Sleep improvement in athletes: use of nutritional supplements

Fernando Mata Ordóñez[1,2], Antonio J. Sánchez Oliver[3], Pedro Carrera Bastos[2], Laura Sánchez Guillén[1], Raúl Domínguez[4]

[1]Instituto Internacional de Ciencias del Ejercicio Físico y Salud. Alicante. [2]NutriScience. Lisboa. [3]Universidad Pablo de Olavide. Sevilla. [4]Universidad Alfonso X el Sabio. Madrid.

Received: 21.06.2016
Accepted: 14.10.2016

Summary

Sleep is the physical and mental resting state which is fundamental for recovery of the biological system, regulating key mechanisms and metabolic homeostasis. It is recommended to sleep around 8 hours/night, and sleep restriction is considered when a person sleeps less than 6 hours during 4 or more consecutive nights. Some environmental factors adversely affecting sleep will reduce quality of life and may increase mortality risk. Sports performance is obviously a key factor that needs to be successful in a competition period. It is well known that insufficient rest reduces physical fitness and favors the onset of mood disorders. For that reason, multiple lines of research are focused on finding the best way to improve the quality and quantity of sleep in athletes. It has been found that both nutrition and good training periodization are important to improve the rest and sleep of athletes. To get to sleep and its disruption in the previous days to competition, hour of training, athletes' lifestyle and its impact, nutrition and supplementation, are the key topics addressed in this review about sleep in athletes. There is an urgent need of more research to understand and use different strategies, including nutritional supplements, in improving sleep in athletes.

Key words:
Sleep. Performance. Nutrition. Training. Supplement.

Mejora del sueño en deportistas: uso de suplementos nutricionales

Resumen

El sueño es el estado de reposo físico y mental fundamental en la recuperación del sistema biológico, regulando mecanismos claves y ejerciendo su papel en la homeostasis metabólica. Las recomendaciones lo sitúan en torno a las 8 horas/noche, considerándose que una persona sufre restricción del mismo con tiempos inferiores a 6 horas durante 4 o más noches consecutivas. Éste se ve afectado por diferentes factores ambientales de forma negativa lo que conlleva efectos perjudiciales para la esperanza y la calidad de vida. En el ámbito deportivo, el rendimiento es el factor clave para el éxito en la competición. El sueño es pieza clave en el entrenamiento invisible, jugando un papel fundamental en el rendimiento. Está comprobado que la falta de descanso es desencadenante de una menor capacidad física y de la aparición de trastornos anímicos que dificultan la toma de decisiones. Por ello existen un gran número de investigaciones centradas en estudiar cómo mejorar la calidad y la cantidad del sueño de los atletas a partir de una correcta programación de los entrenamientos y/o una nutrición adecuada, y así minimizar la interferencia o mejorar la fase de conciliación del sueño. La conciliación del sueño, la alteraciones de este los días previos a la competición, el horario de entrenamiento, el estilo de vida del deportista y su influencia en el mismo, la alimentación y la suplementación son los principales temas tratados en esta revisión sobre el sueño en deportistas. Es necesario un mayor número de estudios y un mayor nivel de evidencia para poder conocer y usar las diferentes estrategias que mejoren la calidad del sueño en deportistas.

Palabras clave:
Sueño. Rendimiento. Nutrición. Entrenamiento. Suplemento.

Correspondence: Antonio Jesús Sánchez Oliver
E-mail: asanchez@upo.es

Introduction

Sleep is a state of physical and mental rest in which a person passes into a relatively inactive and unconscious state[1] that is associated with recovery processes, for which numerous biological functions will intervene. Sleep recommendations are set at 8 hours a night, considering that a person suffers from restricted sleep when the amount of hours spent sleeping is reduced to periods of time below 6 hours for 4 or more consecutive nights[2].

Recent studies have revealed that sleep is fundamental in the regulation of key molecular mechanisms, as well as in metabolic homeostasis[3]. However, in the duration or quality of sleep, various factors such as light, jet-lag[4], nutrition[5] and genetics[6] come into play. Despite the complexities surrounding sleep, it must serve a major purpose for human beings, as it has survived thousands of years of evolution[6]. As such, restricting sleep or reducing its quality are factors that can entail damaging effects on life expectancy and quality (Table 1).

Different dietary precursors influence the synthesis and function of diverse neurotransmitters related to sleep, such as serotonin. As such, some substances such as coffee are associated with sleep alterations[7], whilst others, such as tart cherries or kiwis reduce the time needed to fall asleep[8], or reduce awakenings, increasing the sleep time[9].

