THE INFLUENCE OF A SHORT DAYTIME NAP AND THE INFLUENCE OF ITS TIMING ON PSYCHOMOTOR EFFICIENCY

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Abstract: A decrease in quality and quantity of sleep has a negative impact on efficiency during wakefulness, which shows particularly in case of people who interact with technological systems, for example system operators, vehicle drivers, etc. Day sleep can positively influence the following vigilance but in the time immediately after the sleep, the psychomotor performance is influenced by sleep inertia whose intensity depends on time and length of sleep.

The aim of the study was to compare day psychomotor performances of people suffering from sleep disorders and a control group of healthy people, and to test the hypothesis that a short, 15 minute long sleep causes more important sleep inertia at 3 p.m. than at 1 p.m.

Sleepiness was objectively evaluated on a group of 35 tested probands, consisting of 29 patients (13 women and 16 men) with given excessive daytime sleepiness accompanying sleep disorder, and of a control group of 6 healthy subjects, with help of Multiple Sleep Latency Test (MSLT) and subjectively with help of Alertness Visual Analogue Scale (VAS). Psychomotor performance was examined by Psychomotor Vigilance Task (PVT).

We found out an unimportant difference in the intensity of sleep inertia after a sleep at 1 p.m. and 3 p.m. We proved significant prolongation of a reaction time and an increase in number of lapses on the group with pathologically shortened sleep latency in MSLT compared to the group with the normal sleep latency. Our work also shows the difference between the subjective and objective evaluation of sleepiness of subjects. Our results show that the prolonged reaction time and increase in number of lapses of the patient group are significant in all PVT examinations compared to the control group. Further, it is obvious that the PVT test is a more sensitive method for judging psychomotor performance and indirectly for judging sleepiness than the MSLT.

These facts seem to be important especially from the two following reasons:

1. They can be a help for recommendation of improved regime for driver relaxation.
2. They can help in search for deeper understanding of mechanisms of attention decreases.

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1. Introduction

A chronic deficiency of sleep relates to health problems including sleep disorders, to work duties, social life and leisure time activities [1]. A chronic sleep reduction and acute sleep deprivation have a negative impact on efficiency during vigilance [2] and on abilities of respective persons to interact reliably with various mechanical systems (namely of transportation nature), which are part of a modern life. They manifest in vigilance decline, increase in attention outages, cognition slow-down, defects of a short-time memory, deficit in frontal lobe functions, and imperative sleepiness [3].

It has been proved for example that tired train drivers have a lower ability to react fluently (and drive the engine); the trains driven by them have a higher consumption of fuel and make more speed offends than those driven by their well-rested colleagues [4]. It is known that a considerable number of road accidents are caused by tired and sleepy drivers [5]. According to air traffic safety statistics, up to 7% commercial air disasters are related to fatigue [6].

There is a big inter-individual variability in susceptibility to sleepiness. For example, it has been found out that a 44 hour long continual wakefulness reduces work performance of some people by more than 40% while the performance of others has not almost changed. It is shown that susceptibility to fatigue depends e.g. on a type of personality, age and total every day need of sleep [2]. But none of these attributes can serve as an accurate indicator for setting a degree of perceptivity towards fatigue.

The estimation of relevant state of sleepiness includes mainly three of its basic components: 1. relevant circadian internal clock setting, 2. homeostatic sleep pressure, 3. sleep inertia (an older term is sleep drunkenness) it means temporary inability of a perfect mental and physical activity after awakening [7].

In situations when sleep quantity is limited, a short nap is the most effective non-pharmacological technique for maintaining vigilance. It is proved that a "nap" during a long period of continual vigilance is extremely beneficial [8].

Timing of a sleep/nap is important. Taking a nap during a day before a night shift improves efficiency during the night when compared to the efficiency without such a prophylactic nap. Although taking a nap later at sleep deprivation is also useful, these naps have to be longer than the prophylactic naps in order to attain the same positive effect on performance. It was shown that a nap before a continual 52 hour long performance was useful for keeping efficiency and vigilance during the first 24 hour period [8].

Another important factor is the length of a sleep. The relation between the length of a sleep and efficiency was investigated in the study when the subject underwent 2, 4 or 8 hour long sleep before a 52 hour long performance. The results show a relation between the length of a nap – efficiency during the first 24 hours of sleep deprivation, dependent on the batch. It is concluded that the sleep before the night shift shall be as long as possible to attain maximum performance [8].

