*Pharmacology Biochemistry and Behavior*, Vol. 44, pp. 573–576, 1993
Printed in the U.S.A. 

0091-3057/93 $6.00 + .00


# Coffee Consumption, Blood Pressure Tonus and Reactivity to Physical Challenge in 338 Women

ILSE HÖFER[1] AND KARL BÄTTIG

*Comparative Physiology and Behavioral Biology Laboratory, Swiss Federal Institute of Technology Zürich, ETH-Zentrum, TUR, CH 8092 Zürich, Switzerland*

Received 7 August 1992

HÖFER, I. AND K. BÄTTIG. *Coffee consumption, blood pressure tonus and reactivity to physical challenge in 338 women.* PHARMACOL BIOCHEM BEHAV 44(3) 573–576, 1993.—The relationships of coffee consumption habits and cardiovascular tonus at rest and in response to an orthostatic and an ergometric challenge were determined in 338 nonsmoking women. Habitual coffee consumption was unrelated to blood pressure. Coffee consumption on the test day was associated with slightly higher systolic blood pressure at rest and with smaller increases due to ergometer cycling. The latter was confirmed by a similar relation with saliva caffeine concentrations measured in a subsample ($n$ = 200). These findings are discussed in terms of a transient stabilising effect of caffeine on blood pressure.

Coffee consumption    Blood pressure    Physical stress

INCREASES in blood pressure due to caffeine seem to be acute and transient. Single caffeine doses in the order of 3 mg/kg have been demonstrated unequivocally to elevate systolic blood pressure (SBP) and diastolic blood pressure (DBP) moderately when administered to nonusers or to users who previously had abstained from all caffeine sources [cf. (7)]. On the other hand, habitual coffee consumption seems hardly associated with increased blood pressure measures. This is suggested by large-sample cross-sectional studies, where blood pressure was mostly unrelated to or even slightly negatively correlated with self-reported coffee consumption (7,11,12), as well as by field studies that compared regular with decaffeinated coffee over several weeks (switching) and detected only minimal or no decreases of blood pressure upon withdrawal of caffeine [(1,10,15); for review, cf. (2)].

Another question concerns the possible interaction of cardiovascular responses to caffeine and stress. In previously abstaining subjects, mental stress and caffeine were unequivocally observed to be simply additive (5,6,9).

Investigations of the effects of caffeine and physical stress on cardiovascular parameters are rare, although acute caffeine has been reported to have a positive effect on endurance and work output (4,14). Sung and coworkers (13) studied the effect of caffeine (3.3 mg/kg) and physical stress (submaximal bicycle exercise with workloads stepwise increased every 3 min) on diastolic and systolic blood pressure in abstaining consumers. With low to moderate workloads, the effects were additive, with increasing workloads the caffeine effect was weakened, and it disappeared with maximal workloads (>600 kg × m/min). So far, no study has investigated possible relations between everyday coffee consumption and the cardiovascular response to physical stress in nonabstaining consumers.

The present study investigated the relationship between coffee consumption and cardiovascular parameters both under resting conditions and under physical challenge (orthostatic reaction, ergometer cycling). Both habitual coffee consumption and actual coffee consumption on the testing day were assessed by self-report; in addition, caffeine concentration in saliva was determined in a subsample.

## METHOD

### *Subjects*

Subjects were paid volunteers recruited by advertisement in daily newspapers and women's magazines, asking for nonsmoking females aged between 20 and 40 years; most ads asked explicitly for coffee consumers. During the first contact by phone, the exclusion criteria were checked (smoking, pregnancy, hypertension, other diseases). Of the 502 initial subjects, 352 were tested (21.7% cancellations, 8.2% nonarrivals), 14 of which were excluded from the statistical analysis (mismatch to sample criteria, missing data). The resulting

[1] To whom requests for reprints should be addressed.

sample of 338 subjects had a mean age of 28.9 years (SD 6.4), mean height of 166.3 cm (SD 5.9), mean weight of 59.4 kg (SD 9.2), and mean body-mass-index of 21.8 $kg^2/cm$ (SD 7.1). Twenty-four percent had had primary, 37 intermediate, and 36 higher education (3% gave no information); 34 percent were in professional training, 44 were employed, and 23 were housewives. As requested, subjects were widely normotensive (cf. Table 1); 17 subjects had one or more borderline measures ($139 < SBP < 160$; $89 < DBP < 95$; supine or sitting at rest, for details cf. procedure and data reduction), 4 subjects had one or more measures indicating hypertension ($94 < DBP < 100$).

