Review

Yawning and thermoregulation

Andrew C. Gallup,⁎ Gordon G. Gallup Jr.

⁎ Corresponding author. Tel.: +1 518 727 2473.
E-mail address: a.c.gallup@gmail.com (A.C. Gallup).

ABSTRACT

We review a growing body of medical and physiological evidence indicating that yawning may be a thermoregulatory mechanism, providing compensatory cooling when other provisions fail to operate favorably. Conditions such as multiple sclerosis, migraine headaches, epilepsy, stress and anxiety, and schizophrenia have all been linked to thermoregulatory dysfunction and are often associated with instances of atypical yawning. Excessive yawning appears to be symptomatic of conditions that increase brain and/or core temperature, such as central nervous system damage, sleep deprivation and specific serotonin reuptake inhibitors. Yawning is also associated with drowsiness, and subjective ratings of sleepiness are correlated with increases in body temperature. This view of yawning has widespread application for the basic physiological understanding of thermoregulation as well as for the improved diagnosis and treatment of diseases associated with abnormal thermoregulation.

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1. Introduction

Yawning is characterized by a large gaping of the mouth and eye closure, accompanied by a deep inhalation of air, and shorter expiration [1]. A yawn can occur without gaping [2,3], but gaping of the mouth during the peak of a yawn is essential for increases in facial blood flow that in turn alter cerebral blood flow as a result [4]. This may be why participants who are asked to clench their teeth while yawning report the yawns as abnormal and less satisfying [3].

Yawning is widespread and has been observed among most classes of vertebrates [5]. In humans, yawning occurs before birth and as early as 20 weeks after conception [6]. In a recent study investigating the frequency of yawning in preterm infants, researchers found a marked
decrease in daily yawns between 31 and 40 weeks of age [7], and attribute this to the development of circadian and homeostatic control of sleep and waking. After birth and development, yawning occurs throughout life in a consistent fashion for most adults. It is well documented that yawning often occurs during the first hour after waking and the last hour before sleeping [7–9].

Among humans there is no evidence for sex differences in the incidence of yawning. In some primates, however, males are more prone to show threat yawns that display their enlarged canine teeth [10,11]. These yawns may functionally differ from normal yawns, and can be distinguished from such because the eyes do not close. During a threat yaw, the individual keeps their eyes open during the peak of the yaw in order to monitor the effect of the threat on the target.

Yawning has long been thought to be a sign of boredom and is commonly interpreted as disrespectful when done in the presence of others. Yawning is also contagious. Seeing, hearing, reading, or even thinking about yawning can trigger yawns, and attempts to shield a yaw do not prevent its contagion [12]. Under laboratory conditions, 10 to 50% of college students yawn in response to seeing videotapes of people yawning [2,3,13]. But people are less likely to yawn when they suspect they are being observed by scientists [14]. Individual differences in susceptibility to contagious yawning have been shown to be related to differences in empathic ability and self-processing [13]. Witnessing people yawning has also been shown to activate parts of the brain associated with self-processing [15].

Yawning can occur as a consequence of a variety of interactions among neurotransmitters and neuropeptides in the brain [16], including dopamine, excitatory amino acids, acetylcholine, serotonin, nitric acid, adrenocorticotropic hormone-related peptides and oxytocin. In contrast, yawning is inhibited by opioid peptides [16]. While the neurochemical mechanisms underlying yawning are not completely understood, the ability to induce yawning using drugs under laboratory conditions has proven to be a valuable research tool. Changes in yawning can be an important factor in our understanding of the physiopathology of certain diseases and action of new drugs, particularly those that have dopamine involvement [17].

Attempts to identify the adaptive/functional/biological significance of yawning (reviewed by Smith, 1999) have lead to little consensus [12,18]. Theories about yawning range from increasing alertness [8,14], an expression of boredom, unconcern, or indifference [14,19], to aiding in the removal of potentially infectious substances from the tonsils [20]. Yawning has also been thought to be an indicator of hemorrhage [21], motion sickness [22], and encephalitis [23]. A commonly held view is that yawning functions to equilibrate CO2 and/or O2 levels in the blood [24]. A spin off of this theory is that yawning functions to correct imbalances in cerebral oxidative metabolism [25]. Contrary to public opinion, however, having subjects breathe increased levels of oxygen or carbon dioxide leaves yawning unaffected [26]. But despite this evidence some researchers continue to look at yawning as a response to localized hypoxia in the brain [27]. Olivier Walusinski maintains an open-access, growing collection of selected current as well as historical research on yawning [28].

