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Abnormal uterine bleeding patterns determined through menstrual tracking among participants in the Apple Women's Health Study

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Abstract

BACKGROUND: Use of menstrual tracking data to understand abnormal bleeding patterns has been limited because of lack of incorporation of key demographic and health characteristics and confirmation of menstrual tracking accuracy.

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The other authors report no conflict of interest.

OBJECTIVE: This study aimed to identify abnormal uterine bleeding patterns and their prevalence and confirm existing and expected associations between abnormal uterine bleeding patterns, demographics, and medical conditions.

STUDY DESIGN: Apple Women's Health Study participants from November 2019 through July 2021 who contributed menstrual tracking data and did not report pregnancy, lactation, use of hormones, or menopause were included in the analysis. Four abnormal uterine bleeding patterns were evaluated: irregular menses, infrequent menses, prolonged menses, and irregular intermenstrual bleeding (spotting). Monthly tracking confirmation using survey responses was used to exclude inaccurate or incomplete digital records. We investigated the prevalence of abnormal uterine bleeding stratified by demographic characteristics and used logistic regression to evaluate the relationship of abnormal uterine bleeding to a number of self-reported medical conditions.

RESULTS: There were 18,875 participants who met inclusion criteria, with a mean age of 33 (standard deviation, 8.2) years, mean body mass index of 29.3 (standard deviation, 8.0), and with 68.9% (95% confidence interval, 68.2–69.5) identifying as White, non-Hispanic. Abnormal uterine bleeding was found in 16.4% of participants (n=3103; 95% confidence interval, 15.9–17.0) after accurate tracking was confirmed; 2.9% had irregular menses (95% confidence interval, 2.7–3.1), 8.4% had infrequent menses (95% confidence interval, 8.0–8.8), 2.3% had prolonged menses (95% confidence interval, 2.1–2.5), and 6.1% had spotting (95% confidence interval, 5.7–6.4). Black participants had 33% higher prevalence (prevalence ratio, 1.33; 95% confidence interval, 1.09–1.61) of infrequent menses compared with White, non-Hispanic participants after controlling for age and body mass index. The prevalence of infrequent menses was increased in class 1, 2, and 3 obesity (class 1: body mass index, 30–34.9; prevalence ratio, 1.31; 95% confidence interval, 1.13–1.52; class 2: body mass index, 35–39.9; prevalence ratio, 1.25; 95% confidence interval, 1.05–1.49; class 3: body mass index, >40; prevalence ratio, 1.51; 95% confidence interval, 1.21–1.88) after controlling for age and race/ethnicity. Those with class 3 obesity had 18% higher prevalence of abnormal uterine bleeding compared with healthy-weight participants (prevalence ratio, 1.18; 95% confidence interval, 1.02–1.38). Participants with polycystic ovary syndrome had 19% higher prevalence of abnormal uterine bleeding compared with participants without this condition (prevalence ratio, 1.19; 95% confidence interval, 1.08–1.31). Participants with hyperthyroidism (prevalence ratio, 1.34; 95% confidence interval, 1.13–1.59) and hypothyroidism (prevalence ratio, 1.17; 95% confidence interval, 1.05–1.31) had a higher prevalence of abnormal uterine bleeding, as did those reporting endometriosis (prevalence ratio, 1.28; 95% confidence interval, 1.12–1.45), cervical dysplasia (prevalence ratio, 1.20; 95% confidence interval, 1.03–1.39), and fibroids (prevalence ratio, 1.14; 95% confidence interval, 1.00–1.30).

CONCLUSION: In this cohort, abnormal uterine bleeding was present in 16.4% of those with confirmed menstrual tracking. Black or obese participants had increased prevalence of abnormal uterine bleeding. Participants reporting conditions such as polycystic ovary syndrome, thyroid disease, endometriosis, and cervical dysplasia had a higher prevalence of abnormal uterine bleeding.

Keywords

chronic nongestational abnormal uterine bleeding; digital health; menstrual cycles

Introduction

The menstrual cycle is considered a vital sign because regular menstruation requires normal functioning of the hypothalamic-pituitary-ovarian axis.[1,2] Abnormal uterine bleeding (AUB) may be a symptom of an endocrinopathy such as polycystic ovary syndrome (PCOS),or anatomic pathology such as fibroids, malignancies, or infections.[3–6] People track menstrual bleeding for a variety of reasons, such as trying to conceive, avoiding pregnancy, period prediction, or monitoring a condition.[7] Tracking bleeding is one way for patients to inform conversations with clinicians and for researchers to evaluate AUB from large samples.[8] The options for tracking have evolved, and menstrual tracking is most often done using digital platforms such as smartphone apps.[9–11]

There exist evolving guidelines related to AUB to guide clinical research and care.[12,13] Definitions derived from these guidelines can be used to estimate the rates of AUB. Analysis of digitally tracked menstrual bleeding can present its own challenges, with absent, incomplete, or intermittent tracking limiting interpretation.[14] However, if self-tracking can be confirmed as accurate, the potential for AUB identification using app-based tools may bridge the gap between the self-tracked data and early screening for disease. Furthermore, this may facilitate population-level AUB analysis.[15]

This study aimed to identify AUB patterns and their prevalence, and confirm existing associations between AUB patterns, demographics, and medical conditions in the Apple Women's Health Study (AWHS) after confirming the accuracy of tracked data.

