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Doctoral thesis abstract

The Effects of Head-and-Neck Temperature Manipulation and Motor Task Type on Central and Peripheral Fatigue, Motor Accuracy, and Stress-Related Blood Markers in Men With Multiple Sclerosis

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1. BACKGROUND AND OBJECTIVES

Multiple sclerosis (MS) is a chronic neurological disorder characterised by immune-mediated demyelination and axonal degeneration, leading to impaired motor control, fatigue, and reduced quality of life (Dobson & Giovannoni, 2019). Fatigue in MS arises from both central and peripheral mechanisms, with central fatigue linked to impaired neural drive and peripheral fatigue reflecting reduced muscle contractility (Tornero-Aguilera et al., 2022). Thermal stress further exacerbates fatigue in people with MS (PwMS), with heat impairing neural conduction and cooling, showing potential to improve performance and reduce exertion (Flensner et al., 2011; Grahn et al., 2008). The head and neck are highly thermosensitive regions, making them strategic sites for targeted thermal interventions (Desruelle & Candas, 2000). While cooling may enhance central motor drive and stress regulation via activation of cold-sensitive TRP channels (Gordon et al., 2020; Thapa et al., 2021), heating could worsen fatigue in thermally sensitive PwMS (Christogianni et al., 2018). Furthermore, motor task complexity – ranging from constant to unpredictable force demands – modulates central and peripheral fatigue expression (Kyguolienė et al., 2018; Taylor & Gandevia, 2008). However, the interactive effects of localised head-and-neck cooling or heating with different task complexities under thermoneutral conditions remain poorly understood. The dissertation aimed to address these gaps by investigating how localised thermal modulation influences central and peripheral fatigue, perceived exertion, and hormonal responses during submaximal isometric exercise in men with MS and healthy controls, providing novel insights for rehabilitation and fatigue management strategies.

2. METHODS

The dissertation comprised four randomised crossover studies with a minimum seven-day washout designed to evaluate the effects of localised head-and-neck cooling (18°C) and heating (44 ± 0.5°C) on central and peripheral fatigue during submaximal isometric knee-extensor exercise in men with relapsing-remitting multiple sclerosis (RRMS) and healthy controls. Ethical approval was obtained (BE-2-35), and the trial was registered (NCT06370403). Participants were men aged 18–45 years with RRMS or healthy controls.

Studies I (COLD) and II (HEAT) were designed as separate investigations, each comparing localised head-and-neck cooling (18°C) or heating (44 ± 0.5°C) with a non-thermal control, to assess fatigue, neuromuscular performance, muscle contractility, and stress-related hormonal responses during 100 intermittent submaximal isometric contractions. Study III (COLD + TASKS) investigated how head-and-neck cooling interacts with motor task complexity (constant, predictable, unpredictable) to modulate neuromuscular responses, while Study IV (HEAT + TASKS) evaluated head-and-neck heating across the same task structures.

Neuromuscular function was assessed via isokinetic dynamometry and surface EMG of the vastus lateralis, with outcomes including maximal voluntary contraction (MVC), central activation ratio (CAR), electrically evoked torque, contractile properties, and EMG root mean square (EMGrms). Muscle temperature was recorded intramuscularly, and venous blood samples were analysed for cortisol, prolactin, and dopamine. Perceived exertion was rated using the Borg scale, and motor accuracy was quantified via constant and absolute errors. Data were analysed using repeated-measures and mixed-design ANOVA with Bonferroni corrections, with significance set at $p < 0.05$.

3. RESULTS

Study I (COLD): Head-and-neck cooling improved central activation ratio (CAR) immediately post-exercise ($p = 0.048$) and during recovery ($p = 0.017$) and preserved submaximal torque at 25–50% MVC ($p = 0.038$). However, cooling increased force variability and error ($p = 0.041$). It also attenuated cortisol elevations ($p = 0.029$) and maintained higher dopamine in healthy men ($p = 0.032$). **Study II (HEAT)**: Head-and-neck heating reduced MVC torque more than control ($p < 0.001$) and lowered CAR ($p < 0.04$), particularly in men with MS. Evoked force at 20 Hz (P20) and 100 Hz (P100) declined ($p < 0.04$ and $p < 0.03$), along with slower relaxation rates in MS. Muscle temperature increased under heating ($p < 0.001$), dopamine rose in healthy men ($p < 0.03$), and prolactin increased in healthy men but less so in MS ($p < 0.001$ and $p < 0.04$). **Study III (COLD + TASKS)**: Head-and-neck cooling enhanced MVC under unpredictable tasks ($p = 0.047$) and improved CAR across constant, predictable, and unpredictable tasks ($p = 0.003$–0.019). In contrast, evoked force production (P20, P100) decreased during unpredictable tasks ($p = 0.016$–0.026), indicating greater peripheral fatigue despite improved central drive. Cortisol was also lower post-exercise in predictable tasks ($p = 0.016$), reflecting improved recovery. **Study IV (HEAT + TASKS)**: Head-and-neck heating impaired central drive (reduced CAR) during and after unpredictable tasks and one hour post constant task ($p < 0.05$). MVC remained lower post-exercise under constant and unpredictable tasks ($p < 0.015$). Cortisol was lower at baseline (unpredictable, $p = 0.002$) and after predictable tasks ($p = 0.032$); prolactin increased with exercise ($p < 0.05$), dopamine was unchanged, and torque accuracy declined, particularly at 50% MVC during unpredictable tasks ($p = 0.003$–0.032).

4. CONCLUSIONS

The present investigations demonstrate that local head-and-neck cooling and heating have distinct, task-dependent effects on central and peripheral fatigue in men with MS during submaximal exercise. For instance, Studies I and III showed that head-and-neck cooling (18°C) enhanced central activation, improved CAR and perceived exertion, and increased intramuscular temperature, with the greatest benefits observed during unpredictable tasks. Cooling also amplified peripheral fatigue, reflected by greater reductions in electrically induced torque and contractility, while motor accuracy, EMGrms amplitude, and stress-related blood markers remained largely unaffected. In contrast, Studies II and IV revealed that head-and-neck heating (44°C) impaired central drive, reduced MVC and CAR, and elevated perceived effort, particularly in unpredictable and high-intensity tasks (50% and 75% MVC). Heating attenuated peripheral fatigue by preserving the rate of force development and the rate of muscle relaxation but reduced muscle contractility during unpredictable tasks, lowered cortisol and prolactin levels, and left EMGrms unchanged. Overall, these findings indicate that local thermal modulation can differentially influence exercise performance and fatigability in men with MS, with more pronounced effects than in healthy individuals, and that task type plays a key role in mediating these responses.

Keywords: thermoregulation, motor performance, exercise, task variability, torque

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