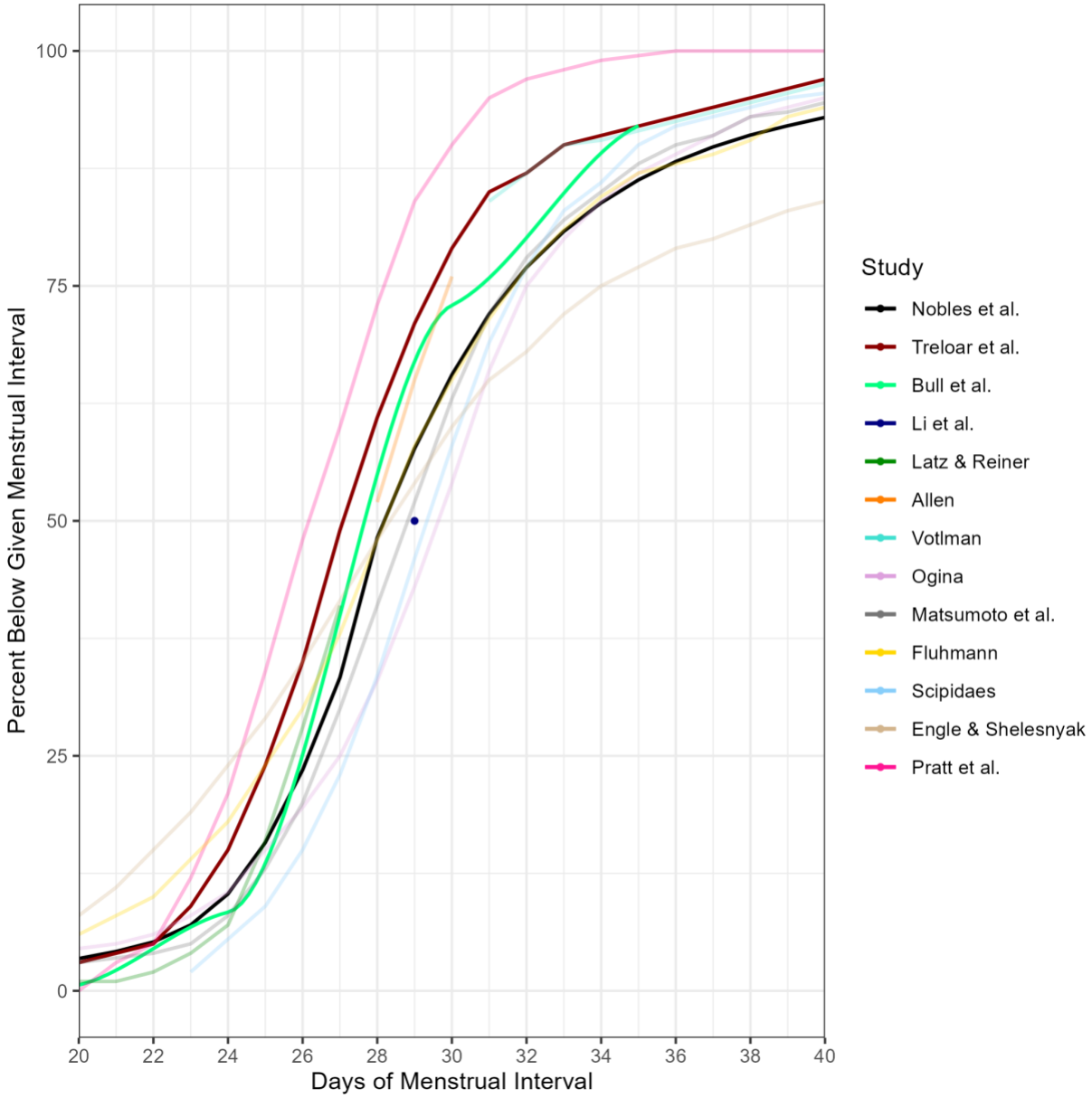
Online materials for
"Menstrual Irregularity as a Biological Limitation to Early Pregnancy Awareness"

