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ORIGINAL ARTICLE

The Effects of 24-Hour Sleep Deprivation on Cognitive and Motor Skills of Male College Students

[1]Iman Ghanbari, [1]Hamid Reza Taheri*, [1]Mahdi Sohrabi
[1]Faculty of Sport Science, Ferdowsi University of Mashhad, Mashhad, Iran.

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ABSTRACT

Background. Sleep is assumed to be a critical factor for human physiological and cognitive function. Lack of sleep is a common condition in daily life. **Objectives.** The purpose of this study was to evaluate the effects of 24-hour sleep deprivation on cognitive and motor skills in university students**. Methods.** The participants were volunteers that consisted of 290 male students aged 19-25 years. After primary screening, the subjects were randomly divided into two groups of cognitive tests and motor task test. Cognitive tests were included the reaction time (simple and choice), the working memory test (1-back & 2-back task) and attention (selective and divided). In the motor group, the subjects were divided into four experimental groups including (physical, observational, mental and combined training) and four paired control groups who were exposed to badminton short service training. The experimental groups were trained with 24-h sleep deprivation and the control group was trained without sleep deprivation. In the acquisition stage, each subject was trained using his routine training method. After training, the subjects were followed a normal day-night sleep pattern. At 24, 72 and 168 h after acquisition, a short-service retention test was taken from participants. **Results.** The results of cognitive tests showed that sleep deprivation had no effect on reaction time, working memory (1-back) and selective attention, but it had a major effect on working memory (2-back) and divided attention (p=0.02). The results of motor test showed that sleep deprivation did not have an effect on acquisition and retention in both physical and combined groups. (p>0.05).Sleep deprivation did not have an effect on the skill acquisition in the observation group (p>0.05); however, in the retention tests, the control group significantly showed a better performance. Skill acquisition in the mental training group was significantly affected by sleep deprivation and this effect was obvious in the retention tests (p=0.0001). **Conclusion.** The results showed that, under conditions of sleep deprivation, some cognitive functions (working memory 2-back test & divided attention) were affected and that physical and combined training were preferred at the time of training to acquire new motor skills.

KEY WORDS: ***Cognitive Function, Physical Training, Observational Training, Mental Training, Combined Training, Sleep Deprivation.***

INTRODUCTION

Sleep is assumed to be a critical factor for human physiological and cognitive function (1). Lack of sleep is a common condition in everyday life (2). Unfortunately, not everyone receives adequate amounts of sleep in order to function properly throughout the day. These poor performances as a result of poor sleep quality and sleep deprivation is especially evident among college students. Since college students have such busy work, school, and social schedules to keep up with, their sleep cycles become negatively affected by it. They tend to have irregular sleep-cycles depending on the day of the week and

*. Corresponding Author:
Hamid Reza Taheri, Professor,
PO.Box: 9177948979, Department of Motor Behavior, Faculty of Sport Science, Ferdowsi University of Mashhad, Mashhad, Iran.
E-mail: hamidtaheri@um.ac.ir

report dissatisfaction with sleep as a result of poor sleep quality (3).

In an effort to understand the function of sleep, researchers predominately study the effects of sleep deprivation (SD) (4). SD can affect both cognitive functions and motor tasks (5). The most important cognitive functions include reaction time (RT), work memory (WM) and attention. In most studies, investigations mainly focused on cognitive task and in a single session, without any discussion of process and stage of learning. In these studies, the negative effects of SD have been shown on learning-related functions such arousal (6), memory (7), selective attention and constant attention (8). The relationship between attention and memory and their effects on motor learning have been indicated in some researches (9). Some other researchers have indicated the negative effect of SD on hippocampus-dependent learning (10, 11), reaction time (8, 12-14), and visual-motor sequence learning (15). However, there are also studies that did not show this effect(show conflicting results) (1, 16).

