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Effects of hour of training and exercise intensity on nocturnal autonomic modulation and sleep quality of amateur ultra-endurance runners

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ABSTRACT

Sleeping problems can affect physiological adaptations and the recovery process. The aim of this study was to analyse the effect of the intensity and the hour of the training session on sleep quality and cardiac autonomic activity in amateur ultra-endurance athletes. We used a comparative, randomized crossover design to test the effect of moderate (M) or vigorous (V) intensity and morning (m) or evening (e) training journey, separated by 72 h of recovery, on actigraphic and subjective sleep quality and nocturnal cardiac autonomic activity in fourteen ultra-endurance male runners. No significant differences among training sessions were found in nocturnal heart rate variability or in subjective sleep quality, but participants experienced significantly higher calm sleep after Mm than Me ($p = 0.028$; ES = 0.7) and more refreshed after awakening when they performed a Me than Vm ($p = 0.04$; ES = 0.6). Higher sleep efficiency was found when the training is performed in the morning compared to the evening sessions in both intensities, and it was also observed in Me vs Ve ($p = 0.012$; ES = 0.8). Significantly lower numbers of awakenings were observed when the training was performed in the morning, and actual sleep time was significantly lower when participants performed a vigorous training session compared to a moderate one (Vm vs Mm: $p = 0.035$; ES = 0.6; Ve vs Mm: $p = 0.036$; ES = 0.6). Moderate exercise performed in the morning had a higher sleep efficiency compared to other types of training and intensity training is more important than the time of the day of training on sleep quality.

1. Introduction

Sport training is characterized by the correct distribution of intensity, duration and frequency of training stimuli [1]. The properly combination of training stimuli and recovery periods produces physiological adaptations and increases sports performance [1]. Athletes use numerous methods and tools such as nutrition and ergogenic aids, compression garments, massage or cryotherapy [2] in order to optimize the recovery phase, looking for performance improvement. However, sleep is the most important method for recovery from daily load [3].

Sleep assists in the recovery of the nervous and metabolic cost imposed by the waking state [4] and sleep quality can be enhanced by regular physical activity [5,6]. However, sleep problems and insomnia are increasingly reported in modern societies [3] and they are associated with lower quality of life and diminished physical and mental health [7]. Specifically, sleep disturbance in athletes can impair glycogen resynthesis, muscle damage repair, and it can increase mental fatigue and produce cognitive function impairment [3]. Thus, sleep problems can affect the recovery process and future physiological adaptations in the training process.

Previous studies [8] focused on the relationship between physical activity and sleep, suggesting that some factors affect sleep quality and recovery, such as the chronotype of the athlete or the intensity or time of the day of the training session. In this way, regular light and moderate physical activity can produce beneficial effects on sleep [9] especially if performed early in the evening [10]. This fact is related to premise that exercise-induced body heating may activate both temperature down regulation and sleep through the anterior hypothalamus-preoptic area in the brain [11] and to the energy conservation and tissue restitution theories of sleep [5,12]. However, vigorous acute exercise, especially when performed close to bedtime [13], may produce increased arousal and affect sleep behaviour [14]. Of note, there is a sleep hygiene recommendation that suggests not performing intensive exercise within the last 3 h before bedtime [3] but this recommendation has not been adequately tested experimentally because some studies [14–16] are not in accordance with this affirmation. In this way, these studies showed no relationship between exercise before bedtime and disturbed sleep when the intensity of the exercise performed was

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moderate [14] or if the exercise was high-intensity [12]. In addition, it is possible that moderate intensity exercise completed close to bedtime reduces the latency time [17].

