

Emotional Antecedents of Hot Flashes During Daily Life

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Objective: Hot flashes are among the most frequently reported menopausal symptoms. However, little is known about factors associated with their occurrence. Moreover, despite the wide use of self-report hot flash measures, little is known about their concordance with physiological flashes. This study evaluated emotional and behavioral antecedents of subjectively and objectively measured hot flashes during daily life. It also examined individual differences predicting concordance between objective and subjective hot flashes. **Methods:** Forty-two perimenopausal or postmenopausal women (mean age = 50.5 ± 4.8 years) reporting daily hot flashes completed 2 days of ambulatory sternal skin conductance monitoring, behavioral diaries 3 times an hour, and psychometric questionnaires. Hot flashes meeting objective physiological criteria and subjectively reported flashes not meeting physiological criteria were assessed. Likelihood of hot flashes following emotions and activities were examined in a case-crossover analysis. **Results:** Relative to nonflash control times, objective hot flashes were more likely after increased happiness, relaxation, and feelings of control, and less likely after increased frustration, sadness, and stress. Conversely, subjective hot flashes not meeting physiological criteria were more likely after increased frustration and decreased feelings of control. Questionnaires revealed increased negative mood and negative attitudes were associated with fewer objective flashes and higher false-positive reporting rates. **Conclusion:** Increased positive and decreased negative emotions were associated with objective hot flashes, whereas increased negative and decreased positive emotions were associated with subjective flashes not meeting physiological criteria. The anecdotal association between negative emotions and hot flashes may be the result of self-reported flashes lacking physiological corroboration. **Key words:** menopause, hot flashes, hot flushes, vasomotor symptoms, emotions, stress.

HRT = hormone replacement therapy; **BDI-II** = Beck Depression Inventory, Second Revision; **STAI** = State Trait Anxiety Inventory; **DSI** = Daily Stress Inventory; **SCL-90-R** = Symptom Checklist-90, Revised; **RR** = rate ratio.

INTRODUCTION

Hot flashes are considered the “classic” symptom of menopause, with estimates ranging from 57% (1) to 74% (2) of naturally menopausal American women reporting hot flashes. Among surgically menopausal women, prevalence estimates are even higher (3,4). Reported hot flashes have been associated with negative mood (5,6) and subjective sleep disturbance (7) and are a leading cause of treatment-seeking among menopausal women (8). Despite their prevalence and apparent impact on women’s lives, little is known about factors associated with their occurrence, including individual differences rendering women more vulnerable to hot flashes and behavioral factors directly preceding their occurrence.

One commonly reported antecedent of hot flashes is negative emotional arousal. In 1 study of 506 women, the majority of participants (59%) cited negative emotions as the leading trigger of hot flashes (9). Other largely anecdotal reports have linked negative emotions to hot flashes (10,11), and indirect evidence from relaxation intervention studies has suggested a relationship between negative emotional arousal and hot flashes (12–16). One laboratory study (17) designed to provoke hot flashes with behavioral stressors suggested an impact of stressors on hot flashes. However, most existing studies have been very small in size (12,16–18), uncontrolled (12,16), or assessed self-reported flashes only (12,15,16,18). No studies have examined emotions as precursors of physio-

logical hot flashes in an ambulatory context. Thus, the role of negative emotions in hot flash occurrence remains unclear.

Most information regarding hot flashes has been derived from studies of self-reported hot flashes. Despite the wide use of these measures, little is known about their relationship to objectively defined physiological hot flashes. Importantly, physical symptom reporting may be subject to recall and reporting biases (19,20). One such influence is mood, with evidence linking negative affect with somatic magnification or amplification (21,22). However, little is known about the concordance between objective and subjective hot flashes during daily life, and particularly factors influencing their reporting.

Recent technologic advances have enabled physiological measurement of hot flashes. Laboratory studies have established sternal skin conductance as the most sensitive and specific physiological measure of hot flashes (23–25), and unlike palmar and plantar skin conductance, is relatively unresponsive to psychologic stimuli (24,26). Sternal skin conductance has been adapted and validated (24,27) for use in an ambulatory context with high levels of sensitivity (72–100%) (24,27) and specificity (70–86%) (24,27). Physiological measures are particularly important in studies of mood and emotions, given the influence of psychologic factors on symptom perception and reporting (21,22).

This study examined the role of emotional arousal in the occurrence of hot flashes during daily life. This study also examined the influence of moods and emotions on hot flash reporting. Hot flashes were physiologically measured through ambulatory sternal skin conductance. The case-crossover analytic technique, previously used to examine triggers of myocardial events (28,29), was used to examine precursors of hot flashes. We hypothesized that hot flashes would be more likely to occur after elevated negative emotion and would be less likely to occur after increased positive emotion compared with control times. We hypothesized that women with more frequent hot flashes would have increased negative mood. Moreover, we hypothesized that women with more negative

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mood would have an increased false-positive reporting rate. Finally, we explored the relationship between “false-positive” hot flashes (reported subjectively but lacking physiological corroboration) and emotions.

METHODS

Participants

Forty-two perimenopausal or postmenopausal women were recruited from the community through flyers, public service announcements, and newspaper advertisements. The following were required for study entry: 1) female; 2) age 40 to 60; 3) reporting daily hot flashes; 4) postmenopausal (amenorrhea \geq 12 months), late perimenopausal (amenorrhea 3–12 months), or early perimenopausal (irregularity in menstrual cycle frequency/length) status; and 5) provision of informed consent and ability to follow study procedures.

The following were exclusionary criteria: 1) taking the following medications: hormone replacement therapy (HRT), oral contraceptives, clonidine, tamoxifen, raloxifene, pellagra, tibolone; 2) hysterectomy without bilateral oophorectomy (as a result of inability to establish menopausal status); 3) history of menstrual irregularities in peak reproductive years; and 4) history of medical or psychiatric conditions associated with hot flash sensations (panic disorder, pheochromocytoma, leukemia, pancreatic tumor). All participants were compensated \$50.

