Meditation as a Voluntary Hypometabolic State of Biological Estivation

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Abstract

Meditation, a wakeful hypometabolic state of parasympathetic dominance, is compared with other hypometabolic conditions, such as sleep, hypnosis, and the torpor of hibernation. We conclude that there are many analogies between the physiology of long-term meditators and hibernators across the phylogenetic scale. These analogies further reinforce the idea that plasticity of consciousness remains a key factor in successful biological adaptation.

Introduction

Meditation, characterized physiologically as a wakeful hypometabolic state of parasympathetic dominance, is traditionally presented as an altered state of consciousness derived from Asian cultures and is usually associated with the attainment of higher spiritual states. The present review, however, attempts to set aside the various religious explanations of this phenomenon and to recast the physiology of meditation by considering it in the context of biological evolution as an adaptive response in humans that has analogies to lower organisms across the phylogenetic scale. To do this, we propose to look at the induction of a hypometabolic state, a selected aspect of specific types of meditative practice for which empirical evidence has been adduced.

Hypometabolism serves a variety of functions in the survival of organic life throughout the plant and animal kingdoms (5). We plant perennials in our garden that reemerge each year from a state of inactivation. The shutdown of photosynthesis in trees, shrubs, and grass during the winter months represents a state of arrested metabolism. Viruses and bacteria will often lay dormant until the conditions are right for mass reproduction. Various types of rodents, reptiles, and mammals hibernate during the winter, just as frogs and snails will exhibit estivation, a periodic slowing down of metabolism during the summer months, especially as a way to survive particularly hot desert climates.

The range of adaptation is also variable. Some reptiles can exist in a state of complete oxygen deprivation; others can survive only on drastically reduced oxygen reserves. In fact, true hibernation is seen only in small animals, whereas larger animals are often active and alert during the entire period of hibernation, but they still remain in a hypometabolic state that is adapted to scarcity of food and other resources. Large bears, for example, will hibernate in the winter and awaken frequently, at which time the females will bear and care for the young while still remaining in a state of reduced metabolism. The body temperature drops but not to the level of the surrounding environment. This suggests that, especially for larger animals, hypometabolism during hibernation is more like estivation or what has also been called a state of torpor (4).

The hypometabolic response can also be seen in fish as well as in birds that engage in deep diving. In what is called the diving reflex, there is, among other changes, a dramatic drop in heart rate to conserve energy during both descent and ascent from the depths. Indeed, humans who have learned to do deep diving with mammals such as the porpoise or the whale have successfully adapted the techniques of these aquatic forms to the level of ability of humans and have subsequently been able to perform spectacularly deep dives beyond what *Homo sapiens* had previously been able to accomplish.

In humans, hypometabolism is a naturally occurring phenomenon of sleep; it appears in conditions of starvation and during hypnosis. The metabolic level can now be manipulated to the advantage of the species; drastically lowering temperature can preserve embryos and sperm for later fertilization and preserve transplant organs for transport between donor and recipient. Likewise, one of the newest emergency interventions for severe head trauma is lowering body temperature to reduce metabolism.

Meditation, however, represents a special case of the hypometabolic response. Subjects who are asked to sit quietly in an environment of reduced illumination while attending exclusively to their breathing cycles begin to show immediate changes in their physiology similar to other hypometabolic conditions (6). The most characteristic elements include decreased oxygen consumption and carbon dioxide elimination and decreased respiratory rate and minute ventilation with no change in respiratory quotient. But the most significant difference is that the body appears to move into a state analogous to many, but not all, aspects of deep sleep, while consciousness remains responsive and alert.