Thus, there are some discrepancies in reports of sleep behaviour and exercise time and intensity and it is necessary to analyse these relationships to determine if the type of session training and the journey can modify sleep quality and the recovery process. This is specifically interesting in amateur ultra-endurance runners because these kinds of athletes have limited time to train and optimize their performance. Most of them perform their training session close to bedtime because it is their free time, and this is an important issue, considering that these types of events consist of very long distances. Thus, the amateur runner's training must be optimized, and it is necessary to apply the most efficient training session in order to improve the recovery process and aerobic performance. However, the effects of the intensity of the training session and the hour of the training session on sleep quality and nocturnal cardiac autonomic activity have not been studied sufficiently. To our knowledge, no research has identified the most effective training session to improve sleep quality in amateur ultra-endurance runners. Therefore, the aim of the present study was to analyse the effect of the intensity of the training session (moderate vs vigorous intensity) and hour of the training session (morning vs evening) on actigraphic sleep quality, subjective sleep quality and nocturnal cardiac autonomic activity in amateur ultra-endurance athletes. Our hypothesis was that vigorous intensity training performed in the evening training would decreases sleep quality through subjective and actigraphic impairment. We additionally hypothesized that continuous training performed in the morning would increases sleep quality in ultra-endurance runners.

2. Methods

2.1. Design

The present study used a comparative, randomized crossover design to test the effects of moderate and vigorous intensity and morning and evening training journey on actigraphic sleep quality, subjective sleep quality and nocturnal cardiac autonomic activity in amateur ultra-endurance athletes. Subjects performed two types of training sessions in two different journey times each on separate occasions in a random order: (1) moderate intensity training session at 10.00 am (Mm); (2) moderate intensity training session at 20.00 pm (Me); (3) vigorous intensity training session at 10.00 am (Vm); and (4) vigorous intensity training session at 20.00 pm (Ve). All training sessions were monitored and sleep quality and actigraphy the night before the training sessions were analysed.

2.2. Participants

Fourteen recreational ultra-endurance male runners participated in the research ($n = 14$; age: 27.6 ± 7.4 years; height: 175.7 ± 8.1 cm; weight: 70.4 ± 10.4 kg; fat mass 9.1 ± 4.9%; VO_2máx: 66.4 ± 7.2 ml/kg/min). Volunteers trained 7.0 ± 1.8 h per week, had > 3 years of experience in ultra-endurance training and had a national level performance in ultra-endurance events. A written and signed informed consent was obtained from all subjects before starting the study and the study was approved by the University's Institutional Science Ethics Committee and in accordance with the Declaration of Helsinki.

2.3. Procedures

Subjects came to the laboratory one time and during the following two weeks performed a total of four training sessions (two in the morning, vigorous or moderate intensity) and two in the evening (vigorous or moderate). Each training session was separated by at least 72 h of recovery. In the visit to the laboratory, body composition was assessed using a segmental multifrequency bio impedance analyzer (Tanita BC-601, TanitaCorp. Tokio, Japan) and the velocity for maximum oxygen uptake for each subject was determined. In addition, chronotype was determined using the Morningness-Eveningness Questionnaire (MEQ) [18], which uses cumulative scores to characterize individuals as evening type (16–41), morning type (59–86) or neither type (42–58).

Three days later, subjects performed the running training session under one of the four conditions (Mm; Vm; Me; Ve) on an official athletics track. The other training sessions consisted of the remaining experimental conditions. The order of the conditions for each running training session was randomized. In addition, subjects were asked to maintain their habitual diet and hydration status and not to ingest caffeine or alcohol at least 24 h before each testing session or to perform an exhaustive training bout in the 48 h preceding each visit.

2.4. Treadmill running test

During the testing visit to the laboratory, participants completed an incremental test to exhaustion on a treadmill (Run Med Technogym, Cessena, Italy) in standard environmental conditions, with the grade set at 1%. The tests were performed between 10 am and 12 pm in the laboratory with room temperature kept between 20 and 22 °C. The subjects were instructed not to ingest caffeine for 4 h before the test, to ingest a light meal 2 h before and to avoid intense physical efforts the day before. Participants started running at 8 km/h for 5 min. Subsequently, the work rate was increased by 1 km/h every minute in a progressive manner until exhaustion to obtain the value of maximum oxygen consumption (VO_2 max). The corresponding heart rate was also determined by a Polar RS800CX heart rate monitor (Polar Electro, Kempele, Finland). Verbal encouragement was given to ensure maximum physical effort. The test was concluded according to traditional physiological criteria [19]. Gas analyzer system was calibrated in accordance with the manufacturer's recommendations.

