Review on Effect of Biological Clock on Diet and Exercise Performance

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Abstract

Day-night reversal and external environment change will affect people's biological clock. When the biological clock cannot synchronize with external environment, jet lag occurs, influencing people's sleep and bringing them fatigue, inappetence, indigestion, emotional lability and other body-mind problems. Many world records of athletics events were broken in the afternoon or at dusk, during which people's temperature reaches the plateau period. For instance, athletes of long-distance running and short-distance swimming can have better performances in the afternoon or at dusk. However, the nerve conduction velocity is fast when the body temperature reaches the plateau period, leading to the inverse relation between speed and accuracy for those simple and repetitive events. Therefore, athletes of events (e.g. archery)required by higher stability and accuracy have relatively worse performances. This thesis is aimed to make a summary on the effect of physiological changes on nutriology, including the effect on gastrointestinal functions, substance digestion and metabolism and hormone. The purpose of the thesis is to provide theoretical basis for lowering theses effect.

Keywords

Diet Nutrition; Jet Lag; Biological Clock; Exercise Performance.

1. Introduction

There are two main factors influencing the dietary habit. One is internal environment, e.g. biological clock, while the other is external environment. The usual daily dining time is 6:00-8:00 for breakfast, 12:00-14:00 for lunch and 18:00-20:00 for supper. This dinning pattern reflects people's visceral functions, insulin secretion cycles and metabolic rules of food. Generally, only the effect of external environment instead of internal one on changes of dietary habit will be noticed, such as effect of Ramadan of Muslim on the dietary habit in that month, effect of several jet-lagged flies of flying trapezes on their appetites and the dietary habit change of night workers,. Most people only notice the effect of external environment in the above mentioned examples. However, the effect of internal environment also exists. Are the effects of internal and external environment on diet of same importance?

Undoubtedly, the effect of internal environment on diet does exist, but its effect is slight. Concept of equilibrium is one of the important topics of Physiology and Biochemistry. In order to maintain the stability of physiological function, it will return to another equilibrium state when disturbed. The case of biological clock is a good example. When the body temperature lies between 36.5-37.5℃, it will be kept within the scope no matter in environment with high or low temperature. Similarly, this also goes for blood sugar, which means the blood sugar will be kept within a certain scope even without any meals. From the aspect of biochemistry, biochemical analysis [1, 2] in different scope can be conducted in

different time intervals in spite of the collection of small amount of blood, buccal mucous or other body fluid. Researches on gastrointestinal functions from physiological cycle are short in numbers, but those on internal temperature are plenty. The cycles of body temperature will be broadly used as the theories explaining physiological cycle, which may be used to discuss the survey of meals. By now, not all cycles are resulted from the change of lifestyle, for example, those theories can still apply to the change of sleep-wake cycle after the change of jet lag. Apparently, most of sport matches are arranged in the afternoon or at dusk, which may intend to assort with people's biological clock other than the coordination with TV broadcasting. At the same time, most of the world record breaks also occur in the afternoon or evening, which may indicate its relation to the cycle of biological clock. Yet, does the cycle of biological clock synchronize with the 24-hour cycle of a day? How to adjust it to synchronize with the 24-hour cycle if it does not? If the biological clock can be adjusted to the same condition of usual training, athletes will certainly gain the best performance during the competition.

2. Operation Mechanism of Biological Clock

If the cycle of daily body temperature varies with the change of personal lifestyle and that of environment, the time difference change or night-shift work may cause immediate or proper changes of some cycles. However, the fact is that they are not the same. Cycles do not immediately change. This is how so-called jet lag generates. The symptoms of jet lag include sleep deprivation, fatigue, depression, distracted-attention, lowered-appetite as well as the change of gastrointestinal functions. Moreover, the cycle of body temperature has been changing and adjusting itself to the same state of the new time zone or to the working time zone of the day-night reversal. During the adjustment, the above symptoms persist all the way. Such result indirectly proves that some of the factors are involved with lifestyle and environment. There are two methods that are broadly used to discuss the cycle of body temperature, namely the constant routine method and the forced uncoordinated method when the daily cycle observed are completely influenced by lifestyle and environment [3-5].

There are two groups of cells near the pituitary gland of human brain, separately located in the frontal lobe and posterior lobe to control the temperature pattern, hormone secretion, appetite and sleep. One experiment can prove this fact. If this kind of cells are transplanted into the brain of a creature, the regular cycles can be observed, while that without such cell transplantation will not be observed of regular cycles under the same circumstances.

