

Short-term sleep deprivation and its effect on muscle performance in healthy young males

- Literature review

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Background

Sleep loss is a common symptom in athletes who suffers from the overtraining syndrome (OTS) (*Meuseen et al. 2006*), and it seems like athletes have less qualitative sleep than non-athletes even though it still remains within the range for healthy sleep (*Leeder et al. 2012*). However, it's not clearly investigated whether temporary and short-term sleep affects the athletes' physiological performance. It's shown in studies on rats, that paradoxical sleep deprivation leads to hormonal disturbances such as reduced serum testosterone levels that may mediate muscle atrophy (*Dattilo et al. 2012*).

Earlier studies have shown that sleep loss (36h) significantly reduces the work time to exhaustion during aerobic exercise (*Bruce, J.M. 1981*) and anaerobic exercise (*Souissi et al. 2003*). One more recent study has confirmed the results from older studies by showing that 30h of sleep loss led to reduced sprint performance and lowered muscle glycogen content in male athletes. However, it's unclear if the decline in performance after the sleep loss was due to the sleep loss itself or the lowered glycogen content (as a result of higher grade of muscular activity between tests) in the test group (*Skein et al. 2011*).

If the athlete suffers from short-term sleep deprivation, both the aerobic and anaerobic performance might be reduced according to the literature provided. However, there is a great deal of unknown answers for how sleep loss/deprivation affects performance and fatigue, does it matter when the sleep loss occurred, time of sleep loss and so on? According to a study by Souisse et al. (2008), four hour of partial sleep deprivation at the end of the night (early awakening) affected the performance the following day more than partial sleep deprivation at the beginning of the night (delayed bedtime). There has also been shown that when sleep deprivation occurs, the performance on the following day is better in the afternoon than early morning. There might be some unknown compensatory effects that affect the body during the day to compensate for the sleep loss (*Bougard & Davenne. 2012*). However, the results seemed to differ regarding to which test they used and if it was in the field or in the lab, making the results inconsistent. Research have also been testing the hypothesis with short-term sleep deprivation and its effect on muscle performance, which shows that 4h of sleep loss during the night caused by an early

awakening decreases peak performance and mean performance in the afternoon but not in the morning (*Abedelmalek et al. 2012*).

So, the recent literature shows that long-term (>20h) decreases performance (*Orzel-Gryglewska. 2010*), but the exact mechanism is unclear, it seems that hormonal changes such as lowered testosterone and increased cortisol might be one explanation together with lowered muscle glycogen (*Cote et al, 2012; Epub ahead of print*). However, short-term sleep deprivation (< 8h/sleep during a 30h period) in combination with physical exercise has failed to show any larger changes in plasma hormones (*Opstad & Aakvaag. 1983*). So this is really an area where it's needed more research regarding the effects on muscular performance after short-time sleep deprivation. Most literature has investigated the effects from sleep deprivation on cognitive function, body weight, hunger feelings and mood, but very little is done in the physiological area when it comes to short-term sleep deprivation/partial sleep loss.

The literature also presents the findings that sleep loss affects performance, but unequally on different time of the following day which might be of interest to coaches when they plan the athletes' training schedule.

Purpose

The purpose of this literature review was to focus on the short-term sleep deprivation (0-8h sleep during a 30h period) and its effects on human physical/exercise performance and fatigue in healthy humans.

Method

The selection criteria for the included studies were that the researcher had to be able to get access to the full-length article; the study had to be peer-reviewed (maximum one review article) and report a relationship between short-term sleep deprivation (< 8h/sleep during a 30h period) and human physical performance. The studies also had to be reported in Swedish or English (due to limitations of the researcher) and published between 1995 and 2012.

The reviewed studies were published in; *International Journal of Sports Medicine, Journal of Sports Science and Medicine, Asian Journal of Sports Medicine, Physiology and Behavior and European Journal of Applied Physiology.*

All of the reviewed articles included males only since I couldn't get access to articles including females.

Database search and its procedure is shown in Table 1.