Appendix Table 1: Complete analytic sample sizes and descriptive statistics, unweighted

Estimates	Cycles (%)	Total N	Persons (%)	% Persons Irregular	Total N
Age: 18-24	219,666 (13%)	1,678,999	40,375 (15%)	31%	267,209
25-29	473,679 (28%)		80,441 (30%)	27%	
30-34	644,205 (39%)		98,729 (37%)	21%	
35-39	341,449 (20%)		47,664 (18%)	16%	
Race: NH Black	47,046 (6%)	733,536	6,683 (6%)	22%	103,413
Hispanic / Latina/o	50,725 (7%)		7,219 (7%)	30%	
NH White	494,736 (67%)		69,530 (67%)	24%	
NH Asian	16,320 (2%)		2,156 (2%)	23%	
Multi-race	120,657 (17%)		17,260 (17%)	27%	
Other	4,052 (<1%)		565 (<1%)	25%	
PCOS	101,252 (11%)	888,663	14,858 (11%)	43%	129,754
Type II Diabetes	7,885 (1%)	675,328	1,059 (1%)	35%	93,634
Obesity	86,335 (21%)	402,371	11,256 (21%)	32%	54,203
Hormone Irregularity	224,818 (19%)	1,204,766	32,345 (19%)	34%	174,345
Thyroid Dysfunction	48,684 (8%)	617,117	6,341 (8%)	27%	83,065
Birth Past Year	3,811 (1%)	283,686	602 (1%)	28%	41,164
Trying to Conceive	1,294,946 (77%)	1,678,999	208,962 (78%)	24%	267,209
App Use: 5-10.6 days/mth	525,465 (31%)	1,678,999	101,484 (38%)	22%	267,209
10.6-15.3 days/mth	576,326 (34%)		82,288 (31%)	24%	
15.3-31 days/mth	577,208 (34%)		83,437 (31%)	24%	
Using Contraception: Yes	41,373 (2%)	1,678,999	4,996 (2%)	27%	267,209
No	540,774 (32%)		72,072 (27%)	24%	
Missing	1,096,852 (65%)		190,141 (71%)	23%	

Appendix Figure 1: Cumulative distribution of cycle lengths in the present study and previously published studies of menstrual cycle characteristics.



Note: The black line describes the distribution of cycle lengths in the sample used in this study. The bright green line describes cycle lengths in a study using data from a different app (Bull et al., 2019). The dark red line describes cycle length in Treloar's landmark study, which tracked cycle lengths in a non-digital format.

Full specification estimates from Figure 1, Panel A

Model 1: Irregular Cycles by Age Unweighted Without Controls

Age 18-24	2.00
	[1.94,2.05]
Age 25-29	1.69
	[1.65,1.73]
Age 30-34	1.33
	[1.29,1.36]
Age 35-39	1.00
	[1.00,1.00]

Note: 95% confidence intervals in brackets.

Model 2: Irregular Cycles by Race Unweighted Without Controls

Asian	1.05
	[0.96,1.15]
White	1.09
	[1.04,1.15]
Latino	1.40
	[1.32,1.49]
Multiracial	1.25
	[1.19,1.31]
Other Race	1.18
	[1.02,1.37]
Black	1.00
	[1.00,1.00]

Note: 95% confidence intervals in brackets.

Model 3: Irregular Cycles by PCOS Unweighted Without Controls

PCOS	2.15
	[2.10,2.20]

Note: 95% confidence intervals in brackets.

Model 4: Irregular Cycles by Hormone Irregularity Unweighted Without Controls

Hormone Irregularity	1.62
	[1.59,1.65]

Note: 95% confidence intervals in brackets.

Model 5: Irregular Cycles by Obesity Unweighted Without Controls

Obesity	1.52
	[1.47,1.57]

Note: 95% confidence intervals in brackets.

Model 6: Irregular Cycles by Type II Diabetes Unweighted Without Controls

Diabetes	1.45
	[1.34,1.57]

Note: 95% confidence intervals in brackets.