When people live in the environment without clocks, e.g. in caves, various cycles such as sleep-awake cycle, body temperature, hormone release and other activities still continue to operate. This testifies the existence of internal environment. However, the mentioned cycles are between 24 to 25 hours instead of 24 hours. Compared to the external environment, the cycles inside the trial subject are obviously lagged behind. Such cycle driven by biological clock is named as circadian. As the time giver, circadian rhythm makes the biological clock unceasingly adjust itself to maintain the synchronization with the solar day. And these cycles are directly or indirectly resulted from the influence of environment. For human, the most important time givers are light-dark cycle and the secretion of pineal gland and melatonin. The effect of light ray changes with the solarized time while its pulsation is within six hours of the window period after the lowest temperature. Normally, the body temperature reaches the lowest figure during 4:00-6:00 in the morning. Solarization before the lowest temperature will cause the delay of biological clock; solarization at the lowest temperature will advance the biological clock. If the light ray is out of the zone of the lowest temperature for too long, its influence will be greatly decreased or even vanished. And the time zone without any influence is called dead zone. The effect of sunlight is much more than that of indoor lamplight, which means that the moved distance of biological clock caused by sunlight is further than that of sunlight even though people mostly stay indoors and get little solarization. Consequently, waking up in the morning, the biological clock of people, stimulated by indoor lamplight, will move and finally synchronize with the time of solar day. Melatonin has the same effect of advancing or postponing the biological clock, but it works in an opposite way from the effect of light. For example, injecting melatonin in the morning will postpone the biological clock while such injections in the

afternoon or evening will advance it. On the contrary, sunbathe in the morning will advance the biological clock while that in the afternoon or evening will postpone it (right after the lowest temperature of people). As the periodic change of solarization or melatonin secretion, the social structure of personal lifestyle also changes, comprising those of dinning time, social intercourse, psychological and physical activities. That is to say, people tend to have meals and participate in activities during daytime, and contrarily, people tend to sleep in the evening. Even so, other potential time givers are found not that relatively important.

Regular functioning of biological clock generates daily periodic activities, such as the change of body temperature and hormone concentration, the output of neural information and sleep. The biological clock has two general effects: first, such activities include physical, psychological, biochemical and heart changes. For instance, glucose metabolism and fat storage occur during daytime, while the consumption occurs during night. Second, the physical condition can be altered any time, e.g. shifting to sleep status from activity status or otherwise. Those changes require a series of command to increase or decrease biochemical and physiological activities, which shall all be well set before such events as sleeping or wakening. In order to reach those goals, stable power is required to drive normal functioning of biological clock. But external environment like personal lifestyle or model shall not be changed all times.

Periodic activities include internal environment and external environment. Periodic activities include internal environment and external environment. The former is driven by biological clock while the latter is driven by personal life style and environment, which can be applied to all variables. In fact, there are different effects between variables. Firstly, personal sleep-wake cycle and environment have effect on the surveyed external environment of periodic activities. Blood pressure, heart beat and respiratory tract width have alike effect on body temperature because physical and mental activities raises the body temperature and sleeping drops it. The melatonin secretion is suppressed by light and the level and categories of abdominal muscle and secretion. The hormone secretion is affected by food digestion and the release of antidiuresis hormone is affected by water ingestion. Generally, internal and external environments play different roles, and the role of external environment matters much more than the internal one, such as in activities of heartbeat, blood pressure and kidney and the hormone secretion (when sleeping) from pituitary gland. But in such activities as the release of potassium ions in urine and melatonin release (the secretion of adrenal cortex autacoid is accompanied by its metabolism), the internal environment plays a more important role. Nevertheless, body temperature has same effect on both factors.

3. Effect of Physiological Cycle on Gastrointestinal Functions and Metabolism

There are some periodic activities in people's daily life, such as regular meals, gastrointestinal motility, food digestion and absorption. Most people have different frequency of having meals, with some twice a day, some thrice, and even four to five times (afternoon tea and late snacks). Tradition dining habit shall be thrice a day, namely breakfast, lunch and supper. However, the dining habit is influenced by social intercourses and religions. Those periodic activities can be considered as with strong external environment, i.e. there are interaction effects between diet and activities during waking time. Yet, some evidences prove that those periodic activities are slightly affected by internal environment, for instance, people's appetite and enjoying degree of food gradually drops after several jet-lagged flies; the diet of those night-shift workers who keep eating snacks instead of lunches also rapidly change. Those result all come from having meal in wrong time of biological clock. Among those changes, how important is the role of biological clock? There is an example: when flying from Britain to Xiamen, China (in winter time, there are about eight hours of time difference, and about seven hours in summer time), the breakfast time in Xiamen is around 23:00h of Britain evening and the lunch time is around 04:00h of Britain morning; the supper time in Xiamen is around 09:00h of British time, meaning the external environment is in Xiamen time while the biological clock is still in British time. Earlier researches [6-7] indicate that having meals and the feeling of it will recover soon before the cycle of body temperature turns into the new local time, but the jet lag will not recover.