Table 1: Database search

Database	Search word	# of hits	Reviewed	Selection #1	Selection #2
PubMed #1	short term sleep deprivation	299	0	0	0
PubMed #2	Short term sleep deprivation AND performance	114	7	5	1
PubMed #3	partial sleep deprivation AND performance	89	14	7	2
Science Direct #4	human performance AND sleep deprivation AND NOT cognitive	3495	5	3	2

Results

The results are presented in the following five lists with the five head articles reviewed. Results are also presented in text below the lists where other similar studies are included as well. The five articles reviewed all included young (17-25 years) males only.

Article	Title	Abstract	Introduction	Method	Results	Discussion	References
Souissi, N., Sesboüé, B., Gauthier, A., Larue, J & Davenne, D, 2003 Effects of one night's sleep deprivation on anaerobic performance the following day. <i>European Journal of Applied Physiology</i> 89 (3-4), 359-366.	Contains 12 words. Reflects the content of the study well	Quite long abstract but it is very descriptive	Describes the problem very well and explains why this study is needed. Use references to previous studies done in the same area	Intervention study with a cross-over design. Well explained method and statistics. The method is easy to follow and repeat	Well explained results. Good use of tables and figures even though their placement is a little bit misleading	Good and informative discussion regarding study design, method and results. Good connection to other studies. Discuss limitations and gives us suggestions for further studies.	Lot of references, although some of them are old and some more recent, ranging from year 1961 to 2000.

Article	Title	Abstract	Introduction	Method	Results	Discussion	References
Oliver, S.J., Costa, R., Laing, S.J, Bilzon, J & Walsh, N.P, 2009. One night of sleep	Contains 9 words. Reflects the content of the study	The abstract describes the study and explains the results very	Introduce us to earlier research and explains why this study is needed. Well	Intervention study with a randomized cross-over design. Well explained	Well explained results. Shows us the most important	Good and informative discussion regarding study design, method and	Not that many references, and some of them are old and some

deprivation decreases treadmill endurance performance. <i>European Journal of Applied Physiology</i> 107, 155-161.	pretty well. Does not mention the preload or subjects	well	formulated aim in the end of the introduction.	method and statistics. The method is easy to follow and repeat	results in the beginning. Very messy results with a lot of numbers in the text. Needs more tables and figures	results. Good connection to earlier studies. Does not discuss limitations. Gives us no suggestions for further studies.	more recent, ranging from year 1964 to 2009.
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Article	Title	Abstract	Introduction	Method	Results	Discussion	References
Taheri, M & Arabameri, E, 2012. The Effect of Sleep Deprivation on Choice Reaction Time and Anaerobic Power of College Student Athletes. <i>Asian Journal of Sports Medicine</i> 3 (1), 15-20.	Contains 16 words. Reflects the content of the study well. Does not specify time of sleep deprivatio n.	Short but informative abstract. Does not describe the method very well.	Introduce us to earlier research and explains why this study is needed. The aim of the study is being described in the end on the introduction but a little vague.	The study design is not very well described, probably a cross-over design. Well explained method and statistics.	Describes part of the method in the results. The result is very short and gives us the important information but no more than that. Good use of tables and figures.	Vague discussion, does not connect to earlier findings and lacks references from statements done in the discussion. Limitations are discussed and they give us suggestions for further studies	Not that many references, but most of them are new ranging from year 1981 to 2010.

Article	Title	Abstract	Introduction	Method	Results	Discussion	References
Vardar, S.A., Öztürk, L., Kurt, C., 2, Bulut, E., 1, Sut, N & Vardar, E, 2007. Sleep deprivation induced anxiety and anaerobic performance. <i>Journal of Sports Science and Medicine</i> 6, 532-537.	Contains 7 words. Reflects the content of the study pretty well. Does not specify time of sleep deprivation nor subjects.	Informative and well explained abstract.	Introduce us to earlier research and explains why this study is needed. The aim of the study is being described in the end on the introduction.	Very well explained method and statistics, easy to understand and repeat.	Short but descriptive results. Good use of tables and figures.	Discuss the results and method and make good connections to earlier studies. Discuss confounding factors and limitations very well.	Uses many references, most of them are new but they are ranging from year 1970 to 2007.

