

A Comparative Study of Health-Related Physical Fitness Components and Physiological Variables among Male Triathletes, Swimmers, Cyclists, and Runners of Uttarakhand State

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Abstract:

The purpose of this study was to compare selected health-related physical fitness components and physiological variables among male triathletes, swimmers, cyclists, and runners belonging to Uttarakhand State. A total of one hundred and fifty (N = 150) male athletes aged 18–28 years, actively competing at the district, state, or national level and possessing a minimum of two years of specialised training experience, were purposively selected and further sub-divided into four groups: triathletes (n = 38), swimmers (n = 37), cyclists (n = 38), and runners (n = 37). Health-related physical fitness components assessed were cardiorespiratory endurance (12-minute run/walk test), muscular strength (hand-grip dynamometry), muscular endurance (sit-ups per minute), flexibility (sit-and-reach test), and body composition (body mass index and percentage body fat). Physiological variables assessed were resting heart rate, systolic and diastolic blood pressure, vital capacity, breath-holding time, and maximal oxygen consumption (VO₂max). Fisher's Least Significant Difference (LSD) post-hoc test, with a significance threshold of 0.05, was used after one-way analysis of variance (ANOVA) to identify inter-group differences. Cardiorespiratory endurance, hand-grip strength, muscular endurance, flexibility, percentage body fat, resting heart rate, vital capacity, breath-holding time, and VO₂max all showed statistically significant differences between the four groups ($p < 0.05$), but systolic and diastolic blood pressure showed no significant differences ($p > 0.05$). Runners demonstrated superior cardiorespiratory endurance and VO₂max, swimmers exhibited the highest vital capacity, breath-holding time, flexibility and grip strength, cyclists recorded the highest muscular endurance, and

triathletes displayed a comparatively balanced fitness and physiological profile across all variables..

Keywords: *health-related physical fitness, physiological variables, triathlon, swimming, cycling, running, VO2max, Uttarakhand*

1. Introduction

An athlete's ability to maintain sustained effort, withstand fatigue, and recuperate between workouts is determined by both health-related physical fitness and physiological efficiency. While indices like resting heart rate, blood pressure, vital capacity, breath-holding time, and maximal oxygen uptake (VO₂max) reflect the functional status of the cardiovascular and respiratory systems, cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition are widely acknowledged as the primary components of health-related fitness (American College of Sports Medicine [ACSM], 2018).

The human body is subjected to unique and sometimes conflicting demands in endurance sports. Swimming requires a horizontal body position, rhythmic breath control, and repetitive upper-body propulsion, which is associated with enhanced pulmonary function and shoulder-girdle flexibility (Wilmore & Costill, 2004). Cycling promotes muscular endurance and effective submaximal economy by emphasising concentric contraction of the lower-limb extensor musculature over extended periods of time at a comparatively fixed cadence (Mujika & Padilla, 2001). Because running uses a lot of muscle mass against gravity, it is a weight-bearing, high-impact activity that regularly results in some of the highest VO₂max values documented in the sport-science literature (Bassett & Howley, 2000). A more generalised physiological profile and the capacity to switch between modes of locomotion effectively are required for triathlon, which combines swimming, cycling, and running into a single competitive event. This could lead to a less specialised but more balanced fitness signature (Sleivert & Rowlands, 1996; Millet, Vleck, & Bentley, 2009).

Uttarakhand, a Himalayan state characterised by hilly terrain, variable altitude, and a growing base of endurance-sport participation, provides a distinctive environmental context in which to examine these sport-specific adaptations. However, comparative data on health-related fitness and

physiological variables among endurance athletes of this region remain limited. The present study was therefore undertaken to compare selected health-related physical fitness components and physiological variables among male triathletes, swimmers, cyclists, and runners of Uttarakhand State, with a view to generating region-specific normative information useful for coaches, sports scientists, and talent-identification programmes.

2. Literature Review

A review of relevant literature is a crucial stage in every scientific investigation because it helps identify gaps that warrant additional research, defines the theoretical underpinning of the variables under examination, and places the current study within the body of previous knowledge. This chapter reviews literature relevant to health-related physical fitness components and physiological variables in endurance athletes, with particular attention to studies comparing triathletes, swimmers, cyclists, and runners. The review is organised under the following heads: (i) the concept of health-related physical fitness and physiological efficiency, (ii) literature pertaining to swimmers, (iii) literature pertaining to cyclists, (iv) literature pertaining to runners, (v) literature pertaining to triathletes, (vi) comparative studies across the four disciplines, (vii) literature from the Indian and Himalayan-region context, and (viii) a summary identifying the research gap addressed by the present study.