### *Caffeine Questionnaire*

On a detailed questionnaire, subjects indicated the number of cups of coffee (and tea and cola) habitually consumed at different times of day (wakeup, breakfast, . . . , after dinner), and also whether the beverages in general contained caffeine or were caffeine free. For the present report, the figures for caffeine-containing beverages were summed up over the different occasions, separately for coffee, tea, and cola.

On the experimental day, subjects reported how many cups of coffee they had consumed before arriving at the laboratory (actual coffee consumption).

### *Caffeine in Saliva*

Caffeine concentrations in saliva (μmol/l) were determined in a subsample of 200 subjects from 5-ml saliva samples collected over 5–10 min, 15 min after rinsing the mouth with tapwater. Saliva samples were stored at −70°C until analysis. Caffeine concentration was determined automatically on a Cobas-Bio (Roche, Basel, Switzerland) with an enzyme immunoassay method (EMIT by SYVA) at the Institut für Klinische Chemie, Universitätsspital Zürich.

### *Cardiovascular Parameters*

SBP, DBP, and heart rate (HR) were determined automatically via a blood pressure device (Tonomed, Speidel & Keller, Germany; Korotkoff sounds).

### *Procedure*

After the first phone contact, subjects were mailed several questionnaires to be completed at home.

Subjects came to the lab for one session lasting about 45 min; sessions were distributed between 8 a.m. and 5 p.m. After general information, a blood pressure cuff was fixed to the left arm.

The first task was the Schelling test for orthostatic reaction: Subjects had to lie down with their feet elevated (27 cm) for 5 min. Then, they were told to get up quickly and stand quietly for 7 min with the registration arm supported in a horizontal position; during this period, music was played.

In the subsequent pause, subjects filled out another questionnaire and gave a saliva sample (200 subjects only).

The second task was the ergometer test, carried out with a stepwise increasing workload: Subjects first sat quietly on the ergometer cycle for 2 min. Then, they started cycling, beginning with a workload of 50 W, which was increased in steps of 25 W every minute by adding a 0.5 kg-weight. Subjects continued cycling until they reached their submaximal heart rate limit. This was defined as 75–80% of 200 minus the subject's age. During both tests, blood pressure and heart rate were measured automatically at 1-min intervals.

TABLE 1

BLOOD PRESSURE MEASURES:
MEANS AND SD AND CORRELATIONS WITH CAFFEINE EXPOSURE INDICATORS

| | | Pearson Correlations | | | Partial Correlations (adjusted for age) | | |
|---|---|---|---|---|---|---|---|
| | Mean ± SD | Habit. Coffee* | Actual Coffee* | Saliva Caffeine† | Habit. Coffee* | Actual Coffee* | Saliva Caffeine† |
| Orthostatic test | | | | | | | |
| SBP rest, supine | 106.9 ± 11.0 | 03 | 15‡ | 00 | 04 | 15‡ | 01 |
| DBP rest, supine | 73.3 ± 7.5 | 04 | 12§ | −01 | −02 | 08 | −03 |
| SBP final, upright | 91.6 ± 10.7 | 13§ | 20¶ | 11 | 09 | 17¶ | 11 |
| DBP final, upright | 73.1 ± 8.4 | 04 | 09 | 07 | 01 | 07 | 07 |
| SBP reaction | −15.3 ± 9.3 | 11§ | 05 | 12 | 06 | 01 | 11 |
| DBP reaction | −0.2 ± 7.8 | −00 | −02 | 09 | 03 | 00 | 11 |
| Ergometer test | | | | | | | |
| SBP rest, sitting | 98.9 ± 11.0 | 13§ | 24¶ | 10 | 10 | 22¶ | 09 |
| DBP rest, sitting | 77.3 ± 7.8 | 09 | 18¶ | 05 | 03 | 15‡ | 04 |
| SBP final, cycling | 137.0 ± 14.5 | −06 | −01 | −07 | −04 | 01 | −06 |
| DBP final, cycling | 91.7 ± 8.9 | 07 | 16‡ | 08 | 03 | 13§ | 07 |
| SBP reaction | 38.1 ± 15.5 | −14‡ | −18¶ | −13 | −11 | −15‡ | −11 |
| DBP reaction | 14.4 ± 9.6 | −01 | −00 | 02 | 00 | 00 | 03 |
| SBP reaction per step | 10.0 ± 4.6 | −12§ | −20¶ | −15§ | −13§ | −21¶ | −16§ |
| DBP reaction per step | 3.8 ± 2.7 | −00 | −03 | −03 | −03 | −04 | −03 |

Decimal points omitted.
*$n = 338$.
†$n = 200$ (subsample with saliva caffeine).
§$p < 0.05$, ‡$p < 0.01$, ¶$p < 0.001$, significance level.

