

The Importance of Sleep for Optimal Testosterone Production

Contributed by Robbie Durand
Wednesday, 18 February 2009

Sleep is commonly viewed as a restorative process that influences the nervous, neuroendocrine and immune systems. Sleep is considered critical for the maintenance of health; abnormal sleep patterns are associated with increased risk of cardiovascular disease, mood disorders, chronic pain and a shortened lifespan.¹¹ In a lot of ways, sleep is like sex— you can never get too much of it. In addition, sleep is a lot like your boss when he’s working...don’t disturb him or he gets pissed. Well, your body is the same way— don’t disturb its sleep or he will take it out on you.

The Importance of Sleep for Optimal Testosterone Production

“Sleep is a symptom of caffeine deprivation.” —Author Unknown

Sleep is commonly viewed as a restorative process that influences the nervous, neuroendocrine and immune systems. Sleep is considered critical for the maintenance of health; abnormal sleep patterns are associated with increased risk of cardiovascular disease, mood disorders, chronic pain and a shortened lifespan.¹¹ In a lot of ways, sleep is like sex— you can never get too much of it. In addition, sleep is a lot like your boss when he’s working...don’t disturb him or he gets pissed. Well, your body is the same way— don’t disturb its sleep or he will take it out on you.

The Consequences of No Sleep

All bodybuilders know that getting eight to 10 hours of sleep a night is important for training recuperation, but this guideline is often neglected. Who the hell has time for eight to 10 hours of sleep anymore? People have chaotic work deadlines, kids, a social life and hitting it hard in the gym. Sleep is the one thing bodybuilders (or anyone else for that matter) will sacrifice to get a few more things done. As stated earlier, not getting the right amount of sleep will cause harmful effects on glucose tolerance, GH secretion and lower immune parameters, as well as increasing cortisol and adrenaline.^{1,2}

A 1999 study in *The Lancet* reported that when healthy young men had four hours of sleep for six nights, it resulted in a harmful impact on carbohydrate metabolism and endocrine function. Subjects experienced an increase in insulin resistance and reduced thyroid levels. In addition, evening cortisol and increased sympathetic activity of the nervous system was also reported.¹⁸ Other studies have documented that sleep deprivation doesn’t give the nervous system a chance to rest and results in elevated adrenaline levels. One study demonstrated that subjects exposed to sleep deprivation (i.e., 3.3 hours of sleep) resulted in a significant elevation in circulating levels of norepinephrine and epinephrine during the night.¹⁵ Circulating catecholamines are normally supposed to decline with sleep.

Another less well-known hormone identified as increasing during sleep is prolactin. Now don't freak out, you're not going to start squirting milk out of your nipples like a breastfeeding mother, but circulating levels of prolactin rise during the night with sleep. There's a linkage between GH and prolactin secretion during non-REM sleep in humans. Prolactin and GH share 40 percent of the same protein sequence. Prolactin is secreted in the anterior portion of the brain, but is also synthesized and secreted by a broad range of other cells in the body, including various immune cells. It's interesting that sleep deprivation reduces nightly prolactin levels, which may explain why there's reduced immune functionality with sleep loss. Mice that are made genetically deficient in prolactin are immunocompromised to which sleep loss shares a resemblance.¹² Prolactin has also been shown to be a regulator of testosterone. When men were given the anti-depressant drug, haloperidol (which lowers dopamine, but results in an increased release of the prolactin), the resulting significant increase in prolactin corresponded with a significant increase in testosterone 60 minutes later. In the same study, the control group's mean testosterone levels showed the normal decline during daytime hours. This delay between increased prolactin and increased testosterone is consistent with a similar delay between the increases of these two hormones occurring at night during sleep.¹³

As you know, GH is supposed to rise during the night, but sleep deprivation resulted in an attenuation of GH that doesn't rise until after sleep onset. In addition, cortisol was significantly elevated the next day, as well as catecholamines.⁹ If that's not the kiss of death for maintaining an anabolic state I don't know what is. Sleep is also critical for testosterone regulation and lack of sleep can lower testosterone levels; the total time sleeping is an important regulator as well.⁴

