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Sleep and gravity

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A B S T R A C T

What is known about sleep results from years of observation at the surface of the Earth. Since a few decade man has been able to reach space, escape from the earth attraction and spend days and nights in a weightless condition. Some major physiological changes have been observed during long stays and in particular the sleep duration in space is shorter than on ground.

This paper reviews a novel hypothesis proposing that sleep is partly due to gravity. Gravity is a fundamental part of our environment, but is elusive and difficult to apprehend. At the same time, all creatures on Earth undergo cycles of activity and periods of rest (although not always sleep).

Careful analysis of previous research on sleep, on Earth, in space and in water, shows that gravity differs in these three situations, and sleep also varies, at least in its duration.

On Earth, Rapid Eye Movement (REM) sleep is conditioned by gravity; in space, astronauts have a shorter sleep duration and this is even more striking when a test subject is immersed in water for a week. In conclusion, sleep is partly due to gravity, which acts on our body and brain during the wake period.

Introduction

Gravity affects all living creatures, from cells to humans; at the same time, all creatures on Earth undergo alternative wake and sleep periods.

This unalterable cycle raises the question “why do we sleep?”. And the hypothesis presented here is that sleep is partly due to gravity.

Scientists have developed several theories that explain why part of life is devoted to sleep. As gravity is a parameter of our environment that is elusive, pervasive and difficult to apprehend and understand, it has almost never been held accountable for unique traits of our behaviour, except for the most obvious [1].

The sleep duration of mammals has been extensively investigated [2,3], and in a recent paper, it was demonstrated by the author that gestation length, rather than weight, is the predominant determinant of sleep duration [4]. For other species, like water and ocean species, the Archimedes force opposes the effect of gravity and, as a result, sleep in these species is different from the sleep of mammals. One particular trait of the sleep in fishes is that the Rapid Eye Movement (REM) phase of sleep is not apparent [5]. For insects, it is now believed that there are alternate active and passive periods [6]. Even unicellular organisms, such as plankton move lower at night and toward the surface before and during daytime, thus occupying different habitats during the day and night. The circadian rhythm seems to correspond to the necessity of using the energy from the sun to produce vegetal matter (photosynthesis) [7].

There are salient points common to sleep and gravity. Both are “universal”. For terrestrial creatures the posture during sleep is often the horizontal position of the body and in particular during REM sleep. As discussed below during sleep the brain reduce its sensitivity to all the parameters of the external world like light sound and also gravity which is one important component of our environment.

Man has lived for millions of years in the presence of gravity, but in recent decades, with the advent of space-flight, for the first time, man was able to live in the absence of gravity for short and long durations.

The purpose of this paper is to identify the effect that gravity has on sleep.

Method

This research article is not based on either human or animal observation or neurophysiological measurements.

Direct evidence supporting this hypothesis is based on an extensive and attentive review of the results of scientific studies on sleep, performed either on the ground, in water or in space. Although the “medical” aspects of sleep have received an enormous amount of attention, the effects of gravity on sleep has rarely been studied. On the ground, the simulation of the absence of gravity has essentially been performed by bed-rest studies [8]. The conclusions of these studies are important to predict some of the effects of a reduced exposure to gravity, but obviously gravity cannot be completely suppressed, and the significance and relevance of bed-rest studies are thus limited. There is little data on sleep obtained from bed-rest studies.

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Another approach to compensate for gravity, which was used many years ago by the United States Air Force (USAF), was to immerse a subject completely into water, and the results of this fundamental and original experiment are reviewed later in this paper.

In space, gravity is compensated by the centrifugal force produced by the circular motion around the Earth. There are no tools to suppress gravity, it exists everywhere and can only be compensated; it is also not possible to shield gravity.

Sleep has not yet been investigated in hyper-gravity situations, and would not be easily feasible if man were to be the subject. High accelerations are produced at launch and landing of space vehicles, but during short periods.

Proofs of evidence

On Earth

For gravity, “g” is the abbreviation used in physics to designate the value of this acceleration on Earth. It is equal to $9.8\,\mathrm{ms}^{-2}$ and is essentially due to the mass of the Earth. Applied to a mass, either of an object or a living creature, this acceleration gives the weight. Sleep at one g has been extensively analysed and measured. Gravity has an influence on REM sleep; Jouvet, a French scientist [10] involved in sleep studies observed that a cat on a platform surrounded by water did not experience REM sleep. He further showed how the tonicity of the muscles disappears during REM sleep. Muscle tone is the continuous and passive partial contraction of the muscles, and helps maintain posture against gravity.

When falling asleep the brain reduces its sensitivity to the stimulations of the external world: light, sound, contact and weight which is produced by gravity.

