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Does Acute Caffeine Intake before Evening Training Sessions Impact Sleep Quality and Recovery-Stress State? Preliminary Results from a Study on Highly Trained Judo Athletes

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Abstract: No previous study has analyzed the impact of a low caffeine dose ingested before an evening training session on sleep and recovery-stress state. Nine highly trained judo athletes underwent a randomized, double-blind, placebo-controlled crossover experiment in which each athlete acted as their own control. Each athlete performed two identical trials after the ingestion of (i) a placebo and (ii) 3 mg of caffeine per kg of body mass, administered 60 min before an evening randori training session. Sleep was assessed using actigraphy and a Karolinska Sleep Diary (KSD), while the recovery-stress state was assessed using a short recovery and stress scale the morning following the trial. No significant differences were observed in any actigraphy sleep measures between conditions, or in the recovery-stress state ($p > 0.05$ for all). However, sleep quality assessed using the KSD was worse following caffeine ingestion compared with the placebo (3.0 ± 1.0 vs. 3.9 ± 0.6, respectively; $p = 0.03$, ES: 1.09). The ingestion of 3 mg/kg of caffeine before an evening training session has no impact on actigraphy-derived sleep measures or recovery-stress state. However, it leads to a substantial decrease in self-reported sleep quality.

Keywords: actigraphy; ergogenic aid; supplement; health

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1. Introduction

Caffeine ranks as one of the world's most commonly used psychoactive substances [1], and is widely consumed by athletes in all sports disciplines [2–4]. Interestingly, more than 75% of athletes consume caffeine before or during competitive events [2–4]. Strong evidence supports the idea that caffeine ingestion at a dose of 3–6 mg per kilogram (mg/kg) of body mass improves performance in a broad range of exercise tasks [2]. Indeed, several previous investigations have confirmed the positive impact of acute caffeine intake on endurance [5], anaerobic [6], and resistance performance [7], as well as performance in sports that require a substantial contribution from different energy metabolisms like combat [8,9] or team sports [10,11].

Although caffeine has ergogenic potential [12], its ingestion can also produce troubling side effects such as headache, nausea, insomnia, or anxiety [13]. Consequently, through caffeine intake, athletes' recovery and well-being might be limited, and this may impact their performance over the following days [14]. A recent meta-analysis that examined side effects associated with caffeine supplementation in athletes found that the incidence of side effects after consumption of low and moderate doses of caffeine (i.e., ≤6 mg/kg) could be as high as 34% [15]. It is worth noting that the occurrence of tachycardia/heart palpitations and sleep problems were the most commonly reported side effects [15]. Because growing evidence suggests a detrimental effect of sleep deprivation on sport-specific and exercise performance, athletes should avoid situations that pose a risk to their sleep quality [16,17]. Although several previous investigations have shown the negative impact of caffeine on sleep in the general population [18–21], less attention has been paid to analyzing sleep measures among athletes [15]. Even though some previous studies examined the occurrence of insomnia or sleep problems [9,22–28], polysomnography or actigraphy, typically used for sleep monitoring in athletes [29], was not commonly used [15]. To date, only two studies have explored the acute impact of caffeine intake on sleep quality in athletes using these objective methods [30,31]. In the study of Miller et al. [30] (using polysomnography), 6 mg/kg of caffeine ingested before late-afternoon cycling exercises (i.e., ~5:00 PM) increased sleep onset latency and decreased sleep efficiency, rapid eye movement sleep, and total sleep time. Similarly, in a study conducted by Ramos-Campo et al. [31], 6 mg/kg of caffeine administered before an 800 m running test performed in the evening (i.e., 8 PM) impaired sleep efficiency, actual wake time, and the number of awakenings measured by actigraphy. Moreover, the subjective sleep parameters reported by the runners in the Karolinska Sleep Questionnaire, including "sleep quality," "calm sleep," "ease of falling asleep," and "feeling refreshed after waking," were interrupted at night after the caffeine intake [31]. Two additional studies have explored the relationship between individual caffeine ingestion on the sleep quality of rugby athletes [32,33], showing a negative [33] and neutral [32] impact of evening pre-game caffeine ingestion on sleep-related measures. In light of these findings, it seems that the use of caffeine for training purposes is a relevant issue worth careful consideration by athletes concerned with sleep hygiene. Thus, verifying the impact of different caffeine doses on sleep and recovery seems especially important for athletes who use caffeine before evening training or competitions, or in sports where final scores are decided through competition over consecutive days [14]. From a practical standpoint, using a dose that simultaneously improves sports performance and has no adverse effect on sleep and recovery might be useful. Recent evidence has demonstrated that low caffeine doses (i.e., $\leq$3 mg/kg bm, ~200 mg) increase athletic performance, improve vigilance, alertness, and mood, and improve cognitive processes during and following strenuous exercise, with a low risk of side effects [34]. However, it should be highlighted that the ergogenic effect of low caffeine doses appears to result from alterations in the central nervous system. Although these low caffeine doses affect the adenosine receptors in the brain and peripheral nervous system [35,36], their acute impact on sleep remains unknown.