2. Yawning as a brain cooling mechanism

The brain is a metabolically expensive organ second only to the gut, responsible for about 16% of our total energy consumption [29]. Brain temperature in humans is determined by a number of variables, including the temperature of arterial blood going to the brain, rate of blood flow, and rate of metabolic heat production [30]. There are specific chemical and thermoregulatory mechanisms that operate to maintain optimal brain temperature [31,32].

Based on fossil evidence of brain expansion in humans over the past several million years, it has recently been determined that as much 52% of the variance in cranial capacity can be accounted for by global cooling [33]. Consistent with this finding, Falk (1990) has championed the view that brains can only grow as large as they can be effectively cooled; known as the radiator hypothesis [31]. The radiator theory posits that emissary veins grew in tandem to support the cooling needs of larger brains during human evolution. In other words, as brains evolved and grew larger, there had to be corollary adaptations that increased venous cooling.

We recently advanced the hypothesis that yawning may function as an evolved brain cooling mechanism [2]. The physiological consequences of yawning are analogous to those needed to effectively cool the brain, such as increases in peripheral and cerebral blood flow [4,34–36]. In addition, there is growing evidence that yawning occurs before, after, and during instances of abnormal thermoregulation, heat stress, and hyperthermia.

According to this hypothesis yawning serves as a compensatory cooling mechanism that functions to maintain optimal levels of mental efficiency. There are two forms of selective brain cooling (SBC) that operate in humans: precooling of arterial blood destined to the brain, with cool venous blood returning from the nose and forehead, and the use of venous blood to cool the brain directly [37]. Specifically, SBC involves a reduction in brain temperature below that of arterial blood from the trunk. In order to test the hypothesis that yawning may be a SBC mechanism, we manipulated nasal breathing and forehead temperature in participants watching videotapes of people yawning. Nasal breathing operates by precooling arterial blood destined to the brain with cooler venous blood that drains from the extracranial evaporative surfaces [38], while direct cooling of the forehead and facial emissary veins simulates a combination of both cooling mechanisms [39].

Results showed that nasal breathing and forehead cooling virtually eradicated contagious yawning in college students [2]. Although previous research has reported the apparent impossibility of “noesy yawns” [9,26], participants in this study were not instructed to close their mouths or keep their mouths closed and were therefore free to yawn at any time.

There is considerable evidence that nasal breathing and forehead cooling are specific brain cooling mechanisms [38–41]. The vertebral venous plexus, located in the brainstem, is cooled by the vertebral artery as a result of nasal breathing [38]. Nasal breathing has also been shown to cool other parts of the brain including the frontal cortex [40]. Nasal mucosal blood flow decreases in response to skin cooling, increases in response to skin warming, and rises in response to increases in core temperature [42]. Cooling the forehead has been shown to cool blood in the emissary, diploic, ophthalamic, and facial veins which is transferred via the dural venous sinuses to the dura mater [39].

If yawning serves as a compensatory cooling mechanism, one would expect yawning to be related to ambient temperature. As ambient temperature rises it becomes increasingly more difficult to maintain optimal thermal homeostasis, and therefore one would expect yawning to occur more frequently. This prediction was tested recently in parakeets (Melopsittacus undulatus) [43] which were chosen due to their large relative brain size [44]. As ambient temperature increased there was a significant increase in the incidence of yawning. In addition, yawning became progressively more frequent as ambient temperature rose to within 5 °C of parakeet body temperature, indicating a breech in thermal homeostasis occurring at or near this point [43].

2.1. The brain cooling hypothesis

Body temperature is a balance between heat production and heat dissipation. By lowering brain temperature slightly under conditions of thermal stress to maintain thermal homeostasis, our model predicts that mental efficiency and vigilance should be raised as a result. Yawning increases blood flow and acts like a radiator by removing hyperthermic blood from specific areas while at the same time introducing cooler blood from the lungs and extremities.

