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Laboratory and Ambulatory Evaluation of Vasomotor Symptom Monitors from the MsFLASH Network

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Abstract

Objective—To evaluate monitors for assessing vasomotor symptoms (VMS) in laboratory and ambulatory settings prior to use in the MsFLASH network clinical trials testing VMS therapies.

Methods—This was a 3-phase study: Phase 1 - laboratory testing of the Freedman and prototype Bahr Monitor™; Phase 2 - laboratory testing of the commercial Bahr Monitor™ and Biolog™; and Phase 3 - ambulatory testing of the commercial Bahr Monitor™ and Biolog™. All phases enrolled midlife women with VMS, midlife women without VMS, and young women without VMS. Participants self-reported VMS by pressing event marker buttons. Questionnaires assessed demographics (all phases) and monitor acceptability (phases 2 and 3).

Results—Phase I testing was stopped due to sensitivity of the Freedman device to ambient humidity changes and lack of analytic software for the prototype Bahr Monitor™. In phases 2 and 3, agreement between event-marked and commercial Bahr or Biolog™-recorded VMS was higher in the laboratory than the ambulatory setting, however, agreement between monitors was poor in 2 of 3 laboratory groups (midlife no VMS and young no VMS) and all ambulatory groups. During ambulatory monitoring, the mean number of Bahr Monitor™ VMS was 16.33 in midlife women with VMS, 9.61 in midlife women without VMS, and 14.63 in young women without VMS (software version March, 2011). The Bahr Monitor™ was more acceptable than the larger

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Biolog™, but feedback reflected annoyance at having to wear a device that itched and was visible under clothing.

Conclusions—The Bahr Monitor™ and Biolog™ appear suitable for use in controlled, laboratory conditions over short periods of time. However, the current versions of these monitors may not be suitable for ambulatory clinical trials at this time.

Keywords

Menopause; vasomotor symptoms; sternal skin conductance; hygrometer; hot flashes; symptom assessment

Introduction

Vasomotor symptoms (VMS; hot flashes, night sweats) are the cardinal symptom of menopause. Careful selection and evaluation of VMS measures are integral to evaluating the efficacy / effectiveness of potential interventions for VMS. Objective measurement of VMS frequency using monitoring devices has been recommended as an adjunct to subjective measurement of frequency, severity, bother, and/or duration. The advantages of objective VMS monitoring are that results are thought to be unbiased by placebo effects,¹ sleep-wake cycles,²³ or reporting difficulties.²⁴ Disadvantages are the inability to objectively capture severity, bother or duration,⁵ the participant burden associated with wearing such devices, and the resources required for data analysis. Although some investigators believe that subjective ratings are the only measure that should be used to assess VMS because women seek treatment based on their subjective experiences, others believe that objective measures can give important information about the physiologic effects of an intervention. Thus, objective monitoring is generally viewed as an adjunct to, not as a replacement for, subjective measurement.⁶

Currently available VMS monitors are limited. Sternal skin conductance is the most widely accepted objective measure of VMS. Sternal skin conductance rises rapidly and transiently during VMS events, even in response to very small amounts of sweating. One skin conductance monitor (Biolog™, UFI, Morro Bay, CA) has been used in menopause studies over the past two decades.¹²⁴⁷⁻⁹ However, widespread use has been limited by its cost, size and weight, relatively short monitoring capacity of 24 hours, and need for customized conductive paste and electrodes. Further evaluation of the Biolog's™ performance is warranted since the customized electrodes recently were re-engineered. Two additional miniaturized monitors have been developed to overcome limitations of the Biolog™. One is a sternal skin conductance monitor (Bahr Monitor™, Simplex Scientific, Middleton, WI) that attaches directly to the skin via a specially designed self-adhesive electrode patch. It has an event marker button and will record for 7 days. The other is a hygrometric (humidity) monitor (Freedman monitor, Kolar Engineering, Royal Oak, MI) that attaches directly to the sternal skin via adhesive tape without electrodes or gel.¹⁰ It records for one month but does not have an event marker button.

The purpose of this 3-phase study was to evaluate VMS monitors prior to use in randomized controlled trials of VMS therapies within the MsFLASH research network (Menopause Strategies Finding Lasting Answers for Symptoms and Health). In this study, each monitor was compared to event marked (self-reported) VMS and one other monitor. Phase 1 evaluated feasibility of the Freedman and prototype Bahr Monitor™. The Bahr Monitor™ and Biolog™ were then evaluated under laboratory (phase 2) and ambulatory conditions (phase 3).

To be acceptable for use in MsFLASH clinical trials, a monitor had to show: (1) high agreement between event marked and monitor-recorded VMS in the laboratory, including the absence of monitor-recorded VMS in midlife and young women not reporting VMS; (2) high agreement between event marked and monitor-recorded VMS in ambulatory settings, including the absence of monitor-recorded VMS in asymptomatic midlife and young women; (3) high participant acceptability ratings; and (4) high data capture rates (e.g., minimal loss of data).

