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The Impact of Partial Sleep Deprivation on the Diurnal Variations of Cognitive Performance in Trained Subjects

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Abstract

The aim of this study was to investigate the effect of partial sleep deprivation on the diurnal variations of cognitive performance of handball goalkeepers. Twelve handball goalkeepers (18.5±1.7 years; 8.3±2.4 years of experiment) performed 3 cognitive tasks by the use of the reaction time (RT), the stroop, and the barrage tests (to evaluate the RT, the selective and supported attention respectively) following 2 situations of sleep deprivation (in the beginning or in the end of the night) and a control situation. The tests were performed at 08:00 and 16:00. Our results showed an increased RT and a fall of the level of the attention after the partial sleep deprivation in the afternoon hours. However, the partial sleep deprivation didn't affect the morning cognitive performance. In conclusion, partial sleep deprivation affects the diurnal variation of cognitive performance by increasing the RT and reducing the attentional capacities in the afternoon hours.

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Keywords: Partial Sleep Deprivation, Time-of-Day, Reaction Time, Attention, Handball Goalkeepers;

1. Introduction

Athletic performances are highly dependent on one of the main biological rhythms, namely the sleep–wakefulness circadian cycle. While asleep, the organism is inefficient; this part of human lives is devoted to rest and the recovery from the other parts of the cycle, which are dedicated to alertness and physical and cognitive activities (Davenne, 2009).

The most obvious disruption to the normal circadian rhythm is when the sleep period is perturbed due to complete or partial sleep deprivation (Abedelmalek et al., 2012; Souissi et al., 2012a). Partial sleep deprivation

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refers to a night of reduced or interrupted sleep, which may be due to work schedules (i.e., shift work), sleep disorders (i.e., sleep apnea), medical conditions, medications (i.e., drugs), and lifestyle (Davenne, 2009; Souissi et al., 2012b). The partial sleep loss is a common source of stress both among athletes and non-athletes (Reilly & Edwards, 2006; Jarraya et al., 2012) which could lead to an impairment in the physical and cognitive performances (Reilly & Edwards, 2006; Davenne, 2009; Jarraya et al., 2012). In this context, we recently reported that partial sleep deprivation affects the reaction time (RT) and the attentional capacities of handball goalkeepers.

In more than sleep disruption, most basic components of performance (e.g., temperature, muscular strength and power, flexibility, metabolic and psychomotor functions) have rhythmic peaks and troughs that follow a circadian pattern: peak in the afternoon or early evening and through in the early morning (Chtourou & Souissi, 2012). For psychomotor capacities, particularly when the skill involved depends on RT and sustained attention, a significant time-of-day effect was previously observed with early morning nadirs and afternoon higher values (Davenne & Lagarde, 1995; Aktinson & Davenne, 2007).

Actually, to the authors' knowledge, no studies have previously investigated the effect of partial sleep deprivation on cognitive performance in the morning and in the evening. However, concerning physical performance, it has been shown that both partial (Souissi et al., 2008) and total (Souissi et al., 2003) sleep deprivation may affect muscle power during the Wingate test in the evening, but not in the morning hours.

In view of the above considerations, the aim of this study was to investigate the partial sleep deprivation effect on the diurnal variations of cognitive performance Handball goalkeepers.

2. Methods

2.1. Subjects

12 handball goalkeepers took part in the study (age: 18.5±1.7 years, level of experiment: 8.3± 2.4years, height: 1.80±5.8 cm, weight: 79±4.2 kg). The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Ethic Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS).

2.2. Experimental goalkeepers

After a familiarization session, subjects performed 6 test sessions in a randomized order over 6 days with a recovery period of 72-h in-between: (i) a reference-night (RN) condition during which subjects slept from 22:00 to 07:00 of the following day, (ii) a partial sleep deprivation session in the beginning (SDB) of the night during which subjects slept from 03:00 untill 07:00h, and (iii) a partial sleep deprivation session at the end (SDE) of the night during which subjects slept from 22:00 to 03:00. During each sleep condition, the subjects performed the RT and a selective (SA) and a constant (CA) attention tasks in the morning (08:00) and in the afternoon (16:00).