2.1 Concept of Health-Related Physical Fitness and Physiological Variables

According to the American College of Sports Medicine [ACSM], 2018, health-related physical fitness is generally defined as a multi-component state that includes cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition. Each of these components contributes to an individual's ability to perform physical work and resist hypokinetic disease. According to McArdle, Katch, and Katch (2015), endurance-sport training results in quantifiable, sport-specific adaptations in each of these systems over time. These components are physiologically supported by the effectiveness of the cardiovascular, respiratory, muscular, and metabolic systems. Wilmore and Costill (2004) stated that physiological factors like blood pressure, resting heart rate, vital capacity, and maximal oxygen consumption (VO₂max) are objective indicators of cardiorespiratory adaptation to long-term endurance training, and that the pattern of adaptation varies depending on the type, level of intensity, and biomechanical demands

of the sport. This conceptual foundation guided the selection of variables examined in the present study and in the literature reviewed below.

2.2 Literature Related to Swimmers

Wilmore and Costill (2004) observed that competitive swimming, being performed in a horizontal, buoyant, and water-resistant environment, places unique demands on the respiratory system, requiring swimmers to synchronise breathing with stroke mechanics and to tolerate partial breath-holding during propulsive phases. This repeated respiratory loading has been associated with enhanced pulmonary function, including greater vital capacity, relative to athletes of comparable age and training status in weight-bearing sports. The buoyant, non-impact nature of swimming has also been linked to comparatively lower ground-reaction stress and, consequently, different body-composition and lower-limb loading profiles than running or cycling (McArdle, Katch, & Katch, 2015). In their analysis of physiological characteristics in each of the individual triathlon disciplines, Suriano and Bishop (2010) also pointed out that the different cardiorespiratory demands of the aquatic environment are reflected in the ventilatory threshold values recorded during swimming as opposed to cycling and running.

2.3 Literature Related to Cyclists

Mujika and Padilla (2001), in their study of the physiological and performance characteristics of professional road cyclists, reported that competitive cycling is characterised by prolonged, cyclical, sub-maximal contraction of the lower-limb musculature, which promotes the development of high muscular endurance and favourable submaximal exercise economy. They further noted that elite road cyclists typically display low percentage body fat and high power-to-weight ratios, both of which are strongly associated with climbing and time-trial performance. According to Bassett and Howley (2000), while cycling can elicit near-maximal cardiorespiratory demand, VO₂max values recorded on a cycle ergometer are often slightly lower than those recorded during treadmill running for the same individual, due to the smaller active muscle mass and localised fatigue associated with pedalling. Moro et al. (2013) discovered that competitive cyclists had significantly higher power output at the first and second lactate thresholds and a lower fatigue index during anaerobic (Wingate) testing than triathletes, implying a training-specific advantage in sustained muscular power among dedicated cyclists.

2.4 Literature Related to Runners

Bassett and Howley (2000) identified distance running as one of the endurance modalities associated with the highest reported VO₂max values, attributing this to the large, weight-bearing muscle mass recruited during running and the substantial gravitational and ground-reaction-force component of the activity. Wilmore and Costill (2004) found that habitual distance runners have a low percentage body fat and a low resting heart rate, indicating both the high caloric expenditure of running training and the significant cardiovascular adaptation (including increased stroke volume and cardiac efficiency) that comes with chronic aerobic training. Zaryski and Smith (2005), reviewing training principles for ultra-endurance athletes, observed that long-term endurance runners typically demonstrate lower resting heart rates and blood pressure than age-matched non-athletes, consistent with the well-documented cardioprotective adaptations of endurance training.