Methods

Sample inclusion and exclusion criteria

Each testing phase included three groups of participants: mid-life women with self-reported VMS, mid-life women without VMS, and young women without VMS. Inclusion criteria were: 1) female; 2) able to read, write, and speak English; 3) willing to wear monitors and provide feedback; and 4) report taking no hot flash treatments during the past month (e.g., hormones, antidepressants, gabapentin, clonidine, bellargal). Exclusion criteria were: 1) pregnant or lactating; 2) diagnosis of Sjogren's syndrome (causes decreased sweating and altered skin conductance); 3) reported allergy to tape / adhesives or other skin sensitivities; and 4) inability to follow the study protocol.

In addition, the midlife VMS group: 1) was aged 40-62 years; 2) reported being in the late menopause transition (> 2 skipped cycles and an interval of amenorrhea > 60 days) or postmenopausal (at least 12 months amenorrhea); and 3) reported four or more VMS per day (28 or more per week). The midlife no VMS group: 1) was aged 40-62 years; 2) reported being in the late menopause transition or postmenopausal as previously defined; and 3) denied having any VMS in the past three months. The young no VMS group: 1) were aged 18 to 35 years old; 2) reported having monthly menstrual cycles; and 3) denied having any VMS.

Measures

Participants activated event markers when they felt VMS. Women waved a magnet over the monitor (Bahr Monitor™ phase 1) or pressed 1-2 small buttons on the monitors (Bahr Monitor™ and Biolog™ phases 2 and 3). The Freedman monitor does not have an integrated event marker so women pressed buttons on a small wrist actigraph (Actiwatch 2, Respironics, Murrysville, PA) that was time synchronized to the VMS monitor. Self-reported or event marked VMS have been the comparison standard for monitor recorded VMS in other similar device testing studies because no other validated objective measure of VMS is available²⁷¹⁰⁻¹².

The Freedman monitor continuously measures relative humidity and is a lightweight (14 grams), small, round disk (3.8 cm diameter × 1cm) that attaches to the sternal skin via double-sided adhesive tape. It is powered by a small hearing aid-type battery to allow for up to one month of recording. VMS are defined as a 3% per minute increase in relative humidity.

The Bahr Monitor™ in phase 1 was a pre-production 6.2 × 5.7 × 0.1 cm prototype resembling a small green circuit board. The prototype circuitry is identical to the commercially marketed 7.0 × 3.5 × 1.2 cm Bahr Monitor™ tested in phases 2 and 3. The Bahr applies a pulsed alternating current to the sternal skin (0.5 volt for 250 milliseconds alternating with a -0.5 volt for 250 milliseconds) every 10 seconds. During the pulse, the current that passes between a single unit electrode skin patch containing 2 snaps is measured in Siemens. The monitor is powered by a lithium button battery that lasts for approximately

one week of recording. VMS are defined as a sudden spike in skin conductance of ≥ 2 units (phase 1) or using a 5-pattern recognition algorithm (phases 2 and 3).

The Biolog™ uses 2 custom electrode skin patches and a 0.5 constant voltage circuit. The electrode skin patches are filled with a custom gel. Lead wires snap onto the electrodes and then are linked to the $12.5 \times 6.7 \times 3.5$ cm monitor. The Biolog™ contains a microprocessor that samples skin conductance each second. It is powered by a 9 volt battery that can record for up to 7 days. VMS are defined as an increase in skin conductance of 2.0 or more micromhos within a 30-second period (FlashTrax, UFI, Morro Bay, CA).

Questionnaires were used to assess basic demographic information, record height and weight measured by study staff, and obtain feedback on the feasibility and acceptability of wearing each monitor. The latter included a series of open ended questions (data available from the author) as well as structured questions for rating various aspects of wearing the devices on a 5-point scale from very satisfied to very dissatisfied.

Procedures

Staff posted study information in newsletters and on bulletin boards in the study buildings, local universities, and within the community. Interested women were instructed to call the study staff. Study staff provided more information about the study and determined eligibility. Interested and eligible women were scheduled for a study visit.

Laboratory visits took place in a private room at a clinical research center. Written informed consent and authorization to use health information was obtained prior to the start of data collection. Women were connected to the monitors, instructed on their use and care, and were instructed to sit or lie quietly (reading, watching television) for the 4-hour session with cell phones turned off. After four hours, staff disconnected the monitors. Participants received a \$25 gift card as compensation. Phase 1 was conducted in February, 2009. Phase 2 was done between July 2, 2010 and September 16, 2010.

