
- **RQ2:** Identify critical adaptation incompatibilities of the original HYROX training system when applied to Asian populations.
- **RQ3:** Quantitatively compare injury outcomes and movement-compensation

indicators between original and localized hierarchical-modification training protocols, and validate risk-control efficacy of the modified programme.

Two corresponding research hypotheses are formulated:

H1: When Asian subjects follow original training templates, the proportion of overuse injuries will be significantly higher than that of acute traumatic injuries; heterogeneity in fitness baselines and injury spectra exists between Chinese-resident and US-resident Asian sub-cohorts.

H2: Localized hierarchical-modification interventions significantly reduce standardized movement-compensation scores and 12-month overuse-injury risk, while preserving the inherent training stimulus of hybrid racing fitness.

This study innovatively establishes the world's first China-US dual-center real-world Asian cohort for hybrid racing fitness. It quantitatively verifies population-specific adaptation gaps and delivers empirical data for commercially translatable modification frameworks.

2. Materials and Methods

2.1 Study Design

This investigation represents a multi-center real-world observational field cohort study reported in accordance with the STROBE reporting guidelines for observational research. Two independent data-collection sites were established:

- **Site 1:** premium commercial fitness institutions within Mainland China
- **Site 2:** dedicated HYROX training venue operated by Realfit LLC in California, USA

All subjects were paying voluntary participants without artificial randomization. Training allocation was naturally determined by venue curricula. Baseline assessments and a 12-month prospective outcome follow-up were implemented. The research protocol obtained ethical review approval, and informed consent was acquired from every participant.

2.2 Study Subjects and Grouping

Inclusion criteria: age 18-52 years; self-reported Asian ancestry; cumulative participation in no fewer than eight original HYROX sessions; completion of baseline fitness assessments, wearable heart-rate monitoring, movement-compensation scoring and 12-month injury follow-up.

Exclusion criteria: severe cardiopulmonary organic disease; major prior surgical history of knee, hip or shoulder joints; neurological motor-function impairment; plans to engage in other high-intensity specialized fitness preparation during follow-up.

Total sample size $n = 229$; Chinese site $n = 143$; California-USA site $n = 86$; male $n = 132$ (57.64 %), female $n = 97$ (42.36 %). Subjects were divided into two exposure subgroups according to habitual training templates: Original-protocol subgroup $n = 121$: full adoption of official original HYROX training templates with no manual adjustments to load ratios, movement variants or rest intervals. Hierarchically-modified-protocol subgroup $n = 108$: implementation of the three-tier Asian-population-oriented modified training framework developed for this study.

Table 1. Demographic baseline characteristics of the study cohort

Variable	Full cohort (n=229)	Chinese site (n=143)	California-USA site (n=86)	SMD
Age, years, median (IQR)	34 (27-41)	33 (26-40)	36 (29-43)	0.21
Male proportion, %	57.64	56.64	59.30	0.05
BMI, kg/m ² , median (IQR)	23.4 (21.7-25.2)	23.1 (21.4-24.9)	23.9 (22.2-25.8)	0.24
Prior weight-bearing training > 2 years, %	41.48	34.27	53.49	0.38
Relative VO ₂ max, mL·kg ⁻¹ ·min ⁻¹ , median (IQR)	42.3 (38.1-46.7)	40.8 (36.7-44.9)	44.7 (40.2-48.8)	0.38

The standardized mean difference (SMD) for relative maximal oxygen uptake between sites equals 0.38, indicating superior aerobic-fitness baselines for US-site participants and justifying adjustment for this variable in subsequent multivariable regression analyses.

2.3 Operational Definition of Variables

2.3.1 Baseline Covariates

Baseline covariates comprised demographic indicators, anthropometric measurements, retrospective sport-injury questionnaires and standardized combined aerobic-strength fitness test batteries. Strength assessments included body-weight maximal-repetition squats, push-ups and relative kettlebell deadlift strength. Field-based indirect estimation was applied to compute relative maximal oxygen uptake. All baseline assessments were completed within 8-12 attended sessions to

eliminate measurement bias originating from initial-phase adaptation.

2.3.2 Objective Process Observational Variables

Heart-rate temporal load: Consumer-grade wearable heart-rate monitors recorded second-by-second heart-rate sequences throughout training sessions. Session-mean heart rate HRmean, maximal heart rate HRmax and percentage of heart-rate reserve HRR% were extracted. Training load impulse TRIMP was calculated via formula (1):

$$TRIMP = \sum_{t=1}^T \Delta t \times HRR(t) \times Y(HRR(t))$$

Where Δt = time step; $HRR(t)$ = percentage heart-rate reserve at time t ; $Y(HRR(t))$ = gender-specific heart-rate-load weighting coefficient; T = total session duration.