The most effective methods of practice skills can be physical practice, mental practice, and observational practice. However, physical practice is considered as the most basic method of learning a skill (17), observation of a model and mental imagery can facilitate learning a wide range of behavior (18). Observational learning represents a crucial adaptation strategy in different real-life situations. Indeed, an observer does not physically practice the task and consequently he or she does not risk injury or expend the same amount of energy as a practitioner during learning (19).Mental practice is a dynamic state in which the subject evokes an imaginary representation of a motor action or skill in order to learn or perfect that action(20). MP is a cognitive strategy procedure based on extensively repeated motor imagery tasks, which can enhance the acquisition of motor ability and functional performance, without physical execution of movements (21). Both motor imagery and action observation have been shown to play a role in learning or re-learning motor tasks (22).

Evidence from some neurophysiology as well as psychophysical and Electromyography (EMG) work suggests that physical, observational, and mental learning might share common neural substrates (23), But recent researches often consider different neural structures for a variety types of practices (24).On the other hand, some scholars believe that the learning processes of observation and mental practice are more cognitive processes, and learning occurs under these two practice conditions more explicitly; But the person engages in a motor process with physical practice, and learning will happen more implicitly (25, 26).

However, when we talk about the learning process, we need to divide it into two stages of acquiring motor skill and stabilizing it over time (27). It has been shown that following an effective acquisition of skill at the acquisition stage, the occurrence of a memory representation induces the necessary adjustments during the detraining period, which is referred to the process of consolidation of memory (28). In fact, memory consolidation is stabilization of memory trace that occurs during the acquisition phase. This leads to increased stability against interventions and even tangible progress in execution, after a period of detraining (29). Classically, the term memory consolidation refers to a process whereby a memory becomes increasingly resistant to interference from competing or disrupting factors in the absence of further practice, through the passage of time (30). This process is defined as time dependence and sleep dependence (31). Sleep-dependent consolidation refers to the fact that consolidation is greatest over sleep, compared to wake, for most tasks (32). Accordingly, Whereas SD prior to learning may particularly reduce acquisition and impairs the memory encoding phase, post-learning SD seems to impair memory formation (11, 33, 34). So it seems that because of SD before training, effective acquisition doesn't happen during the training and in fact the main characteristics of skill are not acquired, even after a full sleep period, one should not expect the consolidation of motor memory and therefore motor learning.

It seems that in investigation the effect of SD on learning, the stage of learning (acquisition or retention) that a person is on it has very important. The researchers, by testing on tasks that required communication learning indicated that over time, the storage site from the cerebellum cortex is transferred to the cerebellum core, and then it may be transferred to another location outside the cerebellum (35). However, in some complex motor tasks, it was shown using rTMS, although the acquisition of the task at the acquisition stage is dependent on the primary motor cortex, its reminder and retention depends on the different nervous systems (36). Therefore, regardless of the type of function or task, an agent that disturbs the acquisition of the task at the acquisition stage, targets a different neurological position and mechanism relative to the other factor that impairs its retention and consolidation.

Generally, regarding that it has been shown that the process of learning under physical training differs from observational and mental training, it is possible that SD has a different effect on these three types of training or a combination of them and in situations where we have to endure SD guideline us to the best way. On the other hand, the functions studied in the past studies are often cognitive, that we have also used it as a pilot in the present study. However, some researchers believe that positions and neuronal mechanisms controlling the process of learning cognitive tasks are different from the neuronal mechanisms associated with the learning process of different motor tasks (37). In the laboratory setting, a variety of performance tasks have been shown to be affected by sleep deprivation(13); therefore, necessity of this research is to investigate the effect of SD on a motor skill that is applicable in real life and that There has been no research in relation to different types of learning and SD until today.

Also, considering that the effect of SD before training on acquisition is different from the effect of SD on retention (38), and has not been addressed in previous studies, this study intends by a special protocol investigate the process of susceptibility of the various stages of learning under different training methods from SD.

So, the objectives of this study was to assess the effect of sleep deprivation on reaction time, working memory and attention; and the effect of sleep deprivation before physical, mental, observational and combined training on the acquisition and retention of badminton short service skill.