Waterhouse believes that inappetence and jet lag are neither tightly related nor obviously differentiated. Result of research shows a weak relation between them. This might be partly caused by normal fatigue and worse jet lag caused by insomnia. In a new environment, different food (or different ways of making food) may also lead to those changes. Similarly, result from a lab experiment based on eight hours of time difference eastwards shows that dinning time will be immediately adjusted, in other words, the diet will match up with the local time [8]. Some experiment results [9] indicate that the adjustment of biological clock is very slow, e.g. the external environment has passed Beijing Time, but the biological clock is still in British time. Hence, the breakfast time in Xiamen is about the dinner time in Britain, and the late snack time in Xiamen is about the supper time in Britain. Wee hours in Britain are the time when people are not likely to have hot food. Such pattern recovers to its usual status on the third day, i.e. pattern having hot food for lunch and supper. This, again, proves the weak relation between diet and biological clock. Factors like lack of cookers or inconvenience of shopping may be the reason explaining the immaturity of the dinning environment for night-shift workers. Or due to biological clock (its adjustment is slow and those workers work at night and sleep at daytime), they might feel that they are having meal at the wrong time. Maybe a great meal is not suitable to be arranged before or after their working time (breakfast or supper provided to those who don't go on night-shift).

There are scholars [10-11] applying meal questionnaires to nurses in the hospital concerning their work time and weekends. The questionnaire is filled every three hours. They found that the dinning conditions of medical workers are affected by hunger and possibility of getting used to be provided with food from social work. Besides, night-shift workers usually like eating snacks other than meals. Wrong time of meals is one of the factors affecting their diet, and the other possible reason is that their dining time must match up with their work time. This result is obtained from the findings of two different groups of workers. Compared to daytime workers, the meals for night workers in the evening is greater limited. This is why snacks are more popular among night-shift workers. In addition, as for the feeling degrees after meals, night-shift workers enjoy a lower feeling than daytime workers. It is partly because snacks are usually more popular. The above phenomena do not occur on weekends or breaks, when the two groups of subjects react pretty alike toward dinning. They all want to have meals for they are hungry. The feeling degrees after meals are positive and the frequency of having hot food is also comparatively higher.

Night-shift workers' reaction towards dinning is different from that of daytime workers, indicating that the free dinning time of the former is more limited than that of the latter. Furthermore, this difference may also originate from the effect of biological clock, because night is usually the sleeping time when the body temperature reaches the lowest point. Oppositely, daytime workers have meals at the time of highest body temperature.

As mentioned above, forced asymmetric lifestyle and the separation of internal and external environment occur. Fourteen trial subjects are gathered for such experiment [13-16]. They are guided to live in the day of 28 hours which are divided into 9.33 hours for sleeping and 18.67 hours for non-sleeping. During the non-sleeping hours, subjects are given some work to do and they can choose to eat what they like freely. Likewise, they are also required to fill questionnaires about their reaction towards dinning. Judging from their answers, other than food provision or time pressure, hunger is the main reason why they have meals. Statistically, they have different reactions at different period of time. For example, they like dessert for breakfast, small amount of hot food for lunch and big amount of hot food for supper. In spite of the amount of hot food, it is in direct proportion to the hunger level and the enjoying level. But later, the satiation degree of hot food is greater than that of cold food. After several hours of time difference, they will adjust their diets to fit the new local time. Contrarily, the effect of biological clock on meal categories and reactions after meals is weak and it merely achieves the notable level of statistics. That is to say, such result is the same as the previous research conclusion. The match of the dinning time and the highest point and lowest point of body temperature might be a coincidence. The importance of external environment, instead of internal environment is seen as the natural internal discordance, which is barely known by people. But those phenomena can be observed from the subjects

living in free time (so-called free operation) when their body temperatures circulate in the cycle of 24.5 hours per day. The sleep-wake cycle is adjusted to 16 or 33 hours. In those two researches, the normality and coordination of internal and external environments do not exist. Meanwhile, the dinning time is still in accordance with sleep-wake cycle. Thus, breakfast is still taken after waking up in the morning (no matter what status the body temperature is in) and the period between breakfast and lunch changes direct-proportionally with the non-sleeping time. In brief, proofs from sleep-wake cycle show that internal environment has a very slight effect on dinning and feeling afterwards.