Materials and Methods

Study population

The AWHS is a digital, longitudinal study of menstrual health conducted using the Apple Research app.[16] Enrollment began on November 2019 and is ongoing. Inclusion criteria include having ever menstruated, having a compatible iPhone and version of iOS, living in the United States, age of at least 18 years (at least 19 years in Alabama and Nebraska, at least 21 years in Puerto Rico), ability to communicate in written and spoken English, being an exclusive user of an iPhone and iCloud account, and consenting to participation. For this analysis, participants with at least 180 days of menstrual tracking data during the study time frame from November 2019 through July 2021 were included. Participants aged >50 years or reporting menopause, pregnancy, lactation, or hormonal contraception use immediately preceding study enrollment or at any point within the study time frame were excluded. The study was approved by the Institutional Review Board at Advarra (CIRB PRO00037562) and registered on ClinicalTrials.gov (ClinicalTrials.gov Identifier: NCT04196595).

Demographic and anthropometric characteristics

At enrollment, participants provide year of birth, race/ethnicity, gender identity, sociodemographic information, weight, and height.[17] Report of race/ethnicity used a single "select all that apply" question to determine race and ethnicity from the National Institutes of Health–sponsored All of Us study.[18] Survey content related to medical and reproductive

histories has been published previously.[19] Participants self-reported medical conditions (eg, fibroids, cervical dysplasia) using survey responses.

HealthKit data

HealthKit provides a central repository for health and fitness data on iPhones and Apple Watches, and is viewable to participants through the Apple Health app. AWHS participants contribute HealthKit data after granting permission to the Research app. HealthKit stores data merged from multiple sources and contains data such as tracked menstrual bleeding, heart rate, exercise, and sleep. Bleeding is manually tracked in Cycle Tracking in the Health app or in any third-party menstrual tracking application that the participant permits to write to HealthKit. Menses, identical to those in Cycle Tracking in the Health app, were defined as follows: the minimum number of flow days for a menses was 1, with no maximum.[20] Menstrual bleeding separated by 1 day of missed tracking or no flow was merged into 1 menses, and ≥2 days without tracking was not merged.[21] The first day of flow was labeled as the first day of a cycle.[22] Spotting was not included as menstrual flow. The minimum number of days in a cycle was set to 10, with no maximum.

Definitions of abnormal uterine bleeding

Four types of AUB patterns were defined: irregular, infrequent, and prolonged menses and intermenstrual bleeding. Definitions were derived from recommendations by the International Federation of Gynecology and Obstetrics and are identical to those embedded in Cycle Tracking in the Health app[12,13] (Figure). Irregular menses was defined as varying lengths of cycles of ≥17 days within each of 2 consecutive 90-day analysis windows. Infrequent menses was defined as ≤1 menses in each of 2 consecutive 90-day analysis windows. Prolonged menses was defined as ≥2 menses lasting ≥10 days in a 180-day window. Intermenstrual bleeding (spotting) was defined as spotting tracked between menses at least once in each of the 2 consecutive 90-day windows.[8] Spotting adjacent to menstrual bleeding was excluded to account for the spotting datatype being used to mean light menstrual flow at the start or end of menses.

Defining tracking confirmation

Using the Monthly Survey, Menstrual Update, participants confirm the accuracy of the previous month's tracked data by responding to "Are all your period days during the previous calendar month accurately reflected in the Health app?" by selecting "Yes, they are accurate," "No, they are not accurate," or "I prefer not to answer." An optional, direct link to review and update the tracked data was offered before responding. If AUB was detected, we then defined an analysis window as having tracking confirmed if every month included in analysis had a response of "Yes, they are accurate." Analysis windows with ≥1 "No, they are not accurate" response or no response (missing response) were considered as tracking not confirmed.

Statistical analysis

Descriptive statistics were calculated, including means and standard deviations for continuous variables (eg, age, body mass index [BMI], etc.), and proportions and 95%

score confidence intervals (CIs) for categorical variables (eg, race/ethnicity, gender identity, exercise minutes, sleep hours, etc.).[23] Proportions and 95% CIs were also calculated when estimating the prevalence of the AUB categories

To understand associations between AUB and other characteristics for each AUB condition (any, irregular, infrequent, or prolonged menses, and spotting), multiple log-binomial models were estimated, with each containing a single subject characteristic as the independent variable.[24] In the regression of AUB prevalence against race/ethnicity, the reference group was White, non-Hispanic, with age and BMI being categorical covariates to isolate the effect of race/ethnicity. In the regression of AUB prevalence against BMI category, the reference group was the healthy weight group (18.5–24.9), with age and race/ethnicity being categorical covariates to isolate the effect of BMI category. Age categories were <25, 25 to 34, 35 to 44, and 45 to 50 years. BMI categories were underweight (<18.5), healthy weight (18.5–24.9), overweight (25–29.9), Class 1 obesity (30–34.9), Class 2 obesity (35–39.9), and Class 3 obesity (>40).[25–28] BMI was reported as kg/m^2 using self-reported height and weight. A directed acyclic graph for covariate selection is provided in supplemental materials. Because of the low numbers of participants reporting any individual medical condition, controlling for all combinations of medical conditions was not possible in the analysis evaluating the effects of BMI and race/ethnicity (Supplemental Figure).