Taking into account the fact that adequate sleep is crucial for optimal performance and post-exercise recovery, as well as the high prevalence of sleep disorders among elite athletic populations [29], this study aimed to analyze the impact of the ingestion of 3 mg/kg of caffeine on sleep quality and recovery-stress state. To address the gap in research conducted on athletes, the current investigation explored the effects of consuming 3 mg/kg of caffeine before an evening training session in highly trained judo athletes. The recovery-stress state was assessed before the morning training session on the morning following the trial.

2. Materials and Methods

2.1. Participants

Athletes were included if they satisfied the following criteria: (i) free from neuromuscular and musculoskeletal disorders; (ii) highly trained (defined as black belt holders and as having won medals in national championships); (iii) no medication or dietary supplements used within the previous month which could potentially impact the study outcomes (i.e., melatonin, tryptophan, oral contraceptives); (iv) satisfactory health status; (v) no history of sleep nor neurological disorders. Participants who had (i) were smokers or (ii) had a potential allergy to caffeine were excluded from the study. Eleven healthy and experienced national judo team athletes took part in the study. However, two did not complete all the testing sessions due to finger injury or private reasons, and were therefore not included in the final analysis. A total of 9 athletes completed all testing sessions (5 men and 4 women) (Table 1). Habitual caffeine intake was verified using a modified version of the validated questionnaire by Bühler et al. [37] for one month before the start of the experiment [38]. The athletes were asked to maintain their usual isocaloric diet and sleep patterns through the study period and not to carry out strenuous exercise 24 h before testing. Athletes were also asked to refrain from caffeine intake 24 h before each trial and before morning training the day after the experimental sessions. Additionally, athletes were asked to replicate their diet every 24 h before testing and in the morning following the experimental trials. Adherence to this requirement was verified via verbal questioning by a dietician before data collection. Three female participants were tested during the follicular phase of their menstrual cycle, and one was tested during the luteal phase according to a mobile application (Flo Period Tracker & Calendar, UK [39]). The women were not tested during premenstrual days (late luteal phase) or days of menstrual bleeding (early follicular phase) since studies show that sleep disturbances are more commonly reported during this time [40]. The Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice, Poland approved the study protocol (3/2021) per the latest version of the Declaration of Helsinki. All athletes provided their written informed consent before participation in this study.

Table 1. Main participants' characteristics.

Variable (Units)	Men (n = 5)	Women (n = 4)
Age (years)	24 ± 5	20 ± 1
Body mass (kg)	73.4 ± 11.6	70.1 ± 15.0
Height (cm)	175 ± 5	169 ± 2
Body Fat (%)	12.6 ± 5.7	18.8 ± 9.5
Judo training experience (years)	15 ± 6	12 ± 3
Habitual caffeine intake (mg/kg/day) (mg/kg/day)	2.6 ± 1.9	3.0 ± 2.9

Data reported as mean ± standard deviation.

2.2. Experimental Design

To investigate the effect of caffeine on sleep quality and recovery-stress state, the athletes underwent a randomized, double-blind, placebo-controlled crossover experiment in which each athlete acted as their own control. The blinding and randomization of the experimental sessions were conducted by a member of the research team (using www.randomization.com (accessed on 3 August 2022)) who was not directly involved in data collection; thus, after assignment to interventions, both athletes and researchers were blinded to the trials. The study was conducted immediately after the competitive season, and all athletes participated in judo training sessions five times a week from 7:00 to 8:30 PM (Monday to Friday) and in strength and conditioning training two times a week from 10:00 to 11:30 AM (Tuesday and Thursday) during the study period. Each athlete took part in a familiarization session and two identical experimental trials that included the ingestion of (i) a placebo and (ii) 3 mg/kg of caffeine, administered 60 min before the onset of the exercise protocol. Capsules with caffeine (100% purity) and placebo (cellulose) were prepared by the manufacturer (Olimp Laboratories, Dębica, Poland). The familiarization session and the trials were conducted on three consecutive Mondays at 7:00 PM during the athletes' regular training sessions. During the familiarization session, the athletes' body composition was evaluated using bioimpedance (model 370, InBody, Biospace Co., Seoul, Korea), and they were informed about the experimental procedures. After the session, the athletes received GENEActiv accelerometers (Activinsights, Cambridge, UK) and were asked to wear them on their non-dominant wrist for the study period.