Procedures

Participants underwent telephone and in-person screening. Eligible participants were equipped with an ambulatory skin conductance monitor between 7:30 and 10:00 AM on a typical weekday, wore the monitor during the day and overnight at home, removed it on morning waking, and returned to the laboratory. They repeated this protocol on a second workday within 2 weeks. Two days of monitoring were estimated to yield adequate power to evaluate study hypotheses, to establish reliable hot flash estimates, and to provide time and participant matched control periods while minimizing participant burden.

During waking monitoring hours, participants completed a structured behavioral diary, which they were prompted to complete on a fixed schedule 3 times an hour through a portable signaling device worn around the wrist or on the belt (WatchMinder Training and Reminder System; Advanced Multi-Media Designs, Great Neck, NY). They were also instructed to complete a diary entry during a subjective hot flash. Participants were instructed to report subjectively experienced hot flashes by pushing the monitor’s event buttons and completing a diary page. Participants completed a battery of psychometric questionnaires on the first monitoring day.

Measures

Ambulatory Skin Conductance Monitoring

Hot flashes were objectively measured with a Biolog ambulatory skin conductance monitor (UFI, model 3991/1-SCL; Morro Bay, CA), a lightweight, portable, single-channel device allowing continuous measurement of sternal skin conductance during daily life. It contains 2 MB of memory, is powered by 1 9-V battery, and samples at 1 Hz (once/second) with a 0.5 constant voltage circuit (30). Two Medi-trace silver/silver chloride electrodes (Graphic Controls, Buffalo, NY), 1.5 cm in diameter filled with 0.05 M potassium chloride Unibase/glycol paste (31), were affixed to the sternum. Its 2 event mark buttons, pressed simultaneously, provides a date- and time-stamped subjective event report. Participants were instructed to avoid engaging in rigorous activities or showering while wearing the monitor.

Data were downloaded into a personal computer after each day and scanned for hot flashes visually and using DPS Software Support Package (UFI). Events meeting hot flash criterion of \geq 2 micro-mho (μ mho) increase in a 30-second period were electronically flagged and visually inspected by a trained analyst in 5-minute, 1-minute, or 30-second windows to distinguish flash from artifact. Additionally, all data were visually inspected in 10-minute intervals to ensure all hot flash events were coded. The minimum interflash interval, during which no flashes were scored, was 20 minutes after flash onset (24,27). Independent coding of 10% of files by expert J. Carpenter

(27,32), who was blinded to participants’ diary recordings, revealed $\kappa = 0.74$, indicating adequate interrater reliability.

Subjective hot flash reports by diary or event marker were compared with physiologically recorded or objective hot flashes to establish reporting rates. A true positive flash was a subjective flash report accompanied by the physiological criterion within 5 minutes. A false-negative flash was an objective hot flash with no subjective report within 5 minutes, and a false-positive flash was a subjective flash report not meeting the physiological criterion within 5 minutes (23,27). A true negative was a 20-minute interval, corresponding to the interflash scoring interval, without a reported or objective flash. True-positive (true positive/total waking objective flashes), false-positive (false-positive/total waking subjective flashes), false-negative (false-negative/total waking objective flashes), and true-negative (true-negative/total waking 20-minute intervals without objective flash) reporting rates were calculated.

Behavioral Diary

Participants completed a pocket-sized, structured paper diary during waking monitoring hours. The validated behavioral diary of Hedges and colleagues (33), predictive of ischemic events (28,34), was adapted for hot flashes (9,18). Each page assessed time of entry, dichotomous ratings of hot flash and physical exertion occurrence at time of entry, indication of caffeine, tobacco, and alcohol consumption since last entry, and 5-point ratings (“not at all” to “very much”) of the following emotions: frustrated, sad, tired, stress, relaxed, happy, and in control, and mental and physical effort.

Psychometric Questionnaires

Participants completed a battery of questionnaires selected for established reliability and validity, use in prior menopause studies, and assessment of key domains relevant to hot flashes.

1. The Attitudes Toward Menopause scale is 7 items assessing stereotypical attitudes about menopause (35,36) shown to be predictive of menopausal symptom reporting (37).
2. The Beck Depression Inventory–II (BDI-II) (37) assesses 21 symptoms experienced within the previous 2 weeks. It is a reliable and valid measure (38) and a preferred scale for depressive symptom assessment among symptomatic menopausal women (39).
3. The Daily Stress Inventory (DSI) (40) assesses the occurrence and perceived stress associated with 58 events occurring over 24 hours.
4. The Symptom Checklist-90-R (SCL-90-R) is a 90-item inventory assessing 9 symptom dimensions (41), including somatization, considered in these analyses. It is reliable, valid, and has strong internal consistency (41).
5. The Spielberger State-Trait Anxiety Inventory (STAI) (42), a 40-item scale with strong psychometric properties (42), assesses anxiety present at testing (state anxiety) and the propensity toward anxiety (trait anxiety).

Statistical Analyses

The primary analysis involved identifying antecedents of 1) “objective” hot flashes (hot flashes meeting physiological criteria); and 2) “false-positive” hot flashes (reported hot flashes failing to meet physiological criterion). In the case-crossover analytic technique (28,29), exposure before an event is compared with exposure before 1 or more nonevent control periods (43). Each participant passes through exposure and nonexposure periods, serving as her own control and eliminating between-person confounds.