A recent study by Axelsson et al.⁴ examined what the most important factor regulating testosterone production during sleep was—circadian rhythms (a daily cycle of rhythmic activity based on 24-hour intervals, observed in many organisms—including us!) or total sleep. The researchers looked at traditional day workers who slept at night as well as people who worked the nightshift and slept during the day. Results of the study found that the time of day or night when the workers slept didn't affect testosterone levels. The most important finding of the study determined that total sleep, rather than circadian rhythms, was critical for testosterone regulation. The study suggests with respect to testosterone function, that there's a linear increase in testosterone across the sleep cycle suggesting that sleep length is critical for testosterone levels. It seems that sleep can be added to the list of factors affecting testosterone levels in addition to training level, diet and age. So the next time your boss walks in on you sleeping on the job tell him to “F**K OFF” you're trying to get big!!

Testosterone, Circadian Rhythms and Sleep

Testosterone follows circadian rhythms or patterns during sleep. Testosterone levels increase during sleep and peak about the time of waking in men and slowly decrease during the day.⁵ Interestingly the diurnal rhythm of testosterone already exists before puberty starts. One study investigated the effect of the testosterone circadian rhythm both before and after puberty. Thirty-two prepubertal and 14 pubertal boys between the ages of five and 19 years of age were studied. Diurnal rhythms of LH, FSH and testosterone were apparent in all subjects, including those aged five years old, however the average 24-hour LH and testosterone concentrations were much greater with those developing puberty.¹⁰ Testosterone levels peak at around 8 a.m. and are at their lowest around 8 p.m.⁶ It's been reported that in young men, the sleep-related rise in testosterone has been linked to the first episode of rapid eye movement (REM).⁵ REM sleep is an active period marked by intense activity in the brain and rapid bursts of eye movements. At the same time, REM sleep is when dreaming occurs. The stimulus for testosterone production is regulated by gonadotropin-releasing hormone (GnRH), which then stimulates leutinizing hormone (LH) production from the hypothalamus (see figure 1).

During sleep, episodic bursts of LH drive testosterone production in men. The frequency and amplitude of these pulses are essential for appropriate testosterone production. There's generally a 40-minute lag time from when the first burst of LH is secreted to stimulation of testosterone production.⁷ So, now you understand that during normal sleep there are episodic pulses of LH-stimulating testosterone production, however when sleep is disrupted, the circadian rhythm of testosterone is disrupted as well.

Partying Without Sleep Is Bad for Testosterone

Who the hell wants to stay home at night when you could be dancing with some hot MILF at the club?! Well, while you're trying to "score," the loss of sleep can be detrimental to your testosterone levels. Schiavi et al.⁸ reported that in a group of healthy young men, sleep deprivation causes decreases in sleep quality and REM episodes, which were associated with lower bioavailable testosterone levels, regardless of one's age. Every bodybuilder knows he should be getting eight to 10 hours of sleep a night, but most of us take it with a grain of salt.

A single night of disrupted sleep can really take its toll on your testosterone levels. For example, when young men were exposed to a night of partial sleep loss, it resulted in a blunted testosterone response during the night. In that study when men were allowed to get a full eight hours of continuous sleep, all subjects had a nocturnal rise in testosterone. When the same subjects were allowed two hours of sleep, none of the subjects without REM sleep showed any rise in testosterone during the night.⁵

Another study examined testosterone levels of internal resident students in medical school. As you know, internal medical students work all hours of the night and don't get much sleep. When the serum testosterone levels of the medical student residents were compared to other hospital personnel, the LH responses were similar, but the internal medicine residents demonstrated subnormal testosterone levels.¹⁴ Just about any occupation that doesn't allow a good night's sleep is going to impair testosterone production, which is especially true for new shift workers.

