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EFFECT OF DAY TIME NAPS ON PROBLEM SOLVING SKILLS: A POLYSOMNOGRAPHY BASED EVALUATION OF HEALTHY INDIVIDUALS.

Physiology

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ABSTRACT

Introduction- Sleep is vital to ensure normal human cognitive performance and cognitive enhancement. It has been found that not only sleep but even a short term nap can have some enhancing effect upon different aspect of cognitive performance of human brain. Present study is an attempt to assess whether sleep has any role in problem solving skills or not and if yes, which sleep stage is more involved in logical problem solving capabilities.

Material and Method- Sixty eight healthy volunteers of the age group 18 to 24 years of age from both sexes has been recruited for the study after due ethical clearance from the Institutional Ethical committee. As a test protocol, all the participants including both case and control group were given a standard set of SUDOKU with graded difficulty levels. Each group participants were given 10 min. to 12 min. for each level. All the sleep study parameters were recorded and comparison was made between control and test group whether they are able to solve the given task and whether any of sleep stages that is slow wave sleep and REM sleep have any role to play in problem solving abilities.

Results- Results showed that the test group volunteers have significantly better performance in the problem solving and completing the task in comparison to the control group individuals. Both slow wave sleep group individuals chi square value of 14.41 and P value of 0.0001) and REM sleep group individuals (chi square value of 8.988 and P value of 0.002) have shown significant difference when compared to the control group individuals for completion of task in time.

Conclusion- In this study it has been observed that day time nap causes significant improvement in the problem solving skill in the human subjects comparative to wakeful rest period. Both slow wave sleep as well as REM sleep during the day time nap has shown significant impact upon the uncompleted numerical logical tasks suggesting nap being a useful behavior for cognitive enhancement.

KEYWORDS

Sleep, Polysomnography, problem solving.

Introduction-

Sleep is a necessary phenomenon occurring in almost every living being. Human spends about one third of their lives in the sleeping state1. Sleep is a state of reduced consciousness and is a useful mechanism for physiological recreation and also for the consolidation of memory traces and acquisition of newly learned informations[2].

It is a state of the organism that differs fundamentally from the wake state with regard to the neurochemical milieu, brain activity patterns and mental states.

Sleep is vital to ensure normal human cognitive performance and cognitive enhancement. In other words sleep is one of the important components for amplification or extension of core capabilities of our mind that goes beyond normal healthy conditions3.

Lack of enough sleep may result in disturbance of various cognitive functions like attention, language, reasoning, decision making, learning and memory4.Sleep deprivation for even one or two nights may result in slowing of reaction time5, reduce focused attention6, increase perseveration7 , impair risk assessment8 and strategic planning and can deteriorate divergent thinking9 as well as language and communication skills. The largest amount of research on enhancing cognition during sleep, however, has focused on the domain of learning and memory. Memory is one of the most essential cognitive functions involved in almost all other cognitive processes. Our individual memories and our ability to learn new things are an integral part of our identity and influence our prospects of a successful and happy life. Considering that memory is of critical importance for individuals as well as for societies. Sleep plays a pivotal role in enhancement of memory learning and other cognitive functions.

Various earlier studies suggest that even a short term nap can have some enhancing effect upon different aspect of cognitive performance of human brain10.

Present study is an attempt to assess whether sleep has any role in problem solving skills or not and if yes, which sleep stage is more involved in logical problem solving capabilities.

MATERIAL AND METHODS:

Sixty eight healthy volunteers of the age group 18 to 24 years of age from both sexes has been recruited for the study after due ethical clearance from the Institutional Ethical committee (IEC no= IEC/AIIMS/PAT/191/2017) and well explained informed written consents. The volunteers included consenting MBBS and nursing students of the institute. Participants with history of any sleep disorder, history of neurological and psychiatric disorders, smoking and drug abuse, use of stimulant, depressor or hypnotic medication have been excluded from the study.

Participants were instructed to abstain from any food or beverage that contained caffeine 24 hours prior to the study. Out of all participants 31 participants were randomly assigned to the test group and 37 in control group.