In the field of sport, on-going sleep restriction can result in over-training, which can result in mood disorders and affect decision making[10], cognitive performance, the immune system and appetite regulation[11]. Due to the important role that sleep may play in sporting performance, as well as the possible effect of nutritional factors on its modulation, the main aim of this literary review has been to analyse the controllable factors that may directly or indirectly affect the hours of sleep of the athlete, and to assess the nutritional supplements that may improve the quality of sleep, as well as their correct dosage.

Table 1. Effects of restricting sleep on different physiological processes.

Parameter	Physiological effect
Immune Function	Hyperactivity of the T cells and increase of the levels of leukocytes, neutrophils, monocytes and the natural killer cells7, flattening of the circadian rhythms[8]
Inflammation	Stimulation of TNF and IL-6 levels[9]
Metabolic	Less sensitivity to the action of insulin and the capacity to regulate blood sugar[10]
	Reduction of levels of leptin and increase of those of ghrelin[11] Increased feeling of hunger[12]
Neuro-endocrines	Inverse relationship between the duration of sleep and the levels of cortisol[13] and catecholamines[14]
	Reduction in IGF-1, GH and testosterone levels[3]
Psychological factors	Increase of the effects of psychological stress[15] Increase in the risk of suffering from anxiety and developing depression[16]

GH: growth hormone; IGF: insulin-like growth factor; IL-6: interleukin-6; TNF: tumour necrosis factor

Method

This literary review was performed based on scientific works indexed in the Pubmed and Web of Science databases. The search strategy, using key words, included the terms *sleep, insomnia* and *"sleep loss"* in combination with *sport, exercise, "physical activity"* and *"nutrition"*. Later, only the intervention works that were published in English or Spanish were selected, that directly studied sleep or the restriction of sleep on the athlete population and/or with guidelines that may modulate sleep alterations.

Results

Prevalence in sleep disorders among the athlete population

In a study performed on Olympic athletes, it has been proven that despite them spending longer in bed compared to the non-athlete population, the total sleep time is not different, as athletes require more time to fall asleep[12]. However, various research studies have not confirmed these results. As such, the athlete population may present difficulties in covering the daily sleep requirements (8 hours), even with naps[13], especially when going through states of over-training[14] and on days leading up to a competition[15,16].

In a study with 632 high-performance athletes, it was observed that 65.8% of them presented sleep alterations the day before a competition[17], though other works found even higher rates, reaching 80%[16]. Some research studies that assessed the duration of sleep the day before a competition discovered average values of 6.5 hours in cyclists[14] and 5.4 hours in swimmers[16], whilst the time taken to fall asleep may reach 50 and 41 minutes respectively.

Training schedules may have a direct influence on sleep restriction. Here, despite athletes that train first thing in the morning aim to combat the deficit by going to bed earlier, they present a higher rate of sleep restriction[13,18]. Furthermore, the sporting modalities that cause the most subjective pressure on the athlete (individual modalities) present a higher rate of sleep alteration[15], as opposed to sex, which does not appear to be a determining factor in the quality or quantity of sleep in the athlete population[5].

Exercise factors that interact in sleep regulation

The duration of sleep and the time it takes to fall asleep both improve after performing exercise, when it is carried out at least 4 hours before going to bed[4]. In the non-athlete population it has been demonstrated that 12-month exercise interventions improve the

quality and duration of sleep[4], whilst shorter programmes (16 weeks) may improve the subjective perception of sleep[18]. However, exercise performed in the 4-hour period leading up to bed time may reveal an inverse relationship with the quantity and quality of sleep[4]. To gain a better understanding of these results, the responses occurring in the phases after exercise that may interfere with sleep should be studied.

As well as increasing the body temperature, once the intensity at which the aerobic-anaerobic transition occurs is exceeded, exercise is accompanied by an increase of the activity of the sympathetic nervous system, characterised by an increase in catecholamine levels[19]. This increase in sympathetic activity may last for hours after exercise.

Body temperature reveals a direct relationship with sleep, in that increases of 1.5-2ºC impede sleep, whilst reductions of around 0.5ºC promote its appearance[20]. In the same way, it has been shown that heart rate (HR) increases (20 beats a minute) are one of the main factors that intervene in sleep interruption[21].

Given that exercise, once the early recovery phase has been overcome, leads to greater activation of vagal tone, it may explain why performing exercise before the 4-hour period could improve the quantity and quality of sleep. On the contrary, hyperactivity of the sympathetic tone that occurs on the days prior to a competition, as well as the first stages of over-training, could explain the sleep alterations experienced by athletes before competing[12,13], or in states of over-training.