During exercise-induced heat stress (hyperthermia), blood flow is increased from the surface of the head into the cranial cavity [45]. Yawning causes an increase in both blood pressure [34] and heart rate [36,46], and the constriction and relaxation of facial muscles during a
yawn also increase facial blood flow which in turn may alter cerebral blood flow [4]. The increase in facial blood flow due to yawning aids in the dissipation of heat through emissary veins. In addition, increases in arousal as measured by skin conductance occur during yawning [35], and this may promote further cooling through vasodilation. Similar physiological adjustments occur during powerful stretching, and yawning is often accompanied by stretching [9]. The garbage of the mouth and deep inhalation of cool air taken into the lungs during a yawn can also alter the temperature of the blood going from the lungs to the brain through convection. Tearing of the eyes that some people experience at the peak of a yawn may likewise play a role in dissipating heat from the skull. Not only does nasal breathing and forehead cooling block yawning, we have noticed that a deep nasal inhalation can extinguish a pending need to yawn.

2.2. Further predictions of the model

According to the brain cooling hypothesis there ought to be as yet unidentified mechanisms that serve to constrain yawning to a relatively narrow range of ambient temperatures, or what can be referred to as a thermal window [2]. The model predicts that yawning should increase in frequency as ambient temperature approaches body temperature [2,43], but should not occur when ambient temperatures reach or exceed body temperature (37 °C in humans) because that would serve to send warm rather than cool blood to the brain. Likewise when temperatures fall below a certain point, perhaps −10 °C, yawning would cease to be adaptive because sending a wave of unusually cool blood to the brain could cause a thermal shock.

Another counterintuitive but testable implication of the model is that yawning should diminish during fever. An elevation of body temperature can occur either due to thermoregulatory failure (hyperthermia), or from intact homeostatic responses such as fever [47]. It is well-established that fever is an adaptive host defense mechanism and an essential defensive response to infection by pathogens [48]. Consistent with this notion Mariak et al. (1998) found that brain temperature during fever is not selectively suppressed by any specific thermolytic mechanisms [49], and research has shown that attempts to treat fever can have harmful effects on critically ill patients, leading to an increase in mortality [50,51]. Therefore, the mechanisms that trigger an increase in the thermoregulatory set point (fever) in the hypothalamus may, as a testable implication of our model, override or turn off normal operating thermal mechanisms such as yawning (also in the hypothalamus) to fight the infection. An alternative possibility is that fever stimulates an increase in ambient temperature and reduces the likelihood of yawning for the reasons mentioned previously.

3. Yawning and abnormal thermoregulation

3.1. Multiple sclerosis

Multiple sclerosis (MS), an inflammatory, demyelinating disease of the central nervous system has been linked to thermoregulatory dysfunction [52–54]. An underlying mechanism involved in the enhanced sensitivity to changes in temperature among MS patients is the direct influence on both the sodium channels and current necessary for polarization of the axon [55]. Increases in temperature diminish the depolarizing current, while decreases in temperature (cooling) have the opposite effect. An additional symptom of MS is sweat gland function impairment [56]. Blood from the face and forehead is cooled by the evaporation of sweat from the surface of the skin [39,40,45]. Therefore, impaired sweat gland function has detrimental effects on the ability to dissipate heat, and this has proven to be fatal for some MS patients who develop severe hyperthermia during hot baths [57].

Consistent with the view that yawning is involved in thermoregulation, excessive yawning is a common symptom of MS [58], and some MS patients experience temporary relief of symptoms following a yawn. Changes in temperature can have significant effects on the severity of MS symptoms; daytime heating from the sun’s radiation can worsen the symptoms, while a cold shower can relieve the symptoms [55,59]. Head and neck cooling have proven particularly effective for alleviating MS symptoms [60]. Just as applying cold packs to the forehead blocks yawning, cooling of similar parts of the body relieves MS symptoms.

3.2. Epilepsy

Epilepsy is a seizure disorder caused by abnormal electrical discharges from neurons in the cerebral cortex. Frequent and repetitive yawning is associated with some forms of epilepsy [17,61–63], and the feeling or act of yawning may also be a part of the epileptic seizures themselves. Recent data show that some epileptic patients notice yawning before and after seizures [63]. In addition, 50% of these patients reported that yawning made them feel at least “slightly better” [63]. Yawning has also been described as a possible aura of epileptic seizure [64], and has even been observed during infantile spasms [65].