2.5. Training sessions

Two different training sessions in two different journeys were performed by the ultra-endurance athletes: (1) moderate training sessions consisted of 60 min at the velocity of the 60% of VO_2max and they were performed in the morning (10.00 am) or in the evening (20.00 pm); and (2) vigorous training sessions consisted of a interval training session with 10 min of warm up (velocity of 60% of VO_2max) + 7 × 3 min at the velocity of 100% of VO_2max with 3 min of passive rest between bouts and 10 min of cool down (velocity of the 50% of VO_2max), performed at the same time as the moderate training session in the morning or in the evening. Heart rate (Polar RS800; Polar Electro Oy, Kempele, Finland) was recorded during the entire training session. Rating of perceived exertion (RPE) (Borg scale 6–20), session distance and blood lactate concentration were used to monitor each session. Blood lactate concentration was measured using a Lactate Pro 2 portable lactate analyzer (Arkray Inc., Kyoto, Japan), while the subjects stood with their arms flexed. Finger prick extractions were made on the right index finger to fill the capillary tube. RPE and blood lactate were obtained at the end of each the training session.

2.6. Actigraphic sleep quality, subjective sleep quality and nocturnal cardiac autonomic activity

Participants were instructed to measure actigraphic sleep quality and nocturnal cardiac autonomic activity (HRV) during sleep after each day with a training session day. Actigraphic sleep quality was recorded using an actiwatch activity monitoring system (Cambridge Neurotechnology, Cambridge, UK) which measures activity by means of a piezo-electric accelerometer. The movement of the non-dominant wrist of each participant was monitored. A low actigraphic sensitivity threshold (80 counts per epoch) was selected, and the data recorded by the actigraph were analysed with Actiwatch Sleep Analysis Software. Each subject received a sleep diary to record bedtime, wake-up time, hours napping, hours without wearing the actigraph and the number of nocturnal awakenings. Data analysis started with the onset of nocturnal rest (bedtime) and ended with the onset of daytime activity (wake time). The following sleep parameters were measured: (I) sleep efficiency (%): percentage of time spent asleep; (II) time in bed (min); (III) actual sleep time (min); (IV) actual wake time (min); (V) number of awakenings; and (VI) average time of each awakening(min).

Together with the actigraph, during the night each subject wore an H7 strap Heart monitor (Polar Electro, Kempele, Finland) to evaluate HRV. Variables of cardiac autonomic activity were analysed for the 4-h period of sleep starting 30 min after reported bedtime [20]. The R-R series were analysed using Kubios HRV software (version 2.0, Biosignal Analysis and Medical Imaging Group, University of Kuopio, Finland). The following HRV variables were assessed: (I) low-frequency (LF) band/high-frequency (HF) band ratio; (II) total power (TP); (III) percentage of differences between adjacent normal R-R intervals > 50 ms (pNN50); (IV) square root of the mean of the sum of the squared differences between adjacent normal R-R intervals (RMSSD); (V) standard deviation of all normal NN intervals (SDNN); (VI) mean heart rate; and (VII) mean R-R intervals.

Participants were also instructed to evaluate their subjective sleep quality in the morning after awakening using the Karolinska Sleep Diary [21], which analyses the following questions: (I) sleep quality (very well [5]-very poorly [1]); (II) calm sleep (very calm [5]-very restless [1]); (III) ease of falling asleep (very easy [5]-very difficult [1]); (IV) amount of dreaming (much [3]-none [1]); (V) ease of waking up (very easy [5]-very difficult [1]); (VI) feeling refreshed after awakening (completely [3]-not at all [1]); (VII) slept throughout the time allotted (yes [5]-woke up much too early [1]).

2.7. Statistical analysis

Data collection, treatment and analysis were performed using SPSS for Windows statistical package (v.24.0). Descriptive statistics (mean and standard deviation) were calculated. Before using parametric tests, the assumption of normality and homoscedasticity were verified using the Shapiro-Wilks W-Test. An analysis of variance (ANOVA) was used to investigate differences in variables. The effect size (ES) was also calculated, as the difference in group means divided by the standard deviation of the pooled data, to quantify the magnitude of difference of the data. Threshold values for ES were > 0.2 (small), > 0.6 (moderate), > 1.2 (large) and > 2.0 (very large) [22]. For all procedures a level of $p \leq 0.05$ was selected to indicate statistical significance.