Phase 3 ambulatory testing was done between July 2, 2010 and September 16, 2010. Eligible and interested participants were scheduled for two, private, study visits one week apart. Written informed consent and authorization to use health information were obtained. At the first study visit, study staff measured each participant's height and weight and provided instructions on event markers and use/care of monitors. Participants provided demographic information, were connected to the Bahr Monitor™, and then were discharged to wear the monitor during their normal activities for one week. Participants who wore the Biolog™ in addition to the Bahr Monitor™ (Indianapolis site only) removed the Biolog™ after 24 hours because of its limited recording capacity. No participants reapplied the Biolog™ at any time during this phase of testing. At the end of the week, they returned for the second study visit. Staff collected monitors and assessed skin integrity at the electrode sites. Participants received \$70.

Data Analysis

Monitor specific software was used to generate reports for monitor-recorded VMS events. The prototype Bahr Monitor™ did not have any analysis software so VMS were defined by a sudden spike in skin conductance of ≥ 2 units. For the commercially available Bahr Monitor™, a 5-pattern recognition algorithm was used by the manufacturer to generate reports for each individual participant listing the date and time of each monitor-recorded VMS and a summed total number of VMS (version March, 2011). These results could not be independently verified or checked for artifact because the analysis was based on a pattern recognition algorithm rather than absolute change in skin conductance value. The Freedman monitor software (FlashMarkPro, Kolar Engineering, Royal Oak, MI) applied an analysis

program to identify monitor-recorded VMS defined as a 3% per minute increase in humidity. Software reports listed the time of each monitor-recorded VMS and the summed total number of VMS for each participant. The Biolog™ software (FlashTrax, UFI, Morro Bay, CA) generated similar results for monitor-recorded VMS defined as a > 2 umho increase in skin conductance within 30 seconds.

Data capture for the commercially available Bahr Monitor™ was evaluated using software output and quality ratings (version March, 2011). The software generated the following summary statistics: 1) number of evaluable monitoring hours; 2) percent evaluable monitor recording (i.e. evaluable monitoring hours/total number of hours); 3) total VMS detected; and 4) average VMS per 24 hours. Evaluable data were defined by the software program as ranging from 0.05 to 30 siemens. In addition, each Bahr data file was visually examined by two individuals who rated the quality of the recordings as good, fair, or poor. Good recordings were defined as those with stable baselines, clear increases in conductance with subsequent return to baseline, no artifact, and >6 days (85%) of recording. Fair recordings were defined as those with 1-2 days of poor data capture (unstable or elevated baselines, data displayed upside down due to the monitor being placed on the chest upside down, noisy signals with multiple episodes of artifact, or lost data signal (sustained recordings at zero umho). Poor recordings were defined in terms of >2 days of poor data capture. Inter-rater agreement was 97% with a discrepancy resolved through discussion to reach 100% agreement.

Demographics and phase 3 acceptability data were analyzed using descriptive statistics and frequency tables. Differences in acceptability between day 3 and day 7 assessments were analyzed using chi-square tests. Responses to open-ended questions were qualitatively examined and grouped into common themes (data available by request from authors).

Results

Phase 1

Phase 1 laboratory testing was stopped after accrual of 6 participants (2 per group) due to problems with both monitors. On the Freedman, there were 4 event-marked and 25 monitor-recorded VMS (see Table 1). Monitor-recorded VMS occurred when the monitor was placed on or removed from the skin (12 of 25 events, 48%) or when the monitor was on a desktop immediately prior to placement on participants (3 of 25 events, 12%). The investigative group stopped further testing due to concerns that the lack of sensitivity for humidity changes as markers of VMS in the controlled laboratory environment would be exacerbated during ambulatory monitoring, thus, rendering it impossible to distinguish VMS events from ambient humidity changes. On the Bahr Monitor™, there appeared to be 5 event-marked and 6 monitor-recorded VMS (see Table 1). On the Bahr, 100% of monitor-recorded VMS were event-marked in the midlife women with VMS but the one monitor-recorded VMS that occurred in the young no VMS group was not event-marked. Further testing of the Bahr Monitor™ prototype was stopped because there was no analytic software for summarizing events and the investigative group was told the commercially available production version of the monitor would soon be available.

Phase 2

Fifteen participants completed phase 2; 5 midlife women with VMS, 5 midlife women without VMS, and 5 young women without VMS. Demographics are shown in Table 2.

On the Bahr Monitor™, there were 14 event-marked and 19 monitor-recorded VMS (see Table 1). On the Biolog™, there were 14 event-marked and 19 monitor-recorded VMS. For event-marked VMS, 100% on the Bahr Monitor™ and 86% on the Biolog™ occurred in

conjunction with a monitor-recorded VMS. For monitor-recorded VMS in the midlife VMS group, 72% on the Bahr Monitor™ and 80% on the Biolog™ were event-marked. In the no VMS groups, there was 1 Bahr Monitor™-recorded VMS (with an event mark) and 4 Biolog-recorded VMS, none of which were event-marked. There was modest agreement between the Bahr and Biolog in midlife women with VMS (74%) but no agreement in midlife women without VMS (0%) or young women without VMS (0%).