Epilepsy has been linked to thermoregulation, and exposure to hot water or increased temperature can aggravate epileptic symptoms [66–68]. Hot water epilepsy is a form of reflex epilepsy, where a seizure is precipitated by an external sensory stimulus [69]. In this form of epilepsy, immersion in hot water (often due to bathing) can promote seizures [67]. A substantial number of patients find these seizures pleasurable and a significant proportion attempt to trigger these heat-induced seizures themselves [69]. In a parallel fashion normal individuals often feel a sense of pleasure/gratification during a yawn [3], and this has been attributed to the effect that yawning has on dopaminergic activity in the central regions of the brain [17]. Further research could investigate the possible connection between seizure activity and dopamine release.

Circadian thermoregulation is disrupted in limbic epileptic rats and correlates to regional hypothalamic neuronal loss [70], with the highest seizure frequency occurring after the circadian temperature peak. An infrared study investigating facial temperature has shown that mesial temporal lobe seizures may activate (or be activated by) thermoregulatory mechanisms in humans [71], and temperature regulation has been documented in focal epilepsy as well [72]. This is consistent with reports of yawning and/or the feeling of a need to yawn during epileptic seizures [63–65].

3.3. Headaches

A migraine prodrome is a constellation of symptoms occurring before a migraine headache. Yawning is a common precursor to a migraine headache [73,74], and can enable the individual to anticipate and predict the attack, and excessive yawning has been reported as a migraine premonitory symptom [73]. In a study that investigated the signs and symptoms before, during, and after migraines over a 3 month period, yawning was one of the best predictors of the onset of headache [75]. Blau (1991) also reports that yawns are common after an attack [76].

Headaches, including migraines and cluster headaches have been consistently linked to direct or indirect increases in brain and/or core temperature [77–79]. Kelman (2007) studied over 1200 migraine patient evaluations for possible triggers to the onset of an acute migraine [78]. Over 75% of the patients reported being conscious of specific triggers to an attack. Of the triggers, stress was listed most frequently (nearly 80%), while sleep disturbance (50%), heat (30%), and exercise (22%) were also mentioned; all of which can have a significant impact on core and brain temperature. Consistent with this interpretation, Gomershall and Stuart (1973) found that migraine headaches significantly increase on days when there are 2 or more hours of sunshine [80].

During cluster headaches it has been reported that there is an increase in medial forehead sweating [81]. Peres et al. (2000) also describes how increased body heat might precipitate cluster headache
attacks by the alteration of melatonin concentrations [79]. In one study, exercise, a hot bath, or elevated environmental temperature provoked cluster headaches within an hour in 75 out of 200 patients [77]. Further evidence shows that heat exhaustion is often accompanied by dizziness and headache [82,83]. Elevated indoor air temperature can also increase headache intensity [84]. Specific cases have been reported where hot baths or even pouring hot water over one’s head can lead to headaches [85,86].

3.4. Stress and anxiety

As an extension of the brain cooling hypothesis, it seems reasonable to suppose that propensity to yawn should increase while people are engaged in difficult mental tasks [2]. At the metabolic level, heightened mental activity would be expected to promote an increase in brain temperature and eventually trigger compensatory yawning. Recent research shows that decreases in hippocampal glucose are associated with cognitively demanding tasks in rats [87]. Glucose metabolism due to mental processes supports the argument that increases in cognitive load would be expected to increase localized brain temperature. Conditions that promote stress and anxiety may work in a similar fashion.

Being under stress has been shown to be conducive of yawning in humans [88]. In rats, yawning and grooming often occur during mild stressors such as shocks [89]. Interestingly, animals respond differently to constant vs. intermittent stressors [90], with intermittent stressors (foot shock and swimming) increasing the frequency of yawning while constant stressors decreased yawning. Yawning has also been shown to be a common symptom of a variety of stressors and measures of anxiety in primates. Displacement activities (including yawning) tend to occur in non-human primates during psychosocial stress [91]. To list a few, yawning has been used as an indicator of anxiety in chimpanzees [92] and olive baboons [93]. Castle et al. (1999) report that yawning increased by 40% in female olive baboons when the nearest animal was a dominant individual opposed to a subordinate [93].

Stress raises core body temperature and can lead to stress-induced hyperthermia [94], and direct evidence of stress-induced hyperthermia has been widely observed in mice [95–97]. The fact that stress has been shown to produce both increases in core body temperature and increases in yawning frequency is consistent with the idea that yawning may be a thermoregulatory mechanism.

3.5. Schizophrenia

Clinical observations reveal that schizophrenics yawn less [25]. In addition, schizotypal personality traits, as a measure of premorbid schizophrenic tendencies have also been shown to diminish the propensity to show contagious yawning among college students [13,15].