The last considered factor is the timing of a nap regarding the relevant circadian situation. The tendency to sleep is the most prominent within low body temperature (at night) and smallest by day. Naps in the period of circadian temperature decrease are more problematic from the point of view of the ability to wake up. It is shown that the sleep inertia is higher and the performance is lower immediately after awakening from a nap in the period of a circadian fall in temperature than after awakening from a nap that was in the period of a circadian temperature peak. But an advantage can be gained from improved quality of a sleep within the period of a circadian temperature fall if we avoid the negative impact of sleep inertia with help of awakening approx. 1 hour before the expected beginning of work performance [9].

From the above mentioned it results that a day sleep can favorably influence the subsequent vigilance but in the period coming immediately after the sleep, the psychomotor efficiency is influenced by sleep inertia, which manifests itself with various intensity based on an individual. The intensity of this sleep inertia also depends on the time of a sleep.

Considering the presented facts, we decided to test day psychomotor efficiency on patients with sleep disorders and on a healthy control group, and to verify the hypothesis that a short, at maximum 15 minute long, sleep at 15 hours causes a more pronounced sleep inertia than that at 13 hours.

2. Methods

2.1 Cohort

29 patients, who were examined for excessive daytime sleepiness (EDS) accompanying sleep disorders in the Sleep Laboratory at the Neurologic Department of the 1^{st} Faculty of Medicine, Charles University, were included into the study. They were patients with sleep related breathing disorders, most often with obstructive sleep apnea (OSA), then patients with sleep related movement disorders – with the restless legs syndrome (RLS) or with periodic limb movement disorders (PLMS), and further the patients with excessive daytime sleepiness due to idiopathic hypersomnia. We did not include people with circadian rhythm sleep disorders or narcolepsy.

The cohort consisted of 13 women at the age of 20–60 years (38.6 in average) and of 16 men at the age of 18–72 years (48.3 in average). Further, 6 volunteers at the age of 34–67 (56.3 in average) who did not suffer from excessive daytime sleepiness formed a control group.

2.2 The examinations carried out

Multiple Sleep Latency Test (MSLT)

The MSLT is an electrophysiologic laboratory examination to prove and quantify excessive daytime sleepiness by measuring sleep latency repeatedly during a day.

Three basic polysomnographic parameters EEG, EOG and EMG of chin muscles are registered during the MSLT. The night before the MSLT examination the patient is polysomnographically observed to exclude skewing results by current change of sleep and to find possible abnormality of a night sleep. Five measurements in two-hour intervals are taken during the MSLT when the proband must not sleep between particular tests and before the first morning test. During the measurement, the proband is laid down in a dark quiet room, takes an optimum position on a bed and is instructed to lie with closed eyes and not to resist a sleep. If he/she falls asleep within 20 minutes, the registration goes on for 15 minutes from the moment of falling asleep, then the proband is woken up by the nurse. If the proband does not fall asleep within 20 minutes, the measurement is ceased [10]. When evaluating the MSLT, the sleep latency is set – the time between the start of measurement – switching off the light and closing the door and the beginning of the first period scored as a sleep. The average sleep latency (average of all latencies of all 5 measurements) is computed and the presence of possible REM sleep is evaluated.

Psychomotor Vigilance Task (PVT)

The PVT is a simple 10 minute long examination of a reaction time taken to measure attention and psychomotor efficiency. A proband reacts to a visual stimulus on a 4-position LED display – to a red number increasing from zero by 1 millisecond. After pressing the response button on the apparatus, the display shows the value informing of a reaction time. For the response, the tested person uses a dominant finger of his/her choice, which stays the same within the whole period of examination. The stimuli appear in irregular intervals from 2 to 10 seconds. The proband is instructed to response the stimulus as fast as possible but not to try to estimate when the next one will come and thus to avoid premature reactions – false starts. The examination takes place in a quiet room with exclusion of all disturbing influences [11, 12]. In the examination, the following dependent variables can be evaluated: reaction time – RT, its mean, minimum and maximum; reaction speed (RRT = 1/RT) – its mean and standard deviation (SD); number of wrong responses; number of false starts – FS, when the reaction time is shorter than 100 ms; further number of lapses – L, when the reaction time is longer than 500 ms and square root transformed lapses (square root of L + square root of (L+1); mean and standard deviation of the slowest 10% reaction times, and mean and standard deviation of the fastest 10% reaction times.

