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Effects of Melatonin on Sports Performance: A Systematic Review

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ABSTRACT

López-Flores M, Luque-Nieto R, Moreira OC, Suarez-Iglesias D, Villa-Vicente JG. Effects of Melatonin on Sports Performance: A Systematic Review. **JEPonline** 2018;21(5):121-138. Melatonin has been examined in relatively few studies, especially in regards to its use in the sports field. There is still controversy as to how it affects the body in relation with physical activity. The purpose of this paper was to identify the effects of melatonin on the sports performance and sleep via a systematic review of articles from year 2000 to 2018 using the PubMed database. Eighteen articles were identified and evaluate for this study. The results show no improvement in athletic performance when melatonin is exogenously ingested up to 1 hr before physical activity is performed. Also, it is possible that a dose of 10 mg of melatonin ingested 30 min before sleep can improve short physical performance and sleep quality. It seems that the bigger the concentrations of melatonin at the time of physical activity, the worse the sports performance due primarily to the effect of sleepiness and sympathetic deprivation.

Key Words: Melatonin, Sleep, Sports Performance

INTRODUCTION

Sleep could be defined as a reversible behavioral state in which the subject is perceptively disconnected from the environment (9). This behavioral and physiological state could be explained in two different phases, depending on eye movement: Rapid Eye Movement (REM) and No Rapid Eye Movement (N-REM). People sleep at least a third part of their life, because functions of sleeping are basic to diary life and health (21,47). Also, sleep has fundamental effects on learning, memory, and cognition (11,13).

Like other physiological processes that occur throughout the body, it is important that the nocturnal and diurnal activity is in harmony (especially in regards to the role of exercise and physical activity). Interestingly, although it has been described in the literature that 150 min of physical activity provides non-pharmacological positive effects to improve sleep quality (36), it has been shown that intense exercise often impairs sleep quality (41) due to the increased cortisol levels that the stimulate sympathetic nervous system and levels of alertness. Also, in this regards, Souissi et al. (53) reported that nocturnal high intensity training could be worse than evening training, given that it could induce poor sleep quality. Yet, in contrast to their findings, O'Connor et al. (42) and Youngstedt et al. (61) did not find any deterioration on sleep after 1 to 3 hrs of vigorous exercise when ending 30 min before sleep onset.

In the recovery context, sleep has been especially interesting for athletes (24). It has been shown that changes in sleep quality and quantity affect sports performance on the next day. For example, total time of sleep reduction may promote exhaustion (43), reduce aerobic capacity (51,54), submaximal force (44), and precision (18,46), while improving reaction time (26) and perceived exertion (19). Trying to mitigate the negative effects on athletes' sleep restriction or circadian rhythms alterations, Cardinali et al. (8) and Samuels (49) investigated the application of sleep induction protocols in order to improve sleep quality.

Among other variables related to performance sport protocols, the influence of endogenous and exogenous melatonin has been a common topic. According to Karasek and colleagues (28), melatonin was discovered in 1958 and chemically identified in 1959. This hormone is produced by the pineal gland of the brain and synthetized by serotonin (a neurotransmitter substance present in neurons); both substances are present in every vertebrate after a light-dark cycle (45). A particular group of nerve cells of the hypothalamus, the suprachiasmatic nucleus (situated directly above the optic chiasm), responds to the light intensity variations and manages the release of melatonin with 10 times increments during night and the lowest levels during the morning hours (37). Light that is received through the eyes acts on pigment cryptochrome retinal. The message is transmitted through retinohypothalamic tract to the circadian clock on the suprachiasmatic nucleus. This signal is transmitted to the upper cervical ganglion, and from there through the postganglionic fibers to the pineal gland (40).