Abnormal thermoregulation is common among individuals suffering from schizophrenia [98–100]. Dysregulation of body temperature among schizophrenics includes different baseline temperatures, abnormal daily range in temperature, diurnal variation with an earlier peak, impaired ability to adapt to heat stress, and the ability to compensate more effectively to cold stress. It is well-established that schizophrenics have a significantly lower metabolism and are at a higher risk for metabolic syndrome [101]. Consistent with the brain cooling hypothesis, Lehmann (1979) argues that the reduced incidence of yawning in schizophrenics may be a result of reductions in brain metabolism (and by implication brain temperature) [25].

3.6. Serotonin

Selective Serotonin Reuptake Inhibitors (SSRIs) are one of three main groups of antidepressants, commonly used in the treatment of depression and anxiety. SSRIs are designed to allow serotonin in the brain to be utilized more efficiently. Inhibition of serotonin reuptake by the presynaptic neuron is thought to increase the level of available serotonin that can bind to postsynaptic receptors. A common and well documented side-effect of SSRI therapy is excessive yawning [102,103]. The use of paroxetine, another SSRI, has also recently been shown to produce excessive yawning [104,105].

Serotonin is a vasoactive compound that regulates skin blood flow, which is a major mechanism in thermoregulation [106]. Increases in serotonin have been linked to increases in brain and core temperatures [107,108], and there is also evidence that increases in serotonin inhibit the ability to effectively deal with heat stress [109]. During exercise, individuals using SSRIs exhibit higher body temperatures than those taking placebos. Night sweats have also been reported by women taking SSRIs for treatment of depression [110]. The evidence suggests that excessive yawning in patients taking SSRIs may be a consequence of increases in brain and core temperature produced by these drugs.

3.7. Opioids

Opioid receptor agonists (kappa receptors) produce a hypothermic response in rats [111], and consistent with the possibility that yawning may be a thermoregulatory mechanism, opioid peptides inhibit yawning [16]. Also consistent with this proposition, naloxone, an opiate antagonist used to counter the effects of opioid overdose, has been shown to produce excessive yawning [112]. Further study could investigate the incidence of yawning in response to a variety of different drug treatments as means of screening drugs for possible abnormal thermoregulatory side effects.

3.8. Head trauma/stroke

Excessive yawning has also been implicated as a symptom in patients with various head injuries, such as brain stem ischaemia [113], and cardiac conditions, such as cardiac tamponade [114]. Hyperthermia is a common consequence of central nervous system injury [115], and brain temperature often exceeds systemic temperature in brain-injured patients [116–118]. Furthermore, it has been found that postoperative hyperthermia after cardiac surgery can produce cognitive dysfunction [119–121]. These problems have recently led to closer monitoring and attempts to control brain temperature in surgical patients with head trauma/stroke [115,118,122,123].

3.9. Hypothalamus

Among its many functions, the hypothalamus operates to regulate body temperature. Core temperature is maintained by a variety of thermoregulatory responses, all of which are largely controlled by the hypothalamus [124–126]. Research based on tissue slices has pinpointed the circuits within the hypothalamus serving thermoregulation [127]. Consistent with the idea that yawning is a thermoregulatory mechanism, yawning is also strongly influenced by the hypothalamus. Yawning is under the control of many neurotransmitter and neuropeptides, and the interaction of these substances in the paraventricular nucleus (PVN) of the hypothalamus has been shown to affect yawning [16]. For instance, injecting neuropeptide orexin-A into the PVN elicits a cortical arousal response followed by yawning in rats [128]. Consistent with our hypothesis, orexin-A has also been shown to induce hyperthermic reactions in rats, increasing colonic [129] and abdominal temperatures [130].

3.10. Sleep

Yawning is commonly associated with being tired or sleepy. Contrary to popular belief, however, yawning is not correlated with sleep duration [131]. Also, yawning does not occur during sleep [132], which is consistent with the idea that the need for optimal mental processing diminishes while asleep. Frequent instances of yawning tend to occur shortly after awakening as well as before going to sleep [8,9,131].
Thermoregulation and sleep are interrelated [133–136]. Research shows that the interaction between thermoregulation and sleep occurs at the level of the preoptic-hypothalamic thermostat [136]. The onset of sleep initiates a decline in the core body temperature curve [137,138]. This reduction in core temperature may be due to a relaxed state that leads to a significant decrease in cutaneous sympathetic nervous system activity, which in turn facilitates enhanced peripheral blood flow [139–141].

