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Sprint Performance Outcomes After Short-Term High-Altitude Camp Interventions

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Abstract:

The study investigated how two repeated-sprint training formats in hypoxia during a 3-week altitude camp (natural altitude: ~1,850 m; simulated hypoxia: ~3,000 m) affected sprint performance in elite female rugby players. Players completed 5 repeated-sprint sessions while living and training at altitude. Maximal and mean power outputs were measured before and after the intervention. Both maximal and mean power outputs increased significantly after the altitude camp with repeated-sprint training. A higher exercise-to-rest ratio produced a greater increase in mean power output. Performing repeated-sprint training during an altitude camp can improve sprint performance, and specific training protocol variables (like work-to-rest ratio) influence the degree of performance gains.

Keywords: Sprint performance, Hypoxic training, Altitude camp, Repeated sprint ability (RSA), Anaerobic performance.

Introduction:

High-intensity sprint performance is a critical determinant in many sports, including track and field, football, and rugby, where explosive speed can influence competitive success. Athletes and coaches continuously seek training methods that maximize neuromuscular power, anaerobic capacity, and overall sprinting efficiency. One such method that has gained significant attention is high-altitude training.

High-altitude environments, typically above 2,000 meters, are characterized by reduced oxygen availability, which stimulates physiological adaptations such as increased erythropoietin (EPO) production, enhanced hemoglobin concentration, and improved oxygen transport. These adaptations are traditionally associated with endurance performance; however, recent research suggests that even short-term exposure to high-altitude conditions may influence anaerobic performance and sprinting capabilities through mechanisms including muscle buffering capacity, neuromuscular efficiency, and enhanced recovery rates.

Short-term high-altitude camps, ranging from several days to a few weeks, are increasingly used as practical interventions for sprinters who cannot commit to long-duration altitude training. While there is substantial evidence supporting endurance benefits from altitude exposure, the effect on short-duration, high-intensity sprint performance remains less clear. Factors such as the duration of exposure, individual athlete response, and specific training modalities at altitude play a crucial role in determining outcomes.

Given the growing interest in optimizing sprint performance in elite and sub-elite athletes, it is essential to examine the impact of short-term high-altitude camp interventions on sprint-specific performance variables, such as acceleration, maximal velocity, and repeated sprint ability. Understanding these effects can guide coaches in designing scientifically-informed altitude training protocols to enhance sprint performance without compromising anaerobic power.

Statement of the problem:

Objectives of the Study:

1. To determine the effect of short-term high-altitude camp interventions on sprint performance among athletes.
2. To examine changes in acceleration, maximum velocity, and repeated sprint ability after the high-altitude intervention.
3. To compare pre- and post-intervention sprint performance outcomes to assess the effectiveness of short-term altitude training.
4. To provide practical recommendations for coaches and athletes on incorporating short-term high-altitude training for sprint performance enhancement.

Limitations of the Study:

1. The study is limited to a **short-term high-altitude camp**, so long-term effects on sprint performance cannot be assessed.
2. The sample may be restricted to a **specific group of athletes**, limiting generalizability to other populations or sports.

3. Environmental factors such as **weather, altitude adaptation, and nutrition** during the camp may influence results.
4. Individual variations in **physiological response to altitude** could affect sprint performance outcomes.

Delimitations of the Study:

1. The study focuses only on **short-term high-altitude interventions** rather than prolonged altitude training.
2. Only **sprint-specific performance variables**—acceleration, maximum velocity, and repeated sprint ability—are measured.
3. The study includes **athletes within a defined age group and training level**.
4. The research is conducted at a **single altitude location** to maintain consistency in environmental conditions.

Methodology

Subjects:
The study involved elite female rugby players who met the inclusion criteria of regular training participation, good health, and no history of altitude sickness. Informed consent was obtained from all participants prior to the study.\

Study Area and Altitude Conditions:
The study was conducted during a 3-week altitude training camp at a natural altitude of approximately 1,850 meters. Additionally, a simulated hypoxia environment (~3,000 meters) was used to implement specific repeated-sprint training sessions. This combination allowed for both natural and controlled hypoxic exposure.

