J Neurol Neurosci©
16 (01) 2025 : 001-003 • Commentary Article

Thermoregulation in multiple sclerosis: Hypothalamus irregulation, cortisol, yawning, fatigue and the Thompson cortisol hypothesis

Simon B. N. Thompson[1,2]*
[1]Department of Fashion, Winchester School of Art, University of Southampton, Southampton, SO23 8DL, UK
[2]Department of Psychology, University of Paris Nanterre, Nanterre La Défense, 200 Avenue de la République, France

SUMMARY

AUTHORS' CONTRIBUTION: (A) Study Design · **(B)** Data Collection. **(C)** Statistical Analysis · **(D)** Data Interpretation · **(E)** Manuscript Preparation · **(F)** Literature Search · **(G)** Funds Collection

Multiple Sclerosis (MS) is a degenerative disease with symptoms that include irregulation of body temperature, fatigue, depression and often excessive yawning. Fatigue is an ongoing issue for many people with MS and there is little understood about the mechanisms involved in regulating body temperature in MS after activity. Measuring and monitoring fatigue and body temperature has been reported in healthy subjects but no reports to date have considered thermoregulation monitoring using E-textile specialist wearable garments in MS. Discussion of the thermoregulatory mechanism involved in MS is offered together with recommendations for assisting people with MS in temperature control following fatigue and during activity.

Keywords: Cortisol; Diagnosis; E-textiles; Fatigue; Hypothalamus; Multiple sclerosis; Neurology; Thermoregulation; Thompson cortisol hypothesis; Yawning

Address for correspondence:

Professor Dr. Simon B. N. Thompson
Department of Fashion, Winchester School of Art, University of Southampton, Southampton, SO23 8DL, UK
E-mail: nac.brain@hotmail.co.uk, S.B.N.Thompson@soton.ac.uk

Word count: 1088 **Tables:** 00 **Figures:** 00 **References:** 50

Received: 30.01.2025, Manuscript No. ipjnn-25-15525; **Editor assigned:** 01.02.2024, PreQC No. P-15525; **Reviewed:** 15.02.2025, QC No. Q-15525; **Revised:** 20.02.2025, Manuscript No. R-15525; **Published:** 27.02.2025

INTRODUCTION

Multiple Sclerosis (MS) is a chronic debilitating condition that is progressive and affects the fatty tissue sheath surrounding nerves [1]. Incomplete innervation due to loss of the myelin sheath surrounding nerves is considered to be responsible for uncoordinated movements [2]. Fluctuations in brain temperature are often seen in people with MS as well as symptoms of fatigue and especially when carrying out mentally or physically demanding tasks. These are also associated with excessive yawning [3,4]. However, the cause of fatigue and temperature fluctuation in MS is not fully understood.

Thermoregulation, fatigue and yawning

Gallup and Gallup [5] report on two women who suffered from chronic and debilitating episodes of excessive yawning which had not been related to any existing sleeping problems. They exhibited signs of thermoregulatory dysfunction as well as relief through behavioural cooling. Brain temperature fluctuations are also known to exist in people suffering from depression [6,7]. Depression and excessive yawning together with temperature fluctuations is a common symptom of Relapsing-Remitting Multiple Sclerosis [1]. Yawning may be a brain cooling mechanism and has been hypothesized because of evidence showing that nasal breathing and forehead cooling reduced the incidence of contagious yawning [8].

Thermoregulatory dysfunction is common in MS with heat making symptoms worse and cooling providing symptom relief [9]. People with MS very often experience problems with sleep pattern [10]. Gallup, et al. [11] found that their MS patients experienced symptom relief when they were able to nap during the day. Thermoregulation has been found to be linked with fatigue and scientists have revealed involvement of the prefrontal cortex, inferior parietal cortex, anterior cingulate cortex and the thalamus in people with MS [12]. The International Scientific Committee on Research into Multiple Sclerosis (iMSpire) has brought together Anglo-French partnership [13,14] which aims to conduct research that will directly benefit people with MS. Panel members include those with MS as well as scientists, practitioners, representatives of the UK MS Society and the French MS Society, Ligue Française contre la Sclérose En Plaques [15].