Physiological evidence shows that sleep and meditation are not the same, however. Electroencephalographic (EEG) recordings are quite different in the waking state, in sleep, and in meditation. Analytic problem solving, for instance, occurs in the normal waking state at 13–26 Hz (beta waves). Deep sleep is characterized by EEG recordings in the 1- to 4-Hz range (delta waves). Lighter stages of sleep are accompanied by intermittent periods of electrical activity in the range of 8–12 Hz (alpha waves) and 4–8 Hz (theta waves). Theta-wave activity is also the level of rapid eye movements, or REM sleep, which is associated with dreaming. Studies with meditators, however, show increased intensity of slow alpha activity (8–12 Hz) in central and frontal regions, occasionally interspersed with high frontal voltage theta activity. Beta and delta waves are either decreased or remain constant during meditation. Studies also show widespread alpha EEG coherence across the cortex in meditation. These data suggest that alpha-theta activity is predominant in meditation, whereas delta activity predominates in deep sleep. Although theta-wave activity is indicative of dreaming, alpha, the predominate wave form in meditation, is most closely associated with a state of wakeful alertness. In wakeful alertness, one's state of consciousness is characterized as empty of any particular content but nevertheless active and alert above the threshold of awareness.

Furthermore, when practiced once or twice a day for just 20–30 min at a sitting, the simplest techniques appear to have persistent and measurable effects on metabolism that are exactly opposite from the fight-flight reflex. In the case of the fight-flight reflex, catecholamine levels increase dramatically, large amounts of glucose become available for quick energy mobilization, respiration rate increases, blood is shunted away from the viscera to oxygenate skeletal muscle, and the organism goes into a state of heightened vigilance.

In the hypometabolic state induced by meditation, catecholamine levels drop, galvanic skin resistance markedly increases, increased cerebral profusion is present, respiration rate and minute volume decrease significantly without significant change in arterial P_{O_2} and P_{CO_2}; there is also decreased vascular resistance, lowered oxygen and CO_2 consumption, and a marked decline in blood lactate. The organism remains awake and vigilant, but the physical body goes into a state of deep muscle relaxation (2).

This pattern is so consistent, especially in the initial stages of meditation, that it has now been called the relaxation response, after the pioneering work of Herbert Benson at Harvard Medical School (6). Benson has postulated that, in addition to having important influences on promoting physical health, the relaxation response is the initial first step defining the physiology of most forms of prayer, contemplation, and meditation across cultures.

Persistent practice of the relaxation response is thought to counter the effects of increasing stress in humans. Hans Selye first identified the stress response as the general adaptation syndrome. Here, the organism continues to adapt successfully to ever-increasing levels of stress in the environment until the point of exhaustion, at which time death intervenes. Particularly in beginning meditators, regular practice of the relaxation response is believed to establish a hypometabolic state of parasympathetic dominance, which continually resets the level of metabolic functioning to a lower rate, despite varying levels of stress. A state of internal metabolic rest becomes the baseline, rather than a constant readiness and perpetual overreaction that characterizes ever-increasing adjustments to changing contingencies in the environment.

The situation with long-term meditators is more complex, however, as shown by extensive studies of transcendental meditation, by far the most well-researched and empirically documented meditation program presently available (2). Although it is generally conceded that a wakeful hypometabolic state of increased parasympathetic dominance characterizes almost all forms of meditation in their initial stages, people who have been meditating for years or even decades show marked differences in both their physiological response and their ability to control their own physiology compared with meditators who have only been practicing a short time.

Hypometabolism is markedly increased in the advanced meditator compared with the beginner. In addition, there is significantly decreased sensitivity to ambient CO_2, and there are increased episodes of respiratory suspension that are highly correlated with subjective reports of what is called in yoga the experience of pure consciousness. Dramatic increases in phenylalanine concentration have also been noted in advanced meditators. Similarly, the urinary metabolite of serotonin (5-hydroxyindole-3-acetic acid) is found to be higher in meditators than in resting controls; levels also increase significantly immediately after the meditation period has ended.