MATERIALS AND METHODS

Participants. The statistical population of this study was male students of the Islamic Azad University of Babol branch, Iran. The participants were volunteers who were 290 male students aged 19-25 years. Student volunteers were asked for initial investigations. Students whose right hand (Edinburgh Handedness Questionnaire (39), who had got normal or normalized vision (Snellen Eye Chart), had no history of health problems, neurological diseases, psychiatric illnesses, behavioral and motor problems, cardiovascular diseases, and epilepsy, and did not take illegal drugs or CNS stimulants (more than 15 cigarettes a day, more than 6 cups of coffee a day, and more than 50 grams of alcohol a day) were allowed to continue participating in the present research. The selected participants then completed the Morningness - Eveningness Questionnaire (40), and only those with scores ranging between 42 and 58 (i.e., neither morning nor evening types) were included in the study.

The general health of the subjects was evaluated by 28 questionnaire of the General Health Questionnaire, and subjects who scored above 6 in each of the scales, and a total score of 22, due to the symptoms of the disease, removed from work (41). Participants recorded the Pittsburgh Sleep Quality Index in order to assess quality and quantity of their sleep during the past week. Only the volunteers remained who obtained a regular sleeping program based on this indicator (42). All methods used in the study were approved by the Ethics Committee Ferdowsi University of Mashhad. IR.MUM.FUM.REC.1396.17

Research Design. After initial screening, the Subjects were randomly assigned into two groups of cognitive tests and motor task test.

Procedure. Cognitive group test: After this initial screening, 58 students remained who were randomly divided into experimental (n=26) and control (n=32) groups. Cognitive tests included the reaction time (simple and choice), the working memory test (n=1, n=2) and attention (Selective and Divided). The Advanced Reaction timer test, the Working memory n-back test and the Selective and Divided attention test of Sina's Cognitive Behavioral Sciences Research Institute was used. All the used tests had face validity and acceptable test-retest reliability (43).

Motor task test: After this initial screening, 64 students remained who were randomly divided into 8 groups. In regard to the individual imagery abilities, subjects also filled out a recent revised version of the Vividness of Movement Imagery Questionnaire (VMIQ-2) to determine (on a 5-point scale) the clarity with which they were able to imagine movements and especially the difference between their capacity to use internal and external visual imagery (44). Participants were divided homogeneously into one of these eight groups according to their score in the questionnaire. After selecting the subjects and obtaining the requirements of inclusion in the study, according to necessary criteria, the research process was explained, their written consent was obtained, and information about personal specifications (name, age, weight, height and athletic background) was collected. During the entire experimental period, the mean ambient temperature and relative humidity of the Gymnasium were kept stable (20.5± 2.1 °C and 56.3 ± 11.6%, respectively). They were prescribed standard isocaloric meals to consume with breakfast at 08:15 h, lunch at 12:30 h, and dinner at 20:30 h. Only water was allowed between meals. During the period of the investigation, caffeinated or alcoholic substances were proscribed. All subjects signed an informed written consent form before participation.

Short badminton serve is the required task of this research that is hit at a particular point of the court. Its scoring method is based on French Short Serve Test applied in previous papers. In this test, the subject hits a short badminton serve 20 times consecutively or in two series of 10. The subject's final score is calculated through adding the score of 20-time repetitions of serves (45).

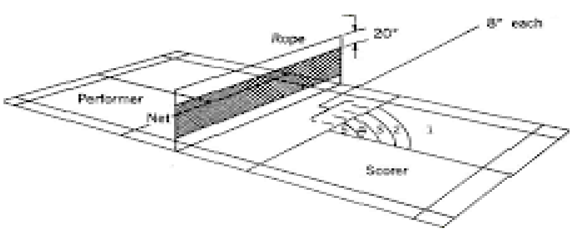

Figure 1. *Court Markings in French Short-Serve Test.*

In the acquisition stage, individuals practiced 60 training attempts in 3 blocks of 20, so that each group practiced on the basis of their training, and between each block had two minutes rest. At this stage, after a few explanations and a limited presentation by the expert (3 times), the physically group individuals trained skills physically and the observation group individuals, viewed training of expert and mental training group trained skills mentally, and individuals of the combined group in each block randomly used one of the training. For evaluation in the process of retention the individuals again made 20 attempts physically.