Alertness Visual Analogue Scale

Alertness Visual Analogue Scale is a linear bipolar scale which is used to set subjective sleepiness. On a 100 mm long line segment, the left end represents a state of maximum alertness (corresponds with value 0) and the right end represents a state of maximum sleepiness (corresponds with value 100). The probands mark with a point on the line segment how alert they feel at the given moment [13]. *The examination protocol* is displayed in Fig 1.

The MSLT subtests were carried out at 9, 11, 13, 15 and 17 hours. The MSLT was carried out in accordance with standard procedures [14]. When evaluating

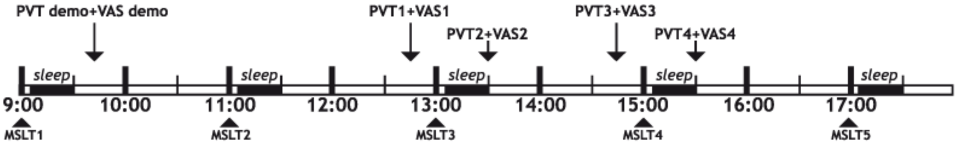

Fig. 1 *Timeline of examinations (MSLT – multiple sleep latency test, PVT – psychomotor vigilance task, VAS – visual analogue scale).*

the MSLT, sleep latency in particular subtests was set, average sleep latency was computed and the REM sleep absence was checked. As the patients with narcolepsy were excluded from the complex, the REM sleep was not observed at any of the examined.

The probands tried the PVT in a one-minute "demo" version after finishing the MSLT1 (after 9 hours). The subjects underwent a 10 minute PVT examination 4 times in total – before and after the subtests MSLT3 and MSLT4. That means at 12:45 and then immediately after finishing the subtest MSLT3 at 13 hour, than at 14:45 and immediately after finishing the subtest MSLT4 at 15 hour. In this study, the following variables were evaluated: mean reaction time RT in ms and number of lapses (L).

To judge the subjective sleepiness, the probands always filled in the *Alertness Visual Analogue Scale – VAS* after concluding the PVT (4 times).

2.3 Statistical analysis of measured data

Basic statistical characteristics were computed from the examination data – mean and standard deviation. The differences between the means of compared groups were tested by a two-tailed t-test.

3. Results and Discussion

We made comparison of reaction times and numbers of lapses in the PVT examination before the MSLT3 and MSLT4 for 29 subjects included into the study. The results in the Tab. I show only a mild prolongation of the reaction time and increase in lapses in the examination before 15 hours compared to that before 13 hours.

Before	**MSLT3**		**MSLT4**		**Significancy**
N = 29	**mean**	**SD**	**mean**	**SD**	**p**
RT	341,07	114,16	348,15	158,74	0,846
L	7,14	11,23	8,69	18,00	0,695

Tab. I *Comparison of the reaction times (RT) and number of lapses (L) before 13:00 and 15:00.*

Therefore the psychomotor performance of the examined patients does not change within this interval, and neither does a short relax or 15 minute long sleep at maximum performance improve the performance. We can deduce that it is necessary to test influence of a longer sleep on patients with excessive daytime sleepiness.

In order to judge sleep inertia, those who did not fall asleep during the MSLT test were excluded from the complex. We compared psychomotor performance before the sleep at 13 hours and after a short sleep, 15 minutes long at maximum, for 28 patients. Tab. II shows an nonsignificant prolongation of a reaction time and a small increase in lapses in the examination after the sleep.

13:00	**Presleep**		**Postsleep**		**Significancy**
N = 28	**mean**	**SD**	**mean**	**SD**	**p**
RT	341,11	116,25	343,09	115,70	0,949
L	7,14	11,43	9,71	18,04	0,527

Tab. II *Comparison of reaction times (RT) and number of lapses (L) before and after sleep at 13:00.*

Similar results are displayed in Tab. III (comparison of performance in the PVT before and after the sleep at 15 hours for 24 patients).