2.3. The barrage test (i.e., a paper-pencil test)

As previously described by Jarraya et al. (2012), the barrage test is a psychometric task which measures visual-spatial ability and recognition, and its scores are given as speed (number of symbols recognized). It is about a visual discrimination; the subject has to sweep the required form in a sequence of forms. The duration of the test is 10 min.

2.4. Stroop color-Word test: it is also about a paper-pencil test

As previously described by Jarraya et al. (2012), there are three components in the Stroop. First, the individual is asked to name a series of color words (Word task). This component is believed to reflect basic reading rate and may be affected by speech motor problems or learning disabilities. Second, the individual is asked to name the color of a bar (Color task) of X's (e.g., XXX in red, blue, or green ink). As with the Word task, performance may be affected by speech motor function; it may also be impacted by the individual's inability to name colors, or colorblindness. The final task is the Color–Word task in which the individual is shown the names of colors printed in conflicting ink colors (e.g., the word "blue" in red ink) and is asked to name the color of the ink rather than the word.

2.5. The reaction time

As previously described by Jarraya et al. (2012), a colored geometric form (used as model) is presented to the subject. When the test starts, there is a run of different colored forms. When the model appears, the subject must press the button to indicate its appearance and the computer will work out the RT. The time between the figures is 300 mille-seconds and each subject has 20 times.

2.6. Statistical analysis

The statistical analysis was performed on a microcomputer using Statistica software (StatSoft, France). Values are expressed as mean ± standard deviation (M ± SD). Once the assumption of normality with the Shapiro-Wilk *W*-test was confirmed, parametric tests were performed. Data were analyzed using a two-way (sleep condition × time-of-day) analysis of variance (ANOVA) with repeated measures. When appropriate, significant differences between means were assessed using the Tukey's HSD test procedure. A probability level of 0.05 was selected as the criterion for statistical significance.

3. Results

Data of the RT, SA and CA recorded at 08:00 and 16:00 are presented in table 1.

Table 1. The reaction time (RT), the selective attention (SA), and the constant attention (CA) recorded at 08:00 and 16:00.

	RN		SDB		SDE	
	08:00 h	**16:00 h**	**08:00 h**	**16:00 h**	**08:00 h**	**16:00 h**
RT	339,65 ± 27,38	398,29 ± 17,02*	455,19 ± 11,91	560,88 ± 25,42*#	535,53 ± 28,1	593 ± 28,66*#
SA	48,42 ± 10,59	41,58 ± 9,07*	17,67 ± 3,39	14,25 ± 3,41*#	27 ± 6,92	21,17 ± 5,08*#
CA	161 ± 16,57	144,75 ± 19,12*	97,25 ± 9,72	86,08 ± 9,45*#	121,92 ± 9,43	100,67 ± 9,87*#

* significant differences between 08:00 and 16:00 h.
# significant differences between RN and SDB and SDE.

3.1. Selective attention

The main effects of time-of-day ($F_{(1.11)}$=92.1, p<0.001) and of sleep condition ($F_{(2.22)}$=70.9, p<0.001) were significant. Moreover, the interaction time-of-day × sleep condition ($F_{(2.22)}$=7.8, p<0.001) was significant. The results showed that SA was significantly reduced between 08:00 and 16:00 ($p<0.001$) and between RN and SDB and SDE ($p<0.001$).

3.2. Constant attention

The main effect of time-of-day ($F_{(1.11)}=89.4$, $p<0.001$) and of sleep condition ($F_{(2.22)}=195.1$, $p<0.001$) and the time-of-day × sleep condition interaction ($F_{(2.22)}=5.8$, $p<0.01$) were significant. The results showed that CA was significantly reduced between 08:00 and 16:00 ($p<0.001$) and between RN and SDB and SDE ($p<0.001$).