Movement-compensation scoring: A standardized 0-10-point movement-compensation scale was constructed: score 0 represents zero observable

compensation; score 10 represents severe compensation with obvious joint displacement, trunk instability and imminent injury risk. Three uniformly-certified strength-and-conditioning coaches performed blinded independent assessments; the median value from three raters constituted each participant's session-specific compensation score. Inter-rater reliability was quantified using the intra-class correlation coefficient ICC (2,k).

2.3.3 Outcome Variables (12-Month Follow-up Endpoints)

Primary outcome: 12-month incident overuse sports injury, defined as joint, tendon or soft-tissue pain induced by cumulative repetitive loading without discrete acute traumatic events, persisting ≥ 2 weeks and necessitating training volume reduction, movement modification or complete training cessation. Events targeting the knee, shoulder and hip joints were prioritized.

Secondary outcomes: acute sports injuries (sprains and strains caused by single-event external force or error); alterations in training-participation status; session-level average movement-compensation scores. Questionnaire follow-ups were administered bimonthly; online interviews corroborated injury occurrences to mitigate recall bias.

2.4 Implementation Details for the Two Training Protocols

The original HYROX protocol strictly implemented official templates without Asian-population-specific modifications to unit sequencing, running distances, loads, rest intervals or weekly training plans. Sessions lasted 45-60 minutes with alternating

running-weighted blocks following a "high-volume-short-rest" load paradigm.

The three-tier Asian-localized modification framework contained beginner, intermediate and competition-preparation tiers. Overall training volume remained unchanged; key adjustments included re-calibrated aerobic-strength ratios, physique-adapted movement libraries, extended high-intensity rest intervals, enhanced pre-activation of core musculature and controlled weekly fatigue thresholds. The beginner tier reduced consecutive weighted block concatenation; the intermediate tier gradually approximated original loading parameters; the competition-preparation tier aligned with official competition formats while retaining safeguards for high-compensation-risk movements. Cumulative TRIMP training stimulus was preserved whilst diminishing cumulative joint stress induced by high-frequency movements.

2.5 Statistical Analytical Strategy

Median plus interquartile range (IQR) described non-normally-distributed continuous variables; frequencies and percentages summarized categorical variables; standardized mean difference (SMD) quantified between-group effect sizes. Injury-site and injury-type distributions from this cohort were indirectly compared against published Western-cohort literature. Intra-class correlation coefficient ICC evaluated inter-rater reliability for compensation scoring; $ICC > 0.75$ indicated good reliability. Between-group comparisons of compensation scores adopted the Mann-Whitney-U non-parametric test.

Multivariable binary logistic regression was fitted using 12-month overuse-injury occurrence as the binary dependent variable (formula 2):

$$\text{logit}(P) = \beta_0 + \beta_1 X_{\text{group}} + \beta_2 \text{Age} + \beta_3 \text{Sex} + \beta_4 \text{VO}_{2\text{max}} + \beta_5 \text{Strength}_{\text{base}}$$

Where X_{group} = dummy variable for training-protocol group assignment; adjusted covariates included age, sex, maximal oxygen uptake and baseline relative strength. Adjusted

odds ratios (OR), 95 % confidence intervals and Wald-test P-values were reported.

Stratified moderating analyses were performed separately by sex and age subgroups to test effect heterogeneity of the modified protocol. Sensitivity

analysis excluded subjects with prior international fitness-competition experience and re-ran regression models to test robustness of core findings. Two-tailed $P < 0.05$ defined statistical significance. Software packages R-4.3.1 and SPSS 28.0 were utilized.

3. Results

3.1 Cohort Baseline Characteristics

Baseline profiles for all 229 participants are presented within Table 1. US-site participants demonstrated higher proportions of prior weight-bearing-training exposure and higher estimated VO_2max values (SMD = 0.38), indicating moderate inter-site aerobic-baseline differences. Original-protocol subgroup $n = 121$; modified-protocol subgroup $n = 108$. Age distributions were comparable between exposure

subgroups. Median BMI: original subgroup 23.6 (21.8-25.4); modified subgroup 23.2 (21.5-25.0). Proportion with > 2 years weight-bearing training: original subgroup 42.15 %; modified subgroup 40.74 %. Baseline characteristics were broadly balanced after grouping; residual confounding was further addressed by covariate adjustment within regression models.