This observation is applicable to all other mammals living on Earth, which have to lie down to experience REM sleep [11]. For instance horses can sleep standing by locking their knees to stay in the upright position, but they can only achieve REM sleep if they lay on the ground, and this is also what happens during REM sleep for elephants [12].

The duration of sleep and REM sleep depends on the work that the muscles associated with the tendons, ligaments and various membranes have performed during the wake period to maintain equilibrium and posture among all other tasks. One phenomenon that has not been investigated concerns the work to maintain cohesion between all organs and parts of the body. The fasciae-dense connective tissue sheets-may play an important role as force transmitters in human posture and movement regulation [13].

“Suddenly deprived of life, the body collapses, inert, plated on the ground by the forces of gravity. The muscles are soft, and the moving parts of the skeleton can be put into any mechanically possible position” [14].

This quotation illustrates the role of the tone of the muscle system components during wake.

During sleep, the REM phase corresponds to the atony of all muscles and a relative reduction in the activity of the network of sensors; eyes are closed, hearing is damped, and the brain does not send signals to keep the body in equilibrium. Gravity is “forgotten” by the brain during REM sleep [12].

REM sleep is when all the muscular components that were active during the wake period relax completely. The atony during REM sleep is the only way to relax muscles, and deprivation of REM sleep can be lethal [15]. For the healthy human, sleep should last for 8 h. Of course there are deviations from this optimum value [16].

For two other classes of vertebrate – birds and fishes – sleep studies are few, as they demand sophisticated means of measurements. Birds have a unique relation with gravity during soaring, gliding and landing. Birds do demonstrate REM sleep, but it is difficult to select a criterion for their sleep duration [17].

The usual posture of birds sleeping is with their head tucked into their back or wing. The explanation is related to energy and heat but it may recall the posture of mammals with their head safely lying on the ground or horizontal support when entering REM sleep. The birds that sleep on one leg certainly do reduce heat dissipation but are in a delicate equilibrium. For birds even during REM sleep this is not an obstacle as they have wings and do not risk falling, they can fly away, while mammals are born with the fear of falling [12]. Non flying birds may have special postures. Young ostriches can pose their head on ground for sleep [18], and penguin chicks do the same [19].

The situation in the Ocean is different as the Archimedes force compensates for gravity. Fishes can control the depth that they inhabit by simply filling their bladder. They do not seem to experience REM sleep as mammals do [5]. Sleep in reptiles and amphibians is ambiguous, and very meticulous experiments have shown similarities with mammals [20].

In space

Manned space flights began more than 50 years ago. The duration of these flights has evolved from a few hours to many months. Although many studies have reported that sleep in space only differs minimally from sleep on Earth [19], a general conclusion is that sleep duration in space is shorter. This has been observed on astronauts whatever their sex, ethnic origin, language, religion or creed. It was often concluded that astronauts were suffering from sleep deprivation, which could be harmful for the good and safe conduct of the mission. Indeed, sleep in space is not as comfortable as sleep on Earth, and this has been reviewed in detail, but the role of gravity is minor in this discomfort. Early in space history, during the Skylab flights, it was noted that the sleep duration was shorter in space than on Earth. As quoted by Frost [21]:

> *“This decrease in sleep time, however, was due not to an unusual amount of time spent in the awake state but instead to a reduction in the total rest period time itself. The subject thus slept quite well on most nights while he was in bed; however, he did not spend as much time in bed as he did during studies either before or after the mission.”*

At this early stage, in 1973, scientists did not invoke the absence of gravity as the potential cause of the reduction in sleep duration. Since then, many other investigations have been concerned with sleep and sleep duration [22]. and come to the same conclusion [23].

> “*Ten years of data show that astronauts normally do not get enough sleep, even though most take sleep medications during space missions. Recognizing that sleeping pills do not solve the problem helps researchers target further research on the effects of medication*”

During space stay, the most frequently used medication is for sleep problems [24,25]. It has been recognised that medication does not solve the issue of sleep duration, but does reduce the effects of stress or other uncomfortable causes, but obviously cannot compensate for the absence of gravity. Countermeasures are numerous, e.g. changing the light wavelength [26], and synchronising ground nights and days with the crew on board [27,28].

Sleep has been one of the concerns of the physiology of man in space, but the most serious and major effect of the absence of gravity concerns muscles and bones [29]. The usual stress which is applied on the ground-due to gravity-is lacking, and its absence produces atrophy of muscles and loss of strength of bones. Bone re-calcification and muscle re-building are slow processes [30], while normal sleep can be recovered within a few days after landing to reach pre-mission values [26,31]. It is understandable and reasonable that the serious alteration of these two physiological processes, muscles and bones, has received more attention than sleep. Surprisingly, the sleep of other mammals has been studied on the ground, with the aim of gaining a better understanding of human sleep [32], while in space there have been no investigations related to the sleep duration of other mammals.