3.3. Reaction time

The main effects of time-of-day ($F_{(1.11)}=237.9$, $p<0.001$) and of sleep condition ($F_{(2.22)}=256.3$, $p<0.001$) were significant. Likewise, the time-of-day × sleep condition interaction ($F_{(2.22)}=20.7$, $p<0.001$) was significant. The results showed that RT was significantly reduced between 08:00 and 16:00 h ($p<0.001$) and between RN and SDB and SDE ($p<0.001$).

4. Discussion

The main finding of this study is that cognitive performances (i.e., RT, SA, and CA) of the handball goalkeepers were significantly affected following SDB and SDE in comparison with RN at 16:00. Indeed, the RT was increased and the SA and CA were reduced in both sleep deprivation conditions. However, the morning cognitive performance was not affected by SDB and SDE. Moreover, the results of the present study showed that RT, SA, and CA were significantly affected by time of the day. Indeed, the RT was significantly higher, and the SA and CA were significantly lower at 16:00 than 08:00.

In agreement with the findings of the present study, Fulda and Schulz (2001) found that neuropsychological functions such as verbal immediate memory, attention, and vigilance were significantly affected by partial sleep deprivation. In this context, the present results advance a slowness of RT following both SDB and SDE which is represented by an increased RT. Previous studies reported that SDB and SDE could affect both physical (Souissi et al., 2003, 2008) and cognitive performances. Our findings are in agreement with the results of Pilcher and Huffcut (1996) which affirm that short sleep deprivations induce the deterioration of the performances during the execution of short cognitive tasks implying the RT. Likewise, Philip et al. (2003) showed that partial or total sleep deprivation affects the RT. Moreover, Wimmer et al. (1992) showed that service in "Trail Making Test" was affected following a partial sleep deprivation. During the Stroop task, MacCarthy and Waters (1997) showed an increase in the RT of the correct answers. Recently, in agreement with the present study' findings, we showed that SDB and SDE could affect the RT, SA, and CA in handball goalkeepers.

In agreement with previous studies (Davenne & Lagarde, 1995; Aktinson & Davenne, 2007), our results also showed that RT, SA, and CA were significantly affected by time of day. However, these diurnal variations were modified by the SDB and SDE. Indeed, both SDB and SDE affect the RT, SA, and CA only in the afternoon hours. To the best of our knowledge, the effect of SDB and SDE on cognitive performances at different time of the day is yet not investigated. However, concerning physical performances, previous studies confirm the findings of the present ones (Souissi et al., 2003, 2008). After one night of total sleep deprivation, Souissi et al. (2003) reported a significant reduction in performances during the 30-s Wingate test in the afternoon hours. However, the morning performances were not adversely affected by the total sleep deprivation. Likewise, after partial sleep deprivation, Souissi et al. (2008) showed that SDE reduce the physical performances during the 3à-s Wingate and the force-velocity only during the afternoon hours. However, the comparison of the present study's findings and those of Souissi et al. must be interpreted with caution. Indeed, in addition to the tasks' nature, there are some differences between the studies (e.g., trained vs. untrained, the time-of-day of testing, etc.).

The reduction of cognitive performances after the partial sleep deprivation could be explained by: (i) the absence of the paradoxical sleep phase which increases at the end of the night and which intervenes in the synchronization of the circadian system and (ii) the increased level of fatigue after being awake for a longer period than during RN (Edwards et al., 2007).

In conclusion, many athletes can worry about the effects of inadequate sleep on cognitive performance that could certainly affect sports activities. Indeed, the RT was increased and the SA and CA were reduced in both sleep deprivation conditions (i.e., SDB and SDE) in the afternoon. However, the morning cognitive performance was not affected by SDB and SDE. These findings may affect the diurnal variations of the cognitive performance observed during the RN. In this context, during the RN, the RT was significantly higher and the SA and CA were significantly lower at 16:00 than 08:00.