Diary entries before an objective or false-positive flash were matched to entries during control periods. Waking flashes only were included as a result of absence of reporting during sleep. A 30-minute case period preceding flashes was the minimum interval with maximum diary entry and associated flash retention. When case periods contained more than 1 entry, the entry closest to the flash was used. Two controls were used: a 30-minute interval not preceding a flash on the opposite monitoring day matched on time and participant and all 30-minute intervals not preceding flashes matched on participant. Minimum induction periods and carryover effects were zero.

Odds ratios and confidence intervals for flash antecedents were estimated with generalized estimating equations (GEE), a class of generalized linear

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models for nonindependent error structures as with repeated observations on individuals (44), controlling for time of day. A model with a binomial outcome distribution and a logit link was estimated. An exchangeable structure was applied to the covariance matrix after examination of actual and estimated covariance matrices. Time of day was divided into 3 periods and dummy-coded with evening as reference. Predictors were diary-reported emotions, physical effort and exertion, and tobacco, caffeine, or alcohol use. The effect period was zero for analyses of emotion during flashes.

Relations between physiological or false-positive flash frequency and individual characteristics were estimated within a generalized linear model with a Poisson distribution and a log link, offset by monitoring duration. A dispersion parameter estimated based on Pearson's chi-square was applied to the variance function to correct for overdispersion. Predictors were depression, anxiety, somatization, daily stress, and attitudes toward menopause scale sums. A sum score for continuous Attitudes Toward Menopause scale items was derived by reverse scoring negative items, yielding a possible score range of 6 to 24, higher scores indicating more positive attitudes (45). Daily stress scores were averaged over 2 days.

Relations between true-positive, true-negative, false-positive, and false-negative reporting ratios, and psychologic variables were estimated within a generalized linear model with a logit link. A dispersion parameter estimated based on Pearson's chi-square was applied to the variance function. All analyses were conducted with and without antidepressants in the model. Unadjusted models are presented given the lack of impact of this covariate on results. Goodness of model fit was determined from examination of deviance and log likelihood values. Analyses were conducted using SAS V8.0 (SAS Institute, Cary, NC).

RESULTS

Sample

Forty-two perimenopausal and postmenopausal women were recruited from the Research Triangle community (Raleigh, Durham, and Chapel Hill, NC). They completed 2 monitoring days, yielding 84 monitoring days.

Demographic and Medical Characteristics

Participants' average age was 50.5 years (standard deviation [SD], 4.8; range, 40–60) and over half (50.5%, $n = 21$) belonged to a minority ethnic group. Although no participants had medical or psychiatric conditions associated with hot flash sensations, participants reported other conditions, most commonly hypertension (28.6%, $n = 12$), arthritis (21.4%, $n = 9$), and hyperlipidemia (14.3% $n = 6$). All participants reported daily hot flashes. Among early perimenopausal women, the average duration of menstrual irregularities was 15.4 months (SD, 9.0), all had irregularities for ≥ 6 months, and none had a history of irregularities during peak reproductive years. Most (88.1%, $n = 37$) women retained their uterus and both ovaries, although 2 had undergone hysterectomy with bilateral oophorectomy and 3 women had had unilateral oophorectomy without hysterectomy. No women had taken exogenous estrogen or progesterone (eg, HRT, oral contraceptives) or other medications known to affect hot flashes within a month of study participation. However, 2 (4.8%) women were taking soy supplements, 5 (11.9%) were taking vitamin E, and 7 (16.7%) were taking antidepressants. Participant characteristics are presented in Table 1.

Psychologic Characteristics

The mean BDI-II score was 10.5 (SD, 10.6; range, 0–50), indicating minimal depressive symptoms (38). However, ap-

TABLE 1. Demographic Characteristics of Study Participants

	No. (%) of Participants ($n = 42$)
Age (mean yrs)	50.5 (SD = 4.8)
Ethnicity	
Caucasian	21 (50.0)
African American	16 (38.1)
Asian	2 (4.8)
Hispanic	2 (4.8)
Native American	1 (2.3)
Education	
High school	5 (11.9)
Some college	14 (33.3)
College	13 (31.0)
Graduate/professional school	10 (23.8)
Household income (median)*	\$45,000–59,999
Employment status	
Full-time	30 (71.4)
Part-time	8 (19.1)
Unemployed/retired	4 (9.5)
Marital status (%)	
Married/live-in relationship	23 (54.8)
Single	5 (11.9)
Divorced	13 (31.0)
Widowed	1 (2.3)
No. of children (%)	
0	6 (14.3)
1	14 (33.3)
2	17 (40.5)
3	5 (11.9)
Menopausal status	
Surgically postmenopausal†	2 (4.8)
Postmenopausal	22 (52.3)
Late perimenopausal	8 (19.1)
Early perimenopausal	10 (23.8)
Antidepressant use‡	
Tricyclic	2 (4.8)
SSRI	5 (11.9)
Other	1 (2.3)

*Three participants declined to answer.

†Hysterectomy with bilateral oophorectomy.

‡One participant is represented in more than 1 category.

SD = standard deviation; SSRI = selective serotonin reuptake inhibitor.

proximately 21.4% ($n = 9$) of participants had mild to moderate (14–28) and 7.1% ($n = 3$) had severe depressive symptoms (>28). Participants exhibited typical state (mean, 35.0; SD, 11.6; range, 20–60) and trait anxiety (mean, 37.9; SD, 10.4; range, 20–67) levels (42). Attitudes Toward Menopause scores revealed women's attitudes to be relatively neutral (mean, 16.2; SD, 2.8; range, 11–24). Somatization (mean, 0.67; SD, 0.66; range, 0–28) was slightly elevated (58th percentile) relative to nonpsychiatric females (41). Although several scale items assessed hot flash-like symptoms (eg, hot and cold spells), this scale was not a proxy for hot flashes, with somatization unrelated to flash frequency (rate ratio [RR], 0.79; 95% confidence interval [CI], 0.58–1.09; $p =$ not significant). Finally, participants indicated relatively low daily stress (mean, 39.0; SD, 29.9; range, 4–142) compared with normative female data (40).