Phase 3

Thirty-five participants completed Phase 3; 15 at the Indianapolis site, 10 at the Seattle site, and 10 at the Oakland site. Demographics are shown in Table 2.

Bahr Monitor™ data from full 7-day monitoring period showed 721 event-marked and 3471 monitor-recorded VMS, or 4.8 times more Bahr Monitor™-recorded VMS than event-marked VMS (see Table 3). Event-marked VMS in the midlife no VMS and young no VMS groups were false button presses since these groups verified they did not have VMS. The percentage of event-marked VMS occurring in conjunction with Bahr Monitor™-recorded VMS was 59% in the midlife VMS group, 20% in midlife no VMS, and 0% in the young no VMS group. Conversely, 19%, < 1%, and 0% of Bahr Monitor™-recorded VMS occurred in conjunction with an event marker in the 3 groups respectively. The average number of Bahr Monitor™-recorded VMS per day [#VMS per group / n per group / 7 days] was 16.33 in midlife women with VMS, 9.61 in midlife women without VMS, and 14.63 in young women without VMS.

Data for the first 24-hours when both the Bahr Monitor™ and Biolog™ were worn by the Indianapolis participants are also in Table 3. For the Bahr Monitor™, there were 39 event-marked VMS and 274 monitor-recorded VMS. The percentage of event marked VMS that occurred with a Bahr monitor-recorded VMS was 78% in the midlife VMS group and 0% in midlife no VMS and young no VMS groups. The percentage of monitor-recorded VMS that were event marked was 23% in the midlife VMS group and 0% in the no VMS groups. For the Biolog™, there were 78 event-marked VMS and 146 monitor-recorded VMS with slightly higher agreement rates than the Bahr Monitor™. The percentage of event marked VMS that occurred with a Biolog monitor-recorded VMS was 44% in the midlife VMS group, 21% in midlife no VMS, and 21% in young no VMS groups. The percentage of Biolog monitor-recorded VMS that were event marked was 45% in the midlife VMS group, 5% in the midlife no VMS group, and 7% in the young no VMS group. Bahr Monitor™ to Biolog™ agreement rates were poor in all 3 groups (32% in midlife VMS group, 22% in midlife no VMS group, 28% in young no VMS group) with the highest proportion of VMS being recorded only by the Bahr Monitor™. In calculating the average number of monitor-recorded VMS per group, we noted that approximately twice as many VMS were recorded by the Bahr Monitor™ as compared to the Biolog™. The average number of Bahr Monitor™-recorded vs. Biolog™-recorded VMS [#VMS per group / n per group] was 22.2 vs. 9.8 in midlife women with VMS, 14.2 vs. 11.0 in midlife women without VMS, and 18.4 vs. 8.4 in young women without VMS.

Data capture rates indicated that Bahr Monitor™ data were not evaluable approximately 20% of the time, for a total of about 1.5 days of missing data per 7 days of monitoring per participant (Table 4). The Biolog™ data capture is limited to 24 hours or a single day and all data were available for that period of observation.

There were no statistically significant differences between acceptability ratings on days 3 and 7, thus, only day 7 ratings are shown in Figure 1. Ratings for the Bahr Monitor™ were more positive in terms of ease of use, freedom of movement, ability to sleep, adherence to skin, comfort and weight. Complaints of itchiness from the electrodes were similar for both

monitors. Responses to open-ended questions for the Bahr Monitor™ reflected annoyance at wearing a device that itched and interfered with clothing choices.

Discussion

This report resembles other device evaluation studies in terms of sample size, higher concordance during laboratory versus ambulatory monitoring, and capture of VMS events in women who do not report VMS. VMS monitors have been evaluated in samples of 20 women with VMS and 5 or fewer women without VMS²¹⁰⁻¹³; with fewer studies including 30 women⁷¹⁴. Although VMS monitors typically perform with near perfect correspondence to event-marked VMS in the laboratory when women are resting and paying attention to VMS¹⁰¹¹, correspondence decreases in the ambulatory setting when women are more physically active and potentially distracted from pushing event markers¹⁵. Our testing was done in both environments, thus, the variation in estimates across phases reflects the setting, rather than low sample sizes. In addition, our data showed that VMS monitors record changes in skin conductance that meet criteria for VMS events in younger premenopausal women without VMS, consistent with prior research.²