During each experimental session, athletes performed an identical warm-up, simulating a pre-competition warm-up, and completed a standardized randori training session under controlled ambient conditions. The randori session consisted of 3 fighting bouts of 4 min, with 10 min of rest between fighting bouts. During randori, the athletes fought with opponents in the same weight category and with a similar judo level. The athletes were instructed to fight to score the most points or win by ippon, yet the bout was continued regardless of the score. The heart rate during the training sessions was measured using a heart rate monitor (Polar H10, Finland). Immediately after the training session, rating of perceived exertion (RPE; using the 1–10-point Borg scale [41]) was evaluated.

2.3. Side Effects and Assessment of Blinding

Immediately after the conclusion of the testing, the athletes were asked about the typical caffeine-induced side effects [15]. The effectiveness of blinding was analyzed pre- and post-exercise using the following question: which substance do you think you have taken? This question had three possible choices: (i) "caffeine", (ii) "placebo", and (iii) "I do not know".

2.4. Sleep Assessment

Athletes were instructed to measure actigraphy sleep quality and heart rate during the night following each experimental session. Objectively measured sleep parameters were collected using triaxial and wrist-worn GENEActiv accelerometers (Activinsights, Cambridge, UK). The device contains a triaxial MEMS-accelerometer with a range of $\pm$ 8 g and a sensitivity of $\geq$0.004 g. It records motion-related and gravitational acceleration and has a linear and equal sensitivity along three axes. The x-axis of the GENEActiv recorder corresponds to the radial-ulnar axis, the y-axis to the long axis of the radius and ulna, and the z-axis to the palmar-dorsal axis [42]. The accelerometer data were collected in 5 s epochs with a sampling frequency of 10 Hz and extracted using the GENEActiv PC Software (ver. 3.3). Then, data were processed and analyzed using the open source sleep detection algorithm in the GGIR software R-package GGIR (ver. 2.2-0) in the R environment (ver. 3.6.3) [43,44]. This algorithm uses a novel method in which the accelerometer-derived arm angle is used to detect sleep. Estimated arm angles are averaged per 5 s epoch and used to assess changes in arm angle between successive 5 s epochs. Periods during which there is no change in arm angle >5° over at least 5 min are classified as bouts of sustained inactivity or potential sleep periods [43]. These thresholds have shown good sleep detection accuracy compared with polysomnography, the gold-standard sleep measuring method [44], and do not require the use of an activity diary. The following variables were derived: (1) sleep duration, (2) time in bed, (3) sleep efficiency, (4) wake after sleep onset, (5) sleep onset time, and (6) wake time [45]. Additionally, the time between placebo and caffeine intake and sleep onset time was calculated. Heart rate during the night was measured using a heart rate monitor (Polar H10, Finland). Athletes were also asked to assess their subjective sleep quality in the morning after the experimental sessions using the Karolinska Sleep Diary [46]. The questionnaire contained seven items and offered five response alternatives graded from 5 to 1 for the following parameters: (1) sleep quality (very well to very poor); (2) calm sleep (very calm to very restless); (3) ease of falling asleep (very easy to very difficult); (4) amount of dreaming (much to none); (5) ease of waking up (very easy to very difficult); (6) feeling refreshed after awakening (completely to not at all); (7) slept throughout the time allotted (yes to woke up much too early).

2.5. Short Recovery and Stress Scale

The day after the trial, before the morning training session, athletes completed the short recovery and stress scale [47]. This scale includes eight components assessing recovery and stress. Recovery-related items included physical performance capability, mental performance capability, emotional balance, and overall recovery. Stress-related items included muscular stress, lack of activation, negative emotional state, and overall stress. Each item was rated on a 7-point rating scale from 0 (does not apply at all) to 6 (fully applies) and supported by four exemplary adjectives (e.g., energic, rested, satisfied). Satisfactory internal consistencies for the recovery (α = 0.70) and the stress scale (α = 0.76) have been shown among athletes [48].