Behavioral Diary

The participants completed 3416 diary entries, with a mean (SD) of 81.3 (15.7) and a range of 32 to 108 entries per person.

Negative Emotions

Diary negative emotion ratings were low. The average (SD) frustration, sadness, stressed, and tired ratings were 0.41 (0.81), 0.21 (0.56), 0.69 (0.95), and 0.97 (1.15), respectively. High (>2) negative emotion levels were infrequent, with 4.0%, 1.5%, and 6.4% of entries associated with high frustration, sadness, and stress, respectively. Approximately 14.4% entries indicated high tired ratings. High negative emotion levels were evenly distributed, with 57.1%, 33.3%, 66.7%, and 78.6% of women indicating high frustration, sadness, stress, and tiredness, respectively, in at least 1 entry.

Positive Emotions

Positive emotions were high, with average (SD) ratings of happiness, relaxation, and control of 2.69 (1.18), 2.30 (1.26), and 3.01 (1.09), respectively. High (>2) positive emotion levels were common, with 66.2%, 49.2%, and 72.9% of entries indicating high happiness, relaxation, and control, respectively. High positive emotions were evenly distributed, with 95.2%, 97.6%, and 100% of participants reporting high happiness, control, and relaxation, respectively, in at least 1 entry.

Health Behaviors

Physical exertion was rare, indicated in 116 (3.4%) of entries, which was expected given instructions to refrain from rigorous physical activities during monitoring. Mean (SD) physical effort ratings were also low, at 0.92 (0.87), and only 5.2% of entries indicated high (>2) physical effort. Tobacco, caffeine, and alcohol consumption was rare, reported in 2.5%, 4.1%, and 1.1% of entries, respectively.

Ambulatory Hot Flash Monitoring

We distinguished two types of hot flashes: objective hot flashes, or flashes meeting physiological criterion ($\geq 2 \mu\text{mho}$ increase in 30-second period) irrespective of self-report, and subjective hot flashes, or subjectively-reported hot flashes lacking a corroborating physiological flash. We considered these latter flashes "false-positive" flashes.

Objective Hot Flashes

Each participant underwent an average (SD) of 27.5 (2.7) waking and 11.3 (4.4) sleeping monitoring hours for a total of 1153.5 waking and 475.7 sleeping monitoring hours across participants. They experienced 923 objective flashes, including 742 waking and 181 sleeping flashes. Each woman experienced an average (SD) of 8.8 (5.6) waking (median, 8; range, 1–25) and 3.7 (2.2) sleeping (median, 2; range, 0–8) flashes per day. For the sample as a whole, participants experienced a flash every 1.5 hours while awake and every 2.6 hours while asleep. Compared with evening flashes (6 to 10 PM), flashes were more likely in late morning/early afternoon (10 AM to 1:59 PM; odds ratio [OR], 1.39; 95% CI, 1.13–1.71; $p = .002$) and late afternoon/early evening (2 to 5:59 PM; OR, 1.50; 95% CI, 1.23–1.84; $p = .0001$). Odds of hot flashes in late morning/early afternoon relative to late afternoon/early evening were similar. See Figure 1 for an example of a sternal skin conductance-recorded hot flash.

Adjusted for waking monitoring duration, the number of waking objective flashes was not significantly related to menopausal status, surgical status, oophorectomy, past HRT use, supplement use, age, race, income, employment, marital status, smoking, or alcohol consumption. However, women with more children (RR, 1.32; 95% CI, 1.08–1.61; $p = .006$) had a higher hot flash rate. Women with a high school education had twice the flash frequency (RR, 2.21; 95% CI,

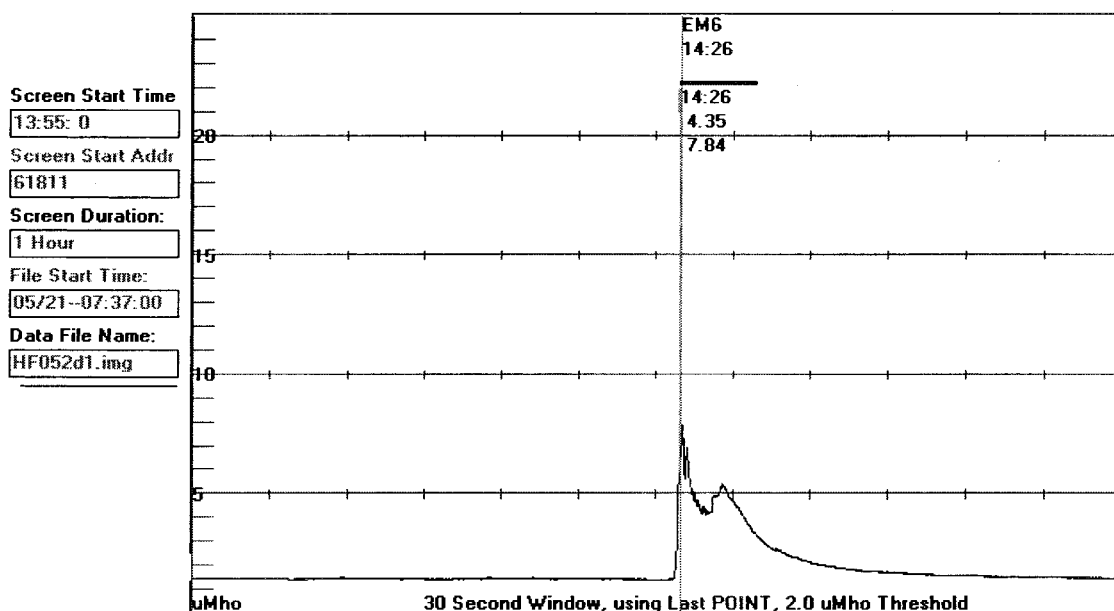


Figure 1. Objectively recorded hot flash.