Article	Title	Abstract	Introduction	Method	Results	Discussion	References
Reilly, T & Edwards, B, 2007. Altered sleep–wake cycles and physical performance in athletes. <i>Physiology & Behavior</i> 90. 274–284.	Contains 9 words. Reflects the content of the study well.	Describes the reviews need and its findings. Includes suggestions for further studies	Describes some basic around the subject and splits up the review in to different areas.	Does not include any inclusion or exclusion criteria for studies involved in this study	Uses some tables and figures to highlight certain parts. Well explained results from earlier studies.	Discuss findings through the study. Ends up with an overview which summarizes the findings and gives suggestions for further research.	Uses a lot of references with a range from 1973 to 2005.

Short-term sleep deprivation or partial sleep is being set as a continuous sleep duration that is less than 8 (0-8) hours over a 30 hour period.

- 1) One study by Souisse et al (2003) showed that neither peak power, mean power or blood lactate concentration were affected among thirteen healthy male students during a 30 second Wingate test after 24h wakefulness (0h of sleep/24h). However, the anaerobic power variables were significantly affected after 36h of wakefulness (*Souisse et al 2003*).
- 2) Another study who investigated the ability among 18 healthy male students to perform anaerobic after 24h wakefulness is the study by Taheri & Arabameri (2012). In their protocol, the subjects also performed a 30 second Wingate test in the morning (10.00-11.00). The results from this study confirmed the results from Mougin et al (1996) and Souisse et al (2003) and did not showed any significant difference in either mean or peak power from one night of sleep loss compared to baseline values. They did however find a difference in reaction time but since that is a cognitive function, it is not of interest for this review (*Taheri & Arabameri 2011*).
- 3) Oliver et al (2009) investigated whether one night of sleep deprivation decreased treadmill endurance performance among eleven healthy males. The authors tested the subjects VO₂max seven to ten days prior to the test. The authors also controlled for the subjects nutritional and hydration status. The study design was a cross-over so all participants performed both trials (one with normal sleep and one after 30 hour of wakefulness).separated by seven days.

During the experimental exercise protocol, the subjects first run during 30 min at 60 % VO₂max (preload) followed by a 30min maximal distance running test. The participants controlled the speed of the treadmill (gradient set at 1 %) themselves and were only aware of the elapsed time, not the distance.

One night of sleep deprivation decreased aerobic endurance performance from 6224 meters down to 6037 meters. After the sleep deprivation night, majority of the participants (nine of eleven) did run a less distance compared to control. However, their perception of

effort was similar compared to the control group; indicating that altered perception of effort might be responsible for the decrease in performance (*Oliver et al 2009*).

- 4) A review study by Reilly & Edwards (2007) states that one night's sleep deprivation (both total and partial) doesn't have an impact on muscle strength (anaerobic) during all-out efforts in healthy subjects. However, the subjects may be unable or unwilling to maintain required performance during sustained submaximal endurance exercise (*Reilly & Edwards 2007*).
- 5) In a study by Vardar et al (2007) the participants completed a 30 second supra-maximal Wingate test. The participants, consisting of thirteen healthy male students who performed the test. No significant differences could be observed between the mean power, peak power and anaerobic fatigue during baseline, total (8h) and partial (4h) sleep loss.

The results from Souisse et al (2003) is confirmed by an earlier study (not reviewed) by Mougín et al (1996) who wanted to see if short-term sleep deprivation affected anaerobic performance during a 30 second Wingate test on eight highly trained athletes. The results showed us that reduced sleep (<6h) compared to normal sleep (8h) did not have a significant effect on either ventilation, lactate or pH levels, neither was the peak power, mean power output or peak velocity modified compared to the reference night with normal sleep. These results indicate that acute short-term sleep loss does not affect supra-maximal anaerobic exercise performance (*Mougín et al 1996*).

None of the five article studies reviewed have investigated the effects on anaerobic performance from partial short-term sleep loss when the sleep loss occurs during several nights after each other.