Melatonin provokes a depressive effect on the central nervous system, which induces the typical nocturnal sleepiness. Its levels are also associated with circadian decrease of body temperature, appearing the lowest temperature levels in the early morning after the highest melatonin levels, and the highest temperature in the late evening when melatonin concentrations are the lowest (7). Circadian rhythm of melatonin secretion is inversely proportional to the normal body central temperature cycle, with increases of melatonin that promote a decrease in body temperature through skin vasodilation (59). Early in the morning, when the body temperature is in its lowest level, melatonin may show peaks 30 times the value during daytime (2).

Some studies (16,22,33) have described the influence of melatonin on sleep, and the physiological processes associated, such as temperature regulation, reproduction, and the regulation of circadian rhythms. Also, its antioxidant effects, aging delay process, and immune system regulation have been investigated. Melatonin is usually consumed as a pharmacological supplement to improve sleep quality. Accordingly, positive effects on performance must prevail over possible adverse effects caused by central nervous system deprivation (57), because a melatonin dose of 5 mg could be enough to induce sleepiness.

Although it has been shown that diurnal consumption of the hormone melatonin in young healthy men may induce sleepiness, fatigue, alertness deprivation, loss of balance, and poor coordination (15), there is some controversy that might be explained by the dose size, the frequency of supplementation (acute or chronic), the time when it is ingested, and the protocol design. As to physical activity and sport, Samuels (49) indicated that there were no negative effects on athletes' health perception, when asking subjects via a questionnaire about their headache, insomniac, hyperactivity, irritability, sickness, constipation, stomach cramps, sleepiness, numbness and tingling, sweating, and feelings of being hungry.

Usually, this hormone is considered as a chronobiotic, according to its regulating functions of circadian rhythms after a light-dark cycle (22). Also, melatonin can improve sleep quality and reduce the symptoms of jet lag syndrome after traveling in several time zones (1). In addition to biorhythm regulation, it has also been found that the administration of exogenous melatonin has hypothermic effects (20). According to body temperature decrease caused by melatonin, its use has been tried on sport performance under high temperatures. Certain studies have looked at its hypothermic effect, showing a body temperature decrease of 0.25 to 0.30ºC during several hours of 5 mg of melatonin consumption (14,25,58). While it is clear that exogenous melatonin has a hypothermic effect, it is unclear of its benefit if any on sports performance.

As to the relationship between melatonin and sports performance, only a certain number of studies have tried to demonstrate a connection between the two. For this reason, the purpose of the study was to present a systematic review and summary of the main results of the application of melatonin on sports performance.

METHODS

The search was made using the PubMed and SPORTDiscus databases. The keywords were “melatonin”, “sleep”, and “sport performance”. In the identification process, the total results identified were 175 (PubMed = 56 SPORTDiscus = 119). Nine papers were discarded after applying a filter to show results from 2000 to 2018. After the first titles and abstracts review, 20 studies were selected for a second revision. A “Full text” filter was applied to discard those with full access, and then we proceeded to discard repeated articles between both databases. The total number of evaluated papers was 31 on the first draft. After the review, we excluded 13 because of the sample characteristics (2 cases), and other characteristics of the study (4 cases). The final number of studies included in this study was 18. The inclusion criteria that were established: (a) full text access; (b) clear relationship of the study with sports performance; (c) study looked at the effects of endogenous or exogenous melatonin on performance; and (d) the studies were of the experimental design. The exclusion criteria were: (a) studies published before the year 2000; (b) studies included non-performance sample; (c) studies where physical activity was not present; and (d) studies were obviously a systematic review.