To understand the differences in AUB between participants with confirmed tracking who did and did not have a self-reported condition, we used a log-binomial model to regress an AUB outcome on each medical condition. The reference group were those who did not report the condition.[24]

Results

During the study period, there were 47,751 eligible enrollees. We excluded those aged >50 years (n=3804), and those reporting menopause (n=4439), pregnancy (n=3209), lactation (n=2260), or hormonal therapy (n= 15,989). Excluded participants could fall into multiple categories. There were 18,875 participant records included in this analysis. The demographic characteristics of included participants were similar to those of participants excluded because of reporting pregnancy, lactation, or hormonal therapy (Supplemental Table 1). Table 1 presents demographics for the total cohort, those with and without confirmed tracking, and those with no AUB and with AUB (tracking accuracy not confirmed and confirmed). The mean age at study entry was 33 years, and the mean BMI was 29.3 (overweight); 68.9% of participants identified as White, non-Hispanic, 8.1% as Hispanic, 5.9% as Black, 4.0% as Asian, and 10.6% reported ≥2 race/ethnicities. The average number of cycles per participant was 16±9 cycles, and the average number of days of data per user was 260±62 days.

Because participants may track bleeding with varying levels of fidelity, and incomplete tracking could introduce error into AUB detection, we excluded participants with AUB who did not confirm tracking accuracy (n=10,619). Before exclusion, we evaluated if those who confirmed tracking differed from those who did not (Table 1). These groups were similar across demographics (Table 1; Supplemental Tables 2 and 3). Although

demographic characteristics of participants did not differ markedly by tracking confirmation status, rates of AUB differed: 43.2% of participants had AUB when not restricting to only those with tracking confirmation, whereas 16.4% had AUB after tracking accuracy was confirmed (Table 2). Of those with confirmed tracking, 2.9% had irregular menses, 8.4% had infrequent menses, 2.3% had prolonged menses, and 6.1% had spotting. The remaining analysis includes data from participants who confirmed tracking accuracy.

Table 3 presents the prevalence of AUB by race/ethnicity after controlling for age and BMI. Black participants had 33% (prevalence ratio [PR], 1.33; 95% CI; 1.09–1.61) higher prevalence of infrequent menses compared with White, non-Hispanic participants, whereas Asian participants had a higher prevalence of irregular menses (PR, 1.41; 95% CI, 0.92–2.14). Prevalence of prolonged menses and spotting did not vary by race/ethnicity. Participants with class 1 and class 3 obesity had 14% (PR, 1.14; 95% CI, 1.04–1.25) and 18% (PR, 1.18; 95% CI, 1.02–1.38) higher prevalence of AUB, respectively, after controlling for age and race/ethnicity (Table 4). No differences in the prevalence of irregular menses or spotting were observed across weight categories. The prevalence of infrequent menses was higher in those with class 1, 2, and 3 obesity than in those with healthy weight. Those with class 3 obesity had 94% higher prevalence of prolonged menses (PR, 1.94; 95% CI, 1.29–2.90).

Controlling for age and race/ethnicity, the association of self-reported medical conditions with AUB was evaluated. Participants with PCOS had 19% higher prevalence of AUB (PR, 1.19; 95% CI, 1.08–1.31) compared with participants without PCOS (Table 5). Those self-reporting endometriosis had a 28% increased prevalence of AUB (PR, 1.28; 95% CI, 1.12–1.45). Participants with hypothyroidism and cervical dysplasia had higher prevalence of AUB (Table 5; Supplemental Tables 4 and 5). Evaluation based on the individual abnormal bleeding patterns demonstrated an increased prevalence of irregular menses (PR, 1.69; 95% CI, 1.04–2.73) and spotting (PR, 1.54; 95% CI, 1.1–2.11) in those self-reporting hyperthyroidism (Supplemental Tables 4, 6 and 7). Endometriosis was more prevalent in participants reporting infrequent menses (PR, 1.58; 95% CI, 1.29–1.95) (Supplemental Table 5). There was an increased prevalence of infrequent menses in those reporting PCOS (PR, 44; 95% CI, 1.23–1.68) (Supplemental Table 5).

Comment

Principal findings—We presented the prevalence of AUB in a large, digital cohort. AUB was reported by 16.4% of participants; 2.9% reported irregular menses, 8.4% reported infrequent menses, 2.3% reported prolonged menses, and 6.1% reported spotting. Use of tracking confirmation may provide a usable tool for limiting data for research analysis. AUB was more commonly identified in Black participants and those with elevated BMI, particularly class 3 obesity. Several conditions known to be associated with AUB, such as PCOS, thyroid disorders, fibroids, endometriosis, and cervical dysplasia, had expected associations with AUB in this study.