15:00	**Presleep**		**Postsleep**		**Significancy**
N = 24	**mean**	**SD**	**mean**	**SD**	**p**
RT	358,88	172,82	363,02	153,81	0,931
L	9,96	19,57	11,38	24,09	0,824

Tab. III *Comparison of reaction times (RT) and number of lapses (L) before and after sleep at 15:00.*

The manifestations of sleep inertia (worsening of psychomotor performance) are not significant. We consider this fact as a consequence of high inter-individual variability in the manifestation of sleep inertia and as a consequence of the fact that displays of sleep inertia after a sleep in day-time are smaller than those after a sleep at night [9].

A short day sleep seems to be advantageous from the standpoint of rise and intensity of sleep inertia. The influence of a longer sleep will have to be evaluated in further studies.

To verify the hypothesis that a sleep at 15 hours causes more prominent sleep inertia than a sleep at 13 hours, we compared the differences of reaction times and number of lapses in the examinations before and after the sleep at 13 hours, and the differences in the examination before and after the sleep at 15 hours. The results of the comparison given in Tab. IV show the differences are minimal.

Based on these results we can conclude that, from the point of view of a rate of sleep inertia, *it is not important* if the patient takes a “nap” at 13 or 15 hours.

Sleep inertia	**at 13:00**	**N = 28**	**at 15:00**	**N = 24**	**Significancy**
	mean	**SD**	**mean**	**SD**	**p**
RT differences	1,98	67,57	4,13	92,66	0,925
L differences	2,57	12,29	1,42	7,34	0,678

Tab. IV *Differences of reaction times (RT) and number of lapses (L) before and after sleep at 13:00 and 15:00.*

This circadian interval is not so different to be reflected in the intensity of sleep inertia manifestations.

From the clinical standpoint it is important to judge psychomotor performance of patients with pathologically shortened sleep latency in the MSLT. Therefore we compared the PVT results of the group with average sleep latency lower than 8 minutes and of the group with average sleep latency 8 minutes and more. Tab. V shows that the group with shortened sleep latency shows prolongation of a reaction time and an increase in number of lapses in the all PVT examinations; while in some of them the difference is significant.

	>= 8	**N = 16**	**< 8**	**N = 13**	**Significancy**
	mean	**SD**	**mean**	**SD**	**p**
Age	39,69	17,02	49,23	14,62	0,116
Latency	13,26	3,63	4,86	2,27	**0,001**
VAS1	40,00	27,20	42,08	27,38	0,840
VAS2	51,50	29,23	46,23	26,35	0,614
VAS3	42,38	27,78	31,92	22,04	0,269
VAS4	50,94	32,53	32,46	18,68	0,067
RT1	289,46	34,82	404,60	144,80	**0,015**
L1	2,44	2,48	12,92	14,86	**0,026**
RT2	299,30	66,93	397,80	136,87	**0,030**
L2	4,38	10,61	16,08	22,60	0,104
RT3	302,01	69,43	404,93	215,50	0,120
L3	6,19	15,27	11,77	21,11	0,433
RT4	313,11	98,98	397,78	175,02	0,138
L4	7,38	22,46	12,92	22,25	0,512

Latency – average sleep latency, VAS – visual analogue scale,
RT – reaction times, L – number of lapses

Tab. V *Comparison of the group with average sleep latency less than 8 minutes and the group with average sleep latency higher than or equal to 8 minutes.*

From these results a negative impact of increased sleepiness on psychomotor performance is obvious. Regarding the fact that the number of men and women in our cohort was almost equal, we did not take the sex of examined probands into account. As it is known, the reaction time is longer in case of older people when compared to younger ones [15, 16, 17]; therefore we also set the criterium of age.

No statistically significant difference in the age of compared groups has been found.

The results from comparing the group of the sleep latency lower than 8 minutes, and the group with the sleep latency higher than or equal to 8 minutes in the MSLT3 or MSLT4 are shown in Fig. 2 and 3 or 4 and 5. We can see a non-significant prolongation of a reaction time and increase in number of lapses in the group with the sleep latency shorter than 8 minutes – with proven excessive sleepiness.