Levels of plasma prolactin also rapidly increase immediately after 40 min of meditation in advanced practitioners. After a 2-h period of meditation, a fivefold increase in plasma levels of arginine vasopressin has also been found, whereas thyroid-stimulating hormone has also been reported to decrease chronically and acutely. In one study, researchers found an extraordinary alteration of intermediary metabolism as well as a change in metabolic rate when they measured the cessation of CO_2 generation in the forearm that occurred after 20 or 30 min of meditation.

Concurrently, an acute and marked decline of adrenocortical activity during meditation has been found in advanced practitioners compared with beginners. There is also increased plasma epinephrine in the presence of decreased heart rate, which reflects a coupled modification of both sympathetic and parasympathetic activity rather than simply reduction or increase of sympathetic activity alone.

This finding seems particularly important because there is clear evidence that, whereas meditation is a state of parasympathetic dominance, in advanced meditators there is also enhanced control over sympathetic activity. Either sympathetic or parasympathetic activation then becomes possible. A hypometabolic state of parasympathetic arousal, however, remains the doorway as well as the fundamental context for these potential changes. In other words, sympathetic control in the presence of parasympathetic dominance is the fundamental principle underlying what has been reported in advanced practitioners as the voluntary control of internal states.

This is corroborated by studies of individual practitioners who have been meditating for decades and who have gained phenomenal control over normally involuntary bodily processes. Tibetan monks studied in their natural environment in a Himalayan monastery practicing G Tum-mo yoga have been shown to first enter any one of several states of quiet meditation, after which they are able to generate such body heat that they can dry wet sheets on their back in freezing weather (1).

It is interesting to contrast this with Indian yogis studied under laboratory conditions of simulated pit burial. One yogi went into a state of deep bodily rest and lowered metabolism and was able to remain in an airtight box with no ill effects and no sign of tachycardia or hyperpnea for 10 h. In a different study done in a more naturalistic setting on a different adept, Yogi Satyamurti (70 yr of age) remained confined in a small underground pit, sealed from the top, for 8 days. He was physically restricted by recording wires, during which time electrocardiogram (ECG) results showed his heart rate to be below the measurable sensitivity of the recording instruments (see Fig. 1).

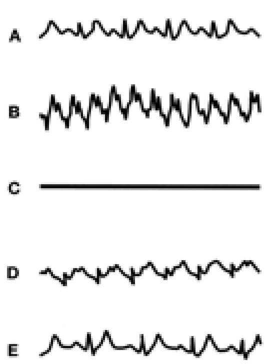

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FIGURE 1. Electrocardiogram tracings of Yogi Satyamurti showing 1st day, normal heart rate (*A*); 2nd day, development of tachycardia (*B*); 2nd day at PM, showing straight line with no electrical disturbance, which continued for 5 days (*C*); 8th day, 0.5 h before end of experiment (*D*); 8th day 2 h after coming out of the pit (*E*). [From Kothari et al. *Am. Heart J.* 86: 282–284, 1973.]

The point is that deep relaxation appears to be the entryway into meditation, but in advanced stages refined control over involuntary processes becomes possible, in which systems can be either activated or inactivated. From the practitioner's standpoint, in a purely naturalistic setting, this is achieved through mastery of a particular technique that is understood in the context of a specific philosophical school of thought, usually communicated under the supervision of a meditation teacher. Here, different phenomenological systems of thought provide elaborate cognitive instructions that are believed to lead to the control of specific physiological states.

Analogies across the phylogenetic scale

From a physiological point of view, there is a set of common problems that all organisms face when entering, maintaining, and leaving the hypometabolic state (3). These include O_2 intake and CO_2 elimination, temperature regulation, elimination of other metabolic wastes, control of heart rate, maintenance of the integrity of the cell, and a simultaneous orchestration of the rise and fall of various bodily systems that all must remain in synchrony when being turned off or on. Evidence shows that organisms up and down the phylogenetic scale have evolved to respond to these demands in different ways, but the generic challenges remain the same. Field mice, for instance, shut down their normal routes of energy metabolism during hibernation and switch over to fermentation as a source of O_2 during reduced metabolism. Similarly, CO_2 cessation in forearm muscles of advanced meditators has been attributed to a shift toward increased fatty acid utilization and beta oxidation by muscle tissue in the hypometabolic condition. Researchers have also noted a rapid decrease of whole blood and red cell glycolysis rate in advanced meditators, a process that appears similar to glycolytic changes seen in lower organisms going into and coming out of hibernation.