3. Results

Regarding training session characteristics, no significant differences were observed between Mm and Me (HR: Mm = 146.7 ± 18.4; Me = 144.8 ± 16.4 beats/min; RPE: Mm = 9.0 ± 1.8; Me = 8.6 ± 1.7 AU; blood lactate concentration: Mm = 2.6 ± 0.9; Me = 2.5 ± 0.6 mmol/l; session distance: Mm = 11,940 ± 912.2; Me = 11886.4 ± 841.8 m). Also, no significant differences were found between Vm and Ve (HR: Vm = 161.4 ± 21.4; Ve = 163.8 ± 19.4; RPE: Vm = 16.4 ± 1.7; Ve = 16.1 ± 2.6; blood lactate concentration: Vm = 13.7 ± 5.7; Ve = 15.6 ± 6.9 mmol/l; session distance: Ve = 9969 ± 617.9; Ve = 9884.8 ± 813.8 m).

Table 1 shows the heart rate variability results. No significant differences among training sessions were found in any variable.

Concerning the actigraphic sleep quality variables, all participants were classified in "neither type" and the mean score in the MEQ questionnaire was 52.5 ± 2.6. No significant differences among training sessions were found in the variable time in bed (min), however, higher sleep efficiency was found when the training was performed in

Table 1
Heart rate variability results of each training session.

	Mean ± SD				Statistical analysis (p and (d))					
	Mm	Me	Vm	Ve	Mm-Me	Mm-Vm	Mm-Ve	Me-Vm	Me-Ve	Vm-Ve
Mean R-R (ms)	1231.1 ± 123.0	1202.1 ± 144.0	1221.0 ± 126.0	1183.2 ± 169.0	0.707 (0.1)	0.732 (−0.1)	0.353 (0.3)	0.563 (−0.2)	0.581 (0.2)	0.184 (0.4)
SDNN (ms)	141.8 ± 41.7	148.0 ± 45.5	149.1 ± 42.4	139.0 ± 45.3	0.499 (−0.2)	0.413 (−0.2)	0.826 (0.1)	0.944 (0.0)	0.432 (0.2)	0.445 (0.2)
HR (bpm)	50.9 ± 5.9	51.6 ± 6.7	50.7 ± 5.4	52.8 ± 7.9	0.567 (−0.2)	0.873 (0.1)	0.22 (−0.3)	0.478 (−0.2)	0.560 (0.2)	0.133 (−0.4)
RMSSD (ms)	30.6 ± 2.9	30.3 ± 3.1	30.6 ± 3.4	30.0 ± 2.8	0.496 (0.2)	0.930 (0.0)	0.341 (0.3)	0.698 (−0.1)	0.628 (0.1)	0.419 (0.2)
pNN50 (%)	10.3 ± 2.5	10.1 ± 2.9	10.5 ± 3.2	9.8 ± 2.7	0.670 (0.1)	0.802 (−0.1)	0.468 (0.2)	0.582 (−0.2)	0.617 (0.1)	0.312 (0.3)
TP (ms^2)	15,538.1 ± 8806.2	27,004.1 ± 44,764.3	23,069.2 ± 24,061.6	14,551.0 ± 7206.7	0.343 (−0.3)	0.277 (−0.3)	0.586 (0.1)	0.780 (0.1)	0.294 (0.3)	0.218 (0.3)
LF (%)	69.9 ± 6.9	70.2 ± 6.4	69.0 ± 5.8	67.5 ± 6.4	0.805 (−0.1)	0.436 (0.2)	0.157 (0.4)	0.391 (0.2)	0.124 (0.5)	0.345 (0.3)
HF (%)	30.2 ± 6.9 ±	29.8 ± 6.4	31.0 ± 5.8	32.5 ± 6.4	0.801 (0.1)	0.440 (0.0)	0.161 (−0.4)	0.391 (−0.2)	0.102 (−0.5)	0.352 (−0.3)
LF/HF	2.3 ± 1.0	2.4 ± 1.0	2.2 ± 0.7	2.1 ± 0.7	0.844 (−0.1)	0.204 (0.4)	0.196 (0.4)	0.267 (0.3)	0.233 (0.3)	0.331 (0.3)

SDNN: standard deviation of all normal NN intervals; HR: mean heart rate; RMSSD: square root of the mean of the sum of the squared differences between adjacent normal R-R intervals; pNN50: percentage of differences between adjacent normal R-R intervals > 50 ms; TP: Total power; LF: low-frequency; HF: high-frequency (HF); Mm: moderate intensity training performed in the morning; Me: moderate intensity training performed in the evening; Vm: vigorous intensity training performed in the morning; Ve: vigorous intensity training performed in the evening. p = p-value; d = Effect size.