Model 7: Irregular Cycles by Thyroid Dysfunction Unweighted Without Controls

Thyroid Dysfunction	1.11
	[1.07,1.16]

Note: 95% confidence intervals in brackets.

Model 8: Irregular Cycles by Pregnant in the Last 12 Months Unweighted Without Controls

Pregnant Last 12 Months	1.31
	[1.16,1.48]

Note: 95% confidence intervals in brackets.

Full specification estimates from Figure 1, Panel B

Model 1: Irregular Cycles by Age with Weights and Controls	
Age 18-24	1.99
	[1.93,2.06]
Age 25-29	1.68
	[1.63,1.73]
Age 30-34	1.32
	[1.28,1.36]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.93
	[0.91,0.95]
Second Tertile of App Use	0.99
	[0.97,1.01]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.12
	[1.10,1.15]
Using Birth Control	1.16
	[1.09,1.23]
Missing Birth Control Data	0.97
	[0.95,0.99]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 2: Irregular Cycles by Race with Weights and Controls

Asian	1.26
	[1.12,1.40]
White	1.15
	[1.08,1.22]
Latino	1.43
	[1.32,1.54]
Multiracial	1.25
	[1.17,1.33]
Other Race	1.33
	[1.11,1.60]
Black	1.00
	[1.00,1.00]
Age 18-24	1.99
	[1.91,2.08]
Age 25-29	1.72
	[1.65,1.79]
Age 30-34	1.34
	[1.29,1.40]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.94
	[0.91,0.98]
Second Tertile of App Use	0.99
	[0.96,1.03]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.14
	[1.09,1.19]
Using Birth Control	1.17
	[1.09,1.25]
Missing Birth Control Data	0.99
	[0.96,1.02]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 3: Irregular Cycles by PCOS with Weights and Controls	
PCOS	1.95
	[1.89,2.01]
Age 18-24	2.02
	[1.94,2.11]
Age 25-29	1.68
	[1.62,1.74]
Age 30-34	1.32
	[1.27,1.38]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.93
	[0.90,0.96]
Second Tertile of App Use	0.98
	[0.95,1.01]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.08
	[1.05,1.12]
Using Birth Control	1.12
	[1.04,1.21]
Missing Birth Control Data	0.97
	[0.94,0.99]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 4: Irregular Cycles by Hormone Irregularities with Weights and Controls

Hormone Irregularity	1.51
	[1.48,1.55]
Age 18-24	2.02
	[1.95,2.10]
Age 25-29	1.71
	[1.66,1.77]
Age 30-34	1.35
	[1.30,1.39]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.94
	[0.91,0.97]
Second Tertile of App Use	1.00
	[0.97,1.02]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.13
	[1.09,1.16]
Using Birth Control	1.14
	[1.07,1.21]
Missing Birth Control Data	0.95
	[0.93,0.97]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 5: Irregular Cycles by Obesity with Weights and Controls	
Obesity	1.49
	[1.43,1.57]
Age 18-24	2.09
	[1.97,2.23]
Age 25-29	1.77
	[1.67,1.87]
Age 30-34	1.39
	[1.31,1.47]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.95
	[0.90,1.01]
Second Tertile of App Use	1.02
	[0.97,1.07]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.12
	[1.05,1.19]
Using Birth Control	1.12
	[1.02,1.23]
Missing Birth Control Data	0.92
	[0.87,0.97]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 6: Irregular Cycles by Type II Diabetes with Weights and Controls