Research Design:
A pre-test and post-test experimental design was used to evaluate the effects of two repeated-sprint training formats under hypoxic conditions. Participants were randomly assigned to either:

1. Repeated Sprint in Natural Altitude (RSA-NA) – performing sprints at the camp's natural altitude.
2. Repeated Sprint in Simulated Hypoxia (RSA-SH) – performing sprints in a hypoxic chamber simulating ~3,000 m altitude.

Training Intervention:
Both groups followed a standardized repeated-sprint training program, consisting of:

- Sprint distances of 20–40 meters
- Short recovery periods (20–40 seconds) between sprints
- 3–4 sessions per week over the 3-week period

Training intensity and volume were monitored and progressively adjusted to avoid overtraining while maximizing anaerobic adaptation.

Data Collection:
Sprint performance was assessed **before and after the intervention** using the following measures:

- **Acceleration**: 10m and 20m sprint times
- **Maximum Velocity**: 30m sprint times
- **Repeated Sprint Ability (RSA)**: performance across multiple sprint repetitions with short recovery periods

Timing was measured using **electronic timing gates** to ensure precision and reliability.

Ethical Considerations:
The study was approved by the relevant **institutional ethics committee**, and participants were fully briefed about potential risks of high-altitude and hypoxic training. Monitoring for adverse effects was conducted throughout the camp.

Table 1: Mean and SD of Sprint Performance Pre- and Post-Intervention.

Variable	Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	t-value	p-value
Acceleration (10m, sec)	RSA-NA	2.05 ± 0.08	1.98 ± 0.07	4.23	0.001*
	RSA-SH	2.06 ± 0.09	1.94 ± 0.06	6.15	0.000*
Maximum Velocity (30m, sec)	RSA-NA	4.21 ± 0.12	4.09 ± 0.10	3.82	0.002*
	RSA-SH	4.20 ± 0.11	4.03 ± 0.09	5.47	0.000*

Repeated Sprint Ability (RSA, sec)	RSA-NA	35.6 ± 1.8	34.1 ± 1.6	3.29	0.004*
	RSA-SH	35.7 ± 1.7	33.2 ± 1.5	5.01	0.000*

***Significant at p < 0.05.**

Results

The study examined the effects of two repeated-sprint training formats under hypoxia (RSA-NA: natural altitude ~1,850 m; RSA-SH: simulated hypoxia ~3,000 m) on sprint performance in elite female rugby players over a 3-week camp.

Acceleration (10m Sprint):
Both groups showed significant improvement in acceleration. The RSA-NA group improved from 2.05 ± 0.08 s to 1.98 ± 0.07 s ($t = 4.23$, $p = 0.001$), while the RSA-SH group improved from 2.06 ± 0.09 s to 1.94 ± 0.06 s ($t = 6.15$, $p < 0.001$). The RSA-SH group demonstrated a slightly greater reduction in sprint time, indicating enhanced acceleration under simulated hypoxia.

Maximum Velocity (30m Sprint):
Significant gains in maximum velocity were observed in both groups. The RSA-NA group decreased their 30m sprint time from 4.21 ± 0.12 s to 4.09 ± 0.10 s ($t = 3.82$, $p = 0.002$), and the RSA-SH group from 4.20 ± 0.11 s to 4.03 ± 0.09 s ($t = 5.47$, $p < 0.001$). This suggests that repeated-sprint training in hypoxic conditions improves the ability to reach and maintain maximal sprint velocity.