This report differs from prior reports in inclusion of the Bahr Monitor™, use of different Biolog™ electrodes, and Freedman monitor findings. This appears to be the first published report of the Bahr Monitor™. The Biolog™ electrodes were manufactured differently than ones used in the past and did not perform well in the ambulatory setting. The importance of the electrode and gel configuration for the Biolog™ has been previously noted¹³. In prior ambulatory studies using various electrodes for the Biolog™, 18-45% of VMS are both monitor-recorded and self-reported, 19-42% are monitor-recorded only, and 22-23% are self-reported only.¹²⁴⁷⁸¹⁴¹⁵ The results we report here may differ from prior reports due to use of different electrodes. In addition, correspondence rates for the Freedman were lower than a prior report showing 100% agreement between 20 event-marked and 20 monitor-recorded VMS recorded among 10 women in a laboratory.¹⁰ We could find no published reports of Freedman monitor testing in midlife women without VMS or young women without VMS, thus, our 0% agreement between monitors in these groups represents a new finding. Our findings were partially due to the Freedman monitor's sensitivity in detecting humidity changes from staff handling during placement/removal/ambient changes. While some of these events could be edited out with careful review by a trained rater (e.g., VMS occurring at placement /removal), it would be quite difficult to discern menopausal VMS from ambient humidity changes during a laboratory or ambulatory monitoring session. Further improvements in device hardware, scoring algorithms, and/or software may help decrease noise due to other physiological processes and may improve detection of menopausal VMS.

Recommendations

Three recommendations emerge from our data. First, the Bahr Monitor™ and Biolog™ appear appropriate for laboratory based studies such as those evaluating VMS etiology. This recommendation is based on high agreement between event-marked and monitor-recorded VMS in midlife women with VMS and relative absence of monitor-recorded VMS in non VMS groups. However, results from either monitor should be interpreted cautiously since both recorded at least some VMS in non VMS groups and the monitors were not perfectly correlated with one another. The lack of monitor to monitor agreement may be attributable to differences in electrical systems, sampling rates, electrode size, configuration, or gel. When used in the laboratory, it may be difficult to interpret which monitor is more accurate since monitors corresponded well to event-marks but not to each other.

Second, currently available VMS monitors may not be suitable for use in clinical trials evaluating the efficacy of interventions for VMS in ambulatory subjects until the systems can be further developed and their present limitations addressed. This recommendation is based on (1) relatively modest agreement between event-marked and monitor-recorded VMS in women with VMS, (2) the large number of monitor-recorded VMS in non VMS groups, (3) the presence of event markers in non VMS groups, (4) participant feedback about device acceptability, (5) loss of data during 7 day monitoring with the Bahr Monitor™, and (6) the lack of a commercially available analysis program or algorithm to independently verify results for the Bahr Monitor™. While it was expected that ambulatory monitors might record more VMS than self-report, both Bahr Monitor™- and Biolog™-recorded VMS far exceeded women's event-marked VMS. The number of monitor-recorded events in the two no VMS groups is of particular concern, as it appears that the monitors are not specific to detecting menopausal VMS and may instead be picking up noise or artifact related to perspiration or other, undetermined physiological processes. These findings raise concerns about whether current monitors are useful adjuncts to subjective reports in ambulatory studies or a new source of VMS measurement error.

Third, further development and refinement of VMS monitoring systems may overcome present limitations. Objective VMS monitors may provide useful information about physiological occurrences of VMS and their ability to capture the time of VMS onset may be useful in etiological studies. However, the excess occurrence of monitor-recorded VMS and the relative lack of agreement between monitor-recorded VMS and event-marked VMS in the ambulatory study suggest that the events measured and defined by the monitors as VMS are not necessarily the same events perceived and reported by respondents as VMS. In certain respects, this is analogous to the lack of congruence between self-reported physical activity and device-based measures of physical activity, such as accelerometry or heart rate monitoring.¹⁶ In the case of physical activity, the physiological processes measured by various devices may not adequately capture the full range and complexity of physical activity behavior, while in the case of VMS, the physiological processes may not always reflect the experience of VMS as perceived by the individual. Continued development and testing of VMS monitors may address this issue and lead to improved ability to measure VMS.

Limitations

Limitations include the following. Freedman device testing was done in a small sample of women. Although we intended to study this device in a larger sample, the initial results showing lack of correspondence between event-marked and monitor-recorded VMS led us to discontinue testing the device. The Bahr Monitor™ that was tested evolved from a pre-production prototype (Phase I) to a commercially available version (Phase II). Although the internal circuitry and electrodes were the same in both versions, the event mark differed from a magnet passing over the monitor to a button on the face of the monitor. This change could have affected results. Bahr Monitor™ results were based on a proprietary algorithm (March, 2011) and could not be independently verified. The algorithm remains under development and subsequent improvements may lead to different results.

