ORIGINAL RESEARCH

Does a single cup of coffee at dinner alter the sleep? A controlled cross-over randomised trial in real-life conditions

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Abstract

Aim: To report changes in the quality of sleep after drinking an evening cup of either caffeinated or decaffeinated coffee, in healthy subjects in everyday life.

Methods: Sixty-three healthy men and women, who considered themselves to be caffeine sensitive were included in a double-blind, cross-over trial, randomised to receive either caffeinated coffee containing 90 mg of caffeine, or, as control, a dose of decaffeinated coffee containing 4.5 mg caffeine, taken after dinner. The primary outcome measure was the degree of sleep disturbance, scored on a visual analogue scale, ranging from 0 (excellent sleep) to 100 (very disturbed sleep). Ancillary criteria were patients' reported estimate of sleep latency, and how often the subjects reported waking.

Results: Mean age of subjects was 30.5 ± 12 years. The quality of sleep was significantly worse with caffeinated (mean 30.8 ± 22.7) than with decaffeinated coffee (mean 19.5 ± 16.9), $P = 0.001$. Caffeinated coffee also significantly increased the sleep latency (mean difference 17 ± 31 minutes, $P < 0.001$) and the frequency of waking (mean 1.3 vs 0.8 episodes in the night, $P = 0.006$) compared with decaffeinated coffee.

Conclusions: Even a single cup of caffeinated coffee consumed before bedtime in real-life conditions causes a deterioration in the quality of sleep in caffeine-sensitive subjects.

Key words: caffeine, coffee, healthy people, real-life condition, sleep, sleep disorder.

Introduction

Coffee is one of the most commonly consumed beverages in the world and many studies recently focused on the beneficial effects of its consumption on cardiovascular risk factors such as obesity, type II diabetes and endothelial dysfunction, although the mechanisms of this association remains to be determined.[1–7] Whether the coffee is caffeinated or decaffeinated, or need to be consumed during or after a meal to cause these effects is still a matter for debate.

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Recently, Sartorelli et al., in a prospective cohort study of 69 532 European women, reported an inverse association between high coffee intake (more than three cups per day) with both regular and decaffeinated coffee and diabetes, as had been previously reported.[8] Drinking coffee at lunch time was associated with a lower risk of diabetes compared with no coffee consumption, independently of other variables. A trend towards an independent protective effect of coffee at dinner was also observed, but failed to reach statistical significance, probably because of the limited number of women in this group. Drinking coffee at dinner may increase the total daily coffee consumption in real life, but most individuals take coffee before 3:00 p.m.[9]

It is well established that caffeine may not only alter the quality of sleep, but also improves alertness and performance during sleep deprivation.[9–13] However, data about its effect at normal doses when taken in real-life conditions is very sparse. Most studies have evaluated high doses, ranging from 250 to 1200 mg per day,[14,15] included mostly men,[11,15–17] or have been performed in artificial settings such as laboratory conditions, using electroencephalogram (EEG) records.[9,16,17]

Moreover, many of these studies involved sleep-deprived subjects.

Many people consider themselves caffeine sensitive, claiming that a single cup of coffee in the evening, or even in the afternoon, disturbs their sleep.[18] This sensitivity has been shown to be at least partially inherited[18] and may be related to individual differences in caffeine metabolism, as sensitive subjects show greater half-life values of plasma caffeine concentrations.[19,20] We have found no published trial of the effect of a normal 'single dose' of caffeine in these caffeine-sensitive subjects.

More data on the effect of normal doses of caffeine in a real-life situation may therefore represent a useful tool to improve public health.

With this in mind, the aim of this trial was to better define and quantify in caffeine-sensitive subjects the effect on an after-dinner caffeinated coffee or decaffeinated coffee on sleep, in real-life conditions.