Shift work can wreak havoc on a person's life during the initial adaptation period. Working at night and sleeping during the day can lead to disrupted sleep patterns, however as documented in the 2005 Journal of Clinical Endocrinology & Metabolism study, when normal sleep patterns are established there are no differences in testosterone levels between those who work at night compared to those who work during the day if they're getting restful sleep. Axelsson et al.¹⁶ reported that low testosterone levels were found in workers who needed more sleep, had disturbed sleep/wakefulness and increased need for recovery after a work shift. The study included 62 shift workers relating how satisfied they were with their jobs, sleep quality and mood; these were then compared to the workers' testosterone levels. Dissatisfied workers had significantly lower testosterone levels that were not related to cortisol or prolactin levels, but were associated with a greater need for sleep quality. Contrary to the dissatisfied shift workers, higher testosterone levels were found with those shift workers who were happy with their jobs and correlated with being well rested and having less disturbed sleep before their morning shifts.¹⁶

Another interesting finding was that the sole predictor of morning testosterone was the workers' quality of sleep. Having sufficient sleep was more predictive of testosterone levels than age, BMI and smoking. In addition to being sleep deprived from work, many sleep disorders can decrease testosterone levels. Sleep quality is affected by many breathing-related disorders such as sleep apnea, which has been shown to affect approximately four percent of middle-aged men.¹⁷

Sleep Apnea Suppresses Testosterone Production!

Sleep apnea happens during sleep when there's a cessation of airflow that occurs for at least 10 seconds (usually 20 to 30 seconds, but rarely greater than two minutes). Apnea is accompanied by snoring, sleep arousals and hypoxia. The term sleep apnea describes two major sleep-related clinical problems: obstructive sleep apnea and central sleep apnea.

Central apnea is caused by neurochemical stimulation, which can result in impairment of respiratory control of breathing. Obesity is often a factor, but not all patients with central sleep apneas are obese. Approximately 18 to 40 percent of affected patients are no more than 20 percent heavier than their ideal bodyweight.

Obstructive apnea is caused by upper airway obstruction at the level of the pharynx and is the most common form of sleep apnea. What should concern bodybuilders is that a large neck circumference (collar sizes greater than 17.5 inches) has been associated with sleep apnea. Obesity is a major contributing factor to sleep apnea as the excess adipose tissue around the neck collapses the trachea during sleep. Sleep apnea results in a reduction in both LH and testosterone levels. Luboshitzky et al.¹⁷ examined healthy young men and compared them to overweight sleep apnea patients and found that sleep apnea resulted in severe testosterone dysfunction. Compared to healthy young men, sleep apnea patients had lower total LH and testosterone levels due to decreased LH pulse amplitude and decreased pulsatile testosterone secretions during the night. When obese patients lose weight, the nightly circadian rhythms of LH and testosterone are restored.¹⁹

Obesity in itself suppresses testosterone levels, but the hypoxia that occurs during apnea suppresses testosterone levels as well. Additionally, when apnea patients are placed on nasal continuous positive airway pressure (CPAP) machines (which delivers air into your airway through a specially designed nasal mask), testosterone levels revert back to normal, demonstrating that obesity alone isn't the sole cause of decreased testosterone levels occurring during sleep.²⁰

When patients with sleep apnea were compared to each other, the degree of testosterone suppression taking place with sleep apnea was directly related to the amount of hypoxia occurring during sleep. Decreased morning testosterone levels, but not LH, is related to the degree of hypoxia.²⁰ For example, Kouchiyama et al.³¹ found that when sleep apnea patients were compared to each other, the patients who had less severe oxygen saturation had testosterone peaks at 6 a.m., whereas the patients who were classified as having severe oxygen desaturation during sleep exhibited delayed peaks in testosterone for example, at 10 a.m.

Test Replacement Isn't a Cure for Apnea

One might think that giving testosterone to sleep apnea patients would result in lifestyle enhancement, but testosterone itself has been linked to sleep apnea. Testosterone is the only androgen that has been attributed to control of breathing, although its role is unclear.

In a study of seven obese men, all but the hypogonadal man had nocturnal hypoxemia or sleep-disordered breathing.³⁴ In relation to sleep-disordered breathing, two randomized, placebo-controlled studies in older men are available and document that high-dose testosterone administration worsens sleep and breathing, although lower dose, steady-state testosterone delivery may be less likely to do so.³⁰ Testosterone alters neurochemical control of breathing and administration of testosterone to hypogonadal men results in disturbed breathing patterns.²¹ Older men given high doses of testosterone resulted in reduced sleep time (approximately one hour) and disrupted breathing during sleep. So how is this happening? The author concluded that even though testosterone increased lean muscle mass and reduced fat mass, the disruption in sleep could have been attributed to the fact that testosterone administration changes nocturnal metabolism, potentially impairing sleep quality. In addition, the large rapid increases in lean mass reflect changes in tissue hydration, which could cause edema in the airways, disturbing breathing.³⁰ Another possible cause of the increased number of sleep disturbances, which can occur with testosterone administration, is that testosterone decreases melatonin production. Patients with GnRH deficiency who have low levels of testosterone have higher levels of melatonin than normal controls. The administration of testosterone enanthate to GnRH patients resulted in a reduction in melatonin to the levels appropriate for age-matched controls.³³ What's interesting is that the pineal gland where melatonin is secreted has the ability to take up and metabolize estradiol and testosterone.³²