Conclusions

We noted limitations in all of the monitoring systems we tested. Recommendations are to (1) use either the Bahr Monitor™ or Biolog™ in short-term laboratory studies with subsequent caution in interpreting findings and (2) carefully consider the development status and limitations of VMS monitoring systems before using any in ambulatory studies, such as those evaluating efficacy of VMS therapies.

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References

1. Carpenter JS, Storniolo AM, Johns S, Monahan PO, Azzouz F, Elam JL, et al. Randomized, double-blind, placebo-controlled crossover trials of venlafaxine for hot flashes after breast cancer. *Oncologist*. 2007; 12(1):124–35. [PubMed: 17227907]
2. Carpenter JS, Andrykowski MA, Freedman RR, Munn R. Feasibility and psychometrics of an ambulatory hot flash monitoring device. *Menopause*. 1999; 6(3):209–15. [PubMed: 10486790]
3. Carpenter JS, Monahan PO, Azzouz F. Accuracy of subjective hot flush reports compared with continuous sternal skin conductance monitoring. *Obstet Gynecol*. 2004; 104(6):1322–6. [PubMed: 15572497]
4. Thurston RC, Blumenthal JA, Babyak MA, Sherwood A. Emotional antecedents of hot flashes during daily life. *Psychosom Med*. 2005; 67(1):137–46. [PubMed: 15673636]
5. Carpenter JS, Azzouz F, Monahan PO, Storniolo AM, Ridner SH. Is sternal skin conductance monitoring a valid measure of hot flash intensity or distress? *Menopause*. 2005; 12(5):512–9. [PubMed: 16145304]
6. Loprinzi CL, Barton DL, Sloan JA. Whose opinion counts? *J Clin Oncol*. 2006; 24(33):5183–5. [PubMed: 17075108]
7. Sievert LL, Freedman RR, Garcia JZ, Foster JW, del Carmen Romano Soriano M, Longcope C, et al. Measurement of hot flashes by sternal skin conductance and subjective hot flash report in Puebla, Mexico. *Menopause*. 2002; 9(5):367–76. [PubMed: 12218726]
8. Sievert LL, Reza A, Mills P, Morrison L, Rahberg N, Goodloe A, et al. Diurnal rhythm and concordance between objective and subjective hot flashes: the Hilo Women's Health Study. *Menopause*. 2010; 17(3):471–79. [PubMed: 20220538]
9. Joffe H, Partridge A, Giobbie-Hurder A, Li X, Habin K, Goss P, et al. Augmentation of venlafaxine and selective serotonin reuptake inhibitors with zolpidem improves sleep and quality of life in breast cancer patients with hot flashes: a randomized, double-blind, placebo-controlled trial. *Menopause*. 2010; 17(5):908–16. 10.1097/gme.0b013e3181dbee1b. [PubMed: 20581724]
10. Freedman RR, Wasson S. Miniature hygrometric hot flash recorder. *Fertility and Sterility*. 2007; 88(2):494–96. [PubMed: 17445808]
11. Freedman RR. Laboratory and ambulatory monitoring of menopausal hot flashes. *Psychophysiology*. 1989; 26(5):573–9. [PubMed: 2616704]
12. Tataryn IV, Lomax P, Meldrum DR, Bajorek JG, Chesarek W, Judd HL. Objective techniques for the assessment of postmenopausal hot flashes. *Obstet Gynecol*. 1981; 57(3):340–4. [PubMed: 7465149]
13. Dormire SL, Carpenter JS. An alternative to Unibase/glycol as an effective nonhydrating electrolyte medium for the measurement of electrodermal activity. *Psychophysiology*. 2002; 39(4):423–6. [PubMed: 12212634]

14. Sievert LL, Begum K, Sharmeen T, Chowdhury O, Muttukrishna S, Bentley G. Patterns of occurrence and concordance between subjective and objective hot flashes among Muslim and Hindu women in Sylhet, Bangladesh. *Am J Hum Biol.* 2008; 20(5):598–604. [PubMed: 18461600]
15. Mann E, Hunter MS. Concordance between self-reported and sternal skin conductance measures of hot flushes in symptomatic perimenopausal and postmenopausal women: a systematic review. *Menopause.* 2011; 18(6):709–22. [PubMed: 21326119]
16. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008; 40(1):181–8. [PubMed: 18091006]

Figure 1.

Field Study Day 7 Monitor Acceptability Ratings

Responses shown are valid percentages of answers to each question accounting for missing data. On day 7, 35 of 35 participants rated the Biolog™ monitor items and 11-14 of 15 participants rated the Bahr Monitor™. The Biolog™ was worn in the ambulatory study only for the first 24 hours by Indianapolis site participants. Solid lines are responses for Biolog™. Dashed lines are responses for Bahr Monitor™.

Figure 2.