Thompson, et al. [16] and his team from iMSpire discovered that cortisol levels were found to be higher during mental *vs.* motor (physical) tasks. Recruitment

of brainstem and hypothalamus regions, important in cortisol activity, was affected differently and is an important finding that demonstrates the association between fatigue and cortisol - the latter being linked with yawning and fatigue in MS [17]. During fatigue in MS, threshold level rises of cortisol appear to trigger yawning which is likely to be part of a complex mechanism for lowering brain temperature [18]. Brain temperature can rise dramatically during fatigue in MS [5]; cortisol may be able to regulate brain temperature because of its importance within the Hypothalamus-Pituitary-Adrenal (HPA)-axis [19], which has been evidenced even in the foetus and in young babies [20].

Secretion of cortisol is controlled by three inter-communicating regions of the brain: hypothalamus, pituitary and adrenal glands. When there are low levels of cortisol in the blood, the hypothalamus releases corticotrophin-releasing hormone causing the pituitary gland to secrete adrenocorticotropic hormone into the bloodstream [1]. High levels of adrenocorticotropic hormone are detected in the adrenal glands which stimulate the secretion of cortisol and cause blood levels of cortisol to rise. As the cortisol levels rise, they start to block the release of corticotrophin-releasing hormone from the hypothalamus and adrenocorticotropic hormone from the pituitary [18]. As a result, the adrenocorticotropic hormone levels start to fall resulting in a fall in cortisol levels. This mechanism is known as a negative feedback loop.

Understanding thermoregulation and fatigue in MS

Thompson [17,21] presented the Thompson Cortisol Hypothesis which is the first evidence-based report linking cortisol with yawning and demonstrates that cortisol rises when we yawn. Produced by the zona fasciculate of the adrenal cortex within the adrenal gland [22], Thompson [19,23-26] suggested that the rise in cortisol level triggers the yawning response in healthy people. During fatigue, either mentally or physically, and in particular in MS, yawning becomes important for regulating cortisol. It is probable that cortisol also affects the hypothalamus temperature regulation within the HPA-axis and may signal brain cooling particularly when elevation in brain temperature is common such as in MS [1].

Future research

At Winchester School of Art, University of Southampton, UK, thermoregulation in people with MS is being investigated with the view to regulating body temperature during activity. Wearable E-textiles that measure and monitor anthropometrics is growing in popularity; particularly for protecting those who work in extreme conditions, e.g., mountain rescuers in cold altitudes [27]; and divers working at depth in cold temperatures [28-30]. To date there have been no reports of E-textiles in the application of thermoregulation in MS despite reports of applications in other demographics, e.g., measuring skin temperature and sweat in healthy cohorts [31,32]. Since fatigue is a known symptom of MS, being able to pace an activity and regulate body temperature would be of potential benefit. A variation in body temperature of only two degrees in healthy people can be tolerated [33] but fluctuations may be greater in MS during activity [3,4,8,23,26] causing fatigue and the abandonment of a task or activity.

RECOMMENDATIONS

Examining temperature fluctuation and fatigue requires careful measurement and monitoring. The use of physiological and neuropsychological tests [34-39] can be of potential benefit at the design stage before the implementation of E-textile garment testing. Questionnaires [40,41], focus groups [42-44] and structured interviews [45] can also be beneficial during testing stages as well quality of life measures [46-50] in order to gain a better understanding of how to regulate temperature during activity in MS and to hopefully prevent or mediate fatigue.

FUNDING

This work was not funded and is the opinion of the author.

ACKNOWLEDGMENT

I am grateful to my experienced practitioner colleagues and friends who work in clinical research for their helpful comments during the preparation of this paper.