Performance

In a study carried out on swimmers, it has been shown that a restriction of 2.5 hours of sleep for 4 consecutive nights does not reduce strength performance, respiratory function or swimming-specific performance, though it is accompanied by increases in symptoms related to depression, confusion, anger, fatigue and reduced vigour[22]. Other later studies, on the other hand, did observe that long-term sleep restriction entails a progressive reduction in the levels of maximum and sub-maximum strength in different exercises[23]. Furthermore, unlike the previous study performed on swimmers[22], in a study with a larger sample, it was proven that restricting sleep may also reduce the respiratory rate and the time to exhaustion in a maximum incremental test in both runners and volley ball players[24].

Sleep restriction is accompanied by alterations on a proprioceptive level and of neuro-muscular control[6], which may be the source of the greatest rate of injuries in athletes that sleep for less than 8 hours each day[25]. Therefore, sleep restriction may become an injury risk factor[20]. Moreover, sleep restriction is associated with an increase of the secretion of pro-inflammatory cytokines[26], possibly affecting the immune function and explaining the greater rate of upper airway infections in athletes with sleep restriction[27]. It should also be considered that sleep restriction is accompanied by an increase of catabolic hormones such as cortisol[28] and a reduction of anabolic hormones such as GH, IGF-1 and testosterone[3], possibly directly affecting the body composition, reducing levels of lean muscle[3]. Therefore, as displayed in Table 2, the quantity and quality of sleep seems to directly affect athletic performance.

The effect of napping on sporting performance

Following sleep restriction, it has been proven that a 30 minute nap improves athletes' performance in speed trials[29]. It has also been shown that naps may improve the cognitive processes affected by sleep restriction[30], which hypothetically may have a positive effect on the technical-tactical performance, when it comes to learning new motor skills or carrying out highly complex motor skills, as well as preventing the appearance of injuries. For this reason, it could be considered that athletes that suffer from sleep restrictions may benefit from a nap, thus turning it into a way of combating accumulated sleep loss.

Lifestyle factors that influence sleep

Lifestyle factors that most influence sleep and that are most represented in the literature are the consumption of caffeine, smoking, exposure to electronic devices, exposure to bright light during the night, and the time dedicated to sleeping[31]. Caffeine increases the state of alertness, antagonising adenosine receptors, which also leads to a reduction in the inclination to sleep. A review of the effects of caffeine on sleep reached the conclusion that there is a strong association between the intake of caffeine and difficulties sleeping[7]. Current evidence does not establish a specific time in which caffeine can be consumed with the aim of avoiding sleep interruption[31].

Table 2. Effects of restricting sleep on different performance indicators.

Performance indicators	Effects of restricting sleep
Performance	Reduction in cardio-respiratory capacity and possible negative effect on maximum and sub-maximum strength levels
Over-training	Interference of the recovery processes that take place during sleep Increase in symptoms such as depression, confusion, anger, fatigue and reduced vigour Increase in levels of catabolic hormones, such as cortisol, in rest and reduction of anabolic hormones, like GH, IGF-1 and testosterone
Predisposition to acquiring an injury	Increased probability of acquiring an injury due to a reduced cognitive performance and proprioceptive and neuromuscular alterations
Predisposition to suffering from infections	The decrease in the immune function may make the athlete more vulnerable to the possibility of suffering from infections, especially of the upper airways
Unfavourable alterations in the body composition	Reduction of lean muscle mass due to an unfavourable anabolic setting

Nutritional supplementing and improvements of sleep indicators

Serotonin and melatonin are the two main molecules responsible for sleep regulation. Given that diverse nutrients can have a direct or indirect influence on the synthesis of melatonin, and especially, on serotonin, nutritional supplementing has been turned to in order to improve the quantity and quality of sleep (Table 3).

Tryptophan

The attempt to increase levels of free tryptophan in the blood is founded on the basis that these levels are closely regulated by the tryptophan/branched-chain amino acids relationship. When an increase occurs in the levels of free tryptophan, whether due to a reduction of the branched-chain amino acids or to an increase of the availability of tryptophan, this amino acid crosses the blood-brain barrier and is transformed into a precursor of serotonin or 5-hydroxytryptamine (5-HT)[32]. In fact, it is considered that the velocity of the tryptophan on a brain level is the limiting factor in the synthesis of 5-HT. Among the functions of 5-HT are those related to lethargy and drowsiness, due to the fact that it acts as a precursor to melatonin in the pineal gland[33].

The modification of tryptophan levels has been performed based on dietary modifications. Thus, the intake of proteins rich in tryptophan such as α-lactalbumin present in whey increases the tryptophan/branched-chain amino acids relationship by up to 130%, increasing the levels of serotonin in the brain. On the contrary, a diet with a nigh content of branched-chain amino acids or with a supplement of them - a very common practice among athletes in both strength and in aerobic resistance - could reduce the levels of tryptophan that cross the blood-brain barrier.