Diabetes	1.47
	[1.32,1.64]
Age 18-24	2.08
	[1.99,2.18]
Age 25-29	1.77
	[1.70,1.85]
Age 30-34	1.35
	[1.29,1.41]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.95
	[0.92,0.99]
Second Tertile of App Use	0.99
	[0.96,1.03]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.14
	[1.09,1.19]
Using Birth Control	1.15
	[1.08,1.23]
Missing Birth Control Data	0.97
	[0.94,1.00]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 7: Irregular Cycles by Thyroid Dysfunction with Weights and Controls	
Thyroid Dysfunction	1.13
	[1.07,1.20]
Age 18-24	2.07
	[1.97,2.17]
Age 25-29	1.76
	[1.68,1.85]
Age 30-34	1.35
	[1.29,1.42]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.95
	[0.91,0.99]
Second Tertile of App Use	1.00
	[0.96,1.03]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.14
	[1.09,1.19]
Using Birth Control	1.16
	[1.08,1.24]
Missing Birth Control Data	0.98
	[0.95,1.02]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Model 8: Irregular Cycles by Pregnant in the Last 12 Months with Weights and Controls	
Pregnant Last 12 Months	1.18
	[1.00,1.39]
Age 18-24	1.95
	[1.82,2.10]
Age 25-29	1.69
	[1.59,1.81]
Age 30-34	1.32
	[1.23,1.41]
Age 35-39	1.00
	[1.00,1.00]
First Tertile of App Use	0.81
	[0.76,0.87]
Second Tertile of App Use	0.94
	[0.89,0.99]
Third Tertile of App Use	1.00
	[1.00,1.00]
Trying to Conceive	1.19
	[1.12,1.27]
Using Birth Control	1.12
	[1.00,1.27]
Missing Birth Control Data	0.95
	[0.90,0.99]

Note: 95% confidence intervals in brackets. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Additional tests:

Cycle length: relative risk of **cycle length exceeding 35 days** by individual demographic and health characteristics

Age 18-24	1.81
	[1.77,1.86]
Age 25-29	1.73
	[1.69,1.77]
Age 30-34	1.39
	[1.36,1.42]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.50
	[1.37,1.63]
White	1.19
	[1.13,1.25]
Latino	1.39
	[1.31,1.48]
Multiracial	1.22
	[1.15,1.30]
Other Race	1.17
	[1.00,1.38]
Black	1.00
	[1.00,1.00]
PCOS	1.91
	[1.86,1.96]
Hormone Irregularity	1.40
	[1.37,1.43]
Obesity	1.40
	[1.34,1.45]
Diabetes	1.39

	[1.25,1.54]
Thyroid Dysfunction	1.10
	[1.04,1.15]
Pregnant Last 12 Months	1.18
	[1.06,1.30]

Note: Relative risks from 8 separate regressions predicting long cycles (>35 days). 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

Sensitivity Tests

(1) Relative risks with covariate adjustment (as in Figure 1) but excluding adjustment for post-stratification weights.

Age 18-24	2.02
	[1.97,2.08]
Age 25-29	1.69
	[1.65,1.74]
Age 30-34	1.33
	[1.30,1.36]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.22
	[1.12,1.33]
White	1.11
	[1.06,1.16]
Latino	1.38
	[1.31,1.46]
Multiracial	1.22
	[1.16,1.29]
Other Race	1.23
	[1.07,1.42]
Black	1.00
	[1.00,1.00]
PCOS	2.11
	[2.07,2.16]
Hormone Irregularity	1.59
	[1.56,1.62]
Obesity	1.55
	[1.50,1.60]

Diabetes	1.54
	[1.43,1.67]
Thyroid Dysfunction	1.18
	[1.13,1.22]
Pregnant Last 12 Months	1.29
	[1.14,1.46]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use.

(2) Relative risk estimated for the sample of women who are not using birth control

Age 18-24	2.10
	[1.98,2.22]
Age 25-29	1.78
	[1.69,1.87]
Age 30-34	1.35
	[1.29,1.42]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.46
	[1.26,1.70]
White	1.19
	[1.09,1.30]
Latino	1.40
	[1.26,1.55]
Multiracial	1.30
	[1.19,1.43]
Other Race	1.33
	[1.03,1.73]
Black	1.00
	[1.00,1.00]
PCOS	2.07
	[1.99,2.16]
Hormone Irregularity	1.54
	[1.48,1.60]
Obesity	1.49
	[1.41,1.58]

Diabetes	1.48
	[1.29,1.69]
Thyroid Dysfunction	1.16
	[1.08,1.24]
Pregnant Last 12 Months	1.26
	[1.01,1.58]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(3) Relative risk of experiencing irregular cycles among women who reported trying to conceive less than 6 months at the time of signing up for the app.