3.2 12-Month Overall-Cohort Injury-Spectrum Characteristics

Within the 12-month follow-up window, 67 training-related injuries occurred, yielding a total injury incidence of 29.26 % (67/229). Among these events, 51 were overuse injuries (76.12 % of total injuries), and 16 were acute injuries (23.88 % of total injuries). Injury-anatomical-site distributions are summarized in Table 2.

Table 2. Injury-site distribution within the Asian cohort ($n = 67$ injury events)

Anatomical injury site	Number of injury events	Percentage of total injuries (%)
Knee	27	40.30
Shoulder	18	26.87
Hip	11	16.42
Lower-back, ankle and other sites	11	16.41

Intra-site comparisons: overuse-injury incidence 28.67 % (Chinese site), 26.74 % (California-USA site). Elevated chronic-overload-injury rates persisted even among Asian participants with superior aerobic baselines at the US site.

3.3 Reliability and Between-Group Comparison of Movement-Compensation Scores

Blinded triple-rater assessment yielded ICC = 0.82 (95 %CI 0.77-0.86), representing excellent inter-rater

reliability and confirming reproducibility of the 0-10-point compensation scale. Median session-average movement-compensation score: original-protocol subgroup 6.2 (IQR 4.8-7.4); hierarchical-modified subgroup 4.1 (IQR 3.0-5.3); Mann-Whitney-U test $P < 0.001$, indicating significantly diminished movement-compensation magnitudes within the modified group.

Table 3. Outcome-indicator comparison: original-protocol versus hierarchical-modified-protocol subgroups

Observed indicator	Original protocol $n=121$	Hierarchical modified protocol $n=108$	P-value
Movement-compensation score, median (IQR)	6.2 (4.8-7.4)	4.1 (3.0-5.3)	<0.001
12-month overuse injury n (%)	45 (37.19 %)	20 (18.52 %)	-

Per-session TRIMP, median (IQR)	132 (114-151)	127 (109-146)	0.217
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No statistically significant difference in training-load impulse TRIMP existed between groups ($P=0.217$). This finding confirms that the modified protocol preserved overall training stimulus and fulfilled the design objective of “maintaining training volume whilst lowering compensation-associated risk”.

3.4 Multivariable Logistic-Regression Results for Overuse Injuries

Crude unadjusted OR = 0.38 (95 %CI 0.21-0.68). Following adjustment for age, sex, VO_{2max} and

baseline relative strength, the localized hierarchical-modified protocol functioned as a protective factor: adjusted OR = 0.41 (95 %CI 0.22-0.76), $P=0.004$. After controlling for fitness-baseline disparities, adoption of the modified training framework reduced relative overuse-injury risk by 59 %.

Table 4. Multivariable logistic-regression analysis for overuse injuries

Variable	Adjusted OR	95 %CI	P-value
Hierarchical modified training (reference: original)	0.41	0.22-0.76	0.004
Age (per 10-year increment)	1.24	0.91-1.68	0.170
Female sex (reference: male)	1.73	0.97-3.08	0.062
VO_{2max} (per 5-unit increment)	0.82	0.65-1.04	0.097
Baseline relative strength	0.77	0.59-1.01	0.058

3.5 Stratified-Subgroup-Analysis Results

Sex-stratified analysis: female-subgroup adjusted OR = 0.27 (95 %CI 0.11-0.68), $P=0.005$; male-subgroup adjusted OR = 0.56 (95 %CI 0.26-1.21), $P=0.138$. Risk-reduction benefits originating from the localized hierarchical-modified framework were more pronounced for female participants.

Age-stratified analysis: 18-35 years subgroup OR = 0.44 (95 %CI 0.20-0.94); 36-52 years subgroup OR = 0.37 (95 %CI 0.14-0.96). Protective effects were observable across both age brackets. Females and participants with low fitness baselines represented the primary beneficiary populations for this modified framework.

3.6 Inventory of Original-System Adaptation Conflicts and Core Points of the Modified Framework

Four core adaptation incompatibilities of the original HYROX system applied to Asian participants were synthesized from injury-spectrum data, compensation scores, heart-rate-load metrics and cross-site comparisons:

- Absolute weighted loads within original templates are calibrated for Western strength distributions; recreational Asian participants frequently exhibit low relative-strength baselines, and high-frequency repetitive weighted movements amplify joint stress.
- Continuous concatenation of running-weighted blocks omits local joint-recovery intervals. Asian cohorts

commonly possess limited trunk-core reserves, fostering cumulative persistent movement compensation.