The demographic data including age, sex, height, weight, BMI from all participants have been duly recorded after briefing them about the study protocol in short. They have also been made to fill a sleep scoring questionnaire known as Morningness Eveningness sleep score (MES), to assess about their basic sleep behavior and pattern. The MES questionnaire is meant for assessment of sleep pattern of participants whether they are more active in morning or evening. After recording the basic demographic details and sleep related information, the subjects were briefed about SUDOKU, a number game based upon logical thinking. They have been given few sets as trial to get them well acquainted with it prior to the actual test. As a test protocol, all the participants including both case and control group were given a standard set of SUDOKU with graded difficulty levels. Each group participants were given 10 min. to 12 min. for each level. When got stuck at certain level of difficulty in the SUDOKU the test group participants were allowed to take a nap whereas the other group (control group) participants were allowed to take wakeful rest. While sleeping complete polysomnographic recording have been done using SOMNOMEDICS 56 channel polysomnography instrument with a wireless sensor and software DOMINO (SOMNOSCREEN Ltd Germany). An impedance level of 1 kohm had been maintained for all the electrodes during the recording. The parameters recorded included EEG data from O1, O2, P3, P4, F3, F4, A1, A2, EOG1, EOG2, ECG

data from bipolar limb leads, chin movement, plethysmography, periodic leg movements and chest and abdomen movements. Blood pressure and pulse oximetry based oxygen saturation etc. The duration of Nap has been decided by the first spontaneous awakening of the participant after attaining stage 2 sleep. Any participant with nap duration of less than 20 minute or unable to sleep after trying for half an hour has been removed from the study. The timing for the recording has been the post lunch 1 PM to 4 PM and has been kept uniform for all. After spontaneous awakening (among test group) or wakeful rest for one hour, the participants have been given the same set of SUDOKU at same level where they got stuck earlier and responses were checked whether the particular level (task) has been completed successfully (Solvers)) or not(Non-solvers). The statistical analysis has been done using graph Pad Prism (ver. 7)

RESULTS:

TABLE1-DEMOGRAPHIC DATA OF SUBJECTS-

S. NO.	PARAMETERS	CONTROL GROUP(MEAN AND STD.	TEST(SLEEP) GROUP(MEAN AND STD. DEVIATION)	P VALUE
1.	NUMBER OF PARTCIPANTS	36	31	
2.	AGE	20.08(1.795)	20.42(1.409)	P = 0.3972
3.	HIGHT	165(10.56)	165.1(11.1)	P = 0.9701
4.	WEIGHT	55.01(10.450)	55.96(11.2)	P = 0.7208
5.	BMI	20.59(4.01)	20.49(3.371)	P = 0.9132

Table 1 shows the demographic details of the volunteers participating in the study. Out of 37 participants in the control group 16 were female whereas 21 were male participants. Among the test group participants 14 were female and 17 were male.

All the relevant parameter including age height and weight including calculated BMI were well matched and there was no any significant difference between the control group and test group individuals on these parameters.

The MES shows equal distribution of sleep pattern with a score range of 31 to 81 for all the participants. Mean value for test group participants was found 61.52+15.26 and for control group mean value 63.11+15.13.

Difference was found to be not significant statistically (p value is 0.6706).

TABLE2- SLEEP PROFILE OF TEST(SLEEP) GROUP SUBJECTS-

S.NO.	SLEEP PARAMETERS	MEAN VALUE	STD. DEVIATION
1.	TST(MIN)	59.66	31.61
2.	LATENCY(MIN)	61.49	33.01
3.	S.EFFIENCY(%)	35.01	18.5
4.	REM	15.5	13.69
5.	REM(%TST)	27.05	21.58
6.	N1	10.06	11.58
7.	N1(%TST)	14.97	9.088
8.	N2	20.53	14.64
9.	N2(%TST)	38.81	22.87
10.	N3	2.715	3.318
11.	N3(%TST)	4.616	5.076
12.	N4	8.477	11.97
13.	N4(%TST)	12.7	16
14.	N3+N4	21.92	22.46

Table 2 shows the detailed sleep profile of the test subjects. The parameters include total sleep time, sleep efficiency, sleep latency, average duration of different sleep stages etc. Total mean sleep time recorded was 59.66 + 31.6 Min. with a mean latency of 61.49 + 33.01 min.