Other examples abound. Some freshwater turtles are able to stop their heartbeat for as long as 6 mo while buried on the floor of a vernal pond. During his 8-day stay in an underground pit, Yogi Satyamurti exhibited a marked tachycardia of 250 beats/min for the first 29 h of his stay. Thereafter, for the next 6.5 days, the ECG complexes were replaced by an isoelectric line, showing no heartbeat whatsoever (see Fig. 1). The experimenters at first thought he had died. Then, 0.5 h before the experiment was due to end on the 8th day, the ECG resumed, recording normal heart rate activity. Satyamurti also exhibited other behaviors similar to hibernating organisms. One of the most economical methods of preserving energy during hibernation requires animals to bring their body temperature down to that of the surrounding environment. Satyamurti, brought out of the pit on the 8th day, cold and shivering, showed a body temperature approximately equal to that maintained in the pit, namely, 34.8°C (

Conservative and restorative effects

When we consider the evolutionary significance of the hibernating and estivating response, the most obvious benefits include conservation of energy and adaptive survival in harsh environments where the weather is bad and the food and water supplies are not always available year round. Studies also show that hibernation is a time to bear the young for some animals, and it also provides a protective environment for metamorphosis. There are other advantages as well. Hibernating mice, for instance, live a significantly longer number of days than their nonhibernating cousins, thus allowing them to have an extra mating season.

Similarly, meditation can have a significant influence in the treatment of hypertension, high cholesterol, and ischemic heart disease and has been found to be effective in the management of acute and chronic pain. Meditation has been shown to have a beneficial effect on a spectrum of human behaviors, ranging from alcohol and drug addiction to creativity and school performance. All of these effects represent significant attempts at increased adaptation to exigencies in the natural as well as man-made environment. Also, because it is a voluntary activity and can be induced at any time, meditation cannot be considered solely as either a hibernating or an estivating response alone. We have chosen to call it an estivating response only because the summer activity of reduced metabolism connotes a condition that is not usually permanent throughout the season but rather varies, and, although the feats of exceptionally advanced meditators look more like hibernation, the normal practitioner of meditation exhibits milder changes that are more like the estivating response.

The problem with trying to understand the evolutionary function of meditation, however, actually reflects the larger problem of how we view the phenomenon of consciousness. Clearly, to the three states previously recognized by scientific medicine, the state of waking, the sleep state with dreams, and the condition of deep sleep without dreams, we must now add a fourth—the wakeful hypometabolic state of parasympathetic dominance, which appears to be a state of deep bodily rest with the potential of acute mental alertness that can have significant effects on increased adaptation.

We may conjecture that Darwin never imagined that, in addition to the biological evolution of the species, *Homo sapiens* would have to contend with ever-accelerating forces defined by the psychological and physical stresses of a modern man-made technological environment. By associating meditation with processes such as hibernation and estivation, we may think of it as the reacquisition of a very old adaptive mechanism. What was before a blind reflexive response developed by certain organisms for survival in natural habitats reemerges in humans as the product of a rational, everyday waking consciousness that has grown more complex, at least beyond adaptation to the natural habitat alone. Now, instead of being merely reactive to environmental variables, such as temperature change or lack of food, human beings must be trained to reenter this conservative and restorative state, but as a voluntary act of will in response to the increasing and unpredictable stresses of man-made environments. From a biological standpoint, this reinforces the view that plasticity of consciousness remains an important key to successful adaptation.

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