### *Data Reduction and Statistics*

*Orthostatic reaction.* The last three measures in the supine position were averaged as baseline, the last three measures in the upright position were averaged as final value, and the difference to baseline was used as orthostatic reaction.

*Ergometer test.* The two measures before cycling were averaged as baseline, the last measure during cycling was considered as final measure, and the difference to baseline as reaction. Further, a "standardized" reaction was computed as reaction divided by the number of workload steps.

*Statistical analysis.* The relationships between caffeine exposure and cardiovascular parameters were assessed by Pearson correlations, simple linear regressions, and partial correlations adjusted for age, which were computed with procedures of the $SPSS^{X}$ statistical package on a Cyber 855.

## RESULTS

The average habitual coffee consumption was reported with 4.4 cups per day (SD = 2.9, range 0–17; 6% nonconsumers). Black tea and cola as additional caffeine sources were of minor importance in this sample (70–77% nonconsumers, 20–25% with one to three cups per day). On the experimental day, subjects had consumed on average 1.9 cups of coffee (SD = 1.3, range 0–10; 12% nonconsumers). The caffeine concentration in saliva amounted to 14.4 μmol/l (SD = 10.6, range 0–45.5) in the subsample of 200 subjects. Habitual and actual coffee consumption were positively correlated ($r$ = 0.55), and both were positively associated with saliva caffeine ($r = 0.45$ and 0.60, respectively, all $p < 0.001$). Habitual coffee consumption and actual coffee consumption, but not caffeine in saliva, increased with age ($r = 0.27$, 0.22, $p < 0.001$, $r = 0.06$, respectively). Therefore, the correlations with the cardiovascular parameters are presented as raw figures and as partial correlations adjusted for age.

Table 1 summarizes the correlations of the caffeine exposure indicators with the BP measurements obtained in the experiment. Excluding the 17 subjects with borderline hypertension and the 4 hypertensive subjects did not change the correlation coefficients.

Habitual coffee consumption mostly failed to correlate significantly, and the obtained values dropped near chance level when adjusting for age. Actual coffee consumption on the experimental day, however, was correlated with a considerable number of blood pressure measures, and significance was maintained after correction for age effects; results were also stable when computed for the subsample with saliva caffeine measures only. Saliva caffeine was correlated with the SBP increase per workload step during ergometer cycling. These correlations were positive for all BP measures of the orthostatic test and for the BP levels of the ergometer test but negative for the overall and the standardized SBP reaction to ergometer cycling.

Heart rate, not shown in Table 1, increased in the orthostatic test from 71.2 ± 11.9 bpm supine to 88.7 ± 13.3 bpm upright and increased from 78.8 ± 10.9 bpm to 139.7 ± 7.9 bpm during ergometer cycling, corresponding to an increase per workload step of 16.0 ± 4.1 bpm. The only correlation with caffeine exposure was obtained for the heart rate increase in the orthostatic test from supine to upright position with actual coffee consumption and with saliva caffeine ($r = -0.19$, $-0.17$; adjusted for age: $r = -0.17$, $-0.16$, respectively, all $p < 0.05$).

Regressional computation revealed increases of the BP levels between 0.70 and 1.96 mm Hg per cup of actual consumption, depending upon the considered BP measure that reached a significant correlation. The SBP increase during ergometer cycling was reduced by 2.04 mm Hg per cup of actual consumption or, considering the increase per workload step, by 0.69 mm Hg per cup and by 0.70 mm Hg per 10 μmol/l caffeine in saliva. The heart rate increase during the orthostatic test was reduced by 1.33 bpm per cup of actual coffee and 1.60 bpm by 10 μmol/l saliva caffeine.

## DISCUSSION

The present study was concerned with the associations between everyday caffeine consumption and BP at rest and under physical challenge. In nonabstaining subjects, this study revealed only a few relationships with habitual coffee consumption, while more such associations were obtained with the actual coffee consumption preceding the measurements on the testing day. Taking into consideration the size of the correlation coefficients (or the amount of explained variance) and the amount of BP changes per cup of coffee, all associations were weak, although in part highly significant due to the relatively large sample size. Further, most of these associations failed to be validated by corresponding associations with caffeine concentrations in saliva, in part due to the smaller sample size.