STASTISTICALANALYSIS-

TABLE3A- COMPARISION OF TEST GROUP(SLEEP) PERFORMANCE WITH CONTROL GROUP(AWAKE) CONTINGENCY TABLE-

PERFORMANCE	CONTROL GROUP(AWAKE)	TEST GROUP(SLEEP)
DONE	6	16
NOT DONE	31	15

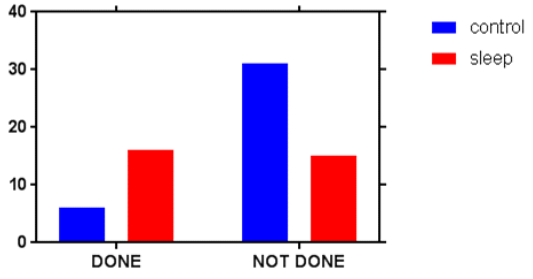
Table 3A shows the comparison of participants of both groups who solved (Solvers) the particular task (SUDOKU) and those who did not solved (Non-solvers).

TABLE 3B- COMPARISION OF PERFORMANCES OF CONTROL GROUP WITH SLOW WAVE SLEEP GROUP- CONTINGENCY TABLE-

PERFORMANCE	CONTROL GROUP(AWAKE)	SLOW WAVE SLEEP GROUP
DONE	6	13
NOT DONE	31	5

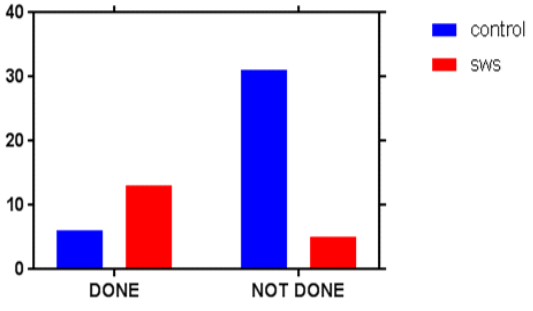
In control group participants out of 37, only 6 were able to solve the given task, rest 31 were not where as in test group participants, out of 31, 16 completed the task, while 15 were not (see image 1).

IMAGE 1- COMPARISION OF PERFORMANCES OF SUDOKU BETWEEN CONTROL(AWAKE) AND TEST(SLEEP) GROUP.



On further comparison (see table 3B) of solvers and non-solvers of control group with that of slow wave sleep group(participants who attained slow wave sleep) 13 out of 18 participants who could attain slow wave sleep have completed the task successfully while 5 of them could not complete the task (image 2).

IMAGE 2- COMPARISION OF PERFORMANCES OF SUDOKU BETWEEN CONTROL(AWAKE) AND SLOW WAVE SLEEP GROUP PARTICIPANTS. GROUP.



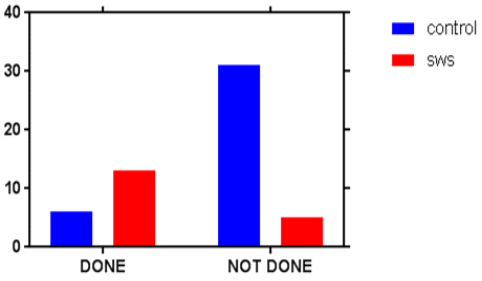
When a comparison has been made between the control group participants to those who attained REM sleep (see table 3C).

TABLE 3C- COMPARISION OF PERFORMANCES OF CONTROL GROUP WITH REM SLEEP GROUP- CONTINGENCY TABLE-

PERFORMANCE	CONTROL GROUP(AWAKE)	REM SLEEP GROUP
DONE	6	13
NOT DONE	31	12

it has been observed that out of 25 participants who could attain REM sleep during the study, 13 were able to complete the task successfully whereas 12 could not finish the task (image 3).

IMAGE 3- COMPARISION OF PERFORMANCES OF SUDOKU BETWEEN CONTROL(AWAKE) AND SLOW WAVE SLEEP GROUP PARTICIPANTS. GROUP.



Further statistical analysis using Chi squire test (table 4) it is evident that the test group volunteers have shown significantly better performance (p= 0.001 with a chi squire value of 9.65) in the problem solving and completing the task in comparison to the control group individuals. Similarly both slow wave sleep group individuals chi square value of 14.41 and P value of 0.0001) and REM sleep group individuals (chi square value of 8.988 and P value of 0.002) have shown significant difference when compared to the control group individuals for completion of task in time.

TABLE 4- RESULTS OF CONTINGENCY TABLES 3A, 3B AND 3C.