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References

Abedelmalek, S., Chtourou, H., Aloui, A., Aouichaoui, C., Souissi, N., & Tabka, Z. (2012). Effect of time of day and partial sleep deprivation on plasma concentrations of IL-6 during a short-term maximal performance. *European Journal of Applied Physiology*. doi: 10.1007/s00421-012-2432-7.

Atkinson, G., & Davenne, D. (2007). New relationships between sleep, physical activity and human health. *Physiology & Behavior*, *90*, 229-235.

Chtourou, H., & Souissi, N. (2012). The effect of training at a specific time-of-day: A review. *The Journal of Strength and Conditioning Research*, *26*, 1984-2005.

Davenne, D. (2009). Sleep of athletes – problems and possible solutions. *Biological Rhythm Research*, *40*, 45-52.

Davenne, D., & Lagarde, D. (1995). Circadian rhythm of vigilance and temperature during 24 hours of continuous and strenuous exercise. *Journal of Medical Sciences Research*, *23*, 767-770.

Edwards, B., Waterhouse, J., & Reilly, T. (2007). The effects of circadian rhythmicity and time-awake on a simple motor task. *Chronobiology International*, *24*, 1109-1124.

Fulda, S., & Schulz, H. (2001). Cognitive dysfunction in sleep disorders. *Sleep Medicine Reviews*, *5*, 423-445.

Jarraya, M., Jarraya, S., Chtourou, H., & Souissi, N. (2012). The effect of the partial sleep deprivation on the reaction time and the attentionnel capacities of the handball’s goalkeeper. *Biological Rhythm Research*. doi: 10.1080/09291016.2012.667981.

MacCarthy, M.E., & Waters, W.F. (1997). Decreased attentional responsivity during sleep deprivation: Orienting response latency, amplitude, and habituation. *Sleep*, *20*, 115-123.

Philip, P., Sagaspe, P., Moore, N., Taillard, J., Charles, A., Guilleminault, C., Valtat, C., Sanchez-Ortuno, M., & Bioulac, B. (2003). Fatigue, sleep restriction and performance in automobile drivers: A controlled study in a natural environment. *Sleep*, *26*, 277-280.

Pilcher, J.J., & Huffcutt, A.I. (1996). Effects of sleep deprivation on performance: a meta-analysis. *Sleep*, *19*, 318-326.

Reilly, T., & Edwards, B. (2006). Altered sleep-wake cycles and physical performance in athletes. *Physiology & Behavior*, *90*, 274-284.

Souissi, M., Chtourou, H., Hdidar, R., Azaeiz, R., Dogui, M., Souissi, N., & Tabka, Z. (2012b). Effects of three types of chronobiotics on anaerobic performances and their diurnal variations. *Biological Rhythm Research*. doi: 10.1080/09291016.2012.667981.

Souissi, M., Chtourou, H., Zrane, A., Ben Cheikh, R., Dogui, M., Tabka, Z., & Souissi, N. (2012a). Effect of time-of-day of aerobic maximal exercise on the sleep quality of trained subjects. *Biological Rhythm Research*, *43*, 323-330.

Souissi, N., Sesboüé, B., Gauthier, A., Larue, J., & Davenne, D. (2003). Effects of one night’s sleep deprivation on anaerobic performance the following day. *European Journal of Applied Physiology*, *89*, 359-366.

Souissi, N., Souissi, M., Souissi, H., Chamari, K., Tabka, Z., Dogui, M., & Davenne, D. (2008). Effect of time of day and partial sleep deprivation on short-term, high-power output. *Chronobiology International*, *25*, 1062-1076.

Wimmer, F., Hoffmann, R.F., Bonato, R.A., & Moffitt, A.R. (1992). The effects of sleep deprivation on divergent thinking and attention processes. *Journal of Sleep Research*, *1,* 223-230.