Results in the context of what is known—Identification of AUB prevalence varies according to definitions, types of AUB included, populations evaluated, and study

methodology, with ranges from 10% to 30%.[29,30] Our estimate of AUB (16.4%) falls in this range. We found 2.9% of participants reporting irregular menses. In a study analyzing 6375 person-years, irregular menses, defined as 3 to 5 periods in 90 days with <3 bleeding-free intervals of ≥14 days, was identified in 3% overall.[8] When defining irregular menses as cycle lengths varying >14 days, 20% of a cohort of 130 participants prospectively keeping menstrual diaries met the definition.[31] Irregular cycles (cycles <24 or >38 days) have been reported, ranging from 8.0% to 8.7% in a digital cohort of 18,076 users, evaluated in relationship to COVID-19 pandemic–related stress.[32] Reports relying on self-categorization demonstrate higher rates of perceived irregular menses. A Danish report, defining irregular as cycle variation >14 days, demonstrated 20.3% self-reporting irregularity in the previous year.[33] We found 8.4% reporting infrequent menses. The Tremin study reported infrequent menses rates ranging from 20% in adolescents to 5% in those in their late 30s, rising to 17% in participants aged >45 years.[8] When defined as >35 days without menses, a meta-analysis including 35 studies reported the mean proportion of those with infrequent bleeding as 13% across the reproductive lifespan.[34]

Prolonged menses was reported by 2.3% of our cohort. When prolonged bleeding was defined as ≥14 days, it was almost never identified in the Tremin study.[8] With a definition of ≥10 days, reports range from 9% to 5.3%.[35,36] The Study of Women's Health Across the Nation (SWAN) reported on >8 days of menses (10.2%) and >10 days of menses (6.6%) in a cohort of 1320 individuals aged 42 to 52 years.[37] The added burden of repeatedly tracking each bleeding day, as compared with surveys based on recall, may account for differences, and may have led to underreporting of prolonged menses in our cohort. Spotting was reported in 6.1% of our participants. This was lower than the 17% reported in an English cohort, which relied on surveys for retrospective reporting, but similar to results from a population-based, cross-sectional study reporting 4.3% of participants with spotting.[38,39]

Previous work examined the relationship between BMI and AUB, with our results supporting this association. In the Nurses' Health Study II, those who self-reported irregular or infrequent menses had a higher BMI than those with very regular menstruation.[6] In a digital cohort limited to cycles with evidence of ovulation, those with a BMI >35 had more cycle length variation and a longer follicular phase compared with those in the BMI range of 18 to 25, although the exclusion of anovulatory cycles may limit the variation described.[40]

In our study, Black participants were more likely to report AUB. In the SWAN study, African-American participants were less likely to have prolonged menses, but more likely to have heavy menses compared with White participants.[37] In an evaluation of menorrhagia incidence in the United States Armed Forces, rates were highest in those of Black, non-Hispanic ethnicity.[41] In an online survey for participants with uterine fibroids, African-Americans were more likely to have heavy or prolonged menses.[42] Our findings support previous work demonstrating differing rates of AUB by reported race and ethnicity.

Several existing relationships between AUB and medical conditions were reinforced with this study. For example, many patients with PCOS present with abnormal menses.[43] Here, those with PCOS had a 19% higher prevalence of AUB. In a study of 27,840 participants with endometriosis, 50.8% reported heavy/irregular periods, whereas we found

a 28% increased prevalence of AUB in our cohort.[44] We found that AUB was more common in those with hyperthyroidism (34% higher prevalence) and hypothyroidism (17% higher prevalence), which supports previous work finding that 58% of patients with hyperthyroidism had oligomenorrhea or amenorrhea.[45] In a study of 79 patients with hypothyroidism, 21.5% had infrequent menses, as opposed to 6.7% of those who were euthyroid.[46] Several limitations should be noted, including reliance on self-report of conditions, the observation that our analysis does not account for those with >1 condition (thus the prevalence may be affected by comorbidities), and exclusion of participants using hormonal contraceptives to manage their AUB.

Clinical implications

Increasingly, digital tools are becoming the preferred method of tracking menstrual information, and self-collection of data may be done with sufficient granularity to detect changes or cycle events.[9,10] The AUB pattern identification presented herein is embedded in the Cycle Tracking feature available in the Health app for consumer use. Tracked data may limit artifacts related to retrospective recall.[47] Identification of AUB may provide opportunities for risk screening and prevention. AUB labeled in medical records or self-reports was a marker for higher risk of developing ovarian cancer, cardiovascular disease, or diabetes mellitus.[4,48,49] With these medical conditions linked to AUB, leveraging menstrual tracking to identify AUB may provide value.

Digital tracking of menstrual data using smartphone apps provides the potential to extract meaningful research information, but there are challenges.[15] One consideration is how to determine the quality or completeness of tracking. Our reported rates of AUB would have been overreported without use of tracking accuracy confirmation. Other studies have used engagement dynamics to exclude cycles, leveraging tracked symptoms to distinguish true long cycles from missed tracking by requiring at least 5 interactions with the app in the month containing menstruation and the following month.[14,24] Another method is exclusion of cycles not confirmed as ovulatory, which allows for analysis of follicular and luteal phase characteristics, but may preclude identification of abnormal patterns.[40]

Research implications—Future investigations are needed to understand the temporal relationships between AUB and the identification of health conditions. In addition, application of definitions of AUB across populations may miss changes in an individual's bleeding pattern. Further investigation into changes from one's baseline and their relationship to disease development may benefit individual patient care and guide screening. Similarly, contextualization of bleeding patterns with logged symptoms may help identify which bleeding patterns and symptom combinations are most associated with disease. Lastly, future exploration of physiological data acquired from sensor-derived metrics, such as sleep, steps, or activity, may better identify AUB patterns of concern. Further validation of the data is provided by the AWHS measures of AUB from tracked data demonstrating expected associations with conditions. As the study continues and data accumulate, we will be able to both investigate additional risk factors for AUB and learn more about its longer-term health consequences.