The subjects were divided into four experimental groups (physical, observational, mental and combined training) and four paired control groups. Groups are:

1. Experimental group 1: sleep deprivation-physically training (SD-PHY)
2. Experimental group 2: sleep deprivation-observational training (SD-OB)
3. Experimental group 3: sleep deprivation-mental training (SD-MEN)
4. Experimental group 4: sleep deprivation-combined training (SD_COM)
5. Control group 1:control- physically training (CON-PHY) that trained physically, without suffering from sleep deprivation.
6. Control group 2: control- Observation training (CON-OB) that trained Observation, without suffering from sleep deprivation.
7. Control group 3: control- mental training (CON-MEN) that trained mental, without suffering from sleep deprivation.
8. Control group 4: control- combined (CON-COM) that trained combined, without suffering from sleep deprivation.

4 experimental groups from 8 am on Thursday attended in the sports complex of the university, and without any sleeping during the day, performed their daily normal activities. At 8 pm and after eating dinner, the subjects during SD night, allowed to do only perform non-violent activities such as watching video, talking, working with electronic equipment, academic activities, reading books, reading newspapers, or playing chess. From 8 am on Friday, experimental groups in four distinct groups learned about Badminton's short service. They were totally awake within these 24 hours and completely under the control of the examiner's orders.

After the training, the subjects had the usual day-night (Sleeping from 11 pm to 7 am) sleep during the following days, so that 24, 72, and 168 hours after the acquisition, Badminton's short-service retention test was taken.

Statistical analysis. In order to analyze the scores of Pittsburgh Sleep Quality Index, a one-way ANOVA was applied. Furthermore, in order to analyze the data on participants' performance in French Test at the acquisition stage, a two-way ANOVA with 4 practice types (Physical, Observational, Mental and Combined) × 2 sleep types (normal and SD) was used. In order to analyze the data in retention tests, a mixed-model ANOVA with 4 practice types × 2 sleep types × 3 (retention tests) was applied.