Similarly to men, administration of testosterone to women results in sleep-disordered breathing. For example, when women were administered testosterone for 12 days via a transdermal patch, (giving them physiological levels of testosterone similar to a man's) this caused disturbances in ventilation during sleep. These changes couldn't be explained by changes in airway mechanics, because the short duration of the study.²³ In addition, women with polycystic ovary disease who have high serum androgen levels also have similar sleep-disordered breathing.²² It's also of interest that the risk of developing sleep apnea related syndromes declines with age, which may be related to decreased testosterone levels.

From Lions to Mice

The military has done extensive research on the effects of sleep deprivation on soldiers and how it can screw a person up. The military wants soldiers who can kick some serious ass!! As you know, testosterone is extremely sensitive to stress changes. Sleep deprivation plus the physical stress of exercise is a double whammy!! Soldiers who are exposed to physical training with sleep deprivation lasting several days experience a decline in DHEA androstendione and testosterone by 70 to 90 percent.²⁴ Norwegian cadets exposed to a similar "hell week" of one to three hours of sleep a day with vigorous physical activity had a decrease in all androgenic steroid hormones (i.e., LH, testosterone androstendione). In addition, all cadets demonstrated clinical signs of hypogonadism such as a lack of initiative to fight, low aggressiveness and a strong decrease in beard growth.²⁵ That's not exactly the kind of responses you want from highly trained killers! Future research involving testosterone replacement during intense training should be warranted by the military.

Responses to Aging

It's no surprise that with aging there's a decrease in testosterone and lean muscle mass. Cross-sectional studies have demonstrated that after the age of 40, testosterone declines by about two percent per year with increases in sex-hormone binding globulin, follicle stimulating hormone and LH concentrations.²⁶ The disruption in testosterone can be attributed to several mechanisms, but the stimulus for testosterone production becomes lower as we age and the male testes don't respond as rapidly. Houston we have a problem!!

That's right. As men age, we experience testicular dysfunction and the testes don't respond to LH like younger males. For example, in healthy elderly men given a dose of human chorionic gonadotrophin hormone, which causes a sharp rise in LH production, researchers found it doesn't increase testosterone like young men. In fact, there's a blunted response in elderly men, which indicates a defect in the Leydig cells in the testes to produce testosterone.²⁸

During sleep, older men demonstrate less testosterone production as pulsatile LH release in elderly men is marked by lower amounts secreted, but are secreted more frequently than pulses in young men.²⁷ This physiological dysfunction can occur as early as 45 years of age. Luboshitzky et al.²⁹ reported that middle-aged men (i.e., 45 years of age) had significantly less pulsatile secretion of testosterone during sleep and more LH bursts secreted at night than younger adults (i.e., 24 years of age). Additionally, the middle-aged men had decreased sleep stages three and four (deep sleep) and an increased number of nocturnal awakenings.³⁰ In one analysis, older men who experienced reduced REM sleep were correlated with reduced serum testosterone levels.⁸

In conclusion, decreases in sleep won't only reduce your immune system, impair GH secretion, raise cortisol and daytime catecholamines, but also lower testosterone production. All hardcore bodybuilders should be getting as much sleep as possible. I remember reading that Lee Haney always made sure he took a nap every day when he was training hard—in addition to his nightly nine hours of sleep. It's hard to think that something as small as sleeping a little more could be all we need to get the most out of training.