Methods

Subjects: Healthy male and female volunteers, aged over 18 years, who having declared experienced sleep disturbances after drinking coffee in the evening, were included. None described acute or chronic insomnia or were they taking psychotropic or hypnotic drugs. There was no history of active disease or recent change in health status, no intestinal or liver disease or any history of gastrointestinal surgery except appendectomy or cholecystectomy. Prescription medication was allowed, providing it had not changed during the two weeks preceding randomisation, or during the study. Subjects were not permitted to consume other caffeine-containing beverages, smoke more than 10 cigarettes per day, to drink more than the equivalent of two glasses of alcohol per day or to drink more than three cups of coffee or tea per day. Subjects were not working night shifts. A checklist was used to clarify inclusion and exclusion criteria and all patients signed an informed written consent. The follow-up study protocol was approved by the Ethics Committee of Lariboisière hospital.

Coffee preparations: The two coffee preparations were either 3 g of regular instant coffee containing 90 mg of caffeine (Nescafé spécial filtre), or 3 g of decaffeinated instant coffee containing 4.5 mg of caffeine (Nescafé spécial filtre décaféiné, Nestlé, Vevey, Switzerland). The data on the caffeine content was provided by the manufacturer. The two coffee bags were equal in presentation and taste and were prepared in our pharmacy, observing strict quality controls. Each coffee bag had to be diluted in warm water (about 200 mL with or without milk and sugar). Subjects took one or other types of coffee, in a cross-over sequence defined by a list prepared by a colleague not participating in the study and working in the clinical pharmacology unit. The randomisation was balanced for every four subjects included according to a random table. Random assignment has been used for every four subjects according to a random table.

Intervention: The study was a randomised, double-blind, cross-over trial, comparing regular to decaffeinated coffee.

After randomisation, subjects received an envelope containing the two numbered coffee bags. They were expected to use one of the two coffee bags during the evening after dinner, on two different evenings during a seven-day period. Subjects were instructed to keep the conditions of intake of the two coffee bags as similar as possible, in terms of day of week, activity during that day, the timing and content of dinner, consumption of alcohol and cigarettes, when they drank their coffee, their bedtime and when they rose the following day. A part of healthy volunteers were working in hospital with differing intensities of work from one week to another. The choice of the second evening was at the discretion of the volunteer with the limit that the day had been as much like the first as possible.

Between the two nights of the study, the aim was for there not to be either any new prescription drugs or any significant life events.

Measurements: The subjects had to complete a report the morning after each study night and return it by mail to the study centre. The primary outcome was the quality of sleep scored by subjects on a visual analogical scale ranging from 0 (excellent night) to 100 mm (very bad night). Ancillary criteria were the subjects' estimate of sleep latency (in minutes) and the number of times the subjects awoke during the night. Subjects were asked to guess in which order they had taken the two types of coffee.

Statistical analysis: Results are presented as mean ± SD. Significance of differences was assessed with repeated-measures analysis of variance (ANOVA) and student's *t*-test for paired data. For categorical data, comparison was made by chi-square test. *P*-value <0.05 was considered significant. According to the hypotheses of mean expected difference of 20 mm on the sleep visual analogue scale and expected standard deviation of 35 mm, using an alpha of 0.05, a power of 0.80, the minimum required number of subjects was 70.

Results

Seventy patients (63% female, 37% male) were included having fulfilled the inclusion criteria. Seven subjects were withdrawn because they did not comply with the conditions of coffee intake or sleep assessment: one subject stated that he had drunk and smoked too much during the two study evenings and six subjects sent incomplete evaluations. Therefore, statistical analysis was performed on 63 subjects (Figure 1).