The few positive associations between habitual coffee consumption and SBP levels (after 7 min upright, sitting at rest) disappeared after adjustment for age. This result is concordant with the recent reports from cross-sectional studies that observed no or weak, mostly negative relationships with blood pressure levels [(3,8,11,12); for reviews, cf. (2,7)].

Actual coffee consumption on the testing day, however, was associated with higher BP levels, especially SBP. Similar observations have been reported from a cross-sectional study for coffee consumption in the last 3 h (11).

Further, coffee consumption was associated with smaller cardiovascular changes due to physical challenge. Actual coffee consumption resulted in a smaller heart rate increase during orthostatic testing. Further, all considered caffeine exposure indicators were associated with smaller SBP increases during ergometer cycling. These relations were more consistent for the "standardized" increase per workload step than for the total increase, ruling out therefore a ceiling hypothesis that might be based upon the fact that ergometer cycling was stopped with respect to a cardiovascular criterion. In addition, the initial SBP values were unrelated to the number of workload steps.

These results with respect to ergometer cycling are consistent with those reported by Sung and coworkers (13), who found initially increased SBP levels after acute caffeine administration that leveled off to the placebo levels with increasing workload.

In conclusion, coffee consumption appears to increase SBP tonus in a transient manner but to reduce the reactivity to physical challenge, especially for SBP. Thus, coffee consumption seems to have a (weak) stabilising effect on SBP at a slightly elevated level.

## ACKNOWLEDGEMENTS

This study was supported by a grant from the International Coffee Organisation, London. The authors thank P. Schmid for technical assistance, B. Schütze for data collection, Dr. K. Gautschi for the determination of the caffeine concentrations in saliva, and B. Strehler for help with the manuscript.

## REFERENCES


1. Bak, A. A. A.; Grobbee, D. E. A randomized study on coffee and blood pressure. J. Human Hypertens. 4:259-264; 1990.
2. Bättig, K. Coffee, cardiovascular and behavioral effects. Current research trends. Rev. Environ. Health 9:53-84; 1991.
3. Birkett, N. J.; Logan, A. G. Caffeine-containing beverages and the prevalence of hypertension. J. Hypertension 6(suppl. 4):S620-S622; 1988.
4. Flinn, S.; Gregory, J.; McNaughton, L. R., et al. Caffeine ingestion prior to incremental cycling to exhaustion in recreational cyclists. Int. J. Sports Med. 11:188-193; 1990.
5. France, C.; Ditto, B. Cardiovascular responses to occupational stress and caffeine in telemarketing employees. Psychosom. Med. 51:145-151; 1989.
6. Lane, J. D. Caffeine and cardiovascular responses to stress. Psychosom. Med. 45:447-451; 1983.
7. Myers, M. G. Effects of caffeine on blood pressure. Arch. Intern. Med. 148:1189-1193; 1988.
8. Periti, M.; Salvaggio, A.; Quaglia, G.; DiMarzio, L. Coffee consumption and blood pressure: An Italian study. Clin. Sci. 72:443-447; 1987.
9. Pincomb, G. A.; Lovallo, W. R.; Passey, R. B.; Wilson, M. F. Effect of behavior state on caffeine's ability to alter blood pressure. Am. J. Cardiol. 61:798-802; 1988.
10. Rosmarin, P. C.; Applegate, W. B.; Somes, G. W. Coffee consumption and blood pressure: A randomized, crossover clinical trial. J. Gen. Intern. Med. 5:211-213; 1990.
11. Shirlow, M. J.; Berry, G.; Stokes, G. Caffeine consumption and blood pressure: An epideomiological study. Int. J. Epidemiol. 17:90-97; 1988.
12. Stensvold, I.; Tverdal, A.; Foss, O. P. The effect of coffee on blood lipids and blood pressure. Results from a Norwegian cross-sectional study, men and women, 40-42 years. J. Clin. Epidemiol. 42:877-884; 1989.
13. Sung, B. H.; Lovallo, W. R.; Pincomb, G. A.; Wilson, M. F. Effects of caffeine on blood pressure response during exercise in normotensive healthy young men. Am. J. Cardiol. 65:909-913; 1990.
14. Tarnopolsky, M. A.; Atkinson, S. A.; Macdougall, J. D.; Sale, D. G.; Sutton, J. R. Physiological responses to caffeine during endurance running in habitual caffeine users. Med. Sci. Sports Exerc. 21:418-424; 1989.
15. van Dusseldorp, M.; Smits, P.; Thien, T.; Katan, M. B. Effect of decaffeinated versus regular coffee on blood pressure: A 12-week, double-blind trial. Hypertension 14:563-569; 1989.