4. Effect of Biological Clock on Exercise Performance

In general, people's body temperature does not main the same figure in 24 hours of a day but vary between 36.5℃ to 37.5℃. Highest temperature has positive effect on exercise performances. The plateau period of body temperature lie normally between 16:00 to 22:00. Body temperature can represent the biological clock of people furthest. Hence, exercise performances during this period are better than that during other period.

The circumstantial evidence proving the effect of biological clock on exercise performances is that the world records are mostly broken in the afternoon or at dusk when people's body temperature reaches the plateau period [17]. However, this might be questioned by people, because the weather is getting pleasant in the afternoon or at dusk, which is the best time for athletes to race. For instance, athletes of long-distance running arranged in the afternoon or at dusk may perform better than that in the morning [19, 20]. But when the external environment is controlled under the same circumstances, we can find that the best performance of 10m and 400m swimming contest also occurs in the afternoon or at dusk [20].

Edwards [22] made a test at 08:00, 14:00 and 20:00 on the service accuracy of badminton. He found that the accuracy at 14:00 was higher than that in the other two time points, and the accuracy of short service was higher than that of long service. Moreover, many sports require both stability and accuracy, e.g. archery. Similarly, the performance of its isometric contraction is also achieved in the afternoon. For short-time events, reaction time is highly required, during which athletes can get the best performances at dusk (plateau period for body temperature). Some researchers [Wingate et al., 1985] point out that the nerve conduction velocity is increased by 2.4m/s every time when the body temperature is raised by 1℃. However, for those simple and repetitive sports, the speed is generally believed to be proportional to the accuracy, indicating that the accuracy may be low at dusk. For psychomotor sports valuing accuracy more than speed such as billiards, the performance of contest will be better in the morning other than afternoon, which also applies to the performance in skills, especially on the stability and balance sense of hands. This may be related to endogenous arousal. When the endogenous arousal is low, it best fits the psychomotor activities or performances of skills. Test on performances of muscle strength such as grip strength test finds that grip strength performance at 14:00 and 19:00 is 6% higher than the average value of 24 hours. Such result has similarity with the test results of concentric contraction and eccentric contraction because its maximum value also occurs at dusk. For sports with instant eruption force such as cycling and standing high jump, their maximum values also occur at 22:00 instead of 6:30.

The rectal temperature of people can best represent the change of biological clock during a day. The function image of rectal temperature remains unchanged when people are exercising [Reilly et al.,1986]. For endurance exercise like Marathon, heat is continuously generated and it will raise the body temperature. When the temperature reaches the plateau period, and together with the heat generated by metabolism, the overheat of the body will cause heatstroke. So researchers hold the point that lowering body temperature before contest will help the athlete to improve his or her exercise performance, on the contrary, the exercise performance will be reduced. This result does not conflict with the previous narrated facts. Afternoon is the best time for exercise if only concerning the cycle of body temperature. Proper time shall be reserved for the thermal load to generate better exercise performances if the heat generated by metabolism is also considered.

The biological clock for human is 25.1 hours], which slightly discords with the solar biological clock of 24 hours [22]. This explains why people are used to sleep late instead of early. There are two ways of adjusting biological clock: the first is the melatonin. Taking melatonin in the morning will postpone the biological clock. Getting sunbath outdoors in the afternoon has the same effect. The other one is diet, which is a time giver. Having three meals regularly everyday will help the biological clock adapt the local time. Slow adjustment towards the synchronization with the local time will help athletes gain their corresponding performances during contests.

5. Conclusion

The effect of biological clock on die is short and the relation is also very weak. Generally speaking, diet is more affected by external environment other than biological clock. Due to time difference, biological clock is always in local time, having difference with the time in new destination. The diet will soon match up with the new time within two days. However, the biological clock may not adjust itself as soon as diet. Therefore, athletes can soon give full play to their strength and show the achievement of daily training if their biological clock can be soon synchronized with the local time of the completion location.

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