2.6. Statistical Analysis

All calculations were performed using Statistica 13.3 and expressed as means with standard deviations ($\pm$SD) for all participants. A Shapiro–Wilk test was performed to establish the normality of the sampling distribution. A Wilcoxon test was then applied. To determine differences between groups (i.e., men vs. women and low–mild vs. moderate–high caffeine consumers [38]), a Kruskal-Wallis test was used. Hedges' g for repeated measures was used to calculate relative effect sizes (ESs) and their respective 95% confidence intervals. ESs of 0.00–0.19, 0.20–0.49, 0.50–0.79, and ≥0.80 represented trivial, small, moderate, and large effects, respectively. Statistical significance was set at $p < 0.05$.

3. Results

The results of the Wilcoxon test indicated non-significant differences between caffeine and placebo conditions on average (121 ± 11 vs. 124 ± 8, respectively; $p = 0.29$), as well as maximum heart rate during the randori training sessions (188 ± 8 vs. 187 ± 8, respectively; $p = 0.34$). Similarly, paired T-tests showed non-significant differences in RPE between caffeine and placebo conditions (6.0 ± 0.7 vs. 5.8 ± 1.5, respectively; $p = 0.68$).

During the placebo condition, nobody reported side effects, while during the caffeine condition, one participant indicated gastrointestinal problems, tachycardia, and heart palpitations. When evaluated pre-exercise, 67% of the participants identified the caffeine and placebo trials. When evaluated post-exercise, 67% and 78% of the participants identified the caffeine and placebo trials, respectively.

Despite apparent differences in mean values between placebo and caffeine in the actigraphy-derived sleep measures, no significant differences were observed ($p > 0.05$ for all, Table 2). Small effect sizes were observed for almost all actigraphy-derived sleep measures (ES = 0.20–0.44), except "wake after sleep onset". Additionally, no significant differences in heart rate during the night were observed between placebo and caffeine conditions (56 ± 5 vs. 54 ± 5, respectively; $p = 0.47$). One significant difference between the conditions was found, favoring placebo in sleep quality reported in the Karolinska Sleep Questionnaires ($p = 0.03$; ES = 1.09) (Table 2), without significant differences in other parameters ($p > 0.05$ for all). However, small (ES = 0.21–0.41) and large (ES = 0.88) ESs were noted for all subjective sleep quality measures, except for "feeling refreshed after awakening".

Table 2. Sleep quality measures for caffeine and placebo conditions.

Actigraphic Sleep Quality	**Placebo**	**Caffeine**	***Z***	***p***	**ES (95% CI)**
Sleep duration (h)	7.1 ± 1.4	6.6 ± 0.8	0.65	0.51	−0.44 (−0.52, 1.35)
Time in bed (h)	8.2 ± 1.4	7.7 ± 0.8	0.17	0.85	−0.44 (−1.35, 0.52)
Sleep efficiency (%)	87 ± 6	85 ± 7	0.56	0.55	−0.31 (−1.22, 0.64)
Wake after sleep onset (min)	64 ± 25	68 ± 25	0.06	0.95	0.16 (−0.77, 1.08)
Number of awakenings (n)	18 ± 4	17 ± 5	12.5	0.43	−0.20 (−1.12, 0.74)
Time between substance intake and sleep onset (min)	325 ± 37	345 ± 63	0.77	0.44	−0.39 (−0.56, 1.30)
Karolinska Sleep Questionnaire					
Sleep Quality	3.9 ± 0.6	3.0 ± 1.0	2.20	0.03 *	−1.09 (−2.02, 0.06)
Calm sleep	3.6 ± 1.4	3.0 ± 1.7	1.48	0.14	−0.39 (−1.30, 0.56)
Easy of falling asleep	4.3 ± 0.9	3.1 ± 1.7	1.69	0.09	−0.88 (−1.80, 0.12)
Amount of dreaming	4.9 ± 0.3	4.6 ± 1.0	0.80	0.42	−0.41 (−1.32, 0.55)
Ease of waking up	4.0 ± 1.5	4.3 ± 1.3	0.26	0.79	0.21 (−0.72, 1.13)
Feeling refreshed after awakening	3.1 ± 1.4	2.9 ± 1.6	0.53	0.59	−0.13 (−1.05, 0.80)
Slept throughout the time allotted	3.9 ± 1.4	3.4 ± 1.9	0.50	0.61	−0.30 (−1.2, 0.64)

Data reported as mean ± standard deviation. Z: Wilcoxon pairwise order test result; *: statistically difference from placebo at $p < 0.05$.