In terms of the intake of carbohydrates, it has been shown that it increases the plasma concentration of tryptophan, which, as we have already mentioned, is a precursor to serotonin and a sleep-inducing agent. Various studies have proven that a large availability of this nutrient may favour the brain's capture of tryptophan through the action of the insulin, due to the fact that it will produce an increase in the capture of branched-chain amino acids in the skeletal muscle, which will increase the levels of free tryptophan[1].

In terms of the necessary dose of tryptophan, it has been revealed that 1g is sufficient to improve both the quantity and the quality of sleep[33].

B-complex vitamins

Sleep is influenced by the action of certain components, such as certain vitamins and minerals, on the synthesis of melatonin, with an association between deficient nutritional circumstances with sleep alterations.

Vitamin B3 or niacin can be produced endogenously from tryptophan. A sufficient amount of this vitamin, through diet or supplements, will mean a smaller amount of tryptophan will be destined to synthesising niacin, by inhibiting the activity of the 2,3-dioxygenase, with a greater amount of tryptophan available to synthesise serotonin[1].

Folate and pyridoxine (vitamin B6) play a crucial role in the conversion of tryptophan into serotonin. The reduced form of the folate 5-Methyltetrahydrofolate increases the tetrahydrobiopterin, which is a co-factor of the Tryptophan-5-Hydroxylase enzyme. This enzyme converts the Tryptophan into 5-hydroxytryptamine (5-HT). The role of Vitamin B6 is related to the aromatic amino acid decarboxylase, which speeds up the transformation of 5-HT into serotonin[1].

For the other part, cobalamin (vitamin B12) also contributes to the synthesis of melatonin, with a possible positive effect on the quantity of sleep in supplement form, proving fundamental for vegetarian athletes, due to the fact that they may present a deficient situation given that this vitamin is found in food sources of animal origin.

It should not be forgotten that supplementing with these nutrients will only have an effect in cases of deficiency or insufficiency. This means that individuals with sufficient levels of them will not need this supplement.

Magnesium

Magnesium is important for the 5-Hydroxytryptamine enzyme N-acetyltransferase to convert 5-HT into N-Acetyl-5-Hydroxytryptamine and which is then transformed into N-Acetyl-5-methoxy tryptamine (Melatonin)[34]. Magnesium is therefore established as a mineral to consider for future research studies to determine its effect on sleep and its dosage.

Zinc

Various studies suggest a relationship between zinc and melatonin[35]. Bediz *et al*.[35] observed the effects of zinc deficiency and the administering of supplements in melatonin levels in rat plasma. The results of this study suggest that the zinc deficiency reduces the levels of melatonin and that supplementing zinc may increase melatonin levels in rats. These results may be cross-checked in humans in order to arrive at more solid conclusions.

Melatonin

Melatonin is a hormone secreted by the pineal gland, which gives information about the lightness-darkness cycle, with its synthesis suppressed by the exposure of the retina to light[29]. From a phylogenetic perspective, it has been linked to the anti-oxidant protection against ionizing radiation and a very oxygen-rich atmosphere, slowing down cellular functions during the hours of greatest exposure to those radiations during the day, to be activated during darkness hours when there is a lower risk[36].

This hormone, associated with the circadian rhythm, will have sedating or hypnotic effects, which is why nutritional supplementing has been carried out as an alternative to sleep disorder treatment[28]. If the nocturnal production of melatonin is not necessary for the appearance of sleep, the presence of darkness during the night is an absolute must[37].

The increase of melatonin concentration in the blood stream induces drowsiness and coincides with a reduction of the body temperature[36].

Effective doses of melatonin seem to be those comprising between 3-12 mg[38], though the possible side effects of this supplement should be taken into account, such as headaches, nausea, drowsiness during the day or nightmares[39], thus affecting performance. We should consider that interventions aiming to manipulate levels of tryptophan ultimately aim to directly influence melatonin levels[29].

Furthermore, melatonin is a lipophilic hormone for which it is capable of crossing cellular, placental and blood-brain membranes in which it performs antioxidant functions[30].

Despite there being no conclusive data regarding the effectiveness of the use of this hormone in increasing hours of sleep, it could improve the capacity of falling asleep[38], particularly among athletes that are continuously travelling to countries with different time zones, as it can reduce symptoms of jet lag[4].

Valerian

Valerian is a herb whose components, valeric acid and its derivatives, target GABA type A receptors, possibly inducing a general calming effect on the body[40] by regulating the degree of excitability of the nervous system.