Strengths and limitations—This was a prospective, digital study using tracked bleeding as opposed to reliance on recall or survey tools. The results expand our understanding of rates of AUB in a diverse and modern cohort. In addition, participants were not restricted on the basis of reproductive goals, medical histories, or particular clinical sites, providing an expanded evaluation of 4 types of AUB (irregular menses, infrequent menses, prolonged menses, and spotting). This study builds on previous cohort data by adding diversity, and extends modern datasets derived from menstrual tracking apps by collecting contextual information related to demographics and medical histories.[32,50] In addition, we addressed concerns about incomplete menstrual tracking related to poor engagement with tracking apps with the requirement that participants confirm their tracking monthly.

This study has several limitations. When drawing comparisons with other studies, the generalizability should be considered in relationship to the use of iPhone as the research platform, and participant race/ethnicity (68.9% White, non-Hispanic; 8.1% Hispanic; 5.9% Black; 4% Asian in AWHS vs 60.1% White, non-Hispanic; 18.5% Hispanic; 13.4% Black; 5.9% Asian in the United States) and reported levels of education (53.3% in AWHS with at least a college degree vs 32.5% in the United States), which varied from the US census.[51] We also may not capture all those experiencing abnormalities with our definitions of AUB. In addition, we do not report on all possible abnormal bleeding patterns. Subjective information on heavy menstrual bleeding or menstrual flow level is not currently captured in our study, which will affect comparisons with studies that include this in composite rates of AUB.[13] Our exclusion of participants who reported pregnancy, lactation, or hormone use during the study may also lead to misestimation of overall AUB rates, although the frequency of their demographic characteristics and reported medical conditions were similar. Medical conditions were only self-reported by a subset of participants, and specific management of those conditions that may alter their current bleeding is absent from our data. The overall small number of participants with any individual condition precluded controlling for effects of such conditions in our analysis of age, BMI, and race/ethnicity; thus, there may be residual confounding by medical condition. Similarly, if a participant has AUB but has not yet been evaluated or diagnosed with a condition, or has a condition not accounted for in our study, this would limit our ability to describe those associations.

Conclusions

Overall, these findings provide the rate of AUB in a large, digital dataset of confirmed menstrual tracking. In addition to expanding our understanding of AUB across a diverse population, our findings confirm existing literature on the associations between AUB and medical conditions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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AJOG at a Glance

Why was this study conducted?

This study was conducted to identify abnormal uterine bleeding (AUB) patterns and their prevalence in participants of the Apple Women's Health Study and to confirm existing and expected associations between AUB patterns, demographics, and medical conditions.

Key findings

AUB was found in 16.4% of the study population; 2.9% had irregular menses, 8.4% had infrequent menses, 2.3% had prolonged menses, and 6.1% had spotting. Prevalence of infrequent periods was higher in Black participants and those with class 1, 2, and 3 obesity. Increased prevalence of AUB was noted with class 3 obesity and conditions such as polycystic ovary syndrome, fibroids, thyroid disease, and cervical dysplasia.

What does this add to what is known?

This study contributes an approach to determine AUB patterns from self-tracked menstrual data.

FIGURE. Visual representation of example abnormal uterine bleeding

Irregular menses was defined as varying lengths of cycles of ≥17 days within each of 2 consecutive 90-day analysis windows. Infrequent menses was defined as ≤1 menses in each of 2 consecutive 90-day analysis windows. Spotting was defined as spotting tracked between menses at least once in each of 2 consecutive 90-day analysis windows. Prolonged menses was defined as ≥2 menses, each lasting for ≥10 days in a 180-day analysis window.

Zhang. Abnormal bleeding patterns among Apple Women's Health Study participants. Am J Obstet Gynecol 2022.