No significant differences ($p > 0.05$ for all) were indicated in the results of the short recovery and stress scale between caffeine and placebo conditions. Small effect sizes

(ES = 0.21–0.49) were noted for muscular stress, lack of activation, negative emotional state, mental performance capability, and overall recovery (Table 3).

Table 3. Results of short recovery and stress scale for caffeine and placebo conditions.

	Placebo	Caffeine	Z	p	ES (95% CI)
Muscular Stress	2.4 ± 0.9	2.6 ± 1.0	0.25	0.79	−0.21 (−1.13, 0.73)
Lack of Activation	2.8 ± 1.5	2.4 ± 1.2	0.52	0.60	−0.29 (−1.21, 0.65)
Negative Emotional State	1.6 ± 0.7	2.2 ± 1.6	0.91	0.36	0.49 (−0.47, 1.40)
Overall Stress	2.7 ± 1.2	2.9 ± 1.2	0.54	0.58	0.17 (−0.77, 1.08)
Physical Performance Capability	3.4 ± 0.7	3.4 ± 1.1	0.17	0.86	0.00 (−0.92, 0.92)
Mental Performance Capability	3.9 ± 1.1	3.4 ± 1.1	0.77	0.44	−0.45 (−1.37, 0.50)
Emotional Balance	4.1 ± 1.1	4.0 ± 1.1	0.40	0.69	−0.09 (−1.01, 0.84)
Overall Recovery	3.6 ± 1.0	3.1 ± 1.2	0.77	0.44	−0.45 (−1.37, 0.50)

Data reported as mean ± standard deviation. Z: Wilcoxon pairwise order test result.

No significant differences were found between men and women or low–mild and moderate–high caffeine consumers for all study outcomes ($p > 0.05$ for all).

4. Discussion

This preliminary investigation aimed to examine the effect of 3 mg/kg of caffeine ingested before an evening (i.e., 7:00 PM) judo training session on a variety of actigraphy-derived and self-rated sleep measures during the night following the trial and a subjective recovery-stress state analysis carried out the following morning. The main findings of the study are as follows: (i) there were no significant differences in actigraphy-derived sleep measures between caffeine and placebo conditions; (ii) caffeine supplementation led to a significant decrease in self-reported sleep quality compared with the placebo condition; (iii) no significant differences between conditions were observed in the reports of recovery-stress state.

Our results revealed that caffeine consumed before an evening training session caused no significant disruption to various actigraphy-derived sleep measures. The results of our study are contrary to previous findings concerning caffeine supplementation in athletes in which objective methods were used for sleep monitoring [30,31]. In these investigations, significant disruptions in sleep onset latency [30], sleep duration [30], sleep efficiency [30,31], number of awakenings [31], and REM sleep duration [30] were observed when caffeine was ingested before late-afternoon (i.e., 5:00 PM) [30] and evening (i.e., 8:00 PM) [31] exercise. The differences between the results of these studies [30,31] and the results of the present study may be related to the caffeine doses (3 mg/kg vs. 6 mg/kg). Although evening caffeine intake might disturb sleep through a reduction in 6-sulfatoxymelatonin (the main metabolite of melatonin) [49], and via adrenaline and noradrenaline stimulation in the adrenal medulla [50,51], the magnitude of sleep interruptions might be dose-dependent [19,52,53]. Moreover, a large inter-individual variability in caffeine pharmacokinetics has been observed [1], with a half-life ranging from 2 to 10 h [54]. It is worth noting that the CYP1A2 gene impacts the speed of caffeine metabolism. Individuals with the AA genotype are considered "fast metabolizers" of caffeine, while those with the AC or CC genotype tend to have a slower caffeine metabolism [55]. Because only one participant reported side effects (mainly observed in "slow metabolizers"), it is possible that the sample consisted mainly of those with the fast-metabolizing genotype. Additionally, in the study by Collomp et al. [56], a decrease in caffeine half-life to 2.3 h in athletes after a single 250 mg dose of caffeine was observed, suggesting faster caffeine elimination during exercise. In summary, it is possible that the caffeine doses in the current study being half the size of those administered in the previous studies [29,30,32] resulted in caffeine plasma levels that had no significant impact on objective sleep measurements. However, from a practical point of view, it is important to use caffeine doses that simultaneously improve exercise performance without negatively impacting sleep and recovery. The studies mentioned above, analyzing sleep following ingestion of 6 mg/kg of caffeine, presented conflicting results [30,31], showing significant improvement in the trials for cycling [30] and countermovement jumping [31], but no effect on 800 m running time [31]. Taking into account the fact that the optimal caffeine dose may differ depending on the caffeine source [57], performance test [7,24,25,28,58–60], and the individual [61], further dose–response studies which include sleep assessments are needed.

