

## **The Effect of Cold Water Immersion and Hydration on Movement Technique in Hyperthermic, Dehydrated, and Fatigued Athletes**

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**Introduction:** Hyperthermia, dehydration, and fatigue are physiological insults that frequently occur during physical activity and impair neuromuscular control, increasing lower extremity musculoskeletal injury risk.

**Purpose:** To determine if an individualized hydration plan and cold water immersion (CWI) improve neuromuscular control in exercise-induced hyperthermic, dehydrated, and fatigued females during a jump-landing task.

**Methods:** A randomized counterbalanced controlled crossover design will be employed to evaluate the effects of an individualized hydration plan during outdoor interval exercise in the heat and CWI after exercise on neuromuscular control during a jump-landing task. Twenty heat acclimatized, recreationally active females without previous anterior cruciate ligament injury will complete three exercise trials in a randomized counterbalanced order: fluid replacement during exercise (HYD), no fluid replacement during exercise but post-exercise CWI (COOL), and no fluid replacement during exercise nor post-exercise CWI (CON). Neuromuscular control will be assessed during a standardized jump-landing task before (Pre-Ex) and after exercise (Post-Ex) and after the cooling intervention (Post-Int). The exercise protocol will occur outdoors in the heat (>35°C, 20% relative humidity) following a predetermined interval program simulating the physiological and biomechanical stress of high intensity intermittent sports. Exercise will continue until gastrointestinal temperature ( $T_{gi}$ )=40.0°C and perceptual fatigue  $\geq 7/10$ . Fluid intake during HYD will match sweat rate losses, minimizing dehydration. Pilot data (n=3) revealed 2.3% dehydration at Post-Ex while mimicking COOL and CON exercise and environmental conditions.  $T_{gi}$  and skin temperature, fluid intake, heart rate, body mass loss, and perceptual scales (perceived exertion, thermal sensation, thirst, and fatigue) will characterize physiological strain throughout the study. Exercise intensity and duration will be recorded during the first exercise trial and repeated during subsequent exercise trials. CWI will consist of full-body immersion to the neck in 10°C water until  $T_{gi}$ =38.0°C or 10 minutes. Neuromuscular control during the jump-landing task will be assessed with both kinetic and kinematic data. Data

collection will occur in a heated indoor lab using both applied (Landing Error Scoring System [LESS]) and laboratory-based (3-D motion analysis system time-synced with dual force plates) biomechanical approaches. These procedures optimize internal (precise lab measures) and external (outdoor exercise) validity. We will evaluate differences between test sessions (HYD, COOL, and CON) and time points (Pre-Ex, Post-Ex, and Post-Int) using repeated measures analyses of variance.

**Experimental Hypotheses and Expected Outcomes:** Subjects will demonstrate better neuromuscular control, as measured by lower total LESS scores, joint moments, ground reaction forces, and greater sagittal plane motion with limited frontal and transverse plane motion in HYD compared to CON at Post-Ex. We expect to observe a similar trend in measures of neuromuscular control at Post-Int after participants complete CWI (COOL) compared to CON.

**Relevance:** This will be the first study to address two prevention strategies (individualized hydration plan during exercise and body cooling after exercise) that may decrease lower extremity musculoskeletal injury risk by mitigating hyperthermia and dehydration. This knowledge will advance the athletic training profession by identifying injurious biomechanical changes during exercise in heat and suggest prevention strategies that can easily be implemented by athletic trainers to mitigate injury risk.