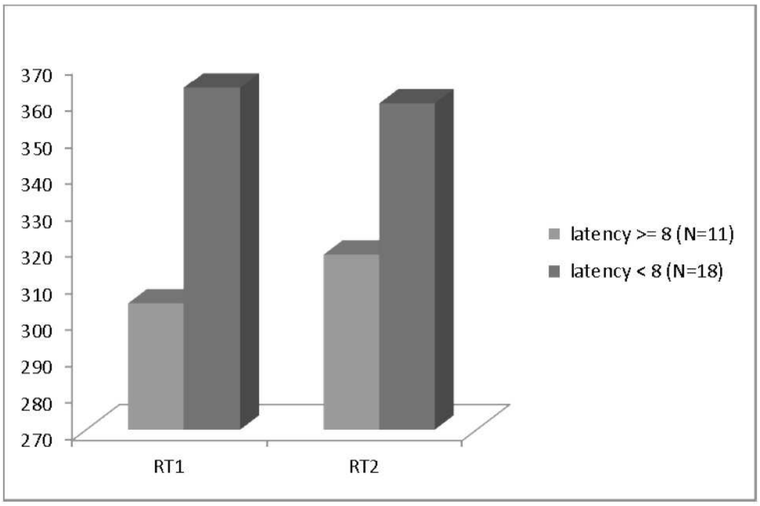

Fig. 2 *Difference of reaction times (RT) in the group with sleep latency less than 8 minutes and the group with sleep latency higher than or equal to 8 minutes.*

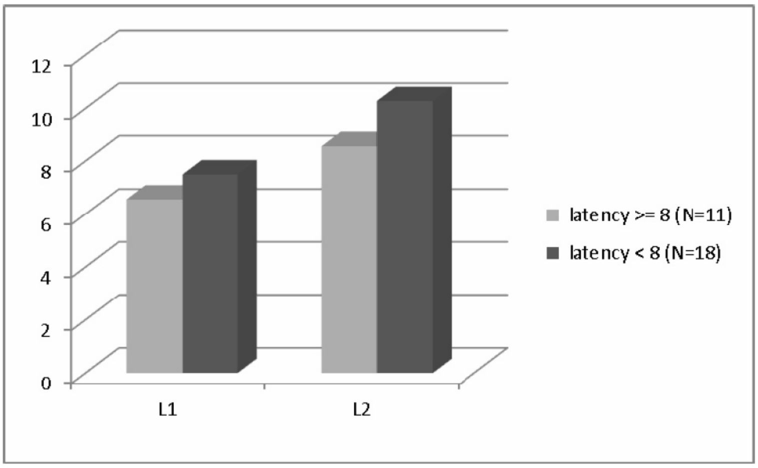

Fig. 3 *Difference in number of lapses (L) in the group with sleep latency less than 8 minutes and the group with sleep latency higher than or equal to 8 minutes.*

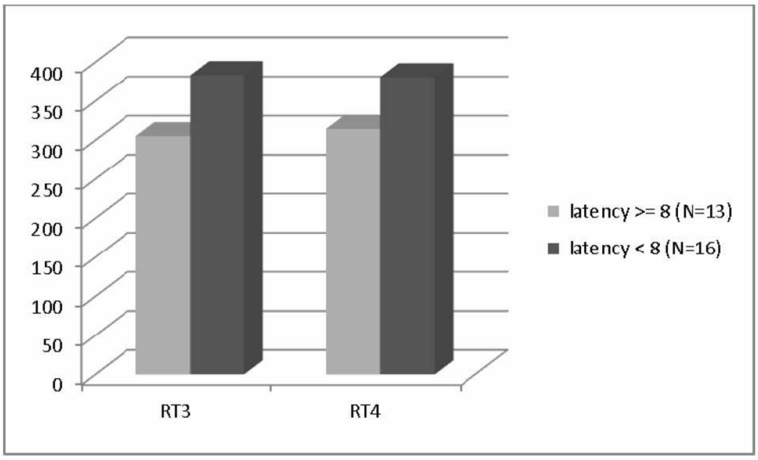

Fig. 4 *Difference of reaction times (RT) in the group with sleep latency less than 8 minutes and the group with sleep latency higher than or equal to 8 minutes.*