Although valerian could improve rates related to the quality of sleep, just as with melatonin, no positive effect has been proven of its supplementing on the quality of sleep[6].

The side effects of valerian include dizziness, drowsiness during the day, as well as the appearance of allergies[37].

L-Theanine

L-theanine is an amino acid that is found in green tea leaves, related to a reduction in stress and with relaxing effects without causing drowsiness[41]. It is the most important amino acid in tea, with some 25-60 mg in every 200 ml. and it has been proven in healthy, young subjects, to cause a state of mental relaxation yet alertness through a direct influence on the central nervous system[42]. It crosses the blood-brain barrier in 30 minutes and strengthens the 1-alpha frequency band of the electroencephalogram approximately 40 minutes after ingestion[41]. It acts by blocking the joining of the L-glutamic acid to its receptor (glutamate receptor). Studies of L-theanine reveal an attenuation in the activation of the sympathetic nervous system, improvements of subjective post-stress relaxation, attenuation in the increase of cortisol levels, a reduction in anxiety and a mitigated increase in high blood pressure in response to stress among adults[40], and in terms of sleep, in rats it was observed that it partially counteracted the reduction of slow sleep waves induced by caffeine[17].

Food as a fundamental element in sleep

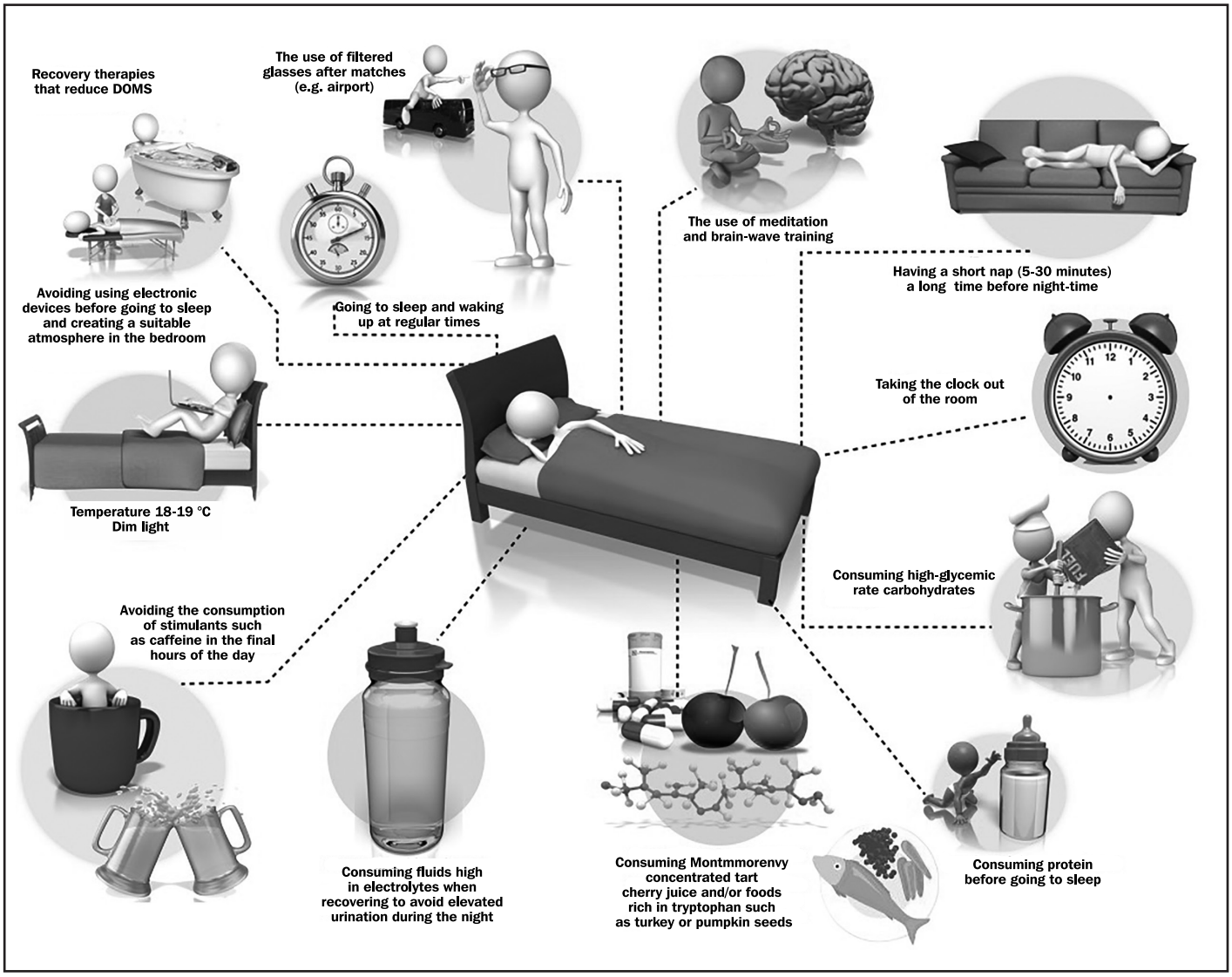
During the review, it became clear how nutritional manipulation via different supplements can influence the improvement of sleep in athletes. It is important to highlight how foods such as fish (>5% fat) constitute a good source of vitamin D and omega-3, important nutrients in regulating serotonin and therefore in regulating sleep[43]. On the other hand, other studies have observed the consumption of fruit in the promotion of sleep[43-45]. As such, consuming two kiwis 1 hour before going to sleep for 4 weeks increased the efficiency of sleep and the total time sleeping measured via actigraphy in adults with sleep disorders[44]. Other fruits such as tart cherries have demonstrated improvements to sleep in different studies, due to its melatonin content[45,46]. Therefore, improved sleep quality seems to be related to a greater consumption of fruit, vegetables and fish, and is inversely related to the consumption of processed foods[47]. A key first step would be to address sleep improvement in athletes by analysing and improving their eating habits.