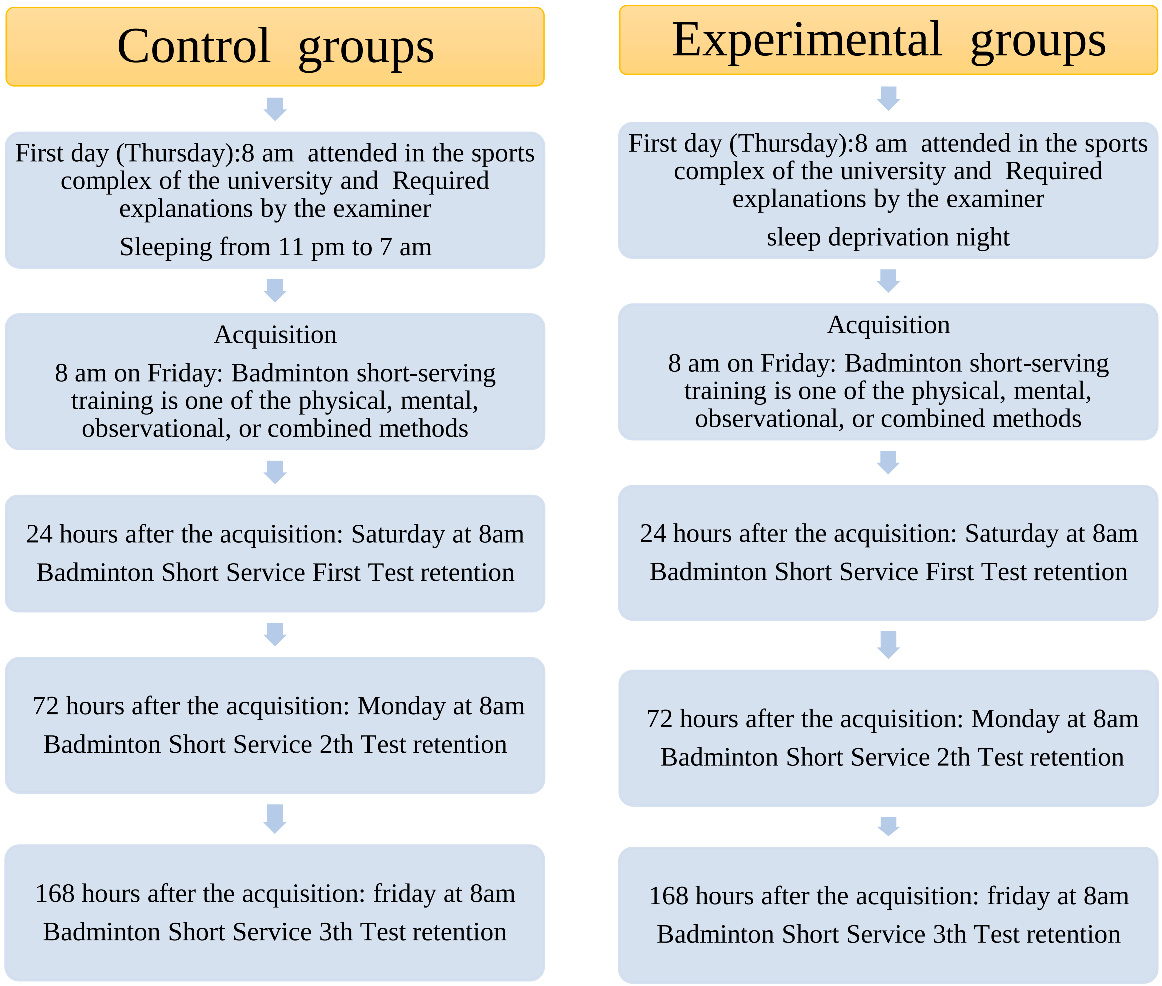

Figure 2. *Schematic of Motor Training design*.

RESULTS

Cognitive Function Tests. Univariate analysis of variance show that SD no affected on simple Reaction Time, choice Reaction Time, Working Memory 1-back and selective Attention ($p>0.05$) and significantly impairs in Working Memory 2-back and divided Attention ($p<0.05$).

Motor Task Test. The results of ANOVA Test for Sleep Quality Index indicated that there is no significant difference between the groups ($F<1$). Figure 3 indicates the diagram of groups' performance at different stages.

Analysis of the One-Way ANOVA in different types of training in the acquisition and retention tests is presented in the table 2.

The results of ANOVA Test for the acquisition stage indicated that the main effect of practice type, were significant, however, the interactive effect of these factors was not significant ($p=0.0001$). Bonferroni Post-Hoc Test indicated that physical practice group was significantly different from other groups except for combined practice group ($p<0.05$). Furthermore, combined practice group was significantly different from observational group and mental practice group ($p<0.05$). However, there were no significant differences between observational group and mental practice as well as physical and combined practice groups ($p>0.05$). The comparison between means indicated that at the acquisition stage, combined group and physical practice group performed better than the imagery group and observational learning group.

Table 1. Descriptive statistics of Cognitive function tests

variable	kind	Pre/Post test	group	Mean	Std. Deviation
Reaction Time	Simple	Pre	EXP.	254.41	39.47
			CON.	284.48	43.16
		Post	EXP.	272.03	50.00
			CON.	272.44	31.10
	Choice	Pre	EXP.	406.82	63.84
			CON.	399.16	62.17
		Post	EXP.	409.46	77.28
			CON.	374.85	66.77
Working Memory (n-back)	N=1	Pre	EXP.	101.00	18.72
			CON.	104.06	8.70
		Post	EXP.	104.88	15.45
			CON.	109.35	3.91
	N=2	Pre	EXP.	72.46	22.09
			CON.	68.75	10.56
		Post	EXP.	73.42	27.47
			CON.	81.31	12.19
Attention	Selective	Pre	EXP.	156.84	17.34
			CON.	157.00	4.75
		Post	EXP.	160.08	6.47
			CON.	158.56	4.91
	Divided	Pre	EXP.	130.76	18.22
			CON.	108.71	6.47
		Post	EXP.	127.73	21.19
			CON.	115.63	4.42