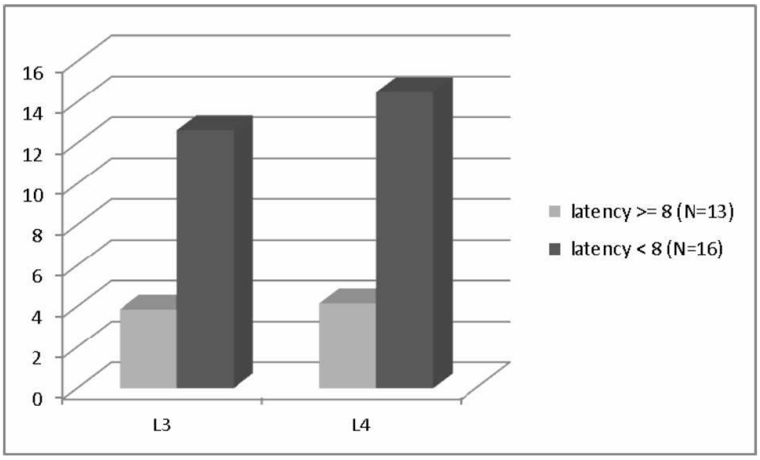

Fig. 5 *Difference in number of lapses (L) in the group with sleep latency less than 8 minutes and the group with sleep latency higher than or equal to 8 minutes.*

In Tab. V the subjective alertness visual analogue scale (VAS) is presented; the higher measured values indicate higher sleepiness felt by patients. The results mostly do not show the supposed higher sleepiness at the group with a shorter sleep in the MSLT. The difference between subjective and objective judgment of sleepiness shows insufficient ability to judge the rate of sleepiness and fatigue by the subject himself. This phenomenon might be very dangerous in case of drivers. The work that was also dealing with subjective evaluation of efficiency points out the fact that most young people do not sufficiently perceive and admit decrease in efficiency after sleep deprivation [18]. This is one fact that explains the increase in number of accidents dependent on sleep of young drivers.

We consider the judgment of the rate of decrease in psychomotor performance in the group of patients with excessive daytime sleepiness as a consequence of a sleep disorder to be of great importance. Therefore we carried out a comparison of performance in the PVT test in the group of patients and in the control group. The results in Tab. VI show that the prolonged reaction time and increase in number of lapses is significant in all examinations that were carried out in the group of patients when compared the control group.

	Patients	**N = 29**	**Control group**	**N = 6**	**Significancy**
	mean	**SD**	**mean**	**SD**	**p**
Age	43,97	16,44	56,33	11,84	0,057
Latency	9,50	5,23	11,48	3,19	0,246
RT1	341,07	114,16	266,16	35,03	**0,007**
L1	7,14	11,23	1,67	1,03	**0,015**
RT2	343,45	113,64	265,43	37,49	**0,006**
L2	9,62	17,72	0,67	0,52	**0,011**
RT3	348,15	158,74	256,30	33,41	**0,008**
L3	8,69	18,00	1,00	0,89	**0,030**
RT4	351,07	142,17	260,10	34,48	**0,005**
L4	9,86	22,14	1,00	1,26	**0,041**

Latency – average sleep latency, RT – reaction times, L – number of lapses

Tab. VI *Age, sleep latency and performance in the PVT test in the group of patients compared to the control group.*

The difference in age of these two compared groups does not query the proved results at all as the average age of the control group was higher. There has not been any statistically significant difference in the average sleep latency in the MSLT between both groups. From this we derive that for judgment of psychomotor performance (and indirectly of sleepiness), the PVT test examination is a more sensitive method than the MSLT examination.

Let the authors point out that out of 11 patients with excessive daytime sleepiness, 7 had a driving license. The worsened psychomotor performance of these patients proved by us can surely have a negative impact when driving a motor vehicle.

4. Conclusions

We have proved a statistically significant deterioration of the psychomotor performance of patients with a sleep disorder compared healthy controls.

Further, we also proved a negative influence of increased sleepiness on the psychomotor performance of people with excessive daytime sleepiness.

We did not prove that a short, 15 minute long sleep at 15 hours causes more prominent sleep inertia than a sleep at 13 hours in case of adults with excessive daytime sleepiness. Thus we conclude that from the point of view of a rate of sleep inertia, it is not important whether a patient takes a regenerative "nap" at 13 or 15 hours.

We showed that the PVT test examination is a more sensitive method than the MSLT examination for judging psychomotor performance and sleepiness of people.

From our study the questions worth further research arise: the influence of a longer regenerative sleep on psychomotor performance in the hours following after the sleep and on the risk of the rise of sleep inertia; development of sleep inertia after a day sleep after sleep deprivation.

We expect that after measuring more data on wider cohorts representing various parts of human population, which we would like to realize in the course of further research, a deeper statistical analysis could open us the way for verification of presented results.

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