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TABLE 2. Individual Characteristics and Frequency of Waking Objective Hot Flashes

	Flash Frequency		
	Rate Ratio	95% Confidence Interval	<i>p</i>
Education			
High school	2.21	1.15–4.11	.01
Some college	1.62	0.56–2.76	.08
College	1.71	0.99–2.94	.05
Graduate/professional school	1.00	—	—
Parity (for each additional child)	1.32	1.08–1.61	.006
Antidepressant use			
Yes	0.53	0.31–0.93	.03
No	1.00	—	—
Regular aerobic exercise			
Yes	0.73	0.51–1.04	.08
No	1.00	—	—

1.15–4.11; *p* = .01) relative to women with a graduate education. Moreover, regular aerobic exercise was associated with a marginally lower (RR, 0.73; 95% CI, 0.51–1.04; *p* = .08) and antidepressant use with a significantly lower hot flash rate (RR, 0.56; 95% CI, 0.22–0.98; *p* = .04).

More negative psychological states were associated with fewer flashes, controlling for monitoring duration. For every 1-unit increase in anxiety, the hot flash rate ratio decreased by 0.98 (95% CI, 0.96–0.99; *p* = .04) for state and 0.98 (95% CI, 0.96–0.99; *p* = .04) for trait anxiety. Women with more positive attitudes toward menopause had more frequent hot flashes (RR, 1.07; 95% CI, 1.01–1.15; *p* = .02). The frequency of objective hot flashes was not significantly related to depression, somatization, or daily stress (see Table 2). Results were largely unchanged restricting analyses to women not taking antidepressants.

Examination of hot flash reporting indicated 44.0% of objective hot flashes were accompanied by a subjective report (true-positive reporting rate), and 56.0% of objective hot flashes were not accompanied by subjective report (false-negative reporting rate; see Table 3). Women with higher state anxiety (OR, 1.03; 95% CI, 1.00–1.06; *p* = .06) and daily stress (OR, 1.01; 95% CI, 1.00–1.01; *p* = .05) had a marginally increased false-negative reporting rate. True-positive results were symmetric to false-negative results.

Emotions and Behaviors Associated With Objective Hot Flash Occurrence

To characterize factors associated with the occurrence of objectively monitored hot flashes, the likelihood of hot flashes

after diary-rated emotions or behaviors were examined relative to control periods.

Emotions

The case-crossover analysis revealed that objective flashes were *less* likely after increased negative emotion. Compared with diary entries not preceding flashes (Case-crossover results are using the control of all nonflash diary entries matched on participant. Analyses using the control of 1 nonflash diary entry on the alternate day of monitoring matched on time and participant yielded no significant results.), the odds of hot flash occurrence were 0.85 (95% CI, 0.74–0.98; *p* = .004) after increased frustration, 0.70 (95% CI, 0.54–0.91; *p* = .005) after increased sadness, and 0.82 (95% CI, 0.73–0.93; *p* = .001) after increased stress, controlling for time of day. Findings for tired were not significant.

Objective hot flashes were *more* likely to occur after increased positive emotion. Compared with diary entries not preceding flashes, odds of hot flash occurrence was 1.17 (95% CI, 1.03–1.30; *p* = .004) after increased happiness, 1.12 (95% CI, 1.03–1.23; *p* = .008) after increased relaxation, and 1.16 (95% CI, 1.01–1.35; *p* = .006) after increased control, controlling for time of day (see Figure 2). Notably, odds ratios are those associated with 1-unit increases in emotion ratings.

Health Behaviors

Two diary measures of physical activity were considered: a dichotomous physical exertion report and a continuous physical effort rating. Results indicated a marginally increased likelihood of hot flashes after physical exertion (OR, 1.49; 95% CI, 0.99–2.25; *p* = .05), controlling for time of day. Hot flashes were significantly more likely after high (>2; OR, 1.51; 95% CI, 1.18–1.95; *p* = .001) versus low (≤2) physical effort. No significant pattern emerged for tobacco, caffeine, and alcohol use.