Photo of VMS Monitoring Systems

The photo shows the monitoring systems used in the study. From left to right are the (1) Freedman FlashMark Pro miniaturized hygrometer with (2) double sided tape ring to adhere the device to the skin; (3) prototype Bahr Monitor™ resembling a small green circuit board, (4) production version Bahr Monitor™, (5) electrode used to adhere the Bahr Monitor™ to the skin; and (6) BiolLog™ with electrode lead wires.

Table 1

Total Number of Events and Percentage Agreement for Phases 1 and 2 Laboratory Studies by Subgroup and Measure

	Phase 1 Laboratory Evaluation			Phase 2 Laboratory Evaluation		
	Midlife VMS (n = 2)	Midlife no VMS (n = 2)	Young no VMS (n = 2)	Midlife VMS (n = 5)	Midlife no VMS (n = 5)	Young no VMS (n = 5)
Bahr Monitor™						
Total # event marks *	5	0	0	13	0	1
Total # monitor VMS *	5	0	1	18	0	1
Bahr Monitor™ to Event Mark						
Event mark + monitor	5	0	0	13	0	1
Event mark only	0	0	0	0	0	0
Monitor only	0	0	1	5	0	0
% event marks with monitor-recorded VMS	100%	NA	NA	100%	NA	100%
% monitor-recorded VMS with event mark	100%	NA	0%	72%	NA	100%
Freedman Monitor						
Total # event marks *	4	0	0	NA	NA	NA
Total # monitor VMS *	12	7	6	NA	NA	NA
Freedman Monitor™ to Event Mark						
Event mark + monitor	4	0	0	NA	NA	NA
Event mark only	0	0	0	NA	NA	NA
Monitor only	8	7	6	NA	NA	NA
% event marks with monitor-recorded VMS	100%	NA	NA	NA	NA	NA
% monitor-recorded VMS with event mark	67%	0%	0%	NA	NA	NA
Biolog™ Monitor						
Total event marks *	NA	NA	NA	14	0	0
Total monitor VMS *	NA	NA	NA	15	4	0
Biolog™ Monitor to Event Mark						
Event mark + monitor	NA	NA	NA	12	0	0

	Phase 1 Laboratory Evaluation			Phase 2 Laboratory Evaluation		
	Midlife VMS (n = 2)	Midlife no VMS (n = 2)	Young no VMS (n = 2)	Midlife VMS (n = 5)	Midlife no VMS (n = 5)	Young no VMS (n = 5)
Event mark only				2	0	0
Monitor only				3	4	3
% event marks with monitor-recorded VMS				86%	NA	NA
% monitor-recorded VMS with event mark VMS				80%	0%	NA
Bahr Monitor™ to Freedman				NA	NA	NA
Bahr™ + Freedman	5	0	1			
Bahr™ only	0	0	0			
Freedman only	7	7	5			
% agreement	42%	0%	17%			
Bahr Monitor™ to Biolog™	NA	NA	NA			
Bahr™ + Biolog™				14	0	0
Bahr™ only				4	0	1
Biolog™ only				1	4	0
% agreement				74%	0%	0%

VMS = vasomotor symptom (hot flash, night sweat).

NA = not applicable, monitor not tested.

* Total event marks and total monitor VMS = number of each after collating to remove duplicate events. Events marks in non-VMS groups can be interpreted as false button presses.

Table 2

Demographics for Participants in Phases 2 and 3

	Phase 2 Laboratory Evaluation			Phase 3 Ambulatory Evaluation		
	Midlife VMS (n = 5)	Midlife no VMS (n = 5)	Young no VMS (n = 5)	Midlife VMS (n = 20)	Midlife no VMS (n = 10)	Young no VMS (n = 5)
Age [M(SD)]	56.40 (2.97)	49.00 (4.85)	24.60 (3.44)	53.55 (4.79)	50.20 (4.47)	25.40 (4.22)
Body mass index [M(SD)]	32.86 (4.72)	26.67 (2.46)	29.65 (7.93)	30.83 (8.18)	30.85 (11.47)	27.37 (8.34)
Ethnicity [n (%)]						
White, non-Hispanic	2 (40)	4 (80)	3 (60)	10 (50)	8 (80)	2 (40)
Black, non-Hispanic	3 (60)	1 (20)	0 (0)	8 (40)	2 (20)	0 (0)
Other, non-Hispanic	0 (0)	0 (0)	2 (40)	2 (10)	0 (0)	3 (60)
Overall Health [n (%)]						
Excellent	0 (0)	3 (60)	1 (20)	5 (25)	4 (40)	1 (20)
Very good	0 (0)	2 (40)	3 (60)	6 (30)	5 (50)	3 (60)
Good / fair	5 (100)	0 (0)	1 (20)	9 (45)	1 (10)	1 (20)
Marital status [n (%)]						
Not married or partnered	4 (80)	1 (20)	5 (100)	12 (60)	4 (40)	5 (100)
Currently married or partnered	1 (20)	4 (80)	0 (0)	8 (40)	6 (60)	0 (0)
Education [n (%)]						
High school diploma / GED	1 (20)	0 (0)	1 (20)	2 (10)	0 (0)	1 (20)
Some training after high school	3 (60)	2 (40)	0 (0)	9 (45)	4 (40)	0 (0)
College graduate	0 (0)	1 (20)	2 (40)	4 (20)	2 (20)	3 (60)
Graduate schooling / degree	2 (40)	2 (40)	2 (40)	5 (25)	4 (40)	1 (20)
Employment						
Full time	3 (60)	4 (80)	2 (40)	14 (70)	7 (70)	3 (60)
Part time	0 (0)	0 (0)	3 (60)	4 (20)	2 (20)	2 (40)
Not currently working	2 (40)	1 (20)	0 (0)	2 (10)	1 (10)	0 (0)
Menopausal status						
Pre	0 (0)	0 (0)	5 (100)	0 (0)	0 (0)	5 (100)
Peri	0 (0)	3 (60)	0 (0)	4 (20)	5 (50)	0 (0)
Post	5 (100)	2 (40)	0 (0)	16 (80)	5 (50)	0 (0)