Table 2
Sleep quality results of each training session measured by actrigraphy and by Karolinska sleep questionnaire.

	Mean ± SD				Statistical analysis (p and (d))					
	Mm	Me	Vm	Ve	Mm-Me	Mm-Vm	Mm-Ve	Me-Vm	Me-Ve	Vm-Ve
Sleep Efficiency (%)	93.5 ± 4.0	88.2 ± 3.5	91.2 ± 5.2	84.3 ± 5.6	< 0.001*** (1.5)	0.059 (0.5)	< 0.001*** (1.9)	0.034* (−0.6)	0.012* (0.8)	< 0.001*** (1.8)
Time in bed (min)	438.4 ± 115.0	462.8 ± 74.4	409.7 ± 87.6	429.0 ± 70.5	0.491 (−0.2)	0.075 (0.5)	0.736 (0.1)	0.083 (0.5)	0.232 (0.3)	0.365 (−0.3)
Actual Sleep Time (min)	410.9 ± 114.0	407.5 ± 65.9	374.9 ± 89.1	363.1 ± 70.9	0.916 (0.1)	0.035* (0.6)	0.036* (0.6)	0.237 (0.3)	0.082 (0.5)	0.549 (0.2)
Actual Wake Time (min)	26.4 ± 16.1	53.9 ± 18.8	34.1 ± 18.6	63.9 ± 22.3	< 0.001*** (−1.1)	0.217 (−0.3)	< 0.001*** (−1.5)	0.008** (0.8)	0.165 (−0.4)	< 0.001*** (−1.4)
Number of awakenings	13.7 ± 7.2	23.4 ± 6.5	15.8 ± 7.8	21.4 ± 4.6	0.008** (−0.8)	0.448 (−0.2)	0.004 **(−0.9)	0.005**(0.9)	0.294 (0.3)	0.01** (−0.8)
Average time of each awakening (min)	1.7 ± 0.8	2.3 ± 0.7	2.0 ± 0.8	3.0 ± 2.7	0.005** (−0.9)	0.242 (−0.3)	< 0.001*** (−1.4)	0.258 (0.3)	0.009** (−0.8)	< 0.001***(−1.3)
Sleep quality	4.0 ± 0.7	3.7 ± 1.0	3.6 ± 0.7	3.5 ± 0.9	0.385 (0.2)	0.218 (0.3)	0.111 (0.5)	0.807 (0.1)	0.385 (0.2)	0.500 (0.2)
Calm sleep	3.9 ± 0.9	3.5 ± 0.8	3.9 ± 0.9	3.8 ± 1.0	0.028* (0.7)	1.000 (0.0)	0.612 (0.1)	0.082 (−0.5)	0.104 (−0.5)	0.547 (0.2)
Ease of falling asleep	3.6 ± 1.2	3.9 ± 1.1	3.9 ± 0.8	3.8 ± 1.0	0.218 (−0.3)	0.414 (−0.2)	0.547 (−0.2)	1.000 (0.0)	0.583 (0.2)	0.547 (0.2)
Amount of dreaming	1.9 ± 0.8	2.1 ± 0.6	2.1 ± 0.5	1.8 ± 0.4	0.547 (−0.2)	0.583 (−0.2)	0.435 (0.2)	1.000 (0.0)	0.165 (0.4)	0.165 (0.4)
Ease of waking up	4.1 ± 0.7	4.0 ± 0.7	3.8 ± 0.6	3.6 ± 0.8	0.752 (0.1)	0.040* (0.6)	0.131 (0.4)	0.272 (0.3)	0.028* (0.6)	0.426 (0.2)
Feeling refreshed after awakening	2.6 ± 0.6	2.6 ± 0.5	2.3 ± 0.5	2.4 ± 0.5	0.720 (0.1)	0.055 (0.6)	0.104 (0.5)	0.040* (0.6)	0.189 (0.4)	0.583 (−0.2)
Slept throughout the time allotted	3.4 ± 1.1	3.3 ± 1.1	3.5 ± 1.0	3.1 ± 1.0	0.793 (0.1)	0.686 (−0.1)	0.302 (0.3)	0.336 (−0.3)	0.487 (0.2)	0.165 (0.4)