Mean age was 30.5 ± 12 years (range: 18–62, 59% women, 41% male). Thirty-two subjects were working, 29 were students and two subjects were retired. Thirteen subjects were taking prescription medication (contraceptive: 8; miscellaneous: 5). During the second period, one patient received a new treatment (a macrolide: josamycine). Nine and 39 subjects did not drink coffee or tea, respectively. The median daily intake was two cups of coffee (range: 1–3) among the 54 coffee drinkers, and one cup of tea (range: 1–2) among the 24 tea drinkers. The usual median time for the last intake was 2:00 p.m. for coffee and 5:00 p.m. for tea.
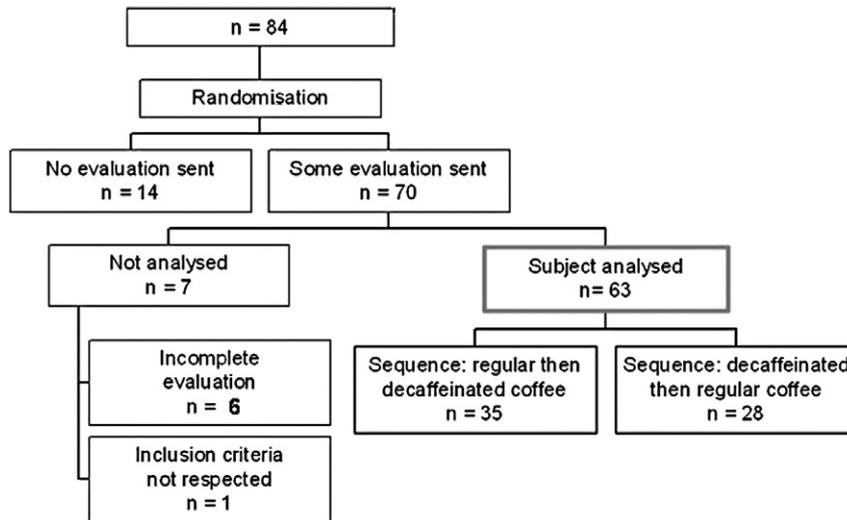
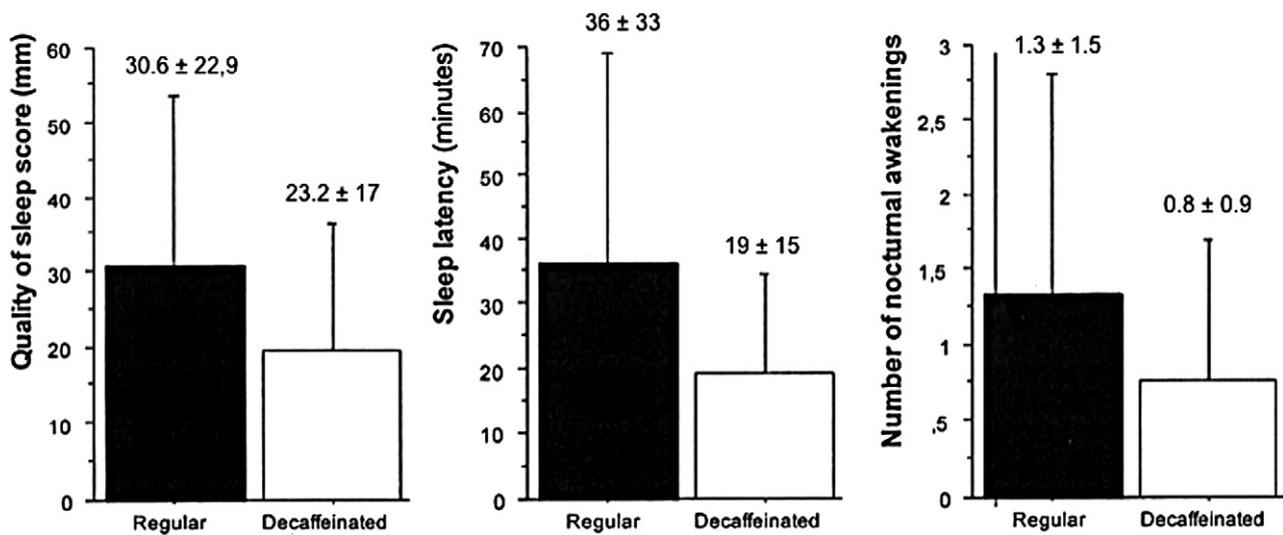**Figure 1** Trial profile: participants flow and follow-up.

Figure 2 Quality of sleep score, sleep latency and number of nocturnal awakenings after intake of regular or decaffeinated coffee in the evening. The quality of sleep score is derived from a visual analogical scale ranging from 0 (excellent night) to 100 mm (very bad night). Results are expressed as means ± SD; the bar represents standard deviation. All differences between regular and decaffeinated coffee are statistically significant ($P > 0.05$, t-test).