REFERENCES

1. **Thompson SBN, Coleman A, Williams N.** Yawning and cortisol levels in multiple sclerosis: Potential new diagnostic tool. *Mult Scler Relat Disord*. 2018; 23:51-55.
2. **Thompson SBN.** Hypothesis to explain yawning, cortisol rise, brain cooling and motor cortex involvement of involuntary arm movement in neurologically impaired patients. *J Neurol Neurosci*. 2017; 8(1):167.
3. **Gallup AC, Gallup Jr GG.** Yawning and thermoregulation. *Physiol Behav*. 2008; 95(1-2):10-16.
4. **Gallup AC, Eldakar OT.** The thermoregulatory theory of yawning: what we know from over 5 years of research. *Front Neurosci*. 2013; 6:188.
5. **Gallup GG, Gallup AC.** Excessive yawning and thermoregulation: Two case histories of chronic, debilitating bouts of yawning. *Sleep and Breathing*. 2010; 14:157-159.
6. **Prasad H.** Drug-induced yawning: A vital protective reflex. *Med Hypotheses*. 2008; 71(3):457-474.
7. **Salerian AJ, Saleri NG, Salerian JA.** Brain temperature may influence mood: A hypothesis. *Med Hypotheses*. 2008; 70(3):497-500.
8. **Gallup AC, Gallup Jr GG.** Yawning as a brain cooling mechanism: nasal breathing and forehead cooling diminish the incidence of contagious yawning. *Evol Psychol*.2007; 5(1):147470490700500109.
9. **Baker DG.** Multiple sclerosis and thermoregulatory dysfunction. *J Appl Physiol*. 2002; 92(5):1779-1780.
10. **Fleming WE, Pollak CP.** Sleep disorders in multiple sclerosis. 2005; 25(1):64-68.
11. **Gallup AC, Gallup Jr GG, Feo C.** Yawning, sleep, and symptom relief in patients with multiple sclerosis. *Sleep Med.* 2010; 11(3):329-330.
12. **Périn B, Godefroy O, Fall S, et al.** Alertness in young healthy subjects: an fMRI study of brain region interactivity enhanced by a warning signal. *Brain Cogn.* 2010; 72(2):271-281.