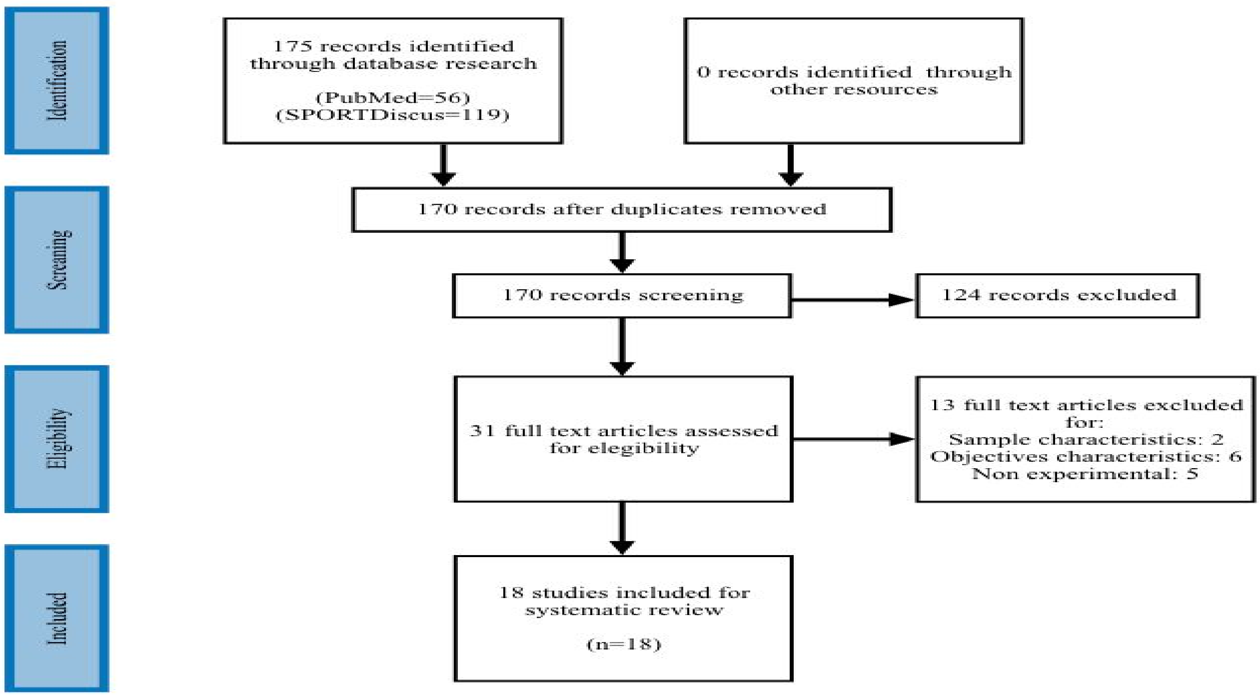

Figure 1. Flow Chart Illustrating the Quality Assessment of Included Studies (PRISMA).

RESULTS

Relation between Melatonin and Sports Performance

Knaier et al. (32) reported that 60 min of bright light exposure induced improvements in the performances of short duration competitions at night, since it reduced the production of melatonin. Kraemer and colleagues (34) carried out performance tests in several moments of the day on highly trained subjects. Melatonin concentrations in plasma were significantly higher in the morning than in the evening, which may reduce the morning agility. Even when velocity was reduced in the morning, it had no other negative impact on the subjects' performance at any other time of the day. Robey et al. (48) showed that water immersion, after fatigued physical exercise, no matter if it was cold or hot, had no influence on the increment of salivary melatonin levels. Also, in Zaho et al. (62), an increment of melatonin levels during sleep resulted after 30-min therapy of red light exposure, making sleep quality and endurance training variables better.

Exogenous Melatonin and Sleep Performance

Cheikh et al. (10) showed that 10 mg of exogenous melatonin after intensive dusk training increased short term cognitive and sport performance, in addition to reduced perceived exertion, reduced DOMS, and increased next morning well-being. A 5 mg dose consumed 15 min before a cycling time trial of 32.2 km did not result in significant changes when compared to the placebo sample (6). On the contrary, after consumption of 5 mg of melatonin at 7.30 a.m., Ghattassi et al. (22) found an increase in the subjects' cognitive performance and an influence on certain physical capacities in the evening trials.

Ghattassi et al. (23) also compared the ingestion of a placebo or 5 mg or 8 mg of melatonin 30 min before physical activity trials. They reported no differences between the placebo or the 5 mg melatonin, but found significant harmful effects on the subjects' performance after ingestion of 8 mg of melatonin. Moreover, when the consumption was 30 min before sleep onset, it did not make any differences on the next morning physical activity trials performance (1). It has also been shown that 6 mg of exogenous melatonin consumed 1 hr before physical activity had non-harmful effects on performance (39).