Table 3. Physiological effect and dosage of the main dietary supplements used to improve the quantity and quality of sleep.

Supplement	Physiological effect	Dosage
Tryptophan	Precursor to serotonin on a cerebral level, hormone responsible for causing sensations like lethargy and drowsiness	1 g•day^{-1}
B-complex vitamins	Vitamin B_3 reduces the activity of the 2-3-dioxygenase, reducing the quantity of tryptophan designated to synthesise this vitamin, leaving a greater amount of tryptophan available to synthesise serotonin	DRI in cases of deficiency
	Vitamine B_6 is involved in serotonin synthesis processes, from tryptophan	
	Vitamina B_{12} is involved in the synthesis of melatonin	
Minerals	Magnesium and zinc intervene in the synthesis of melatonin	DRI in cases of deficiency
Melatonin	Hormone that induces sleep and lethargy	5- 8 mg
Valerian	Reducer of the sympathetic nervous system activity	No positive effect has been demonstrated
L-Theanine	Reducer of the sympathetic nervous system activity	No positive effect has been demonstrated

DRI: dietary reference intakes.

Figure 1. Hygiene measures that may contribute to improving the quantity and quality of sleep in athletes.



Conclusions

Physical exercise, especially that of moderate intensity and performed at least 4 hours before going to bed, may have a therapeutic effect on treating sleep restriction in sedentary people. Athletes with a high level of training, however, may see their sleep disturbed, especially on days leading up to a competition, due to a hyper-activation of the sympathetic nervous system activity or due to time limits when training first thing in the morning or just before going to bed. On the other hand, some nutritional aids, such as melatonin, tryptophan and some vitamins and minerals (in the case of insufficient levels of them through the diet alone), have demonstrated some effects on improving sleep in athletes, with greater levels of evidence required in terms of their effectiveness and the recommended dosage.

Based on everything included in this review, and founding our conclusions on various current reviews about sleep and sport, by means of a summary (Figure 1), some hygienic measures have been displayed that may contribute to improving the quantity and quality of sleep among athletes[48-52].

Bibliography

1. Peuhkuri K, Sihvola N, Korpela R. Diet promotes sleep duration and quality. *Nutr Res.* 2012;32(5):309-19.
2. Van Dongen HPA, Vitellaro KM, Dinges DF. Individual differences in adult human sleep and wakefulness: Leitmotif for a research agenda. *Sleep.* 2005;28(4):479-96.
3. Cummiskey J, Natsis K, Papathanasiou E, Pigozzi F. Sleep and athletic performance. *Eur J Sports Med.* 2013;1(1):13-22.
4. Herxheimer A, Petrie KJ. Melatonin for the prevention and treatment of jet lag. *Cochrane Database Syst Rev.* 2002;2:CD001520.