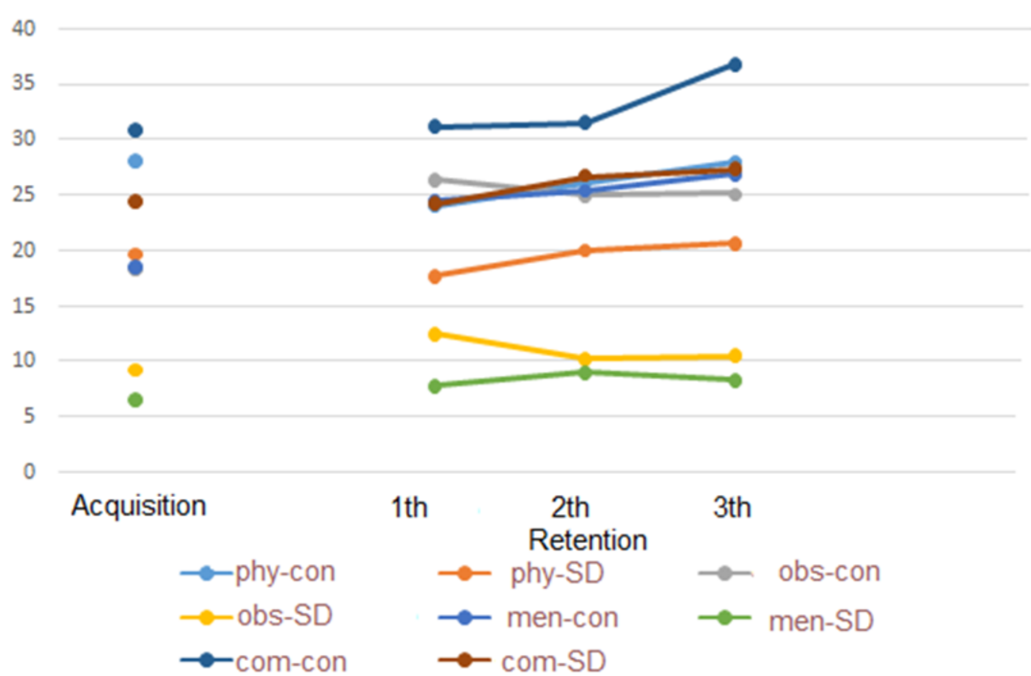

Figure 3. *Diagram of groups' performance at different stages*. **phy-con:** Physical Control, **phy-SD:** Physical Sleep Deprivation, **obs-con:** Observational Control, **obs- SD:** Observational Sleep Deprivation, **men-con:** Mental Control, **men-SD:** Mental Sleep Deprivation, **com-con:** Combined Control, **com-SD:** Combined Sleep Deprivation,

Table 2. Analysis of the One-Way ANOVA in different types of training in the acquisition and retention tests

Group	Stage	Mean difference	Std. Error	Sig.
Physical & Physical Control	Acq.	-8.375	3.097	0.254
	Ret. 1	-6.250	3.189	0.999
	Ret. 2	-6.000	2.643	0.759
	Ret.3	-7.250	3.052	0.588
Observational & Observational Control	Acq.	-9.125	0.097	0.131
	Ret. 1	-14.000	3.189	0.001*
	Ret. 2	-14.750	2.643	0.001*
	Ret.3	-14.625	3.052	0.001*
Mental & Mental Control	Acq.	-11.875	3.097	0.009*
	Ret. 1	-16.750	3.189	0.001*
	Ret. 2	-16.375	2.643	0.001*
	Ret.3	-18.625	3.052	0.001*
Combined & Combined Control	Acq.	-6.625	3.097	0.999
	Ret. 1	-7.000	3.189	0.906
	Ret. 2	-4.875	2.643	0.999
	Ret.3	-9.500	3.052	0.082

Acq: Acquisition, **Ret:** Retention

The results of ANOVA Test for the retention stage indicated that the main effect of practice type, were significant (p=0.0001).