Another study by Reilly & Piercy (1994) who wasn't reviewed in this study did however look at this part. They examined the effects from partial sleep deprivation on maximal and submaximal weight-lifting performance during several nights of partial sleep loss. They used eight healthy males who were restricted to three hours of sleep during three successive nights. The weight-lifting tasks consisted of deadlift, legpress, benchpress and bicepscurl. The results showed that

the decrease in maximal performance were significant after the second night. The decrease was significant on deadlift, legpress and benchpress but not on bicepscurl. The submaximal lift for all the 4 tasks decreased significant after the second night. These results indicate that submaximal lifting tasks are more affected by partial sleep loss than are maximal lifts (*Reilly & Piercy 1994*).

The experimental protocol in all five studies reviewed were similar (four anaerobic and one aerobic) and the performance test occurred between morning and noon in the studies which might be an important factor since it's been shown that when sleep deprivation occurs, the performance on the following day is better in the afternoon than early morning (*Bougard & Davenne 2012*). The age of all subjects included in the reviewed articles varied between 17 and 24 years making the test subjects quite homogeny. The Wingate tests used in a majority (three out of five) of the studies were done according to the methodology, reliability and validity described by Bar-Or (1987).

Discussion

It is difficult to define sleep-loss and its effect on performance according to the studies published. Differences in performance might depend more on the disruption of the subject normal sleep-wake rhythm than the sleep loss per se. Subjects in the studies might also have individual differences regarding their individual sleep need.

All of the studies reviewed were done on males, there is some evidence supporting a gender difference when it comes to sleep, it seems as that adult women have a greater need for sleep than men in the same age (*Ferrara & Gennaro 2001*). There has also been tested to see if there is a gender influence on performance when pilots were tested on flight performance and mood after long-term sleep loss (40h) and still, doesn't find any differences in the ability to perform physically between genders (*Caldwell & Leduc 1998*).

An older study by Reilly & Hales (1988) also showed that the effects of partial sleep deprivation affect both males and females equally (*Reilly & Hales 1988*).

Adequate sleep is important for performance, however, short-term sleep loss does not seem to affect peak or mean or peak anaerobic performance. However, for sports which need more cognitive function, there seems like adequate amount of sleep is essential to avoid impairment in performance.

All studies are performed on healthy young persons (mostly students, age 17-25 years) and it is possible that the result can't be transferred to older people (> 30 years old). The majority of the studies are as earlier mentioned performed on males only, research is a little bit inconsistent but when it comes to performance, the results doesn't seem to differ among gender. Further studies should include both male and female subjects to make the results applicable to all athletes regardless of gender.

One major limitation for this study was my inability to get access to the full text to a number of studies which was an inclusion criterion for this literature review. Further studies should investigate the same area but include more articles with a larger span of age and gender of the subjects.

Coaches should be aware of these findings and educate the athlete within this area. That way, the athlete doesn't have to be stressed regarding one bad night of sleep since the stress itself may be a more negative influence affecting the performance negatively than the sleep deprivation itself.

This literature review haven't treated the question whether there is a change in performance among sleep deprived humans, dependence on which time the following day the performance test occur. Neither has the included studies investigated whether the decreased performance might be caused by a decreased amount of stored muscle glycogen. Three of the included studies have in any case controlled for the participants total energy expenditure (TEE) during the study period, and as a result of the TEE, they have been giving the participant a sufficient amount of energy to consume. Further studies should control the glycogen content in the subjects to exclude a lowered amount of muscle glycogen as a major factor for the possible performance depression after a longer duration of sleep loss.

Conclusion

One single night of sleep loss or partial sleep deprivation during the night doesn't seem to affect maximal physical performance in healthy humans, but it seems as long duration performance might be affected before any changes in maximal physical performance occurs. Wakefulness during a period that exceeds 36h seems to affect performance significantly and the athletes is thereby recommended to get enough sleep before competition or exercise where physical demands are put on them. However, they should not be worried about one single night of bad sleep unless their required performance includes cognitive parts, mental focus and steady hands (Dart, archery, pistol shooting etc.).

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