5. Erlacher D, Ehrlenspiel F, Adegbesan OA, El-Din HG. Sleep habits in German athletes before important competitions or games. *J Sports Sci.* 2011;29(8):859-66.
6. Fernández-San-Martín MI, Masa-Font R, Palacios-Soler L, Sancho-Gómez P, Calbó-Caldentey C, Flores-Mateo G. Effectiveness of Valerian on insomnia: a meta-analysis of randomized placebo-controlled trials. *Sleep Med*. 2010;11(6):505-11.
7. Roehrs T, Roth T. Caffeine: sleep and daytime sleepiness. *Sleep Med Rev*. 2008;12(2):153-62.
8. Pigeon WR, Carr M, Gorman C, Perlis ML. Effects of a tart cherry juice beverage on the sleep of older adults with insomnia: a pilot study. *J Med Food.* 2010;13(3):579-83.
9. Lin H-H, Tsai P-S, Fang S-C, Liu J-F. Effect of kiwi fruit consumption on sleep quality in adults with sleep problems. *Asia Pac J Clin Nutr*. 2011;20(2):169-74.
10. Lastella M, Lovell GO, Sargent C. Athletes' precompetitive sleep behaviour and its relationship with subsequent precompetitive mood and performance. *Eur J Sport Sci*. 2014;14(1):123-30.
11. Spiegel K, Tasali E, Penev P, Van Cauter E. Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann Intern Med.* 2004;141(11):846-50.
12. Leeder J, Glaister M, Pizzoferro K, Dawson J, Pedlar C. Sleep duration and quality in elite athletes measured using wrist watch actigraphy. *J Sports Sci.* 2012;30(6):541-5.
13. Sargent C, Lastella M, Halson SL, Roach, GD. The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiol Int.* 2014;31(10):1160-8.
14. Lastella M, Roach GD, Halson SL, Martin DT, West NP, Sargent C. Sleep/wake behaviour of endurance cyclists before and during competition. *J Sports Sci.* 2015;33(3):293-9.
15. Erlacher D, Ehrlenspiel F, Adegbesan OA, ElDin HG. Sleep habits in German athletes before important competitions or games. *J Sports Sci.* 2011;29:859-66.
16. Sargent C, Halson S, Roach GD. Sleep or swim? Early-morning training severely restricts the amount of sleep obtained by elite swimmers. *Eur J Sport Sci.* 2014;14 Supp 1:310-5.
17. Yang P-Y, Ho K-H, Chen H-C, Chien M-Y. Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. *J Physiother.* 2012;58(3):157-63.
18. King AC, Oman RF, Brassington GS, Bliwise DL, Haskell WL. Moderate-intensity exercise and self-rated quality of sleep in older adults. A randomized controlled trial. *JAMA.* 1997;277(1):32-7.
19. Domínguez R, Garnacho-Castaño MV, Maté-Muñoz JL. Metodología de determinación de la transición aeróbica-anaeróbica en la evaluación funcional. *Arch Med Deporte.* 2016;32(6):387-92.
20. Chennaoui M, Arnal PJ, Sauvet F, Léger D. Sleep and exercise: A reciprocal issue? *Sleep Med Rev.* 2014;20:59-72.
21. Morin CM, Hauri PJ, Espie CA, Spielman AJ, Buysse DJ, Bootzin RR. Nonpharmacologic treatment of chronic insomnia. An American Academy of Sleep Medicine review. *Sleep.* 1999;22(8):1134-56.
22. Sinnerton S, Reilly T. Effects of sleep loss and time of day in swimmers. En: Reilly T, Lees A, editores. B*iomechanics and medicine in swimming: swimming science IV*. London: E and F.N Spon; 1992. p. 399-405.
23. Reilly T, Piercy M. The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics.* 1994;37(1):107-15.
24. Azboy O, Kaygisiz Z. Effects of sleep deprivation on cardiorespiratory functions of the runners and volleyball players during rest and exercise. *Acta Physiol Hung.* 2009;96(1):29-36.
25. Milewski MD, Skaggs DL, Bishop GA, Pace JL, Ibrahim DA, Wren TAL *et al.* Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop*. 2014;34(2):129-33.
26. Vgontzas AN, Zoumakis E, Bixler, Lin HM, Follet H, Kales A. *et al.* Adverse effects of modest sleep restriction on sleepiness, performance, and inflammatory cytokines. *J Clin Endocrinol Metab.* 2004;89(5):2119-26.
27. Hausswirth C, Louis J, Aubry A, Bonnet G, Duffield R, LE Meur Y. Evidence of disturbed sleep and increased illness in overreached endurance athletes. *Med Sci Sports Exerc.* 2014;46(5):1036-45.