Bonferroni Post-Hoc Test, indicated that there is no significant difference between imagery group and observational learning group (p>0.05), while other differences between groups were significant (p<0.05). The comparison between means indicated that combined group has performed better than other groups. Furthermore, physical practice group had performed better than the imagery group and observational learning group.

Regarding the interactive effect of practice type on sleep type, post-hoc test was conducted and its results indicated that in normal sleep conditions, only combined practice group was significantly different from other groups(p<0.05). However, there was no significant difference between other three groups (p>0.05). In SD conditions, the difference between all groups was significant (p<0.05). In all these conditions, combined group performed better than other groups.

Regarding the main effect of test stages, Bonferroni Post-Hoc Test was conducted and its results indicated that the third retention test was significantly different from two other tests (p<0.05). According to the comparison of means, groups performed better in the third retention than in the first and second retentions. Regarding the interactive effect of practice type in test stages, post-hoc test was conducted and its results indicated that groups have performed better in the third retention test than in two other retention tests only in combined and physical practice groups (p<0.05). However, in observational and mental groups, no differences were observed between the third retention test and two other retention tests (p>0.05).

In all groups, subjects that with normal sleep have performed better than subjects who have experience SD. In groups who had experienced SD, both combined group and physical practice group had performed better than two other groups (p<0.05).

DISCUSSION

The purpose of this study was to investigate the effects of 24-hour SD on cognitive and motor skills in university students. In other words, SD how affects to cognitive functions and the acquirer of a motion model through a variety of training methods and, consequently, consolidation and stabilization of that pattern? In fact, the researchers sought to answer the question that if the instructor is in a situation where he has to wake up at night before training, it is better to use what kind of training method that has the highest efficiency.

The fact that SD cannot affect some of the cognitive functions may be due to that the efficiency of alerting and orienting network remains nearly unaltered (46). The excitation of the body's organism that enters a state of defense rather than SD. The effect of SD on more complex functions may be different.

Regard to motor task, since the present research is fundamental to some extent and there are almost no similar researches on this field, furthermore, conducting such a research due to its novelty is one of the requirements of the present study, thus congruent and incongruent papers are not included in this research in order to avoid misleading the readers.

Comparison of the results of the physical training groups with the related control group showed that 24 hour SD did not disrupt the function of this group in the acquisition stage (table 2). These results indicate that the acquisition of the desired skill pattern was well done with physical training. As previously mentioned, SD prior to training may disrupt skill acquisition and memory coding, so if effective skill acquisition does not take place, a memory representation during the detraining period will not take place, and thus the consolidation of motor memory will not be induced (29). A look at Figure3 shows that since the acquisition of a skill pattern has been well done, it has also been consolidated by the passage of time and sleep, so that the performance of individuals has improved in the test of retention.

It seems that one of the reasons for not affecting SD on physical training is the type of task used in this research. Badminton's short service is a skill that does not require the use of such a physical force, and since past research has shown, even several hours of SD cannot affect the motor performance, as well as researches have shown that during the skill physical training, learning and acquiring a pattern happen implicit (that's mean one does not need attention and concentration to acquire a pattern), perhaps the results of physical group is reasonable. On the other hand, it has been shown that the greater the complexity of the skill, the effect of deprivation of sleep will be more (47, 48); Badminton short service skill is not very complicated, therefore, the effect of deprivation of sleep from this vision may be logical. In other words, if we considered a more complex skill for this research, a different result might have been achieved.

In the case of the mental training group, the results indicate a significant impact of SD on both the acquisition and the retention of Badminton's short service skill. Therefore, it is natural that lack of effective acquisition of skill, has no proper consolidation of motion memory, and therefore retention not performed appropriately. It is also worth pointing out that mental imagery is a special ability that needs more focuses and attention, which depends on the imagery ability of individuals (49). Accordingly, in this study, a new version of the motor imagery (VMIQ-2) were used to assess the subjects' imagery capability. Therefore, it seems natural that due to SD there is no proper attention and focus on the image of appropriate pattern of movement and its preservation in the mind, which may lead to a lack of proper acquisition of the motor pattern and consequently lack of proper consolidation (Figure 3).

