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ACUTE COLD STRESS

The effects of combined arterial de-oxygenation and systemic cooling on the rate of muscular fatigue development

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Introduction

Cooling and fatigue are known to have similar effects on muscle performance and physiology [1]. Studies have shown a significantly increased rate of fatigue development during both low, and high intensity work [2, 3]. Numerous researchers have also reported that acute hypoxemia exaggerates the rate of fatigue development, centrally [4, 5, 6, 7] and peripherally [7, 8, 9, 10, 11, 12]. While abundant research exists on cold and hypoxic stressors separately, the interactive effects of combined exposure on the rate of muscle fatigue development remains unexamined. We hypothesised that relative to baseline performance levels, independent exposure to arterial de-oxygenation and systemic cooling will induce a significant increase on post exercise fatigue, compared to values observed during thermoneutral normoxia. During combined hypoxic-cold exposure, we expected a significant synergistic interaction on post exercise fatigue, with peripheral blood flow reductions during cold accentuating the fatiguing effect of low arterial oxygenation.

Methods

Eight physically active, non smoking men were exposed for 1-hour 10-minutes to four conditions in a balanced order. The conditions were control/ normoxic thermoneutrality (N), hypoxic thermoneutrality (H), normoxic cold (C) and hypoxic cold (HC). Thermoneutral conditions were 22°C ambient temperature (Tamb) and cold conditions were 5°C. Hypoxic exposures were 0.13 fraction of inspired oxygen (FIO2). After a 15-minute rest period, participants carried out dynamic forearm exercises at 15% maximal voluntary contraction (MVC) for eight consecutive, 5-minute work bouts, each separated by a 1-minute 50-second rest period. Electromyography and MVC force (Kgf) was used to quantify the rate of fatigue development in the forearm. To test post exposure data for significance, two-way (2 x 2) repeated measures ANOVA was used. A Wilks Lambda Multivariate Analysis of Variance (MANOVA) was also conducted on three fatigue related markers in a combined dependent variable. Multiple regression and Pearson correlations tested for significant relationships with skin temperature (Tsk), laser Doppler Flowmetry (LDF) and Peripheral Oxygen Saturation (SpO2).

Results and Discussion

The results indicate that when compared to exercise in thermoneutral or normoxic conditions, both cold and hypoxia induce significant (p <0.01) increases on indicators of muscle fatigue. Also, the level of fatigue is increased when the stressors are combined, however there is no interactive effect between these stressors. The effect of cold and hypoxia combined is additive. A key dependant variable used to define fatigue in this study – the fatigue index (FI) [3] - showed that when expressed as a percentage of the control condition (FI/N), hypoxia and cold independently increased fatigue by 24 ± 7% and 39 ± 9% respectively. When hypoxia and cold were combined, FI reflected a summative value equal to 62 ± 11%. Furthermore, when physiological markers were combined using multiple regression, the results showed that over 50% of the variance in fatigue was accounted for by varied SpO2 and Tsk (p <0.01, adjusted r² = -0.52).
Conclusions
Altitude is a multi-stressor environment, in which both cold and hypoxia dramatically reduce muscular endurance, thus increasing the risk of overuse injuries or musculoskeletal disorders [13]. When these stressors are combined the level of fatigue is increased further and the effects appear additive, not showing an interaction during low intensity, repetitive exercise.

References