Twenty-eight subjects were first given decaffeinated coffee and then caffeinated coffee and the other 35 subjects had the reverse sequence. The two coffees were consumed within a mean interval of 7 ± 3 days. During the two dinners, only 7% of subjects drank alcohol (mostly one glass) and 11% smoked (mostly two cigarettes). The mean coffee–bedtime interval (122 ± 52 min) was similar for the two groups. The quality of sleep score, the sleep latency and number of times the subjects awoke during the night did not correlated with age, the daily number of cups of coffee or tea, the course of the evening (timing of dinner, bedtime) or the length of sleep.

The quality of sleep score was significantly worse ($P = 0.0014$ ANOVA) with caffeinated coffee (30.8 ± 22.7 mm)

than with decaffeinated coffee (19.5 ± 16.9 mm), with a difference of 11.2 ± 25.7 mm (95% CI 4.7 to 17.7, $P = 0.0014$, ANOVA; Figure 2). No 'period effect' was detected, (ANOVA, $P = 0.2$) although the sleep score for decaffeinated coffee was slightly better during the second period compared to the first period (Table 1).

Estimated sleep latency was significantly increased with caffeinated coffee (36 ± 33 minutes) compared to decaffeinated coffee (19 ± 15 minutes) giving a mean difference of 17 ± 31 minutes (95% CI 9 to 25, $P < 0.0001$, ANOVA; Figure 2). Once again, there was no period effect (ANOVA, $P = 0.4$).

Caffeinated coffee also increased the number of nocturnal awakenings, from 0.8 ± 0.9 with decaffeinated coffee to

Table 1 Quality of sleep score after intake of a single cup of regular or decaffeinated coffee in the evening

| Coffee intake | Quality of sleep score (mm, mean ± SD) | | | |
| | Cross-over periods | | | |
	Period 1	Period 2	Total[b]	
Regular (90 mg caffeine)	30.6 ± 22.9	31.1 ± 22.8	30.8 ± 22.7	Difference = 11.2 ± 26
Decaffeinated (4.5 mg caffeine)	23.2 ± 17	16.6 ± 16.6	19.5 ± 16.9	95%CI = 4.7 to 17.7
Total[a]	27.3 ± 20.7	23.1 ± 20.7		

The quality of sleep score is derived from a visual analogue scale ranging from 0 (excellent sleep) to 100 mm (complete insomnia).
[a] No period effect was observed (ANOVA, $P = 0.2$).
[b] A drug effect was apparent (ANOVA: $P = 0.0014$; t-test $P = 0.001$).

1.3 ± 1.5 with caffeinated coffee (mean difference 0.6 ± 1.6, 95% CI 0.2 to 1, $P = 0.0129$, ANOVA) and with no period effect (ANOVA, $P = 0.3$; Figure 2).

Asked once the study was completed, about two-thirds of subjects (68%) correctly guessed the order in which they had received the two types of coffee because of its effect. Only two subjects stated recognising the type of coffee they drunk because of the taste, but only one of these was correct.

With caffeinated coffee, there was a significant inverse correlation ($r = 0.28$, $P = 0.0255$) between the intake—bedtime interval and the number of nocturnal awakenings: the longer the interval between intake and bedtime, the fewer nocturnal awakenings.

Whatever the period or type of coffee, the quality of sleep score was better among working subjects ($n = 32$, mean age: $36 ± 12$ years) than students ($n = 29$, mean age: $22 ± 3$ years): $20.2 ± 18.7$ mm *vs* $31.3 ± 21.8$ mm, $P = 0.0031$, t-test).

Discussion

In this randomised, double-blind, cross over trial, we found that a single cup of coffee containing a normal amount of caffeine (90 mg), in everyday life conditions, significantly impairs the quality of sleep, lengthens the sleep latency and increases the number of awakenings in caffeine-sensitive subjects, compared to decaffeinated coffee.

The participants in this study felt themselves to be sensitive to caffeine and self-reported feedback demonstrated significant changes to their sleep.