The results of the observation training seem a bit odd, because it shows that, although SD has not affected the acquisition of this group, it has greatly affected the retention of these people at subsequent stages of retention. What is the reason for the lack of consolidation and, consequently, the lack of retention? To answer the question, it might be possible to use the statements of Scully and Newell (50). The researchers stated that through a pure observation training of a dynamic pattern, only the aspects of motor coordination of the body members in relation to the whole body are obtained and the invariant features of movement cannot be easily achieved through observation, and physical training is required. With this interpretation, it can be concluded that both the observational training group and the related control group have not completed their acquisition process through observational training, and therefore, there is no significant difference in the acquisition test. On the other hand, according to Bandura's social learning theory, when one observes a model, translates the observed movement information to memory symbolic cods, and these cods are the basis of a mental image in memory. The memory image is then used as a guide for implementing the skill and criterion for detecting and correcting errors (Bandura, 1977). As understandable from Bandura definition, observational learning is a continuous process that is complemented by obvious cognitive analyzes. Therefore, it seems that after an observation training, both the experimental and control groups have learned the skills similarly, but after the acquisition test, the experimental group, due to the fatigue of awakening in the last 24 hours suffering from lack of attention and concentration and does not enter into cognitive processes and Intelligence analysis. Perhaps this matter would have deteriorate the experimental group than the control group, and consequently, in the next stages, consolidation and retention would not occur properly.

The effect of SD on the combined training group was similar to the effect of SD on the physical training group. In other words, the acquisition of the desired skill model with combined skill training was well done. As mentioned before, and looking at Figure3, it can be seen that with the combined training the skill pattern has been well acquired, and as a result, consolidation has also taken. The main reasons that combined training has good results in acquiring skills include: combined training has advantages of all three methods of training, and on the other hand, this kind of training is interesting for learners, and this increases awareness and motivation and decreased fatigue than other training methods.

The present research has limitations that include: First limitation is the lack of measured task motivation and/or interest. A second study limitation is the lack of objective measures verifying compliance with sleep duration and sleep-wake times (e.g. actigraphy, polysomnography), as well as sleep deprivation.

At the acquisition stage, after three training blocks, each participant performs 20 services physically to evaluate the performance of all groups, that the execution can physically affect the group's results.

It is suggested that in the future research of larger groups, at different ages, different levels of expertise and in female be done.

CONCLUSION

Overall, according to the results of this study, which indicates the superiority of the group of physical training and combined training than the two groups of mental and observation training after applying 24-hour SD.

Since the effect of SD on the learning process seems to be the same in both the physical and the combination training, the combination training is prioritized for reasons such as diversity, attractiveness and prevention of fatigue. However, due to the lack of researches on the effect of SD on the training process and the testing of various motor skills and, on the other hand, the importance of the nature of skill in concluding in this regard, the authors are cautious in generalizing the results of this research and the result of this study Is merely due to the badminton service skill in special circumstances. The type of task also impacts our results. Badminton's short service is a skill that does not require the use of such physical exercise, and since past research has shown, even a few hours of SD cannot affect movement performance, and also where researches have shown that while skill physical training, learning and acquisition of the pattern is implicit (ie, one does not need attention and concentration to acquire the pattern), the results of the physical group may be reasonable. However, in mental and observational training, learning is happened explicit (attention and concentration), and because SD weakens these factors, degradation of performance at the acquisition stage and, consequently, lack of motor memory consolidation in the corresponding groups is normal. However, the interpretation of the result of the combination group is more complicated. It is possible to say that the combination groups has benefited from all the groups, without the continuation of a fatigue or lack of attention and concentration. It can also be said that the difference in nerve positions involves training in various mental and physical models as a reason for the difference between various methods.

APPLICABLE REMARKS

- Since Sleep Deprivation (SD) before learning can negatively affect new task learning, trainers should avoid teaching new skill to learners who have experienced SD the night before training and if they are obliged to teach due to the educational limitations, they can apply mixed practice (combined), so that they can use the advantages of mixed practice, i.e. mixing the benefits of different practices and minimize the negative effects of SD.

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