Melatonin Effects on Sleep and Circadian Rhythm

Jones et al. (27) reported that reading was an effective method to improve melatonin concentration and sleepiness. Also, Cheikh et al. (10) demonstrated that 10 mg of exogenous melatonin after high intensity dusk training improved sleep quality, increased total sleep time, and lowered sleep latency, while Atkinson et al. (1) found no differences on sleep quality after 5 mg of melatonin consumption. Knaier et al. (27) studied the influence of sleep quality after long time bright light exposure. Their results showed that the "long time bright light exposure" activated and readjusted the subjects' circadian clock and balanced an unfavorable chronotype. Thompson and colleagues (55) reported that this type of therapy suppressed the increase in melatonin concentration and reduced sleepiness.

Exercise Effects on Melatonin Concentrations and Sleep

Kilic et al. (30), measured serum melatonin several day times after submitting a sample of athletes to two trials of strenuous exercise (one in the morning and one at night). They reported that no differences were found. Even though, night serum melatonin levels were higher than in the morning, before and after the night trial. Marrin et al. (38) investigated two trials of strenuous exercise on a cycloergometer at 8 a.m. and 5 p.m. They found that melatonin levels were 2 times higher after the subjects' morning trial plus the melatonin levels were increased by exercise regardless of the time of the day. On the other hand, Konarska et al. (33) applied several physical trials (such as an aerobic trial and a strenuous exercise trial on cycloergometer) and found an increase of melatonin levels after maximum intensity exercise, but a decrease with aerobic exercise.

Benefits of Exogenous Melatonin Consumption over Jet Lag Syndrome Symptoms

Cardinali et al. (8) combined several strategies with the purpose to decrease the jet lag syndrome symptoms after a flight from Argentina to Tokyo. The subjects consumed 3 mg of exogenous melatonin 30 min before the onset of sleep and trained twice a day outdoor. All the natural light they received was during the training sessions. The results show an acceleration of resynchronization of the sleep cycle and an absence of disturbance on sleep quality and alertness. In the same way, Lagarde et al. (35) studied the effects of 5 mg of melatonin consumption on sport performance after a flight from United States to France. They found no differences in the performance of the subjects' who had consumed melatonin, but a decrease in performance of the subjects who consumed the placebo. In a trip from London to Australia, Edwards et al. (16) did not find differences between a 5 mg of melatonin consumption or placebo in a grip strength test, sleep quality, and resynchronization.

Table 1. Characteristics of the Included Studies.

Author and Year	Sample	Stimulus	Inter-vention	Register	Results	Conclusions
Jones et al., 2018	**Netball female highly trained players** N = 8 (18 ± 1 yrs) **Group 1** Riddles on tablets **Group 2** Reading on tablets **Group 3** Riddles without tablets **Group 4** Reading without tablets	Cognitively stimulating tasks 2 hrs before sleep onset Passive tasks 2 hrs before sleep onset	5/1/NR	Polysomnographic evaluation Evaluation before sleep onset. Exercise trials Salivary analysis Liquids chromatography	Higher ↑↑ melatonin after Reading than making riddles on tablet Higher ↑↑ sleepiness after reading than making riddles on paper No differences found on exercise trials	Use of tablets 2 hrs before sleep onset did not show ↑↑ in sleepiness Did not harm next sleep Did not harm next day performance
Cheikh et al., 2018	**Teen elite judokas (men)** N = 10 (15.4 ± 0.3 yrs) **Group 1** Double action sustained release melatonin **Group 2** Placebo	10 mg exogenous melatonin after high intensity training Placebo	NR	YOYO test Polysomnography Hooper's Wellbeing index Exercise trails	↑↑ TST, SE, 3rd phase sleep and REM sleep with melatonin ↓ SL, Awakening time, 1st phase sleep and 2nd phase sleep ↑↑ significant short term performance ↑↑ sleep quality ↑↑ TST ↓exertion perception ↓ DOMS	A dose of 10 mg melatonin administration after high intensity dusk training could ↑↑ sleep quality, cognitive performance and well-being on the next day
Brandenberger et al., 2017	**Long distance trained cyclist** N = 10	5 mg exogenous melatonin 15 min before time trial Placebo 15 min before time trial	3/1/NR	32.2 km time trial on cycloergometer. Flexible rectal probe	No significant differences between groups duration, mean power, rectal temperature, mean cadence, HR, VO_2	5 mg exogenous melatonin had no significant effect on performance