Mm: moderate intensity training performed in the morning; Me: moderate intensity training performed in the evening; Vm: vigorous intensity training performed in the morning; Ve: vigorous intensity training performed in the evening. p = p-value; d = Effect size.
Significant diferences between training sessions; $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.

the morning compared to the evening sessions in both intensities (Table 2). Also, significant differences in sleep efficiency were observed in Me vs Ve ($p = 0.012$; ES = 0.8). Moreover, significantly lower actual wake time (min) and lower numbers of awakenings were observed when the training session was performed in the morning. Also, the average time of each awakening was significantly higher when the training session was Ve compared to the other three training sessions and when the training session was Me with respect to Mm ($p = 0.005$; ES = −0.9). Furthermore, the actual sleep time (min) was significant lower when participants performed a vigorous training session compared to a Mm (Vm vs Mm: $p = 0.035$; ES = 0.6; Ve vs Mm: $p = 0.036$; ES = 0.6).

Regarding the subjective sleep quality measured by the KSQ, no significant differences among training sessions were found in the variables sleep quality, ease of falling asleep, amount of dreaming and slept throughout the time allotted. However, the participants experienced significantly higher calm sleep after Mm compared to Me ($p = 0.028$; ES = 0.6) and they felt more refreshed after awakening when they were performed a Me than Vm ($p = 0.04$; ES = 0.6). Also, they felt more ease of waking up when they performed a Mm than a Vm ($p = 0.04$; ES = 0.6) and when they performed a Me vs a Ve training session ($p = 0.028$; ES = 0.7).

4. Discussion

The present study analysed the effects of two types of training intensities and two hours at which the training session occurred (morning vs evening) on nocturnal cardiac autonomic activity, actigraphic sleep quality and subjective sleep quality. The main findings were: (1) hour and intensity of the training session did not modify nocturnal autonomic modulation; (2) higher sleep quality was found when the training was performed in the morning compared to the evening sessions in both intensities; (3) if the training session performed by the athletes was a vigorous intensity, lower sleep quality was observed if this training session was performed in the evening; and (4) intensity and hour of the training session modified the subjective sleep quality of the athletes.

4.1. Effects of intensity and hour of the training session on performance

Sports trainers and coaches should consider the influence of both the time of day and chronotype effect when programming training sessions into specific time periods [23]. Although there are often differences between morning and afternoon performance, the adaptations to training are greater at the time of the day when the training is done regularly [24]. The athletes who participated in our study were neutral on the MEQ; these data could explain that there are no differences in the performance of the same training at different moments of the day. In this line, several studies reported no differences in athletic performance at different times of the day [25,26]. However, if the participants had a chronotype, different responses were found. Therefore, coaches should take into consideration the chronotype of the athletes to optimize the training session because it can impair training session performance.

4.2. Effects of intensity and hour of the training session on HRV

Previous studies have reported that parasympathetic activity is higher during night sleep. In addition, cumulative training effects could increase sympathetic activity [20,27]. However, our results showed that nocturnal HRV did not differ between intensity training and time of day. These results agree with a previous study performed by Myllymäki et al. [20], which concluded that exercise duration but not exercise intensity (moderate vs vigorous) can increase nocturnal HR and HRV. Also, another study [28] found that 30 min of walking and running performed in the morning had no significant acute effects on nocturnal

HR or HRV. In the same way, Myllymäkiet al. [3] showed that late-night vigorous (50–100% $_{HRmax}$) exercise did not disturb HRV during sleep. Furthermore, Gladwell et al. [29] reported that the changes observed after exercise (moderate, hard or vigorous) on cardiac autonomic activity return to baseline after 5–15 min in untrained young adults. In addition, Seiler et al. [30] concluded that highly trained endurance athletes were characterized by rapid recovery of parasympathetic balance after exercise, independent of intensity. Thus, these findings suggest that nocturnal HRV is not sensitive to obtain the changes produced by training load in whole automatic homeostasis of sympathetic and vagal activity as suggested by Kaikkonen et al. [31]. Unfortunately, there are no studies that analysed the hour and intensity of the training. Therefore, HRV seems to be an invalid tool to analyse sleep quality, and other parameters are needed to study this variable.