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TABLE 1

Demographics

Demographic characteristics	Total cohort	Tracking not confirmed	Tracking confirmed	No AUB, tracking not confirmed	No AUB, tracking confirmed	AUB, tracking not confirmed	AUB, tracking confirmed
Sample size	18,875	10,619	8256	5560	5153	5059	3103
Age (y), mean±SD	33.0±8.2	32.5±8.1	33.6±8.2	32.9±8.1	33.6±8.3	32.2±8.0	33.5±8.1
BMI, mean±SD	29.3±8.0	29.3±8.1	29.2±7.9	28.9±7.9	28.8±7.7	29.7±8.2	29.8±8.3
Gravidity, mean±SD	2.6±1.6	2.6±1.6	2.6±1.6	2.7±1.6	2.6±1.6	2.6±1.6	2.5±1.6
Parity, mean±SD	1.7±1.2	1.7±1.2	1.7±1.2	1.7±1.2	1.8±1.2	1.7±1.3	1.6±1.2
Race/ethnicity, % (95% CI)							
White, non-Hispanic	68.9% (68.2–69.5)	68.5% (67.6–69.4)	69.4% (68.4–70.4)	68.1% (66.8–69.3)	70.2% (69.0–71.5)	69.0% (67.7–70.3)	67.9% (66.3–69.6)
Hispanic, Latina, Spanish, and/or other Hispanic	8.1% (7.7–8.4)	8.2% (7.7–8.8)	7.8% (7.2–8.4)	7.9% (7.2–8.6)	7.3% (6.6–8.0)	8.6% (7.8–9.4)	8.6% (7.6–9.6)
Black or African American or African	5.9% (5.6–6.2)	5.8% (5.4–6.3)	6.0% (5.5–6.5)	6.0% (5.4–6.7)	5.6% (4.9–6.2)	5.6% (5.0–6.2)	6.7% (5.9–7.6)
Asian	4.0% (3.7–4.3)	3.9% (3.5–4.2)	4.1% (3.7–4.6)	4.8% (4.2–5.3)	4.4% (3.9–5.0)	2.9% (2.4–3.3)	3.7% (3.0–4.3)
Other	2.3% (2.1–2.5)	2.3% (2.0–2.6)	2.3% (2.0–2.6)	2.0% (1.6–2.4)	2.5% (2.0–2.9)	2.7% (2.2–3.1)	2.0% (1.5–2.5)
>1	10.6% (10.2–11.0)	10.8% (10.2–11.4)	10.3% (9.6–11.0)	10.8% (10.0–11.6)	10.0% (9.2–10.8)	10.9% (10.0–11.7)	10.8% (9.7–11.9)
Prefer not to answer, missing	0.5% (0.4–0.6)	0.6% (0.5–0.8)	0.3% (0.1–0.4)	0.6% (0.4–0.8)	0.2% (0.1–0.3)	0.7% (0.4–0.9)	0.4% (0.2–0.6)
Gender identity, % (95% CI)							
Woman	97.1% (96.9–97.4)	97.0% (96.7–97.3)	97.3% (97.0–97.7)	97.1% (96.6–97.5)	97.7% (97.3–98.2)	96.9% (96.4–97.4)	96.6% (96.0–97.3)
Man	0.1% (0.0–0.1)	0.1% (0.0–0.2)	0.1% (0.0–0.1)	0.1% (0.0–0.2)	0.1% (0.0–0.1)	0.1% (0.0–0.2)	0.1% (0.0–0.2)
Transwoman	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.1)	0.0% (0.0–0.0)
Transman	0.1% (0.1–0.1)	0.1% (0.0–0.2)	0.1% (0.0–0.1)	0.1% (0.0–0.2)	0.1% (0.0–0.2)	0.1% (0.0–0.2)	0.1% (0.0–0.2)
Genderqueer or nonbinary	1.3% (1.2–1.5)	1.3% (1.1–1.5)	1.3% (1.1–1.6)	1.3% (1.0–1.6)	1.2% (0.9–1.5)	1.4% (1.1–1.7)	1.5% (1.1–2.0)
Another gender identity or multiple selected	0.9% (0.8–1.0)	0.9% (0.7–1.1)	0.9% (0.7–1.1)	0.8% (0.6–1.1)	0.8% (0.5–1.0)	1.0% (0.7–1.2)	1.2% (0.8–1.6)
Skip or missing	0.4% (0.3–0.5)	0.6% (0.4–0.7)	0.3% (0.2–0.4)	0.6% (0.4–0.8)	0.2% (0.1–0.3)	0.6% (0.3–0.8)	0.4% (0.2–0.6)
Education, % (95% CI)							
Never attended school or only attended kindergarten	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.0)	0.0% (0.0–0.1)	0.0% (0.0–0.1)	0.0% (0.0–0.0)