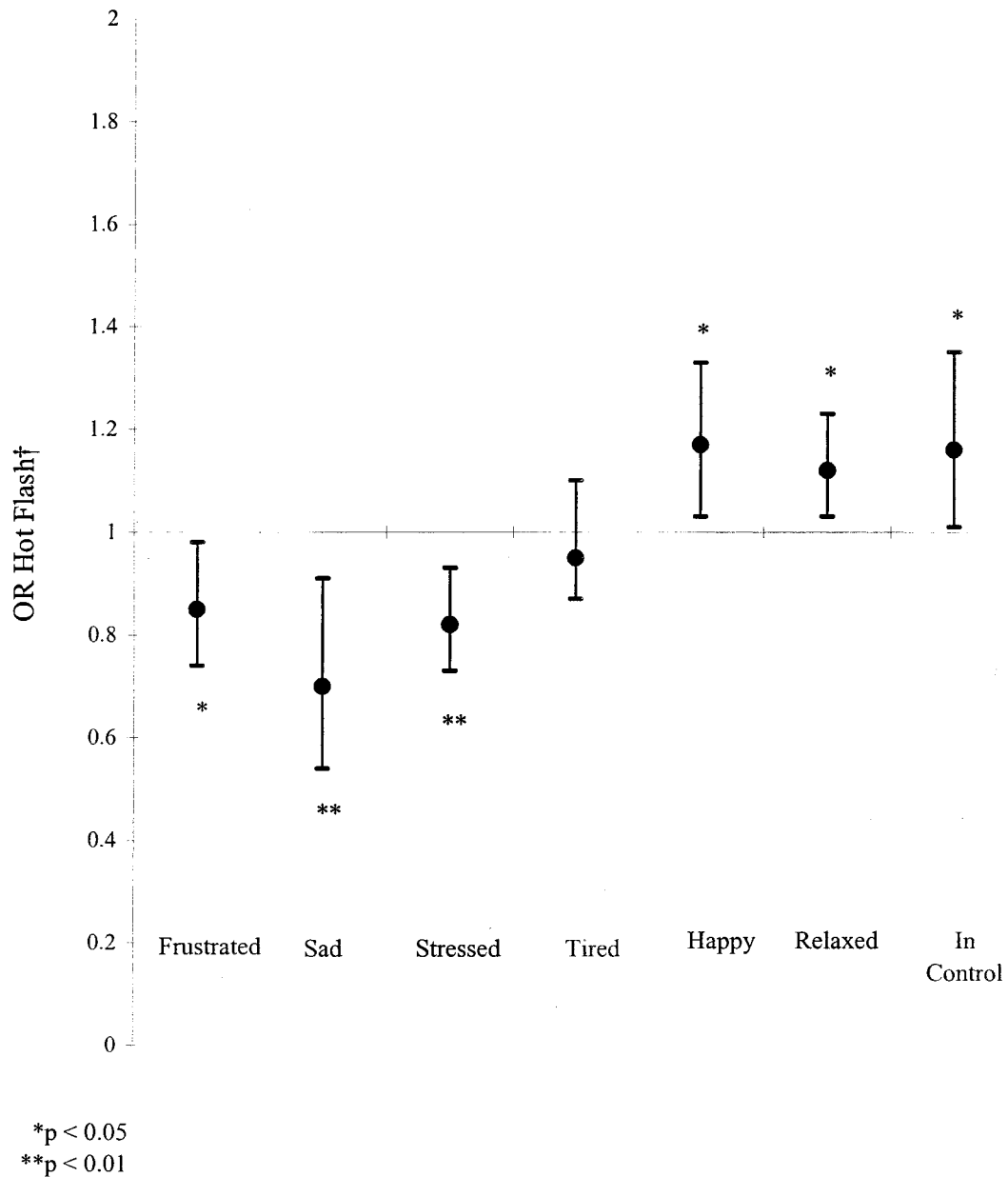
Emotions and Behaviors Occurring During Objective Hot Flashes

No significant pattern of emotions or physical activity was observed at the time of flash onset, both for all objective hot flashes and only those that were reported. However, objective flashes were more likely during caffeine use (OR, 2.24; 95% CI, 1.31–3.81; *p* = .003) relative to control times. Given diary instructions to indicate consumption since the last entry, this finding indicates an increased likelihood of hot flashes during or in 20 minutes after caffeine use.

Together, results indicate that objective hot flashes were less likely to occur after increased negative emotion, more likely after increased positive emotion, and more likely after high physical effort. Hot flashes were also more likely during

TABLE 3. Concordance Between Objective and Subjective Waking Hot Flashes

Subjective hot flash (<i>n</i>)	Objective Hot Flash (<i>n</i>)			Total Subjective 555
		Yes 347 (true-positive)	No 208 (false-positive)	
	Yes	347 (true-positive)	208 (false-positive)	555
	No	394 (false-negative)	2504 (true-negative)	
	Total Objective	741		



† For every one unit increase in emotion scores, ranging from 0 to 4

Figure 2. Odds ratios of objective hot flash occurrence in 30 minutes after emotional arousal.

or shortly after caffeine use. Emotional patterns before hot flashes were not markedly altered controlling for physical exertion, physical effort, or caffeine use. They were largely unchanged simultaneously controlling for antidepressant use, parity, education, anxiety, and attitudes toward menopause. Finally, restricting analyses to only objective hot flashes that were subjectively reported did not markedly alter results.

False-Positive Flashes

Thirty-seven participants experienced 208 false-positive flashes (subjectively reported but lacking physiological corroboration). A mean (SD) of 2.8 (4.2) false-positive flashes

(median, 2; range, 1–28) were reported per woman per day. False-positive flashes showed no significant diurnal rhythm.

Controlling for monitoring duration, women with increased somatization (RR, 1.57; 95% CI, 1.05–2.33; $p = .03$) had more frequent false-positive flashes and African American women (RR, 1.90; 95% CI, 1.03–3.50; $p = .04$) had more frequent false-positive flashes relative to women of other ethnic backgrounds.

The proportion of subjectively reported flashes lacking a corresponding objective flash (false-positive reporting rate) was 43.2% (see Table 3). The percentage of 20-minute monitoring intervals lacking an objective and a subjective hot flash (true-negative report-