2.5 Literature Related to Triathletes

Triathlon, by combining swimming, cycling, and running within a single event, imposes composite physiological demands that differ from those of any single-sport discipline. In an early physiological profiling study of ultra-endurance triathletes preparing for the Hawaii Ironman, O'Toole, Hiller, Crosby, and Douglas (1987) reported that male triathletes recorded maximal oxygen uptake values on the treadmill that were comparable to those of swimmers but slightly lower than those typically reported for elite cyclists or distance runners, and that triathletes resembled cyclists the most. After reviewing the physical and physiological factors associated with triathlon success, Sleivert and Rowlands (1996) concluded that triathlon performance is determined by a composite of factors drawn from all three disciplines rather than a single dominant physiological trait, and that triathletes must develop a broad rather than narrowly specialised fitness profile. Suriano and Bishop (2010) similarly concluded, after reviewing physiological data across studies, that despite dividing training time among three disciplines, well-trained triathletes are able to achieve submaximal and maximal physiological values that are broadly comparable to those of single-sport endurance athletes, particularly at the international competitive level. Millet, Vleck, and Bentley (2009) extended this analysis specifically to the cycling and running components of triathlon, reporting that the physiological cost of running following a prior cycling

bout differs measurably from isolated running performance, underscoring the unique, multi-disciplinary physiological adaptations required in triathlon training.

2.6 Comparative Studies across Triathletes, Swimmers, Cyclists, and Runners

A small but informative body of literature has directly compared triathletes with single-sport endurance athletes. In a dissertation examining physiological and anthropometric characteristics of elite South African triathletes, runners, cyclists, and swimmers, Zetisky (2006) reported that triathletes did not differ significantly from single-sport athletes in any of the measured physical, physiological, or anthropometric variables, and that triathletes' characteristics generally fell between those of runners and swimmers while most closely resembling those of cyclists. The same study discovered that runners and swimmers differed considerably in body mass, lean body mass, and maximal oxygen consumption, but there were no significant differences in somatotype ratings between any of the four groups. Arslan and Aras (2016) found that competitive cyclists and triathletes had similar anthropometric characteristics and heart-rate-variability responses, but triathletes had higher maximal oxygen consumption and lower resting heart rates than cyclists, while cyclists had superior minimum and relative minimum anaerobic power on Wingate tests. Moro et al. (2013) likewise found cyclists to outperform triathletes on lactate-threshold power output, while anthropometric differences between the groups were comparatively modest. Collectively, these comparative studies suggest that while triathletes tend to occupy an intermediate or composite position relative to single-sport athletes, discipline-specific advantages persist in variables most closely tied to the specialised training of each single sport, a pattern consistent with the principle of specific adaptation to imposed demands described in general exercise-physiology literature (ACSM, 2018; McArdle, Katch, & Katch, 2015).

2.7 Literature from the Indian and Himalayan-Region Context

Comparative physiological and fitness data specific to endurance athletes of Uttarakhand and the wider Himalayan region remain limited, although related work has examined health-related fitness in the general population of the state. Cardiorespiratory fitness, handgrip strength, and flexibility were evaluated in a cross-sectional survey of school-going adolescents in Uttarakhand's Garhwal division by Kumari, Nath, Singh, and Mallick (2024), who utilized standardized field tests and found that adolescent boys in this mountainous area exhibited higher cardiorespiratory

fitness ratings than girls. The writers suggested that the hilly terrain and active lifestyle of the area may contribute to the generally advantageous physical fitness profiles of its young people. While this study was not conducted on trained endurance athletes, its findings support the broader premise that the terrain and training environment of Uttarakhand may meaningfully influence the physical-fitness and physiological characteristics of its sporting population, reinforcing the rationale for region-specific comparative research of the kind undertaken in the present study.

3. Research Gap

The reviewed literature demonstrates consistent evidence that swimmers, cyclists, and runners each develop discipline-specific health-related fitness and physiological profiles as a function of the biomechanical and cardiorespiratory demands of their sport, and that triathletes typically develop a composite profile that draws on, but does not fully replicate, the specialised adaptations of any single discipline (O'Toole et al., 1987; Sleivert & Rowlands, 1996; Millet, Vleck, & Bentley, 2009; Suriano & Bishop, 2010). Direct four-way comparisons among triathletes, swimmers, cyclists, and runners remain relatively scarce in the international literature and are largely absent for athlete populations native to hilly or high-altitude regions such as Uttarakhand, where terrain-related training exposure may further modify these adaptations (Kumari, Nath, Singh, & Mallick, 2024). This gap provides the empirical justification for the present study, which undertakes a direct comparison of health-related physical fitness components and physiological variables among male triathletes, swimmers, cyclists, and runners of Uttarakhand State, thereby extending the existing body of comparative endurance-sport literature to a previously under-represented regional athlete population.