Demographic characteristics	Total cohort	Tracking not confirmed	Tracking confirmed	No AUB, tracking not confirmed	No AUB, tracking confirmed	AUB, tracking not confirmed	AUB, tracking confirmed
Grades 1 through 11 (primary, middle, or some high school)	1.5% (1.3–1.7)	1.6% (1.4–1.9)	1.3% (1.1–1.5)	1.5% (1.2–1.9)	1.4% (1.1–1.7)	1.8% (1.4–2.1)	1.2% (0.8–1.5)
Grade 12 or GED (high school graduate)	11.8% (11.3–12.2)	12.7% (12.1–13.4)	10.5% (9.8–11.2)	12.4% (11.5–13.2)	10.5% (9.6–11.3)	13.2% (12.2–14.1)	10.5% (9.5–11.6)
1 to 3 y after high school (technical school or some college or associate's degree)	32.9% (32.2–33.5)	33.7% (32.8–34.6)	31.8% (30.8–32.8)	32.6% (31.4–33.8)	30.9% (29.6–32.1)	34.8% (33.5–36.1)	33.5% (31.8–35.1)
4-y college or more (college graduate)	31.9% (31.2–32.6)	30.8% (30.0–31.7)	33.2% (32.2–34.3)	31.2% (30.0–32.5)	33.4% (32.1–34.7)	30.4% (29.1–31.7)	32.9% (31.3–34.6)
Master's degree	16.6% (16.1–17.2)	16.0% (15.3–16.7)	17.4% (16.6–18.2)	17.0% (16.0–18.0)	18.1% (17.1–19.2)	14.9% (14.0–15.9)	16.3% (15.0–17.6)
Doctorate degree	4.8% (4.5–5.1)	4.4% (4.0–4.8)	5.4% (4.9–5.9)	4.6% (4.1–5.2)	5.5% (4.8–6.1)	4.2% (3.6–4.7)	5.3% (4.5–6.0)
Skip or missing	0.5% (0.4–0.6)	0.6% (0.5–0.8)	0.3% (0.2–0.4)	0.6% (0.4–0.8)	0.3% (0.1–0.4)	0.7% (0.4–0.9)	0.4% (0.2–0.6)
Employment, % (95% CI)							
Employed for pay (part-time, full-time, self-employed)	74.7% (74.1–75.3)	73.9% (73.0–74.7)	75.8% (74.8–76.7)	74.2% (73.1–75.4)	76.1% (74.9–77.3)	73.5% (72.3–74.7)	75.2% (73.7–76.7)
Unemployed	5.3% (4.9–5.6)	5.7% (5.2–6.1)	4.7% (4.3–5.2)	5.6% (5.0–6.3)	4.4% (3.9–5.0)	5.7% (5.1–6.4)	5.2% (4.4–5.9)
Unable to work (ie, disability, illness, other circumstances)	2.7% (2.5–3.0)	2.7% (2.4–3.0)	2.8% (2.5–3.2)	2.3% (1.9–2.7)	2.2% (1.8–2.6)	3.2% (2.7–3.6)	3.8% (3.1–4.4)
In school	10.0% (9.6–10.5)	10.3% (9.7–10.9)	9.7% (9.0–10.3)	10.7% (9.9–11.5)	10.5% (9.6–11.3)	9.9% (9.1–10.7)	8.4% (7.4–9.4)
Taking care of house or family	6.3% (6.0–6.7)	6.3% (5.8–6.8)	6.4% (5.9–6.9)	6.0% (5.4–6.6)	6.2% (5.5–6.8)	6.6% (5.9–7.3)	6.8% (5.9–7.7)
In retirement	0.2% (0.1–0.2)	0.2% (0.1–0.3)	0.2% (0.1–0.3)	0.2% (0.1–0.3)	0.2% (0.1–0.3)	0.2% (0.1–0.3)	0.2% (0.0–0.3)
Prefer not to answer	0.5% (0.4–0.5)	0.5% (0.4–0.7)	0.4% (0.2–0.5)	0.5% (0.3–0.7)	0.4% (0.2–0.6)	0.5% (0.3–0.7)	0.3% (0.1–0.5)
Missing	0.3% (0.2–0.3)	0.4% (0.3–0.5)	0.1%(0.0–0.1)	0.4% (0.2–0.6)	0.0% (0.0–0.1)	0.4% (0.3–0.6)	0.2% (0.0–0.3)
Exercise minutes, mean±SD	20.9±25.0	19.9±24.1	22.2±26.0	20.6±26.3	23.7±27.1	19.2±21.4	19.8±24.1
Sleep, mean±SD	7.3±2.4	7.2±2.4	7.4±2.4	7.2±2.3	7.5±2.4	7.2±2.4	7.4±2.3
Apple Watch paired, % (95% CI)	81.2% (80.6–81.7)	80.3% (79.6–81.1)	82.3% (81.5–83.1)	79.5% (78.5–80.6)	81.8% (80.7–82.9)	81.2% (80.1–82.3)	83.1% (81.8–84.4)

Demographics are presented for the total cohort, those without confirmed tracking and those with confirmed tracking, and for participants with no AUB or with AUB. AUB, abnormal uterine bleeding; *BMI,* body mass index; *CI,* confidence interval; *GED,* general educational development test; *SD,* standard deviation.

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TABLE 2

Proportions of abnormal uterine bleeding patterns

Tracking confirmation	Irregular menses	Infrequent menses	Prolonged menses	Spotting	AUB
Full cohort, %, (95% CI), n	6.1% (5.8–6.5) n=1158	30.0% (29.3–30.6) n=5661	3.9% (3.7–4.2) n=743	10.7% (10.3–11.2) n=2023	43.2% (42.5–43.9) n=8162
Participants with tracking not confirmed, %, (95% CI), n	3.2% (3.0–3.5) n=609	21.5% (21.0–22.1) n=4067	1.7% (1.5–1.9) n=316	4.7% (4.4–5.0) n=878	26.8% (26.2–27.4) n=5059
Participants with tracking confirmed, %, (95% CI), n	2.9% (2.7–3.1) n=549	8.4% (8.0–8.8) n=1594	2.3% (2.1–2.5) n=427	6.1% (5.7–6.4) n=1145	16.4% (15.9–17.0) n=3103

Bleeding patterns were analyzed and AUB meeting the described definition was identified in 8162 participants from the full cohort. Tracking confirmation was used to identify participants with AUB with tracking accuracy confirmed. A participant can be categorized into >1 type of AUB. Rates are all out of the total sample size (18,875).

AUB, abnormal uterine bleeding; *CI,* confidence interval; n, number of participants in the subgroup.