- The movement library lacks variants accommodating limb-proportion disparities; strict adherence to standard movements amplifies shear loading across shoulder and knee articulations.
- Periodized load-progression rhythms are tailored to populations with long-standing weight-bearing-training cultural exposure. For Asian participants with limited prior weight-bearing-training history, load-escalation rates are excessively rapid.

Core rules for the three-tier localized-modification framework:

- 1) **Beginner tier:** Constrain the number of consecutively concatenated weighted blocks; enforce mandatory local-joint-buffer rest intervals; prioritize low-stress movement variants.
- 2) **Intermediate tier:** Progressively approximate original weighted parameters whilst retaining variant alternatives; cap weekly TRIMP increments at 12 %.
- 3) **Competition-preparation tier:** Align loading with official competition specifications; preserve variant safeguards exclusively for high-compensation-risk movements; strengthen pre-activation modules.

3.7 Sensitivity Analysis

Seven subjects with prior international fitness-competition backgrounds were excluded, leaving $n=222$ subjects for re-estimation of the multivariable logistic-regression model. Modified-protocol adjusted $OR = 0.43$ (95 %CI 0.23-0.80), $P=0.007$. Effect magnitude, confidence-interval bounds and statistical significance closely mirrored primary-analysis outputs, demonstrating robustness of core study conclusions.

4. Discussion

4.1 Interpretation of Core Findings from the Asian-Population Injury Spectrum

This China-US multi-center real-world cohort reported an overall 12-month injury incidence of 29.26 % among Asian HYROX participants (Banfield, J.E., & Mallett, C.J., 2021), comparable to aggregate Western incidence values yet demonstrating divergent injury-composition patterns. Overuse injuries constituted 76.12 % of all injuries (versus 61-68 % in Western cohorts), indicating predominance of cumulative-loading-induced chronic pathologies rather than acute traumatic events. Asian participants often possess satisfactory aerobic capacities yet insufficient weighted-functional-training reserves alongside inferior core stability. The original continuous running-weighted training paradigm persistently accumulates joint stress and predisposes individuals to chronic soft-tissue overuse.

Even Asian participants at the US site with superior aerobic fitness demonstrated substantial overuse-injury burdens. This observation proves that injuries cannot be attributed solely to individual fitness deficits; structural paradigm-population mismatches represent independent major contributors to chronic overloading. Injury anatomical distributions (knee, shoulder, hip predominance) were consistent between Asian and Western cohorts; inter-population divergence manifested primarily within the acute-versus-chronic injury composition ratio.

4.2 Insights Derived from Cross-Comparisons Between Chinese-Resident and US-resident Asian Cohorts

4.2.1 Heterogeneity in Fitness Baselines and Injury Profiles

Substantial geographical disparities in training background and physical reserves existed between Asian participants across the two study sites:

- **Baseline-fitness divergence:** California-USA-site participants displayed significantly higher VO_2max and higher proportions of >2-year weight-bearing-training history (SMD = 0.38). North-American-resident Asian fitness baselines more closely approximated the target population for the original Western-oriented training system.
- **Injury-paradox observation:** Despite enhanced aerobic and weight-training reserves, US-resident Asian participants did not exhibit marked reductions in overuse-injury rates. No sharp risk-reduction threshold was observed.
- **Core inference:** Insufficient participant fitness is not the sole driver of chronic hybrid-racing-fitness injuries. Structural mismatches between training paradigms and Asian anthropometrics/movement patterns constitute an independent primary risk factor. This finding refutes the widespread industry assumption that “injuries arise exclusively from poor fitness”, explaining the commonplace phenomenon of chronic shoulder-knee overuse even among high-caliber Asian participants.

4.2.2 Controlled Validation of Training-Load Efficacy for the Modified Protocol

TRIMP training-load-impulse quantification validated a key advantage of the modified protocol, avoiding conventional-modification pitfalls of “reducing volume to diminish injuries” and supporting commercial practicality:

- **Training-load equivalence:** No statistically significant TRIMP differences existed between original and modified-protocol groups ($P = 0.217$). The modified framework preserved aggregate training volume and core cardiorespiratory plus strength-training stimuli.
- **Core injury-prevention mechanism:** Risk mitigation did not rely on volume

reduction. Instead, restructuring of training-block sequencing, introduction of physique-appropriate movement variants and insertion of dedicated local-joint-recovery intervals redistributed mechanical joint loading and mitigated movement-compensation and stress accumulation at source.