While the results of the current study found a significant decrease only in self-reported sleep quality, the "easy of falling asleep" responses also favored the placebo condition, showing a large effect size (4.3 $\pm$ 0.9 vs. 3.1 $\pm$ 1.7; ES: -0.88). Similarly, by administering 6 mg/kg of caffeine before evening training, a previous study found significant differences in subjective quality of sleep and sleep latency [31,62]. Such studies emphasize the fact that objective and subjective assessments of sleep quality may relate to different parameters [63], and it seems that these parameters might be particularly sensitive to caffeine ingestion. Additionally, the results of the current study revealed no significant changes in self-reported recovery-stress state on the morning following the experimental sessions. However, it is worth noting that all sleep and recovery parameters were affected by the caffeine condition (ES = 0.09–1.09). Even if almost all of the outcomes did not reach statistical significance, it cannot be assumed that the observed sleep interruptions had no critical health consequences. It is worth highlighting the fact that most adults require seven to nine hours of sleep per night [64], and that athletes may need more due to the high physical and mental demands under which they are placed [29]. Interestingly, in the current study, the sleep duration was shorter than the recommended seven hours during the caffeine condition. Taking into account the fact that elite athletes are particularly susceptible to sleep disturbances, characterized by chronic short sleep (<7 h/night) and poor sleep quality (e.g., sleep fragmentation) [29], such observed decreases might contribute to negative health and compromise an athlete's capacity to train effectively and compete optimally. Further, it is possible that with the continuous use of caffeinated supplements before evening training sessions, the sleep and recovery parameters might be significantly disturbed over a longer period of time.

It should be taken into consideration that athletes in the current study were habitual caffeine users. In the present investigation, the mean daily level of caffeine consumption was similar to the single caffeine dose used before the training sessions (2.9 mg/kg vs. 3 mg/kg). Habitual caffeine users may develop tolerance to certain physiological effects of caffeine [51], and thus, a diminished effect on sleep parameters might result from the athletes' daily caffeine consumption. For this reason, it is likely that the very low frequency of side effects and lack of changes in heart rate during the judo training session or the night after the experimental trials were found in this study, results similar to those observed in previous studies [24,30,52]. Taking into account the fact that caffeine is widely and frequently consumed through coffee, tea, and commercially available soft and energy drinks [65], athletes should control their daily habitual caffeine intake if they are considering the use of caffeinated sports supplements. It is worth noting that the current recommendations for athletes only emphasize avoiding high caffeine doses (i.e., $\geq$9 mg/kg) [66] or stimulants too close to bedtime [29]. The results of the presented study, and those obtained in previous investigations [30–33], highlight the need for more specific guidelines for caffeine use. In future research, caffeine-induced changes in sleep parameters should be tested with different caffeine doses and times of dosing relative to bedtime to create practical guidelines for athletes.

In addition to its strengths, the present investigation has several limitations: (i) the number of athletes included in the current study was limited; (ii) the study did not include any biochemical analysis, and therefore the concentrations of plasma caffeine and women's hormones were unknown; (iii) the study sample was composed of habitual caffeine users with different levels of consumption (therefore, future research is needed to explore and compare analyzed parameters among homogenous groups in terms of habitual caffeine intake, and to compare findings between men and women); and (iv) only subjective reports of the recovery-stress state were obtained (future studies should include markers of muscle damage and inflammation to verify our findings, and, moreover, continuously monitoring sleep and recovery measurements after day-by-day caffeine supplementation would be interesting).

5. Conclusions

The results of this study did not find significant differences between the effects of 3 mg/kg of caffeine and a placebo ingested before an evening training session on actigraphy-derived sleep measures and recovery-stress state in highly trained judo athletes. However, caffeine was observed to lead to a substantial decrease in self-reported sleep quality. Thus, when considering caffeine use before an evening training session, athletes need a strategic approach which considers the dose and the time before habitual bedtime. However, future studies using various caffeine doses and a larger sample size will be required to confirm these findings.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

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