Knaier et al., 2017	**Endurance elite athletes (men)** N = 69 23 (21 to 29 yrs) **Group 1** Bright light **Group 2** Blue light **Group 3** Control light	60 min Individual light exposure after 10 min of dark	56/3/NR	Cardiorespiratory test of 12 min on cycloergometer 12 hrs after light therapy Salivary melatonin evaluation 60 min before and until 2 hrs after light therapy every 30 min Karolinska Sleepiness Scale Visual motivation scale	↑↑ SP during cardio test after light therapy ↑↑ SP in the second half of the test after light therapy Good adaptation of circadian rhythm since the melatonin increases the time of sleep onset Mild headaches or fatigue	Bright light exposure could improve significantly sport performance in short duration competitions at night ↓TST and suppression melatonin levels depending on underlying mechanisms High doses of bright light could activate the circadian clock and compensate an unfavorable chronotype
Kilic et al., 2016	**Healthy men** N = 10 (22.20 ± 0.24 yrs)	Strenuous exercise once during the day and once at night	NR	2.5 ml blood sample at 10 a.m. and after exercise	No significant differences found on melatonin concentrations resting vs. after day or night exercise Higher serum melatonin levels at night, before and after exercise	Strenuous exercise has no significant effect on serum melatonin levels
Ghattassi et al., 2016	**Tunisian elite soccer players** N = 12 (17.9 ± 1.3 yrs) **Group 1** Melatonin **Group 2** Placebo	5 mg exogenous melatonin at 7:30 a.m. Placebo at 7:30 a.m.	1/2/NR	Oral temperature evaluation Trials at 8 a.m., 12 a.m. and 4 p.m. including: Reaction time Alertness evaluation Medicine ball throwing 5 jumps trial Handgrip test Agility test	↑↑ Cognitive and physical performance at 4 p.m. vs. 8 a.m. significant ↑ of reaction time at 4 p.m. vs. 8 and 12 a.m., with both, placebo or melatonin ↓ significative of time reaction Melatonin consumption could provoke an hypnotic effect before evaluation	5 mg of melatonin ingested in the morning could effect on cognitive performance and certain specific actions and improve them in the evening Melatonin is powerful antioxidant that could have therapeutic benefits on DOMS
Kraemer et al., 2014	**Highly trained men (jockeys and sprinters)** N = 10 (24.4 yrs)	Two different physical trials a day	2/1/NR	Urine test Blood test Physical performance test: CMJ, isometric bench press foot time reaction test	Plasma melatonin and epinephrine rest concentrations significantly ↑in the morning vs. evening	The hour of the day had no impact on performance, except for the velocity In the morning, body functions could ↑↑ through adrenergic excitations when