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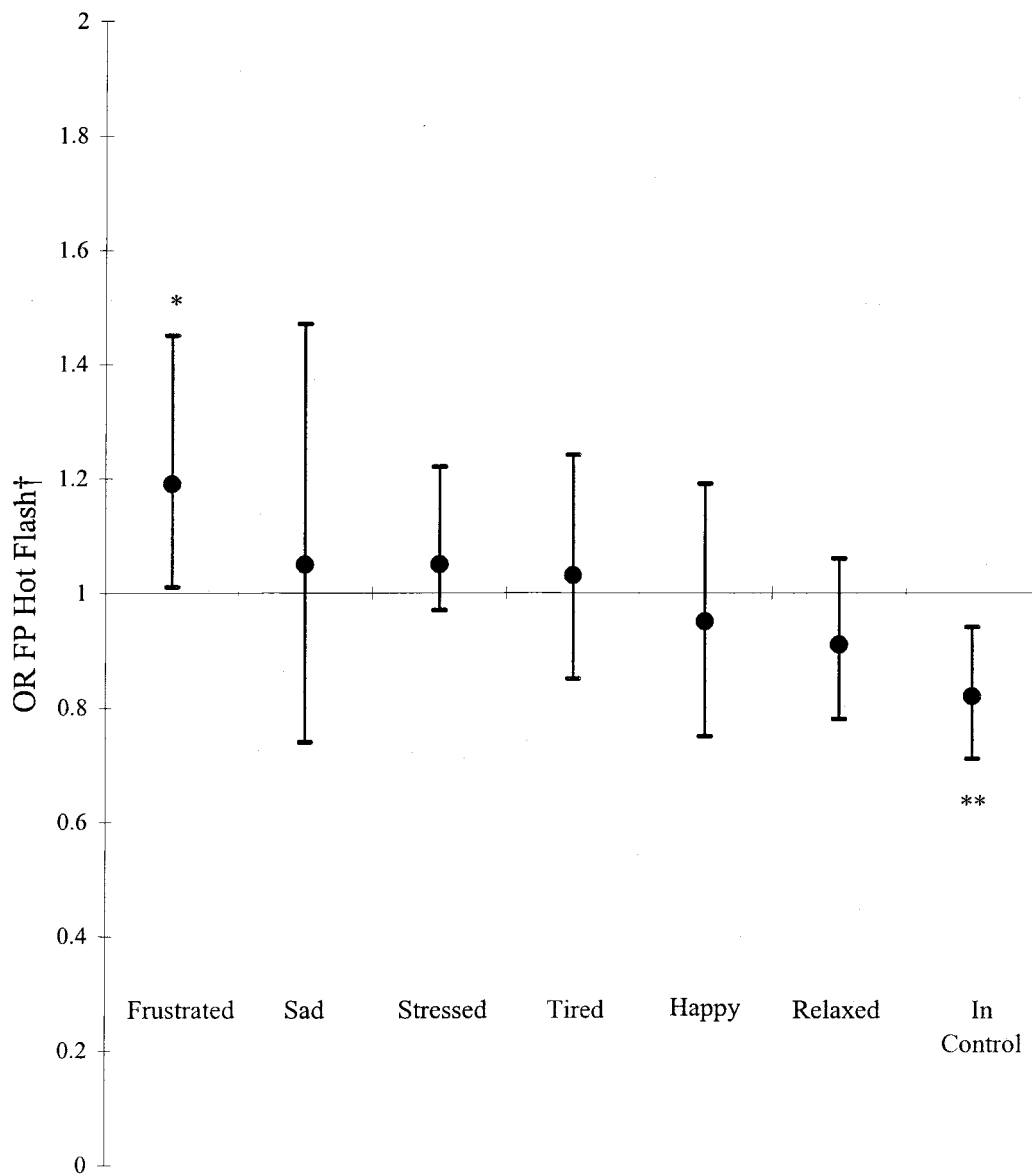
ing rate) was 92.3%. Increased depression (OR, 1.04; 95% CI, 1.001–1.08; $p = .04$), state anxiety (OR, 1.05; 95% CI, 1.01–1.10; $p = .01$), trait anxiety (OR, 1.05; 95% CI, 1.01–1.10; $p = .02$), and somatization (OR, 2.76; 95% CI, 1.36–5.57; $p = .005$), were associated with an increased false-positive reporting rate. More positive attitudes toward menopause was associated with a lower (OR, 0.90; 95% CI, 0.7–0.99; $p = .04$) false-positive reporting rate. Women with increased somatization (OR, 0.63; 95% CI, 0.41–0.97; $p = .03$) had a lower true-negative reporting rate. Thus, increased depression, anxiety, somatization, and more negative attitudes were associated with increased reports of hot flashes lacking a corresponding objective hot flash.

Emotions and Behaviors Associated With False-Positive Flash Occurrence

To characterize factors associated with occurrence of false-positive hot flashes, the likelihood of false-positive hot flashes after diary-rated emotions or behaviors were examined relative to control periods.

Emotions

Results indicated that the likelihood of a false-positive flash was significantly *increased* after increased frustration (OR, 1.19; 95% CI, 1.01–1.40; $p = .04$) and significantly *decreased* after increased feelings of control (OR, 0.82; 95%



* $p < 0.05$

** $p < 0.01$

† For every one unit increase in emotion scores, ranging from 0 to 4

Figure 3. Odds ratios of a false-positive (FP) flash report in 30 minutes after emotional arousal.

CI, 0.71–0.94; $p = .005$) (see Figure 3). Odds ratios are those associated with every 1-unit increase in emotion.

Physical Activity and Health Behaviors

False-positive flashes were significantly more likely after physical exertion (OR, 2.71; 95% CI, 1.61–4.62; $p = .0002$) compared with control times. No significant patterns for tobacco, alcohol, or caffeine use were observed.

Emotions and Behaviors Occurring During False-Positive Flashes

Analyses of emotions coinciding with false-positive flashes revealed that false-positive flashes were marginally more likely during increased frustration (OR, 1.26; 95% CI, 0.99–1.59; $p = .05$) and physical exertion (OR, 2.39; 95% CI, 0.88–6.55; $p = .09$) and marginally less likely during increased happiness (OR, 0.87; 95% CI, 0.74–1.01; $p = .07$) compared with control times. False-positive flashes were significantly more likely during tobacco use (OR, 2.92; 95% CI, 1.32–6.55; $p = .008$), which, given diary instructions, indicates that false-positive flashes were more likely during or in 20 minutes after tobacco use compared with control times.

In contrast to objective hot flashes, false-positive flashes were more likely after increased frustration and decreased feelings of control. They were also more likely after physical exertion and during or after tobacco use. Moreover, the experience of a false-positive flash was characterized by slightly increased negative emotion.