Previous studies have stressed the impact of caffeine on the quality of sleep, finding that its intake 30 to 60 minutes before bedtime increased sleep latency, reduced sleep efficiency and total sleep time, and altered the EEG during sleep.[9,11] Caffeine has been used in normal subjects to cause insomnia and hence to induce symptoms mimicking those of insomnia.[11,16] However, most of these studies employed high doses of caffeine, ranging from 250 mg to 1200 mg a day.[13–15,20–23] The effect of caffeine on sleep has also been reported with lower doses such as 100 to 200 mg caffeine, administered at bedtime.[9,17,24] A small study (nine patients) also found that even given in the morning, 200 mg of caffeine significantly reduced sleep efficiency and total sleep time the subsequent night.[24] The dose of caffeine (90 mg) used in this study is within the usual range (80–150 mg) for a cup of caffeinated coffee as generally consumed in Europe and the USA.[25]

To the best of our knowledge, there has been no published study assessing the impact of regular and decaffeinated coffee on sleep in subjects who considered themselves sensitive to caffeine. One randomised cross-over trial compared the effect of caffeinated coffee versus decaffeinated coffee, but in non-selected people. Subjects drank five daily cups of coffee (420 mg caffeine) for six weeks followed by five daily cups of decaffeinated coffee for a further six weeks or the reverse. Subjects reported falling asleep more easily when they were consuming decaffeinated coffee, but the difference was very small, as the mean score was 88 (range from 0 to 100) with decaffeinated coffee compared to 85 with caffeinated coffee (95% CI: 0.2–5.8).[22]

The impact of drinking coffee on sleep has been related by some authors to the rate of caffeine metabolism. People with a history of caffeine-induced wakefulness were found to have a longer plasma half-life and slower plasma clearance of caffeine compared to subjects not affected by caffeine.[22,23] The caffeine concentration was also higher in patients reporting sleep problems than in those without.[26] However, for Tiffin *et al.*, healthy self-rated poor sleepers had significantly greater variability in caffeine pharmacokinetic parameters than normal sleepers.[27] Our subjects were caffeine sensitive but not poor sleepers, with normal habitual sleeping time and quality of sleep. They regularly consumed coffee or tea, but at low doses (one to three cups a day), and avoided taking it in the evening.

Some authors have used caffeine to develop a model of insomnia in animals and in humans, used to study the effects of hypnotics such as zolpidem.[14,28] Others authors have found that caffeine reversed many but not all pharmacodynamic effect of zolpidem, partially impairing its sedative and performance-impairing effects. It is interesting to note that the mean delay in sleep latency induced by coffee in the present study (17 minutes) is very close to the mean gain (15 minutes) obtained with hypnotic drugs in clinical studies.[29]

The present study is partially limited by our chosen population. We do not know if its results could be applied to people who do not consider themselves caffeine sensitive or the population in general. Another possible limitation is the

effect of tolerance. In habitual coffee drinkers, relative tolerance to the actions of caffeine develops within a few days, even when only one to two cups of coffee are consumed during the day.[30] Satoh et al. reported in their study that habitual coffee drinkers (mean 3.5 cups of coffee per day) showed tolerance in arithmetic skills tests and mean blood pressure values compared with non-habitual coffee drinkers.[31] In this study, the median daily coffee intake was two cups among subjects drinking coffee. There was a non-significant trend towards a tolerance effect on quality of sleep among the group consuming one to three cups of coffee daily (29.6 ± 22.6 mm, n = 54) compared to the group consuming no coffee (39 ± 23.4 mm, n = 9). Finally, we used self-reporting measures, which are of course liable to bias, but their individual variation may be helpful in clinical practice to observe the impact of coffee before bedtime in self-declared caffeine-sensitive subjects.

In conclusion, we demonstrate in this study that a single cup of caffeinated coffee, containing a usual dose of caffeine (90 mg), consumed before bedtime in real-life conditions, significantly impaired the overall quality of sleep in caffeine-sensitive subjects, compared to a cup of decaffeinated coffee. A single cup of caffeinated coffee also significantly increased sleep latency and the number of nocturnal awakenings.

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