					↓Velocity in the morning Equal values in mean power	melatonin is high Morning trainings could require ↑ adrenergic activation in order to balance the sleepiness melatonin effect
Ghattassi et al., 2014	**Tunisian elite soccer players** N = 12 (22.9 ± 1.3 yrs) **Group 1** 5 mg melatonin **Group 2** 8 mg melatonin **Group 3** Placebo	Melatonin consumption of 5 or 8 mg or placebo randomly every 30 min before physical trials	1/3/NR	Physical test: SJ, CMJ, MBT, 5-JT, HG, agility test	No differences were found after the consumption of 5 mg of melatonin or placebo, but results were significantly lower after 8 mg consumption	5 mg of melatonin had no effects on performance in short term, but 8 mg ↓ anaerobic performance
Thompson et al., 2014	**Healthy active men** N = 8 (22 ± 2 yrs) **Group 1** Bright light **Group 2** Control	2500 lux Poly-chromatic light before sleeping	3/1/NR	3 series of 10 min standing cycling on cycloergometer (10 min ests between series). Time trial 10 km Salivary test	Suppression of melatonin concentration increase at night after therapy No difference in the morning melatonin concentrations ↓Body temperature before trials ↑↑ Performance in cycling trials after therapy	Bright light therapy seems to be a good method to increase performance on morning exercise at high temperature
Robey et al., 2013	**Male cyclists and triathletes** N = 10 (29.4 ± 2.5 yrs) **Group 1** Cold water immersion **Group 2** Hot water immersion	2 cycling trials at night followed by 15 min of water immersion, hot or cold.	2/1/45	Salivary analysis 15 min trial at 75% max on cycloergometer 15 min trial on cycloergometer	Body central temperature significantly higher after exercise in both conditions BCT was lower after cold water immersion after 30 to 90 min BCT was always lower after exercise HR significantly reduced after cold water	Cold water immersion after evening fatigued exercise ↓ BCT compared with hot water immersion Water temperature had no influence on the ↑↑of melatonin salivary concentrations

					immersion ↑↑melatonin concentrations, without influence of the water immersion	
Zhao et al., 2012	**Chinese female basketball players** N = 20 (18.60 ± 3.60 yrs) **Group 1** Red light therapy **Group 2** Placebo light	30 min. Therapy every night	2/14/15	Sleep quality evaluation Cooper Test Blood sample analysis	↑↑ melatonin concentrations during sleep ↑↑ endurance performance ↑↑ sleep quality	Red light therapy ↑↑ sleep quality and endurance training, and improves melatonin secretion by the pineal gland what facilitates biological recovery
Marrin et al., 2011	**Active men** N = 7 (27.4 ± 5.1 yrs)	Cyclo-ergometer trial at 8 a.m. and 5 p.m.	5/2/NR	Maximal incremental cycle ergometer test protocol Salivary analysis	Melatonin levels twice higher in the morningv. evening Melatonin levels ↑↑ with exercise at any hour Equal HR in morning and evening sessions Basal HR in the morning ↑↑	Exercise ↑salivary melatonin levels, maybe caused by an altered autonomous reaction of melatonin secretion during exercise
Konarska et al., 2006	**Men U.K. volleyball team** N = 11 (16.0 ± 0.45 yrs)	Physical trials at 8 a.m. and 11 a.m.	1/1/NR	Maximal incremental cycle ergometer test protocol Aerobic test Blood sample analysis	↑↑ melatonin levels after high intensity exercise ↓ melatonin levels after aerobic exercise	Exercise, depending on the type, induces changes on melatonin levels
Mero et al., 2006	**Endurance trained men** N = 10 (24 ± 3 yrs) **Group 1** Melatonin **Group 2** Placebo	6 mg melatonin or 6 mg placebo randomly consumed every 60 min before exercise	2/1/80	Blood sample analysis CMJ Bench press Squat test 2 endurance training sessions: 25 series: 70 and 85% 1RM	No significant differences between melatonin or placebo on performance Significant ↑↑ melatonin levels after exogenous consumption Significant ↑↑ GH levels	6 mg of exogenous melatonin had no effect on GH ↑ Exogenous melatonin show no acute effect on maximal jump capacity or endurance in spite of the ↓ alertness

