18-4 Beneficial effects of artificial carbon-dioxide water bathing on the quality of sleep in healthy volunteers: A pilot study

Shuji MATSUMOTO\textsuperscript{1)}, Keiko IKEDA\textsuperscript{2)}, Kodai MIYARA\textsuperscript{2)}, Hirofumi KANO\textsuperscript{3)}, Yuji SAKASHITA\textsuperscript{3)}, Megumi SHIMODOZONO\textsuperscript{1)}

1) Department of Rehabilitation and Physical Medicine, Graduate School of Medical and Dental Sciences, Kagoshima University
2) Department of Rehabilitation, Kirishima Rehabilitation Center of Kagoshima University Hospital
3) Department of Rehabilitation, Tarumizu Municipal Medical Center, Tarumizu Central Hospital

Objectives: To preliminarily assess the effects of a single warm-water bath (WWB) on the quality of sleep, we measured sleep pattern after WWB in healthy volunteers. The primary objective of the present before–after study was to evaluate whether a single 10-minute WWB at 41°C could modulate sleep pattern in a single group of healthy subjects. In this pilot study, we also assessed the difference in general fatigue and subjects’ satisfaction responses to WWB under two conditions: WWB using tap water (WWB with tap water) and WWB using a bath additive that included inorganic salts and artificial carbon-dioxide (CO\textsubscript{2}) (WWB with ISCO\textsubscript{2}).

Methods: Eleven healthy volunteers aged 20 to 48 years (29.8±8.9 years, mean ± SD) participated in this study. Inclusion criteria were as follows: age 20–50 years; free of cardiovascular disease; not taking medications or supplements. In this within-subject, two-way crossover study, all subjects underwent WWB with tap water or WWB with ISCO\textsubscript{2} in random order for two consecutive nights. Objective sleep measures from sleep sensor mat (sleep-scan) and subjective subjects’ reports were collected. This study was approved by the Ethics Committee of Kagoshima University Hospital and written informed consent was obtained from all of the subjects.

Results: None of the subjects experienced discomfort before, during or after the study period. The objective sleep measures and subjects’ reports were completed safely in all subjects. WWB with ISCO\textsubscript{2} bathing produced significant improvement in objective and subjective sleep latency compared with WWB with tap water bathing (P<0.05). Sleep-scan-determined wake time after sleep onset (WASO), sleep efficiency, and number of awakenings (NA), and patient-reported measures of WASO, NA, sleep quality, sleep depth, and daytime functioning significantly improved following WWB with ISCO\textsubscript{2} bathing versus WWB with tap water bathing (P<0.05). WWB with ISCO\textsubscript{2} bathing also increased deep sleep time and sleep score (P<0.01 for both comparisons), but did not alter REM or slow-wave sleep.

Conclusion: In conclusion, in our group of healthy volunteers, a single warm-water bath was shown to have the potential to modulate the quality of sleep. These findings demonstrate that WWB with ISCO\textsubscript{2} bathing might be effective in improving some domains of sleep quality of healthy volunteers, and the subjects showed acceptance towards the intervention. Strengths and limitations of the present study as well as suggestions for further studies were considered. Further evaluations with larger and longer-term randomized double-blind placebo-controlled
trials based on the present study are needed.

**Keywords:** Carbon-dioxide (CO₂), Sleep