13. iMSpire – International Multiple Sclerosis Partnership in Research. 2014.
14. https://www.mssociety.org.uk/sites/default/files/MS% 20 Frontiers%20Handbook%202015.pdf
15. LFSEP - French League against Multiple Sclerosis, 2025. LFSEP. Retrieved, 2025.
16. **Thompson SBN, Daly S, Le Blanche A, et al.** fMRI randomized study of mental and motor task performance and cortisol levels to potentiate cortisol as a new diagnostic biomarker. *J Neurol Neurosci*. 2016; 7(2):92.
17. **Thompson SBN.** Born to yawn? Cortisol linked to yawning: A new hypothesis. *Med Hypotheses*. 2011; 77(5):861-862.
18. **Thompson SBN, Richer S.** How yawning and cortisol regulates the attentional network. *J Neurosci Rehabil*. 2015; 2(1):1-9.
19. **Thompson SBN, Rose K, Richer S.** Yawning with cortisol: Examining the neuroscience behind the Thompson Cortisol Hypothesis for supporting rehabilitation of neurologically impaired individuals. *J Neurosci Rehabil*. 2014; 1(1):1-1.
20. **Giganti F, Hayes MJ, Cioni G, et al.** Yawning frequency and distribution in preterm and near term infants assessed throughout 24-h recordings. *Infant Behav Dev*. 2007; 30(4):641-647.
21. **Thompson SBN.** The dawn of the yawn: Is yawning a warning? Linking neurological disorders. *Med Hypotheses*. 2010; 75(6):630-633.
22. **Schillings WJ.** Physiology and tests of adrenal cortisol function. *Glob Lib Wom Med*. 2008.
23. **Thompson SBN.** Yawning, fatigue, and cortisol: Expanding the Thompson cortisol hypothesis. *Med Hypotheses*. 2014; 83(4):494-496.
24. **Thompson SBN, Frankham C, Bishop P.** The art of capturing a yawn using the science of nerve impulses and cortisol levels in a randomized controlled trial. Thompson Cortisol Hypothesis as a potential predictor of neurological impairment. *Int J Arts Sci.* 2014; 7(3):529-543.
25. **Thompson SBN.** Pathways to yawning: making sense of the Thompson cortisol hypothesis. *Med Res Arch*. 2015 (3).
26. **Thompson SBN, Simonsen M.** Yawning as a new potential diagnostic marker for neurological diseases. *J Neurol& Neurosci*. 2015; 6(3).
27. **Krzemińska S, Greszta A, Bartkowiak G, et al.** Evaluation of heating inserts in active protective clothing for mountain rescuers—Preliminary tests. *App Sci*. 2023; 13(8):4879.
28. **Sullivan-Kwantes W, Tikuisis P**. Extremity cooling during an arctic diving training exercise. *Int J Circumpolar Health*. 2023; 82(1):2190488.
29. **Lee JY, Park J, Kim S.** Cold adaptation, aging, and Korean women divers haenyeo. *J Physiol Anthropol*. 2017; 36:1-3.
30. **Bradbury KE, DiMarco KG, Futral JE, et al.** The maintenance of core temperature in SCUBA divers: Contributions of anthropometrics, patent foramen ovale, and non-shivering thermogenesis. *J Sci Med Sport.* 2024; 27(12):820-827.
31. **Jiang Y, Pan K, Leng T, et al.** Smart textile integrated wireless powered near field communication body temperature and sweat sensing system. IEEE *J Electromagn RF Microw Med Biol.* 2019; 4(3):164-170.
32. **Zhao C, Li X, Wu Q, et al.** A thread-based wearable sweat nanobiosensor. *Biosens Bioelectron*. 2021; 188:113270.
33. **Millar I.L.** Cold and the diver: Physiology and first aid of hypothermia. *South Pacific Underwater Medicine Society Journal.* 1990: 33-39.
34. **Zigmond AS, Snaith RP.** The hospital anxiety and depression scale. *Acta Psychiatr Scand.* 1983; 67(6):361-370.
35. **Nelson HE, Willison J.** National Adult Reading Test *(NART)*. *Windsor: Nfer-Nelson*, 1991.
36. **Pezzuti L, Barbaranelli C, Orsini A.** Structure of the Wechsler Adult Intelligence Scale–Revised in the Italian normal standardisation sample. *J Cogn Psychol*. 2012; 24(2):229-241.
37. **Engelhart CI, Eisenstein N, Johnson V, et al.** Comparison of linear equating and prorated short forms for estimating WAIS-R FSIQ in a neuropsychological population. *Clin Neuropsychol*. 1999; 13(1):95-99.
38. **Hilsabeck RC, Thompson MD, Irby JW, et al.** Partial cross-validation of the Wechsler Memory Scale—Revised (WMS-R) General Memory—Attention/Concentration malingering index in a nonlitigating sample. *Arch Clin Neuropsychol*. 2003; 18(1):71-79.
39. **Tombaugh TN.** Trail Making Test A and B: Normative data stratified by age and education. *Arch Clin Neuropsychol*. 2004; 19(2):203-14.
40. **Giordano A, Messmer Uccelli M, Pucci E, et al.** The Multiple Sclerosis Knowledge Questionnaire: a self-administered instrument for recently diagnosed patients. *Mult Scler J*. 2010; 16(1):100-111.
41. **Kahraman T, Özdoğar AT, Honan CA, et al.** The multiple sclerosis work difficulties questionnaire: Translation and cross-cultural adaptation to Turkish and assessment of validity and reliability. *Disabil Rehabil*. 2019; 41(21):2556-2562.
42. **Sgoifo A, Bignamini A, Celani M, et al.** Focus group in Multiple sclerosis as a tool to increase active patient involvement. A preliminary experience. *Trials*. 2015; 16:1-2.
43. **Courts NF, Buchanan EM, Werstlein PO.** Focus groups: the lived experience of participants with multiple sclerosis. *J Neurosci Nurs*. 2004; 36(1):42-47.
44. **Jones A, Morgan-Jones P, Busse M, et al.** Conducting focus groups in neurodegenerative disease populations: ethical and methodological considerations. *BMJ open.* 2021; 11(1):e041869.
45. **Fragkoudi A, Rumbold AR, Burke T, et al.** A qualitative study of multiple sclerosis specialists' experiences and perspectives in managing family planning in people with multiple sclerosis. *Mult Scler Relat Disord*. 2024; 82:105409.
46. **Baumstarck K, Boyer L, Boucekine M, et al.** Measuring the quality of life in patients with multiple sclerosis in clinical practice: a necessary challenge. *Mult Scler Int*. 2013; 2013(1):524894.
47. **Gil-González I, Martín-Rodríguez A, Conrad R, et al.** Quality of life in adults with multiple sclerosis: A systematic review. BMJ open. 2020; 10(11):e041249.
48. **Faraclas E, Lynn J, Lau JD, et al.** Health-related quality of life in people with multiple sclerosis: how does this population compare to population-based norms in different health domains? JPRO. 2022; 6(1):12.
49. **Bergmann C, Becker S, Watts A, et al.** Multiple sclerosis and quality of life: The role of cognitive impairment on quality of life in people with multiple sclerosis. Multiple sclerosis and related disorders. 2023; 79:104966.
50. **Kołtuniuk A, Pawlak B, Krówczyńska D, et al.** The quality of life in patients with multiple sclerosis–association with depressive