Key Points:

- Sleep is an important regulator of testosterone function.
- Sleep deprivation results in a blunted nocturnal rise in testosterone.
- Sleep apnea can impair nocturnal rises in LH and testosterone levels.
- High levels of testosterone can result in sleep-disordered breathing through unknown mechanisms.
- Aging is associated with a blunted rise in nocturnal rise in LH and testosterone.

References:

1. Vgontzas AN, Bixler EO, Lin HM, Prolo P, Trakada G, Chrousos GP. IL-6 and its circadian secretion in humans. *Neuroimmunomodulation*, 2005;12(3):131-40.
2. Redwine L, Hauger RL, Gillin JC, Irwin M. Effects of sleep and sleep deprivation on interleukin-6, growth hormone, cortisol and melatonin levels in humans. *J Clin Endocrinol Metab*, 2000 Oct;85(10):3597-603.
3. Axelsson J, Ingre M, Akerstedt T, Holmback U. Effects of acutely displaced sleep on testosterone. *J Clin Endocrinol Metab*, 2005 Aug;90(8):4530-5.
4. Rose RM, Kreuz LE, Holaday JW, Sulak KJ, Johnson CE. Diurnal variation of plasma testosterone and cortisol. *J Endocrinol*, 1972 Jul;54(1):177-8.
5. Luboshitzky R, Zabari Z, Shen-Orr Z, Herer P, Lavie P. Disruption of the nocturnal testosterone rhythm by sleep fragmentation in normal men. *J Clin Endocrinol Metab*, 2001 Mar;86(3):1134-9.
6. Plymate SR, Tenover JS, Bremner WJ. Circadian variation in testosterone, sex hormone-binding globulin and calculated non-sex hormone-binding globulin bound testosterone in healthy young and elderly men. *J Androl*, 1989 Sep-Oct;10(5):366-71.
7. Spratt DI, O'Dea LS, Schoenfeld D, Butler J, Rao PN, Crowley WF Jr. Neuroendocrine-gonadal axis in men: frequent sampling of LH, FSH and testosterone. *Am J Physiol*, 1988 May;254(5 Pt 1):E658-66.
8. Schiavi RC, White D, Mandeli J. Pituitary-gonadal function during sleep in healthy aging men. *Psychoneuroendocrinology*, 1992 Nov;17(6):599-609.
9. Redwine L, Hauger RL, Gillin JC, Irwin M. Effects of sleep and sleep deprivation on interleukin-6, growth hormone, cortisol and melatonin levels in humans. *J Clin Endocrinol Metab*, 2000 Oct;85(10):3597-603.
10. Mitamura R, Yano K, Suzuki N, Ito Y, Makita Y, Okuno A. Diurnal rhythms of luteinizing hormone, follicle-stimulating hormone and testosterone secretion before the onset of male puberty. *J Clin Endocrinol Metab*, 1999 Jan;84(1):29-37.
11. Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. Mortality associated with sleep duration and insomnia. *Arch Gen Psychiatry*, 2002 Feb;59(2):131-6.
12. Kelly PA, Binart N, Freemark M, Lucas B, Goffin V, Bouchard B. Prolactin receptor signal transduction pathways and actions determined in prolactin receptor knockout mice. *Biochem Soc Trans*, 2001 May;29(Pt 2):48-52.
13. Rubin RT, Poland RE, Tower BB. Prolactin-related testosterone secretion in normal adult men. *J Clin Endocrinol Metab*, 1976 Jan;42(1):112-6.
14. Singer F, Zumoff B. Subnormal serum testosterone levels in male internal medicine residents. *Steroids*, 1992 Feb;57(2):86-9.
15. Irwin M, Thompson J, Miller C, Gillin JC, Ziegler M. Effects of sleep and sleep deprivation on catecholamine and interleukin-2 levels in humans: clinical implications. *J Clin Endocrinol Metab*, 1999 Jun;84(6):1979-85.
16. Axelsson J, Akerstedt T, Kecklund G, Lindqvist A, Attefors R. Hormonal changes in satisfied and dissatisfied shift workers across a shift cycle. *J Appl Physiol*, 2003 Nov;95(5):2099-105. Epub 2003 Jul 25.
17. Luboshitzky R, Lavie L, Shen-Orr Z, Herer P. Altered luteinizing hormone and testosterone secretion in middle-aged

obese men with obstructive sleep apnea. *Obes Res*, 2005 Apr;13(4):780-6.

18. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. *Lancet*, 1999 Oct 23;354(9188):1435-9.
19. Grunstein RR. Metabolic aspects of sleep apnea. *Sleep*, 1996 Dec;19(10 Suppl):S218-20.
20. Grunstein RR, Handelsman DJ, Lawrence SJ, Blackwell C, Caterson ID, Sullivan CE. Neuroendocrine dysfunction in sleep apnea: reversal by continuous positive airways pressure therapy. *J Clin Endocrinol Metab*, 1989 Feb;68(2):352-8.
21. Matsumoto AM, Sandblom RE, Schoene RB, Lee KA, Giblin EC, Pierson DJ, Bremner WJ. Testosterone replacement in hypogonadal men: effects on obstructive sleep apnea, respiratory drives and sleep. *Clin Endocrinol (Oxf)*, 1985 Jun;22(6):713-21.
22. Fogel RB, Malhotra A, Pillar G, Pittman SD, Dunaif A, White DP. Increased prevalence of obstructive sleep apnea syndrome in obese women with polycystic ovary syndrome. *J Clin Endocrinol Metab*, 2001 Mar;86(3):1175-80.
23. Zhou XS, Rowley JA, Demirovic F, Diamond MP, Badr MS. Effect of testosterone on the apneic threshold in women during NREM sleep. *J Appl Physiol*, 2003 Jan;94(1):101-7.
24. Opstad PK, Aakvaag A. Decreased serum levels of oestradiol, testosterone and prolactin during prolonged physical strain and sleep deprivation and the influence of a high calorie diet. *Eur J Appl Physiol Occup Physiol*, 1982;49(3):343-8.
25. Opstad PK. Androgenic hormones during prolonged physical stress, sleep and energy deficiency. *J Clin Endocrinol Metab*, 1992 May;74(5):1176-83.
26. Feldman HA, Longcope C, Derby CA, Johannes CB, Araujo AB, Coviello AD, Bremner WJ, McKinlay JB. Age trends in the level of serum testosterone and other hormones in middle-aged men: longitudinal results from the Massachusetts male aging study. *J Clin Endocrinol Metab*, 2002 Feb;87(2):589-98.
27. Veldhuis JD, Iranmanesh A, Godschalk M, Mulligan T. Older men manifest multifold synchrony disruption of reproductive neurohormone outflow. *J Clin Endocrinol Metab*, 2000 Apr;85(4):1477-86.
28. Harman SM, Tsitouras PD. Reproductive hormones in aging men. I. Measurement of sex steroids, basal luteinizing hormone and Leydig cell response to human chorionic gonadotropin. *J Clin Endocrinol Metab*, 1980 Jul;51(1):35-40.
29. Luboshitzky R, Shen-Orr Z, Herer P. Middle-aged men secrete less testosterone at night than young healthy men. *J Clin Endocrinol Metab*, 2003 Jul;88(7):3160-6.
30. Liu PY, Yee B, Wishart SM, Jimenez M, Jung DG, Grunstein RR, Handelsman DJ. The short-term effects of high-dose testosterone on sleep, breathing and function in older men. *J Clin Endocrinol Metab*, 2003 Aug;88(8):3605-13.
31. Kouchiyama S, Honda Y, Kuriyama T. Influence of nocturnal oxygen desaturation on circadian rhythm of testosterone secretion. *Respiration*, 1990;57(6):359-63.
32. Yilmaz B, Kutlu S, Mogulkoc R, Canpolat S, Sandal S, Tarakci B, Kelestimur H. Melatonin inhibits testosterone secretion by acting at hypothalamo-pituitary-gonadal axis in the rat. *Neuro Endocrinol Lett*, 2000;21(4):301-306.
33. Luboshitzky R, Lavi S, Thuma I, Lavie P. Testosterone treatment alters melatonin concentrations in male patients with gonadotropin-releasing hormone deficiency. *J Clin Endocrinol Metab*, 1996 Feb;81(2):770-4.
34. Harman, E, Wynne, JW, Block, AJ, et al Sleep-disordered breathing and oxygen desaturation in obese patients. *Chest*, 1981;79,256-260.