					during exercise and 30 min after, when melatonin or placebo was consumed	
Cardinali et al., 2002	**Atlético Boca Juniors players (Argentina) flying to Tokyo** N = 22 (29.7 ± 8.7 yrs)	3 mg exogenous melatonin 30 min before sleep onset Outside exercise with natural light from 8 to 11 a.m. and from 1 to 4 p.m.	2/9 days total/6	Urine test Sleep diaries	Circadian rhythm resynchronization acceleration No significant effects over sleep or vigil caused by time change ↑↑ melatonin levels early in the morning The sample was synchronized when sleeping with the local time in 24 to 48 hrs of difference, in spite of the 12 hrs travel difference	The combination of treatment and melatonin, an adequate light exposure and exercise could be useful on athletes to reduce *jet lag* symptoms
Atkinson et al., 2001	**Sport Sciences students** N = 12 (19 to 30 yrs) **Group 1** Melatonin **Group 2** Placebo	5 mg melatonin or placebo 30 min before sleep onset	2/2/NR	Ear temperature SL and sleep quality HG Time trial 4 km on cycloergometer in the morning	No effects of melatonin on performance or sleep quality	5 mg of melatonin consumed during nigh had no harm effect on performance, and no improvements on recovery perception
Lagarde et al., 2001	**Healthy air force soldiers fly from USA to France** N = 27 (19 men and 8 women) (20 to 48 yrs) **Group 1** Melatonin	5 mg melatonin 300 mg caffeine with slew effect Placebo	NR	2 physical trials (morning and evening): HG SJ Multijump 15 sec	*Jet lag* reduces performance on HG on the placebo group but melatonin group show no ↓ effect on HG. Caffeine group improve performance of HG in the morning. No differences were found on the dynamic trials	Slow effect caffeine and melatonin had maintained a satisfactory level on static trials

	Group 2 Caffeine **Group 3** Placebo					
Edwards et al., 2000	**Professional athletes and scientist flying from London to Australia** N = 26 (23 men and 3 women) (40 ± 13 yrs) **Group 1** Melatonin **Group 2** Placebo	5 mg melatonin Placebo	1/6/NR	HG Body temperature	No differences were found between groups in the 1st 6 days. Melatonin show no significant effects on resychronization proccess, but it could provoke hypnotic effects	Exogenous melatonin has no significant effect on resynchronization in the new time zone or on *jet lag* symptoms.

DISCUSSION

Exposure to bright light before exercise induces an improvement in sport performance of short duration competitions at night as well as a high reduction in melatonin levels and sleepiness in elite athletes compared to blue light or control light (32). Moreover, it has been shown that a higher aerobic performance occurs in the second half of a time trial after light therapy (12,56). On the other hand, Thompson et al. (55), found that bright light therapy 1 hr before the onset of sleep improves performance in endurance training when the sessions are scheduled early in the morning in hot environments. Kraemer et al. (34) showed that power and upper body force production were not affected, depending on the hour of the day. But, performance in exercises where velocity or precision were needed was better in the evenings than in the morning due to the higher melatonin levels in the early morning. Also, the findings reported by Robey et al. (48) regarding no significant changes on salivary melatonin after exercise or cold water immersion support the results reported by Kauppinen et al. (29).

The findings reported by Zhao et al. (62) suggest that a 14-day treatment of 30 min of red light exposure every night improves melatonin levels just after the light exposure and during sleep. Branderberguer et al. (6), Ghattassi et al., (23), and Mero et al., (39) agree that 5 mg or 6 mg of exogenous melatonin consumed 15, 30, or 60 min before physical activity have no influence on sport performance, as it has been shown in previous works (1,3). However, Ghattassi et al. (23) obtained results of significantly worse performance when the subjects consumed a dose higher than 8 mg 30 min before exercise. On the other hand, Cheikh et al. (10) showed that 10 mg dose of melatonin after high intensity exercise (Yo-Yo test) in the dusk improves short term performance in sports, and also Smits et al. (52) found positive results on performance after 4 wks of 5 mg a day. But, interestingly, Atkinson et al. (1) reported no significant influence on the next day performance when 5 mg of exogenous melatonin was administrated 30 min before the onset of sleep, which is in the contrast to the findings of Cheick et al. (10) who reported that sleep quality improvements were found after a 10 mg intake.