DISCUSSION

Contrary to our expectations, objectively measured hot flashes were significantly *less* likely after increased sadness, stress, and frustration and were significantly *more* likely after increased happiness, relaxation, and feeling in control. Moreover, increased anxiety and negative attitudes toward menopause were associated with fewer hot flashes. Thus, the inverse relationship between negative psychologic states and hot flashes was consistent across between-individual psychologic factors and within-individual emotions.

False-positive flashes, or flash reports lacking corresponding objective physiological evidence, were common, representing over 43% of reported flashes. In contrast to objective physiological flashes, post hoc analyses revealed that false-positive flashes were more likely after *elevated* frustration and *decreased* feelings of control. Moreover, increased depression, state anxiety, trait anxiety, somatization, and more negative attitudes toward menopause were associated with an increased proportion of reported flashes lacking a corresponding objective flash.

Taken as a whole, results suggest that positive emotions were associated with objective hot flashes and negative emotions associated with false-positive flashes. This pattern occurred across diary-rated emotions and questionnaire-assessed mood and attitudes. Thus, commonly held beliefs that “stress” or negative emotion can trigger hot flashes may be the result

of the experience of false-positive flashes with negative emotion.

Emotions and behaviors affect symptom perception and reporting. For example, psychologic processes are central to theories of pain perception (46). In laboratory studies, increased reporting of aches and pain (22) and decreased tolerance for experimental pain (47) is evident after negative mood induction. In contrast, increased pain tolerance is evident with positive mood induction (47). Moreover, in a study of patients experiencing ischemic heart disease (48), 66% of anginal pain reports occurred in the absence of ischemia, and physical exertion, physical effort, and negative emotion increased the likelihood of angina reports. Thus, emotions and behaviors are associated with a range of physical symptom reporting.

Emotions were associated with the occurrence of hot flashes. Mechanisms behind these relationships are not well-characterized, in part as a result of limited understanding of hot flash physiology. Current research indicates a narrowed thermoneutral zone among menopausal women (49), with hot flashes potentially representing a heat-dissipating mechanism. Research also suggests a role of central norepinephrine acting on the hypothalamic thermoregulatory center in hot flash occurrence (50,51). However, other systems, including serotonergic (52) and opiate (53) systems have been implicated. Moreover, other yet unexamined systems may be involved. Oxytocin, a neurohormone associated with relaxation, certain positive emotions, and affiliative behaviors (54,55), when centrally infused, increases core body temperature (54). However, given the limited understanding of hot flash physiology, these links remain speculative.

Hot flashes are believed to be aversive or distressing (9). However, in this study, most hot flashes were not reported and there was no significant pattern of emotions during hot flashes, both for all objective flashes and objective hot flashes that were reported. Notably, false-positive flashes were associated with marginally increased frustration and decreased happiness at the time of the false-positive flash. These results challenge the notion that physiological hot flashes are necessarily accompanied by emotional distress. Moreover, it suggests potential clinical significance of false-positive flashes.

Women with lower education and more children had more frequent hot flashes. Epidemiologic evidence comparing women with and without reported hot flashes have shown similar relationships for education (1,3,5) and to a lesser extent for parity (1). Mechanisms behind these associations are not known but may include differences in body composition, health behaviors, ovarian function, and HRT use. This study is notable for demonstrating these relationships with physiological flash frequency as opposed to single-item self-report measures of hot flashes.

Hot flashes were related to health behaviors. They were more likely after high physical effort, consistent with increased core body temperature acting as a trigger (49). However, regular aerobic exercisers had somewhat fewer waking hot flashes, consistent with epidemiologic studies suggesting hot flashes are less likely (1,7) or less severe (56) among

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regular exercisers, although previous results have been inconsistent and limited by brief self-report measures. Caffeine may be a trigger, with objective flashes over twice as likely during or after caffeine use. Finally, findings suggested that sensations associated with physical exertion and tobacco use may have been perceived as hot flashes in light of their association with false-positive flashes. Thus, preliminary results suggest a role of health behaviors in the occurrence of, propensity toward, and perception of hot flashes.

This study has several important strengths. To our knowledge, it is currently the largest and most ethnically diverse sample of women studied to date in relation to physiological hot flashes. Moreover, it is the only study evaluating emotional antecedents of hot flashes in an ambulatory setting using the case-crossover analytic technique, prospectively assessed emotion, and physiological hot flash recording. However, despite the relatively large sample of women and over 1629 person-hours of monitoring, the study may have lacked adequate power for exploratory and between-person analyses. Although the ethnic diversity and low flash frequency eligibility criteria increase the study's generalizability, given the size and the volunteer nature of the sample, participants may not be representative of menopausal women. Moreover, although sternal skin conductance is the most sensitive and specific measure of hot flashes (23–25,27), further validation of this measure under varying conditions is merited. Furthermore, false-positive flashes were few relative to physiological flashes and were examined in a post hoc fashion. These results must be regarded as tentative. Finally, given the low frequency of physical exertion and alcohol, caffeine, and tobacco use, these results should be regarded as suggestive of these relationships.

In summary, study results suggest an inverse relation between negative emotions and physiological flashes a positive relation between negative emotions and false-positive flashes. Given these findings, the anecdotal association between negative emotion or stress and hot flashes may actually be based on reported flashes lacking physiological corroboration. This finding is important given the current reliance on self-report measures of hot flashes, indicating flash reports may diverge from physiological flashes markedly among certain individuals or in the context of certain emotions. These findings underscore the importance of both objective and subjective measures of hot flashes. Both objective and subjective measures may be particularly important in studies evaluating behavioral or pharmacologic interventions designed to reduce hot flashes that may simultaneously affect psychological functioning.

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