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Original paper

# Effect of cold water immersion on repeated 1-km cycling performance in the heat

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**Abstract**

This study examined the effect of a short cold water immersion (CWI) intervention on rectal and muscle temperature, isokinetic strength and 1-km cycling time trial performance in the heat. Ten male cyclists performed a 1-km time trial at 35.0 ± 0.3 °C and 40.0 ± 3.0% relative humidity, followed by 20 min recovery sitting in either cold water (14 °C) for 5 min or in 35 °C air (control); a second 1-km time trial immediately followed. Peak and mean cycling power output were recorded for both time trials. Rectal and muscle temperature, and maximal isokinetic concentric torque of the knee extensors were measured before and immediately after the first and second time trials. Rectal temperature was not different between cold water immersion and control conditions at any time points. After the second time trial, however, muscle temperature was significantly lower (−1.3 ± 0.7 °C) in cold water immersion compared with the control trial. While peak and mean power decreased from the first to second time trial in both conditions (−86 ± 54 W and −24 ± 16 W, respectively), maximal isokinetic concentric torque was similar between conditions at all time points. The 5 min cold water immersion intervention lowered muscle temperature but did not affect isokinetic strength or 1-km cycling performance.


*Keywords:* Recovery; Neuromuscular; Intervals; Environment

## 1. Introduction

To maintain performance over multiple exercise sessions, various recovery strategies have been used.[1–3] The recovery benefits of a cold water immersion (CWI) intervention have been examined in both sprint and endurance exercise and have produced conflicting results. For example, after 90 min of submaximal running in the heat, CWI in 12 °C for 15 min significantly improved 2 mile running time trial (TT) performance compared with a control condition.[4] Conversely, CWI can reduce sprint cycling performance. Two studies have observed that, compared with passive sitting at room temperature, CWI in 12–14 °C for 15 min decreased peak and average power of sprints performed immediately after immersion.[5,6] Nevertheless both studies were conducted at thermoneutral (<27 °C) temperatures, and it is possible that the sprint response may be different in warmer ambient temperatures.[7]

The most likely cause of the reduction in cycle sprint power output following CWI is a decrease in the contractile speed of the cooled muscle during maximal contraction.[8] Indeed, cold exposure can increase action potential propagation time in muscle,[8,9] and decrease dynamic contractile force by 4–6% for each 1 °C decrease in muscle temperature ($T_{mus}$).[9] Therefore, the CWI interventions used (12–14 °C for 15 min) in the abovementioned sprint studies[5,6] likely decreased subsequent cycling performance through the lowered $T_{mus}$.[9] In addition, the recovery time available for some sport settings can be limited, decreasing the applicability of longer CWI recovery interventions. For these reasons, an investigation into the influence of a short duration (<15 min) CWI intervention on acute power production under high environmental temperatures is needed.

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The purpose of the present study was to determine the effect of a 5 min CWI intervention on rectal temperature ($T_{re}$), $T_{mus}$, maximal isokinetic force and 1-km cycling TT performance in the heat (35 °C and 40% relative humidity). We hypothesised that the shorter CWI intervention would significantly lower $T_{mus}$ compared with a control condition; however, the short exposure time to CWI would limit the deleterious cooling effect on isokinetic force and 1-km TT performance. The findings from this study could be used to improve understanding of the effect of cold exposure on acute power production in sport.

## 2. Methods

Ten male cyclists (age: 29 ± 6 years; stature: 181.7 ± 4.0 cm; mass: 79.3 ± 6.3 kg; $\dot{V}O_2$max: 56.5 ± 5.0 ml kg$^{-1}$ min$^{-1}$) were recruited to participate in this study. All subjects had been training for at least 1 year and at the time of the study, had a weekly training volume that was greater than 200 km week$^{-1}$. At the time of the study, 8 of the 10 subjects were racing primarily in Australian road cycling events at the grade A/B level. Subjects were provided with the procedures and risks associated with participation in the study and gave their written informed consent prior to participation. Subjects were required to complete three testing sessions at similar times of the day, separated by 7.0 ± 1.0 days. Subjects were asked to maintain a similar diet and refrain from intense physical activity in the 24 h period before each testing session. The study was approved by the University's Human Research Ethics Committee.