Knaier et al. (32) and Thompson et al. (55) agree that long term bright light exposure increases melatonin levels and decreases sleep, but Zhao et al. (52), using 30 min of red light therapy, reported improvement not only sleep quality but also sport performance. Exogenous melatonin, when it is administrated alone, has shown no positive influence over jet lag symptoms. Lagarde et al. (35) reported that there were no changes in the subjects' performance after flying from USA to France and consuming an intake of 5 mg, and Edwards et al. (16) reported no effects on resynchronization process or sleep quality.

Nevertheless, Cardinali et al. (8) showed that the combination of 3 mg intake before the onset of sleep, training, and natural light exposure seem to be an adequate method to adjust the circadian clock and to avoid changes in the sleep-insomnia cycle. Also, in regards to the exercise induced melatonin production, Kilic et al. (30), Marrin et al. (38), and Konarska et al. (33) found that melatonin levels are higher in the morning and night compared to evening. In Kilic et al. (30), they did not observe significant effects on sports performance while doing the Bruce test over the melatonin secretion after it. Marrin et al. (38), with a cycloergometer test, found that melatonin levels improved after exercise, no matter the time of the day. The answer to this contradiction could be found in Konarska and colleagues' (33) findings that indicated the subjects' maximal intensity exercises improved melatonin levels, but aerobic exercise decreased them.

Table 2 is recommended as a guide to understand the adaptations that occur with the application of various intervention strategies to improve sleep quality and sport performance. In particular, these recommendations can be useful for athletes suffering from sleep disorders or in any of the situations that cause a decrease in the quality of sleep with an influence on sports performance, some of which have been described.

Table 2. Recommendations to Improve Sports Performance Sleep Quality and Circadian Resynchronization.

Intervention	Objective	Intensity, Volume, and Frequency
Exogenous Melatonin Intake / Red Light Exposure	To improve sport performance and short term sleep quality	10 mg exogenous melatonin, 30 min before sleep onset/red light exposure therapy 30 min before the onset of sleep
Bright Light Exposure	To improve performance in the early morning/night in short duration competitions	2500 lux, 1 hr before exercise or 1 hr before the onset of sleep
Melatonin Intake, Training, and Natural Light	To improve resynchronization of sleep cycle and reduce the symptoms of jet lag	3 mg exogenous melatonin 30 min before the onset of sleep and outdoor exercise from 8 to 11 a.m. and 1 to 4 p.m. after traveling

CONCLUSIONS

Sports performance, sleep quality, and melatonin maintain a relationship that has been demonstrated in the literature. Apparently, the high concentrations of melatonin in the body at the time of physical activity can cause a decrease in sports performance, mainly due to the fact that this hormone has depressant effects on the sympathetic nervous system. But, the evidence indicates that it is a two way relationship. That is, since aerobic exercise has also been shown to be a limiting factor in the production of melatonin and, therefore, harming the quality of sleep after exercise, while various studies indicate that high-intensity physical exercise can increase its production and facilitate its depressive and sleep-inducing effect. It is precisely this effect that makes this hormone so important in inducing sleep. Given that it is used in the readjustment of circadian rhythms, it may be of special interest to the athletic population given the stress and transcontinental travel to those who are habitually subjected.

Although the administration of exogenous melatonin as a regulatory drug of biorhythm has undergone numerous investigations, there have been no positive results when it comes to reducing the effects of jet lag in the context of sports performance (i.e., when the intakes were less than 5 mg or greater than 8 mg, and some late effects were found when 5 mg of melatonin were consumed in the morning). Other strategies such as exposure to bright light or intervention with red light therapies may serve to improve the quality of sleep and sports performance as well. It is precisely the combination of exogenous melatonin, physical exercise, and ambient light that has shown improvements in the resynchronization process after a trip to help avoid the symptoms of jet lag syndrome. The application of these results of prevention of jet lag syndrome and biological recovery should be of great interest to athletes and their desire to improve performance in sports

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