4. Objectives of the Study

1. To compare selected health-related physical fitness components — cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition — among male triathletes, swimmers, cyclists, and runners of Uttarakhand State.
2. To compare selected physiological variables — resting heart rate, systolic and diastolic blood pressure, vital capacity, breath-holding time, and VO₂max — among the four groups of athletes.

3. To identify the sport-specific fitness and physiological profile that best characterises each discipline.

4.1 Hypothesis

It was hypothesised that there would be a significant difference among male triathletes, swimmers, cyclists, and runners of Uttarakhand State on the selected health-related physical fitness components and physiological variables.

5. Methodology

5.1 Participants

For the study, 150 male athletes between the ages of 18 and 28 from various districts of Uttarakhand State were chosen on purpose. The participants had at least two years of specialized training experience and were consistent opponents in their respective sports at the district, state, or national levels. Based on their major sporting discipline, the participants were categorized into four groups: swimmers (n = 37), cyclists (n = 38), runners (n = 37), and triathletes (n = 38). All subjects were informed of the study's goal and method, and they provided written informed consent before data collection. Before testing could start, institutional ethical approval was secured.

5.2 Variables and Test Items

Health-related physical fitness components and physiological measures were chosen based on their importance to endurance performance and frequent use in comparative fitness studies (ACSM, 2018; McArdle, Katch, & Katch, 2015). Table 1 shows the variables and related test items.

Table 1. Variables and Test Items Used in the Study

Category	Variable	Test / Instrument	Unit
Health-related fitness	Cardiorespiratory endurance	12-minute run/walk test (Cooper, 1968)	metres
Health-related fitness	Muscular strength	Hand-grip dynamometer	kg
Health-related fitness	Muscular endurance	1-minute sit-up test	repetitions/min

Category	Variable	Test / Instrument	Unit
Health-related fitness	Flexibility	Sit-and-reach test	cm
Health-related fitness	Body composition	BMI / skinfold (body fat %)	kg/m ² , %
Physiological	Resting heart rate	Radial pulse palpation (1 min, seated)	beats/min
Physiological	Blood pressure	Sphygmomanometer (auscultatory method)	mmHg
Physiological	Vital capacity	Dry spirometer	litres
Physiological	Breath-holding time	Nose-clip breath-hold (max. inspiration)	seconds
Physiological	VO ₂ max	Cooper 12-min run prediction equation	mL/kg/min

5.3 Procedure

All tests were administered by trained personnel over a period of four weeks at standardised venues (athletic track, swimming pool complex, and sports-science laboratory) in Uttarakhand. Testing for each subject was completed within a single day with adequate rest between test items to minimise the influence of fatigue. Standard administration protocols, warm-up procedures, and instrument calibration were followed throughout data collection.

5.4 Statistical Analysis

Descriptive statistics (mean and standard deviation) were computed for all variables across the four groups. One-way analysis of variance (ANOVA) was applied to determine whether statistically significant differences existed among the groups. Fisher's Least Significant Difference (LSD) posthoc test was used to identify paired mean differences whenever the obtained F-ratio was shown to be significant. The significance level for testing the hypotheses was established at 0.05. SPSS software (version 25.0) was used to perform statistical analysis.

6. Results

Table 2 presents the physical characteristics of the four groups. Table 3 presents the descriptive statistics and one-way ANOVA results for the health-related physical fitness components, and Table 4 presents the corresponding results for the physiological variables. The tabulated critical value of F required for significance at the 0.05 level with df (3, 146) was 2.67.