28. Fondell E, Axelsson J, Franck K, Ploner A, Lekander M, Bälter K, *et al.* Short natural sleep is associated with higher T cell and lower NK cell activities. *Brain Behav Immun.* 2011;25(7):1367-75.
29. Waterhouse J, Atkinson G, Edwards B, Reilly T. The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *J Sports Sci.* 2007;25(14):1557-66.
30. Halson SL. Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports Med Auckl NZ*. 2014;44 Suppl 1:13-23.
31. Golem DL, Martin-Biggers JT, Koenings MM, Davis KF, Byrd-Bredbenner C. An Integrative Review of Sleep for Nutrition Professionals. *Adv Nutr Bethesda Md.* 2014;5(6):742-59.
32. Yamamoto T, Azechi H, Board M. Essential role of excessive tryptophan and its neuro-metabolites in fatigue. *Can J Neurol Sci*. 2012;39(1):40-7.
33. Silber BY, Schmitt JA. Effects of tryptophan loading on human cognition, mood, and sleep. *Neurosci Biobehav Rev*. 2010;34(3):387-407.
34. Afaghi A, O'Connor H, Chow CM. High-glycemic-index carbohydrate meals shorten sleep onset. *Am J Clin Nutr*. 2007;85(2):426-30.
35. Abbasi B, Kimiagar M, Sadeghniiat K, Shirazi MM, Hedayati M, Rashidkhani B. The effect of magnesium supplementation on primary insomnia in elderly: A double-blind placebo-controlled clinical trial. *J Med Sci Res.* 2012;17(12):1161-9.
36. Bediz CS, Baltaci AK, Mogulkoc R. Both zinc deficiency and supplementation affect plasma melatonin levels in rats. *Acta Physiol Hung*. 2003;90:335-9
37. Lukaski HC. Vitamin and mineral status: effects on physical performance. *Nutrition.* 2004;20(7-8):632-44
38. McGrane IR, Leung JG, Louis EKS, Boeve BF. Melatonin therapy for REM sleep behavior disorder: a critical review of evidence. *Sleep Med*. 2015;16(1):19-26.
39. Morin CM, Benca R. Chronic insomnia. *Lancet.* 2012;379(9821):1129-41.
40. Blask DE. Melatonin, sleep disturbance and cancer risk. *Sleep Med Rev*. 2009;13(4):257-64.
41. Yoto A, Motoki M, Murao S, Yokogoshi H. Effects of L-theanine or caffeine intake on changes in blood pressure under physical and psychological stresses. *J Physiol Anthropol.* 2012;31:28.
42. Morselli LL, Guyon A, Spiegel K. Sleep and metabolic function. *Pflugers Arch*. 2012;463:139-60.
43. St-Onge MP, Milic A, Pietrolungo CE. Effect of Diet on Sleep Quality. *Avd Nutr.* 2016;7:938-49.
44. Lin HH, Tsai PS, Fang SC, Liu JF. Effect of kiwifruit consumption on sleep quality in adults with sleep problems. *Asia Pac J Clin Nutr.* 2011;20:169-74.
45. Pigeon WR, Carr M, Gorman C, Perlis ML. Effects of a tart cherry juice beverage on the sleep of older adults with insomnia: a pilot study. *J Med Food*. 2010;13:579-83.
46. Garrido M, Paredes SD, Cubero J, Lozano M, Toribio-Delgado AF, Munoz JL, Reiter RJ, Barriga C, Rodriguez AB. Jerte Valley cherry-enriched diets improve nocturnal rest and increase 6-sulfatoxymelatonin and total antioxidant capacity in the urine of middle-aged and elderly humans. *J Gerontol A Biol Sci Med Sci.* 2010;65:909-14.
47. Katagiri R, Asakura K, Kobayashi S, Suga H, Sasaki S. Low intake of vegetables, high intake of confectionary, and unhealthy eating habits are associated with poor sleep quality among middle-aged female Japanese workers. *J Occup Health.* 2014;56:359.
48. Nédélec M, Halson S, Abaidia AE, Ahmaidi S, Dupont G. Stress, sleep and recovery in elite soccer: a critical review of the literature. *Sports Med.* 2015;45(10):1387-400.
49. Nédélec M, Halson S, Delecroix B, Abaidia AE, Ahmaidi S, Dupont G. Sleep hygiene and recovery strategies in elite soccer players. *Sports Med.* 2015;45(11):1547-59
50. Fullagar HH, Duffield R, Skorski S, White D, Bloomfield J, Kölling S, Meyer T. Sleep, travel, and recovery responses of national footballers during and after long-haul international air travel. *Int J Sports Physiol Perform.* 2016;11(1):86-95.
51. Gupta L, Morgan K, Gilchrist S. Does Elite Sport Degrade Sleep Quality? A Systematic Review. *Sports Med.* 2016;1-17.
52. Simpson NS, Gibbs EL, Matheson GO. Optimizing sleep to maximize performance: implications and recommendations for elite athletes. *Scand J Med Sci Sports.* 2017; 27(3):266-274.