4.3. Effects of intensity and time of the day on sleep quality

Sleep quality after training sessions at different intensities and different hours of the day was measured with an actigraphic monitoring system and subjective evaluation (the Karolinska Sleep Diary). With respect to sleep quality measured with a subjective scale KSQ, participants felt calmer with moderate training in the morning (Mm) than in the evening (Me). Moreover, participants felt a greater ease in waking up after vigorous intensity sessions both in the morning and in the evening. Likewise, participants felt less refreshed when they performed a moderate session in the evening than when they conducted a vigorous session in the morning. These results are complementary to those observed with actigraphic sleep monitoring, in which we observed that the vigorous intensity trainings carried out in the evening decreased sleep efficacy compared to the moderate and vigorous sessions held in the morning. These findings are not in accordance with previous studies, which have suggested that the intensity of the training did not disturb sleep quality [3,14,20]. Myllymäki et al. [3], concluded that vigorous late-night exercise (incremental cycle ergometer exercise) does not disturb sleep quality in young adults. Also, Youngstedt et al. [14] found that prolonged, vigorous late-night exercise did not disturb the actigraphic or subjective sleep quality. However, a meta-analytical review [32] showed small effects of acute exercise on sleep. Moreover, several studies [5,33,34] have shown that the exercise could delay REM sleep onset (10 min), increase slow-wave sleep (SWS) and reduce REM sleep (2–5 min) with beneficial effects on total sleep time when compared to a control group. Vitale et al. [8] found worse sleep quality in athletes who perform a high-intensity session at night, but not in the morning. This study [8] reported that these findings are probably due to the athlete's chronotype. In addition, sleep behaviour can be modified significantly according to the typical daily schedule of the athlete [35] and it seems that with greater fatigue there would be greater insomnia [36]. Thus, intense exercise is discouraged near bedtime because it is associated with sleep disturbances, higher sleep onset latency (+14.0 min, $p < 0.05$), lower total sleep time (−14.6 min, $p < 0.05$), and lower sleep efficiency (−3.1%, $p < 0.05$) [37]. Therefore, it seems that moderate exercise performed in the morning has a higher sleep efficiency compared to the other training sessions performed in the present research. Also, the second most effective training that did not disturb the athletes sleep was the moderate intensity training performed in the evening. Thus, our results suggest that the intensity of training is more important than the hour of the training on sleep quality.

The principal limitation of the present study was its low number of participants. Additionally, one factor that could influence sleep behaviour is chronotype and our study only shows results in athletes with a neither chronotype. Moreover, no control session was included in the design. Also, although subjects were asked to maintain their habitual, some studies have shown the influence of type of diet on sleep patterns and quality. However, one of the strengths and novelty of our study is that we used two systems to follow upon the quality of sleep and we analysed the interaction of two important factors (intensity and time of training) for the period of training. The results suggest that there seems to be an association between the intensity and time of day of training on sleep quality.

Our results should be taken into consideration by coaches to optimize sleep hygiene practices and the recovery process of athletes. They can apply the results of the present study in practice manage the time and the intensity of the training session to improve the sleep quality of athletes. Thus, the findings of this research suggest that vigorous training must be performed in the morning to least affect the sleep and recovery process. However, a moderate intensity training session should be conducted in the morning to improve sleep quality. This information can help the coach to optimize the use of the training session to improve the recovery process. Thus, the present research offers an important contribution to understanding how the intensity and time of day of training affects sleep quality and HRV in amateur ultra-endurance runners.

5. Conclusions

Overall, these findings suggest that nocturnal HRV does not differ between intensity and the time of the training session and it may be not sensitive enough to assess the level of impairment in nocturnal cardiac autonomic activity caused by the training session. Furthermore, moderate exercise performed in the morning produced higher sleep efficiency compared to the other types of training and intensity training was more important than the time of the day of training for sleep quality.

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