It has been argued that temperature changes before and after sleep act in a positive feedback loop, and core body temperature and sleep vary inversely [133]. Consistent with this interpretation, Kumar (2004) presents evidence that the circadian modulation of body temperature alters sleep propensity [135]. Increases in the tendency to wake-up occur in tandem with increases in core body temperature in the morning [142]. Yawning in early morning may therefore be a compensatory thermal stabilizing mechanism. Waking also disrupts a relaxed state, and rapid increases in locomotor activity, as well as in conscious brain activity and the ensuing metabolic increases in temperature may trigger yawning.

Prolonged sleep deprivation in rats has been shown to increase deep brain temperature [143]. Subjective ratings of sleepiness in humans correlate with increases in skin temperature while lying down [144] and with increases in core body temperature when standing. In addition, hot water consumption has been shown to increase body temperature as well as sleepiness [145]. Thus, it appears that variation in body temperature is associated with corresponding variation in sleepiness. Consistent with the idea that yawning is triggered by an increased brain metabolic load it is common for the onset of a yawning to prompt people to comment on how tired they feel.

4. Discussion

Evidence from diverse sources is consistent with the idea that yawning may be a thermoregulatory mechanism (see Table 1). Multiple sclerosis, epilepsy, schizophrenia, treatment for opiate withdrawal, sleep deprivation, migraine headaches, stress and anxiety, central nervous system damage, and serotonin have all been linked to temperature regulation/dysfunction, and each of these conditions have been shown to affect yawning. Likewise, drugs that increase brain temperature (e.g., certain serotonin reuptake inhibitors) frequently produce excessive yawning, while drugs that lead to hypothermia (e.g., opioids) inhibit yawning. Being tired and/or bored is commonly associated with yawning, but according to the brain cooling hypothesis yawning functions to antagonize rather than promote sleep [2]. We believe that much like the experience of feeling tired, boredom may also be a byproduct of an increase in brain and/or core body temperature.

Among any number of testable predictions that follow from this hypothesis is that when attention and cognitive processing begin to fade, as a result of rising brain temperature due to an increased metabolic load, yawning would be expected to increase mental efficiency and vigilance by reinstating optimal brain temperature. Contrary to this idea, a recent study has shown that electroencephalographic changes (EEG) indicate no arousing effect after yawning [46]. However, it is possible that yawning increases mental efficiency and vigilance in ways that cannot be accurately detected by EEG. Hoagland (1936, 1938, 1949) found that increasing body temperature resulted in faster alpha rhythms [146–148], and in accord with yawning involvement in thermoregulation, Guggisberg et al. (2007) report a significant slowing in alpha rhythms after yawning [46]. Furthermore, Guggisberg et al. (2007) found an increase in heart rate variability after the onset of yawning [46], which is also consistent with the dissipation of heat from the emissary veins as a result of increases in blood flow and heart rate.

The present review outlines a novel approach and interpretation of the functional significance of yawning. The value of this research extends beyond the study of yawning per se, as theoretical and empirical findings appear to have direct implications to many facets of human physiology and behavior. The integration of diverse fields and disciplines including medicine, disease, and abnormal thermoregulation is consistent with this new view of yawning.

While studies suggest that temperature regulation is controlled by a hierarchy of neural structures, recent evidence indicates that the mechanism that triggers yawning may lie within this foundation. The research presented here suggests the existence of an important connection between yawning and thermoregulation, which has heretofore been overlooked or ignored by modern and traditional theorists. Further research is essential however, before we can completely understand this relationship. But the applications of this research are nonetheless intriguing; ranging from basic physiological understanding, to improved treatment and understanding of diseases such as multiple sclerosis and epilepsy, to using symptoms of excessive yawning as a diagnostic tool for identifying instances of thermoregulatory dysfunction.

References


Table 1

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Yawning enhancement</th>
<th>Yawning suppression</th>
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<th>Temperature decrease</th>
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<td>Schizophrenia</td>
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Yawning is enhanced during conditions of abnormal thermoregulation and hyperthermia. Yawning is suppressed during instances of brain and/or core body cooling, and during situations where yawning would be counterproductive (i.e. extreme ambient temperatures and fever). In schizophrenics the diminished incidence of yawning is attributed to reduced brain metabolism.

* Predicted.


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