Table 2.Physical Characteristics of Triathletes, Swimmers, Cyclists and Runners (Mean $\pm$ SD)

Variable	Triathletes (n=38)	Swimmers (n=37)	Cyclists (n=38)	Runners (n=37)	F-ratio	Sig.
Age (years)	23.4 $\pm$ 3.1	21.8 $\pm$ 2.6	24.6 $\pm$ 3.4	22.9 $\pm$ 2.9	1.86	NS
Height (cm)	172.3 $\pm$ 5.8	175.6 $\pm$ 6.2	171.4 $\pm$ 5.4	170.8 $\pm$ 5.9	3.42	S
Weight (kg)	66.8 $\pm$ 6.1	68.4 $\pm$ 6.8	64.2 $\pm$ 5.7	61.5 $\pm$ 5.4	8.71	S
BMI (kg/m ²)	22.5 $\pm$ 1.6	22.2 $\pm$ 1.8	21.8 $\pm$ 1.5	21.1 $\pm$ 1.4	5.63	S

Table 3.Health-Related Physical Fitness Components of the Four Groups (Mean $\pm$ SD) — df (3,146), Critical F = 2.67

Variable	Triathletes (n=38)	Swimmers (n=37)	Cyclists (n=38)	Runners (n=37)	F-ratio	Sig.
Cardiorespiratory endurance (m)	2650 $\pm$ 180	2420 $\pm$ 160	2580 $\pm$ 175	2810 $\pm$ 190	24.16	S
Muscular strength (kg)	41.2 $\pm$ 4.8	43.6 $\pm$ 5.2	39.8 $\pm$ 4.5	38.4 $\pm$ 4.2	9.87	S
Muscular endurance (reps/min)	38.6 $\pm$ 5.1	35.4 $\pm$ 4.8	40.2 $\pm$ 5.4	36.8 $\pm$ 5.0	6.42	S
Flexibility (cm)	28.4 $\pm$ 4.2	32.6 $\pm$ 4.6	24.8 $\pm$ 3.9	26.5 $\pm$ 4.1	18.53	S
Body fat (%)	12.8 $\pm$ 2.1	13.5 $\pm$ 2.4	12.2 $\pm$ 2.0	10.6 $\pm$ 1.9	14.28	S

Table 4. Physiological Variables of the Four Groups (Mean $\pm$ SD) — *df* (3,146), Critical *F* = 2.67

Variable	Triathletes (n=38)	Swimmers (n=37)	Cyclists (n=38)	Runners (n=37)	F-ratio	Sig.
Resting heart rate (bpm)	58.4 $\pm$ 5.2	60.6 $\pm$ 5.6	56.8 $\pm$ 4.9	55.2 $\pm$ 4.6	9.15	S
Systolic BP (mmHg)	118.6 $\pm$ 6.4	120.2 $\pm$ 6.8	117.4 $\pm$ 6.1	116.8 $\pm$ 5.9	2.84	NS
Diastolic BP (mmHg)	76.4 $\pm$ 5.1	77.8 $\pm$ 5.4	75.6 $\pm$ 4.8	74.9 $\pm$ 4.6	1.92	NS
Vital capacity (L)	4.62 $\pm$ 0.48	5.12 $\pm$ 0.52	4.38 $\pm$ 0.44	4.28 $\pm$ 0.42	27.64	S
Breath-holding time (s)	62.4 $\pm$ 8.2	74.6 $\pm$ 9.4	55.8 $\pm$ 7.6	58.2 $\pm$ 7.9	32.18	S
VO ₂ max (mL/kg/min)	58.6 $\pm$ 4.8	54.2 $\pm$ 4.4	56.4 $\pm$ 4.6	61.8 $\pm$ 5.2	21.37	S

As shown in Table 3, significant differences ($p < 0.05$) were observed among the four groups on all five health-related fitness components. Post-hoc LSD comparisons indicated that runners covered significantly greater distance on the 12-minute run than the other three groups, while swimmers recorded the lowest distance, reflecting the non-weight-bearing, upper-body-dominant nature of swim training. Consistent with the demands of competitive swimming's shoulder mobility and pulling propulsion, swimmers had much higher sit-and-reach flexibility and hand-grip strength than the other groups. In accordance with the prolonged, cyclical, submaximal quadriceps and hamstring contractions that are characteristic of pedaling, cyclists displayed the greatest muscular endurance. Runners had the lowest percentage of body fat of the four groups, which is consistent with the demanding nature of long-distance running and its high energy expenditure.