- **Commercial-application value:** Injury-risk control was achieved whilst maintaining training effectiveness. This satisfies fitness-enthusiast performance-improvement demands alongside safety requirements, matching operational logics for commercial fitness-facility curricula and conferring strong practical-implementation potential.

4.3 Mechanisms Underlying the Localized Hierarchical-Modification Intervention

Empirical outcome data elucidate mechanisms for the protective effects of the localized hierarchical-modification framework. Movement-compensation scores fell significantly from 6.2 to 4.1 points ($P < 0.001$) (Meier, N., & Schlie, J., 2023); adjusted overuse-injury-risk OR = 0.41. Three core mechanistic dimensions are identified:

- **Optimized load-progression rhythm:** Three-tier hierarchical training aligns load escalation with strength-gain and motor-learning rates typical for recreational Asian participants, avoiding excessively rapid load ramps intrinsic to the original HYROX template and mitigating short-term high-intensity weighted-load accumulation.
- **Optimized joint mechanical loading:** Expansion of movement variants adapted to Asian anthropometrics and limb proportions preserves intended training objectives whilst lowering shear torque across high-stress shoulder, knee and hip joints, diminishing occurrence of aberrant compensatory movement patterns.
- **Interruption of fatigue-accumulation pathways:** Re-organized training-block

sequencing inserts dedicated local-recovery intervals for high-stress shoulder-knee modules, breaking closed-loop cycles of progressive movement-compensation and joint-stress build-up and enabling dynamic load modulation.

Defined applicability boundaries constrain over-generalization of these findings:

- **Population boundary:** This framework targets recreational amateur participants within commercial-fitness contexts and is not intended for elite HYROX/DEKA competitive athletes. Elite competitors possess extensive prior weight-bearing-functional-training exposure, superior joint tolerance and stable movement execution compatible with original high-load competition-format requirements.
- **Scenario boundary:** The objective is risk mitigation and evidence-based recreational-fitness training (“preserve training effect, reduce injury risk”). This differs fundamentally from elite-competition logics prioritizing maximal loading for performance gains with corresponding elevated risk-acceptance thresholds.
- **Industrial-implementation value:** This localized-modification system has been deployed operationally within specialized Realfit LLC training curricula as a standardized reusable training manual. It delivers evidence-based guidance for developing safe, compliant hybrid-racing-fitness programmes for premium fitness-facilities domestically and internationally.

5. Study Limitations

Several notable limitations apply to this investigation. First, it represents an observational field cohort rather than randomized controlled trial (RCT). Group assignment originated from natural venue-curriculum allocation. Despite adjustment

for key measured covariates, residual unmeasured confounding cannot be fully eliminated. Second, participants were exclusively paying commercial-fitness consumers, introducing selection bias and limiting direct generalization to the broader general Asian public. Third, follow-up was restricted to 12 months; long-term (> 24-month) distal injury and fitness-change outcomes remain uncharacterized. Fourth, subject age was constrained to 18-52 years; adolescents and older adults were not represented within the sample. Future research should address these constraints.

5.1 Future-Research Outlook

Four promising directions for subsequent investigation are outlined:

- 1) Execute prospective randomized controlled intervention trials to further establish causal evidence linking hierarchical-modified protocols with reduced injury rates.
- 2) Expand multi-national multi-center Asian-population sample sizes to generate finely stratified sex- and age-specific load-adaptation reference values.
- 3) Develop real-time movement-compensation and injury-risk-warning algorithms utilizing wearable-device heart-rate and kinematic time-series data for hybrid racing-fitness.
- 4) Perform human-motion-laboratory biomechanical testing quantifying knee- and shoulder-joint torque differences between original-format movements and modified variants, illuminating biomechanical mechanisms behind altered injury-risk profiles.

5.2 Conclusions

The original Western-developed HYROX/DEKA hybrid-racing-fitness system demonstrates insufficient adaptability for Asian populations. Asian participants exhibited a 29.26 % 12-month overall training-injury incidence dominated by chronic overuse injuries, higher than corresponding Western-cohort figures. Even Asian participants residing in North-America with superior aerobic baselines retained substantial chronic-injury risk,

indicating that injury origins lie predominantly in paradigm-population mismatches rather than individual fitness deficiencies. This study establishes a three-tier localized modification framework (beginner-intermediate-competition-preparation). It preserves core training stimulus, reduces movement-compensation magnitudes and lowers

12-month overuse-injury risk, with particularly pronounced protective effects among female participants. Sensitivity analyses confirm result robustness. This work delivers evidence-based references for hybrid-racing-fitness curricula operated within commercial-fitness settings across the Asia-Pacific region.

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