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TABLE 3

Prevalence ratio of abnormal uterine bleeding pattern by race/ethnicity

Race/ethnicity	AUB	N with AUB in reference group	N with AUB in exposure group	PR	95% CI
Hispanic, Latina, Spanish, and/or other Hispanic, n=775	any	2108	268	1.08	(0.96–1.22)
	irregular	375	52	1.26	(0.91–1.73)
	infrequent	1059	145	1.16	(0.96–1.39)
	prolonged	300	34	0.81	(0.53–1.24)
	spotting	791	94	1.03	(0.81–1.30)
Black or African American or African, n=592	any	2108	209	1.13	(0.99–1.29)
	irregular	375	37	1.12	(0.77–1.64)
	infrequent	1059	127	1.33	(1.09–1.61)
	prolonged	300	24	0.82	(0.51–1.33)
	spotting	791	60	0.92	(0.69–1.22)
Asian, n=388	any	2108	114	0.90	(0.74–1.09)
	irregular	375	28	1.41	(0.92–2.14)
	infrequent	1059	43	0.67	(0.47–0.96)
	prolonged	300	17	0.53	(0.25–1.12)
	spotting	791	45	1.06	(0.78–1.45)
Other, n=211	any	2108	56	0.92	(0.72–1.18)
	irregular	375	8	0.79	(0.38–1.64)
	infrequent	1059	38	1.27	(0.93–1.75)
	prolonged	300	6	0.70	(0.29–1.66)
	spotting	791	16	0.64	(0.37–1.10)

The reference group are White, non-Hispanic participants (n=6940). All records have tracking confirmed. Analysis controlled for age and body mass index.

AUB, abnormal uterine bleeding; *CI,* confidence interval; *n*, number of participants in the subgroup; *PR*, prevalence ratio.

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TABLE 4

Prevalence ratio of abnormal uterine bleeding pattern by body mass index category

BMI category	AUB	N with AUB in reference group	N with AUB in exposure group	PR	95% CI
Underweight, n=176	any	777	58	1.14	(0.91–1.42)
	irregular	136	12	1.27	(0.72–2.25)
	infrequent	363	24	1.00	(0.68–1.47)
	prolonged	112	8	1.02	(0.50–2.05)
	spotting	313	25	1.25	(0.86–1.83)
Overweight, n=2066	any	777	640	1.05	(0.96–1.15)
	irregular	136	117	1.13	(0.89–1.44)
	infrequent	363	325	1.14	(0.99–1.31)
	prolonged	112	69	0.81	(0.61–1.09)
	spotting	313	248	1.00	(0.86–1.17)
Obesity class 1, n=1418	any	777	479	1.14	(1.04–1.25)
	irregular	136	83	1.19	(0.91–1.56)
	infrequent	363	260	1.31	(1.13–1.52)
	prolonged	112	61	1.07	(0.79–1.46)
	spotting	313	169	0.99	(0.83–1.18)
Obesity class 2, n=877	any	777	270	1.04	(0.93–1.17)
	irregular	136	51	1.18	(0.86–1.62)
	infrequent	363	153	1.25	(1.05–1.49)
	prolonged	112	41	1.17	(0.82–1.66)
	spotting	313	90	0.85	(0.68–1.06)
Obesity class 3, n=376	any	777	129	1.18	(1.02–1.38)
	irregular	136	25	1.42	(0.94–2.16)
	infrequent	363	78	1.51	(1.21–1.88)
	prolonged	112	28	1.94	(1.29–2.90)
	spotting	313	36	0.81	(0.58–1.12)

Healthy weight (BMI, 18.5–24.9) is the reference (n=2647). All records have tracking confirmed. Controlled for age and race/ethnicity.

AUB, abnormal uterine bleeding; *BMI,* body mass index; *CI,* confidence interval; *n,* number of participants in the subgroup; *PR,* prevalence ratio.

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TABLE 5

Abnormal uterine bleeding pattern and medical conditions

Condition	Condition not present	Condition present	PR	95% CI
PCOS	4023	533	1.19	(1.08–1.31)
Fibroids	4255	301	1.14	(1.00–1.30)
Endometriosis	4325	231	1.28	(1.12–1.45)
Hyperthyroidism	4437	119	1.34	(1.13–1.59)
Hypothyroidism	4129	427	1.17	(1.05–1.31)
Hyperprolactinemia	4526	30	1.34	(0.98–1.85)
Hemophilia	4527	29	1.15	(0.79–1.68)
Cervical dysplasia	4347	209	1.20	(1.03–1.39)
Hypertension	4128	428	1.05	(0.93–1.18)
Type 1 diabetes mellitus	4523	33	1.36	(0.99–1.86)
Type 2 diabetes mellitus	4441	115	1.14	(0.93–1.40)
Anemia	3401	1155	1.14	(1.05–1.23)
Prediabetes mellitus	4231	325	1.15	(1.02–1.30)

Prevalence ratio of abnormal uterine bleeding pattern by self-reported medical conditions. Participants without the condition are the reference, with 1 model per row/condition. All records have tracking confirmed. Controlled for age and race/ethnicity.

CI, confidence interval; *PCOS,* polycystic ovary syndrome; *PR,* prevalence ratio.

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