VMS = vasomotor symptom (hot flash, night sweat).

Table 3

Total Number of Events and Percentage Agreement for Phase 3 Ambulatory Study by Subgroup and Measure

	Phase 3 Ambulatory Evaluation 7 days			Phase 3 Ambulatory Evaluation 1st 24 hours		
	Midlife VMS (n = 20)	Midlife no VMS (n = 10)	Young no VMS (n = 5)	Midlife VMS (n = 5)	Midlife no VMS (n = 5)	Young no VMS (n = 5)
Bahr Monitor™						
Total # event marks *	705	10	6	32	2	5
Total # monitor VMS *	2286	673	512	111	71	92
Bahr Monitor™ to Event Mark						
Event mark + monitor	439	2	0	25	0	0
Event mark only	266	8	6	7	2	5
Monitor only	1847	671	512	86	71	92
% event marks with monitor-recorded VMS	59%	20%	0%	78%	0%	0%
% monitor-recorded VMS with event mark	19%	<1%	0%	23%	0%	0%
Biolog™ Monitor	NA	NA	NA			
Total event marks *				50	14	14
Total monitor VMS *				49	55	42
Biolog™ Monitor to Event Mark	NA	NA	NA			
Event mark + monitor				22	3	3
Event mark only				28	11	11
Monitor only				27	52	39
% event marks with monitor-recorded VMS				44%	21%	21%
% monitor-recorded VMS with event mark				45%	5%	7%
Bahr™ Monitor to Biolog™ Monitor	NA	NA	NA			
Bahr™ + Biolog™				39	23	29
Bahr™ only				72	48	63
Biolog™ only				10	32	13
% agreement				32%	22%	28%

VMS = vasomotor symptom (hot flash, night sweat).

NA = not applicable, Biolog worn only with Indianapolis site field participants.

* Total event marks and total monitor VMS = number of each after collating to remove duplicate events. Events marks in non-VMS groups can be interpreted as false button presses.

Table 4**Bahr Monitor™ Data Capture Information**

		Study 2 Field Evaluation 7 days		
		Midlife VMS (n = 20)	Midlife no VMS (n = 10)	Young no VMS (n = 5)
Quality ratings ¹	%			
Good		20%	40%	0%
Fair		45%	20%	40%
Poor		35%	40%	60%
Percentage evaluable data ²	%	79%	81%	83%
Time monitored ³ (hh:mm)	M (SD)	168:45 ± 00:10	168:44 ± 00:25	168:38 ± 00:07
Evaluable time ⁴ (hh:mm)	M (SD)	133:15 ± 00:31	136:16 ± 00:12	139:38 ± 00:02
Evaluable 24 hour periods ⁵	M (SD)	5.55 (1.35)	5.68 (0.88)	5.82 (0.96)
Average VMS detected ⁶	M (SD)	26.39 (8.46)	13.97 (7.61)	22.98 (12.28)
Total power events ⁷	M (SD)	4.10 (1.25)	4.90 (3.48)	5.00 (0.71)

¹Quality ratings were defined through visual inspection by two raters. Ideal is 100% good quality.

²Ideal percentage is 100%.

³Ideal time monitored is 168 hours (7 days × 24 hours per day).

⁴Ideal evaluable time is 168 hours (7 days × 24 hours per day).

⁵Ideal number of periods is 7.00 (7 days of monitoring).

⁶Ideal number in midlife no VMS and young non VMS is 0 (no hot flashes or night sweats).

⁷Number of times the unit was powered off and on during the data collection, ideal is 1.