PERFORMANCE	CHI SQUARE VALUE	P VALUE	STATISTICAL SIGNIFICANCE
CONTROL VS SLEEP GROUP	9.656	0.0019	YES(**)
CONTROL VS SLOW WAVE SLEEP GROUP	14.41	0.0001	YES(***)
CONTROL VS REM SLEEP GROUP	8.988	0.0027	YES(**)

DISCUSSION-

Present study focused on the role of sleep in logical problem solving skills. Sleep and its relevance to health and disease has been always been a point of curiosity for human beings. Sleep is the basic property of every living being. It is the necessity of life. As per present knowledge is one of the essential element of homeostatic drive to maintain the normal metabolic state and energy balance of human body[11].

Recent studies suggest that sleep has some role to play in the cognitive enhancement of human brain. In one of the studies role of sleep has been implicated in the fine motor skill enhancement among artists12.
In the present study it has been observed that a short term nap has got a statistically significant positive impact upon the problem solving skills of an individual. The relation is equally valid for the slow wave sleep and REM sleep conditions. As most of the time REM only follows the slow wave sleep during a sleep cycle, to study and compare REM group with slow wave group individuals was not possible practically.

Though we have also observed that subjects who achieved slow wave sleep of any duration were better performer as compared to the subjects who were in REM sleep without achieving slow wave sleep, though the sample size was not enough to make the observation significant. The observations are consistent with the earlier findings by Mednick et al (2003)13. The observations made by them emphasized that brief (60–90 min) naps of 60-90 min duration containing both slow-wave sleep (SWS) and rapid eye movement (REM) sleep have similar impact as that of an standard 8 Hr. sleep on the sleep associate learning in terms of magnitude, sleep-stage dependency and retinotopic specificity. The study suggested that from the perspective of behavioral improvement, a nap is as good as a night of sleep for learning on this perceptual task13. But in contrary to the observation made in the present study Cai and colleagues made an observation in their study on remote association task that subjects engaged in REM sleep were better performer in comparison to the slow wave sleep[14].

It has also been reported that slow wave sleep helps in strengthening of hippocampal dependent memory consolidation15. Sudoku is a number game involving logical cognitive skills16 and attention17, depending on hippocampal memory, suggesting role of slow wave sleep in such kinds of problem solving.

A study conducted by Li and weed on insomnia patients showed that patients who did not attained slow wave sleep had poor attention16. Hippocampal replay of memory traces and role of sleep specific oscillations like slow wave oscillations, hippocampal ripples and spindle, have been suggested as specific feature which takes place only while sleeping or napping, and not during awake state. Earlier studies suggests that hippocampal activation owing to slow wave sleep results in sequential replay of learned activities which is probably responsible for the cognitive enhancement18,19. Subsequent studies also suggests that similar activation of serial replay of memory traces in the awake state do also occurs while performing the navigation and procedural serial reaction time task but the brain area principally involved in such cases are mainly the ventral striatum, visual cortex and prefrontal cortex of the human brain20.21.22.23. This activation also enhances learning and memory in analogous way24. Similar activation of brain areas using reminder cues are also known as "targeted memory reactivation"[25].

Mander et al (2011) also proposed that even a nap can foster acquisition and encoding of new memory traces as suggested in the present study too26. Day time nap has also been proposed to be associated with language skills in some of the studies[27].

Recently it has been proposed that Neocortical slow oscillations, thalamo-cortical spindles and hippocampal ripples are the hallmark oscillations of slow wave sleep that are associated with memory processing. The Hippocampal ripples and spindles occurs mainly during upbeat of slow oscillations, representative of cross talk between neocortex and hippocampus responsible for memory consolidation.

Despite above observations the exact neurophysiological mechanism behind this reactivation of memory following sleep/nap is yet to be understood completely.

Conclusion- Present study aimed to study the effect of day time nap on the problem solving skill of human being. In this study it has been observed that day time nap causes significant improvement in the problem solving skill in the human subjects comparative to wakeful rest period. Both slow wave sleep as well as REM sleep during the day time nap has shown significant impact upon the uncompleted numerical logical tasks suggesting nap being a useful behavior for cognitive enhancement.

Novelty of the study-

Usually nap has got a negative psycho-social stigma and is unacceptable in most of the circumstances especially at work places. The study has attempted to throw some light over its potential usefulness in the cognitive task performance enhancement. Further study with bigger data base could be more conclusive.

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