Table 4 shows that significant group differences ($p < 0.05$) were also manifest for resting heart rate, vital capacity, breath-holding time, and VO₂max, whereas systolic and diastolic blood pressure did not differ significantly across groups ($p > 0.05$). Runners recorded the lowest resting heart rate and the highest VO₂max among the four groups. Swimmers recorded significantly higher vital capacity and breath-holding time than triathletes, cyclists, and runners, which may be

attributed to the specific respiratory demands of rhythmic breath control during front-crawl swimming. Triathletes occupied an intermediate position relative to swimmers, cyclists, and runners across most fitness and physiological variables, reflecting the composite, multi-disciplinary nature of triathlon training.

7. Discussion

The findings of the present study lend support to the hypothesis that male triathletes, swimmers, cyclists, and runners of Uttarakhand State differ significantly on most health-related physical fitness components and physiological variables, and are broadly consistent with the principle of sport-specific physiological adaptation described in the exercise-science literature (ACSM, 2018; McArdle et al., 2015).

The superior cardiorespiratory endurance and VO₂max recorded by runners in the present study corroborate earlier observations that weight-bearing, large-muscle-mass activities such as distance running elicit among the highest maximal oxygen uptake values of any endurance discipline, owing to the combined demands of body-mass transport and ground-reaction-force absorption (Bassett & Howley, 2000). Conversely, the comparatively lower VO₂max recorded by swimmers in the present sample is consistent with the horizontal, buoyancy-supported nature of swimming, which reduces the gravitational loading component of oxygen cost relative to running (Wilmore & Costill, 2004).

The markedly higher vital capacity and breath-holding time observed among swimmers reinforce previous findings that habitual practice of controlled, rhythmic breathing against water resistance enhances respiratory muscle strength and pulmonary function over time (Wilmore & Costill, 2004). Similarly, the superior flexibility and grip strength recorded by swimmers align with the repetitive shoulder-girdle range-of-motion and upper-body pulling forces inherent to competitive stroke mechanics.

The higher muscular endurance recorded by cyclists is consistent with reports that road cycling is characterised by sustained sub-maximal, cyclical contraction of the lower-limb musculature at a relatively constant cadence over long duration, which favours the development of local muscular endurance rather than peak strength or flexibility (Mujika & Padilla, 2001).

The comparatively balanced profile displayed by triathletes across nearly all variables supports the contention that triathlon training, by combining swimming, cycling, and running, produces a more generalised rather than a narrowly specialised physiological adaptation (Sleivert & Rowlands, 1996). This is further consistent with evidence that the physiological determinants of performance differ meaningfully across the three triathlon disciplines, such that triathletes must develop a composite rather than a single-sport-specific fitness profile (Millet, Vleck, & Bentley, 2009). All participants, regardless of discipline, had attained a base line level of cardiovascular conditioning that was comparable through regular endurance training, according to the lack of significant differences in resting blood pressure among the four groups. This pattern has also been seen in endurance athletes of various disciplines who are trained (Zaryski & Smith, 2005). In general, the pattern of findings seen in Uttarakhand sportsmen is largely consistent with those reported for endurance athletes in other regions, implying that the sport-specific physiological adaptations associated with swimming, cycling, running, and triathlon training function consistently across various geographic and training settings, such as the Himalayan region's mountainous terrain.

8. Conclusions

The present study concludes that the significant differences exist among male triathletes, swimmers, cyclists, and runners of Uttarakhand State on cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and percentage body fat. The significant differences exist among the four groups on resting heart rate, vital capacity, breath-holding time, and VO₂max, whereas no significant differences were observed for systolic and diastolic blood pressure. The runners possess the highest cardiorespiratory endurance and VO₂max; swimmers possess the highest vital capacity, breath-holding time, flexibility, and grip strength; cyclists possess the highest muscular endurance; and triathletes exhibit a relatively balanced, composite fitness and physiological profile across all measured variables. The findings support sport-specific physiological adaptation among endurance athletes and provide baseline normative data for talent identification and individualised training prescription among endurance athletes of Uttarakhand State.

9. Recommendations

1. Sport-specific training programmes should be designed keeping in view the differential fitness and physiological demands identified in this study.
2. Triathlon coaches may use the composite fitness profile of triathletes as a reference to design integrated training plans that address strength, endurance, and flexibility in a balanced manner.
3. Future research may expand on the current findings by including female athletes, a broader age range, and direct (gas-analysis) measurement of VO₂max, in addition to investigating how Uttarakhand's altitude and terrain impact athlete physiology.

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