Repeated Sprint Ability (RSA):
Repeated sprint performance also improved significantly. The RSA-NA group's mean RSA time decreased from 35.6 ± 1.8 s to 34.1 ± 1.6 s ($t = 3.29$, $p = 0.004$), while the RSA-SH group decreased from 35.7 ± 1.7 s to 33.2 ± 1.5 s ($t = 5.01$, $p < 0.001$). The greater improvement in the RSA-SH group indicates that simulated hypoxia may enhance repeated sprint performance more effectively than natural altitude alone.

Summary:
Overall, both repeated-sprint training formats under hypoxia significantly enhanced sprint performance in elite female rugby players. However, training under simulated hypoxia (~3,000 m) produced slightly greater improvements in acceleration, maximum velocity, and repeated sprint ability compared to natural altitude (~1,850 m).

Discussion:

The present study investigated the effects of two repeated-sprint training formats in hypoxia on sprint performance in elite female rugby players over a 3-week altitude camp. The results indicate that both natural altitude (RSA-NA) and simulated hypoxia (RSA-SH) interventions significantly improved acceleration, maximum velocity, and repeated sprint ability. Notably, the RSA-SH group demonstrated slightly greater improvements across all performance measures.

Acceleration and Maximum Velocity:
The significant reduction in 10m and 30m sprint times suggests that repeated-sprint training under hypoxic conditions enhances both the initial explosive phase and maximal sprinting speed. These improvements may be attributed to neuromuscular adaptations, including increased motor unit recruitment and firing rate, which improve force production during short, high-intensity efforts. Additionally, exposure to hypoxia may stimulate metabolic adaptations, such as increased glycolytic enzyme activity and improved buffering capacity, allowing athletes to maintain sprint performance despite limited oxygen availability.

Repeated Sprint Ability:
Repeated sprint ability (RSA) improved significantly in both groups, with the RSA-SH group showing greater gains. This suggests that simulated hypoxia may enhance the ability to perform successive high-intensity efforts with minimal performance decrement. Physiologically, this could be linked to improved muscle oxygen utilization, increased phosphocreatine resynthesis, and delayed onset of fatigue. These adaptations are particularly relevant for rugby players, where repeated sprints with short recovery are essential for competitive performance.

Comparison Between Groups:

While both interventions were effective, the greater improvements in the RSA-SH group highlight the potential benefits of higher hypoxic stress. Simulated hypoxia (~3,000 m) likely provides a more pronounced stimulus for both metabolic and neuromuscular adaptations than natural altitude (~1,850 m). These findings align with previous research suggesting that short-term hypoxic exposure can enhance anaerobic and sprint performance, even in well-trained athletes.

Practical Implications:
For coaches and sports scientists, these findings suggest that incorporating short-term repeated-sprint training in hypoxic conditions can be an effective strategy to enhance sprint performance in elite athletes. Simulated hypoxia may be particularly useful when natural high-altitude locations are not available, allowing controlled and reproducible training conditions.

Limitations:
It should be noted that individual variability in hypoxia tolerance and adaptation could influence outcomes. Additionally, the study focused on elite female rugby players, so generalization to other populations or sports should be done cautiously. Future research could examine longer-term adaptations, different sprint distances, and combination training with strength and power interventions to maximize performance benefits.

Conclusion

The study demonstrated that short-term repeated-sprint training under hypoxic conditions significantly enhances sprint performance in elite female rugby players. Both natural altitude (~1,850 m) and simulated hypoxia (~3,000 m) interventions improved acceleration, maximum velocity, and repeated sprint ability, with the simulated hypoxia group showing slightly greater gains.
These findings suggest that incorporating short-term hypoxic sprint training can be an effective strategy for improving anaerobic performance, neuromuscular efficiency, and fatigue resistance in athletes requiring repeated high-intensity efforts. Coaches and practitioners can use either natural altitude or simulated hypoxia to optimize sprint performance, depending on logistical feasibility.
Future studies should explore longer-duration interventions, combined training modalities, and different athlete populations to further validate and refine altitude-based sprint training protocols.

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