During initial testing, subjects completed a maximal graded exercise test on a Velotron cycle ergometer (Racermate, Seattle, USA) starting at resistance of 70 W and increasing by 35 W min$^{-1}$ until volitional fatigue. During the subsequent trials, subjects were required to complete two, 1-km TTs on a Velotron cycle ergometer in an environmental chamber maintained at 35.0 ± 0.3 °C and 40.0 ± 3.0% relative humidity. For each TT, subjects sprinted from a standing start using a fixed resistance (gear ratio of 53 × 14). The gear ratio selected for this study was the largest ratio, determine from pilot research, which would allow a rapid increase in cadence during the first 10 s of the TT and did not limit maximal power production. Subjects were asked to finish each TT in the shortest time possible by sprinting as fast as possible from the start. Prior to the trial, subjects were familiarised with the 1-km TT protocol. The TTs were completed without a preceding warm-up. During the subjects' initial TT, the total time spent in the standing or seated position was recorded and subjects were instructed to follow a similar procedure during subsequent TTs. During the TT, peak power (W), average power (W) and completion time (s) were recorded. Following completion of the first TT, subjects were given 20 min of passive recovery, during which they were randomly assigned to either 5 min of CWI in 14 °C or a control condition, in which the subject sat in the environmental chamber. The 20-min recovery interval was selected, as this recovery duration is similar to that used in previous CWI sprint studies.[5,6] Cold water immersion occurred from 7.5 to 12.5 min of the 20-min recovery period. The timing of the CWI allowed for completion of the isokinetic testing, and for subjects to prepare for the CWI and subsequent TT. Before and after the CWI, subjects sat passively in the environmental chamber (35 °C and 40% relative humidity). Within 2 min following the recovery period, subjects completed a second TT. Rectal temperature, $T_{mus}$ and isokinetic muscle function were measured before and immediately after the first and second TT.

During the 5 min CWI, subjects were submerged in an inflatable water bath in the seated position to the mid-sternal level, wearing only their cycling shorts. Water temperature was maintained at a constant 14 °C by a specially designed water refrigeration unit (iCool Portacovery, Queensland, Australia). The water temperature selected for this study (14 °C) was chosen as it appears as the most commonly used water temperature in previous CWI studies,[4,5,10] has been shown to be effective at lowering body temperature[4,10] and is tolerable to most subjects.

Rectal temperature was measured using a disposable rectal thermometer (Monatherm Thermistor, 400 Series; Mallinckrodt Medical, St. Louis, MO, USA) inserted ∼12 cm past the anal sphincter. Rectal temperature measurements were recorded via a data-logger (Grant Instruments, Shepreth Cambridgeshire, UK) at a sampling rate of 1 Hz. For simplicity and statistical analysis, $T_{re}$ data are presented as an average of a 60 s sample measured before and immediately after the first and second TT and at 4-min intervals during the 20-min recovery session.

Left quadriceps $T_{mus}$ was measured with the use of a needle thermistor probe (model N451; Nikkiso-YSI Ltd., Tokyo Japan) inserted at a 45° angle into the belly of the rectus femoris to a depth of 30 mm. The insertion site was standardised at a distance 2/3 the length of the femur, inferior to the superior iliac spine. The thermometer remained inserted until a stable recording was observed (∼10 s) at which time a single value was recorded. All $T_{mus}$ measurements were conducted on the left leg in order to eliminate any negative effects the procedure may have had on the muscle function testing (see below).

Isokinetic concentric torque production was measured from the right knee extensors using a Biodex isokinetic dynometer (Isokinetics Inc. De Queen, AR, USA). During the measurement, subjects were seated with a trunk angle of 85° and were restrained from extraneous movement with nylon straps. Subjects completed three isokinetic concentric contractions of the knee extensors at a velocity of 240° s$^{-1}$ throughout a 90° range of motion (0–90°) with 30 s of rest between contractions. This movement velocity was selected as it represents the angular velocity of the knee joint consistent with cycling at a common cadence of 90 rev min$^{-1}$.[11] Isokinetic torque was recorded at a frequency of 100 Hz, and the highest value recorded during the three contractions