Age 18-24	1.99
	[1.89,2.09]
Age 25-29	1.65
	[1.57,1.73]
Age 30-34	1.30
	[1.24,1.37]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.19
	[0.97,1.47]
White	1.13
	[1.00,1.27]
Latino	1.33
	[1.15,1.53]
Multiracial	1.24
	[1.09,1.41]
Other Race	1.54
	[1.12,2.12]
Black	1.00
	[1.00,1.00]
PCOS	1.69
	[1.59,1.80]
Hormone Irregularity	1.38
	[1.32,1.44]

Obesity	1.33
	[1.22,1.45]
Diabetes	0.90
	[0.66,1.25]
Thyroid Dysfunction	1.13
	[1.03,1.24]
Pregnant Last 12 Months	1.32
	[1.07,1.64]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(4) Relative risk of experiencing irregular cycles among women reporting that they are not trying to conceive

Age 18-24	2.07
	[1.93,2.22]
Age 25-29	1.73
	[1.62,1.86]
Age 30-34	1.35
	[1.25,1.45]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.20
	[0.90,1.61]
White	1.22
	[1.03,1.44]
Latino	1.42
	[1.16,1.73]
Multiracial	1.34
	[1.12,1.59]
Other Race	1.58
	[1.02,2.43]
Black	1.00
	[1.00,1.00]
PCOS	1.70
	[1.58,1.83]
Hormone Irregularity	1.37

	[1.30,1.44]
Obesity	1.36
	[1.21,1.53]
Diabetes	1.02
	[0.69,1.52]
Thyroid Dysfunction	1.10
	[0.97,1.25]
Pregnant Last 12 Months	1.30
	[0.99,1.73]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(5) Relative risk of experiencing irregular cycles with additional control measures for zip-code level poverty and individual education

Age 18-24	1.89
	[1.78,2.01]
Age 25-29	1.69
	[1.60,1.78]
Age 30-34	1.35
	[1.28,1.42]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.48
	[1.25,1.76]
White	1.24
	[1.13,1.37]
Latino	1.50
	[1.34,1.68]
Multiracial	1.32
	[1.19,1.46]
Other Race	1.33
	[1.01,1.76]
Black	1.00
	[1.00,1.00]
PCOS	1.26
	[1.24,1.28]
Hormone Irregularity	1.54
	[1.48,1.60]

Obesity	1.12
	[1.10,1.14]
Diabetes	1.31
	[1.11,1.55]
Thyroid Dysfunction	1.10
	[1.01,1.18]
Pregnant Last 12 Months	1.17
	[0.93,1.47]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(6) Relative risk of experiencing irregular cycles with inclusion of fixed-effects for number of cycles contributed per person

Age 18-24	1.92
	[1.86,1.98]
Age 25-29	1.63
	[1.59,1.68]
Age 30-34	1.30
	[1.27,1.34]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.26
	[1.13,1.40]
White	1.14
	[1.07,1.21]
Latino	1.42
	[1.32,1.53]
Multiracial	1.24
	[1.16,1.33]
Other Race	1.33
	[1.11,1.59]
Black	1.00
	[1.00,1.00]
PCOS	1.25
	[1.24,1.26]

Hormone Irregularity	1.51
	[1.47,1.54]
Obesity	1.50
	[1.43,1.58]
Diabetes	1.48
	[1.33,1.65]
Thyroid Dysfunction	1.14
	[1.08,1.20]
Pregnant Last 12 Months	1.17
	[0.99,1.37]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(7) Alternative measure of cycle irregularity #1:
The difference in length between the user's longest and shortest cycle >=7 Days

Age 18-24	1.17
	[1.16,1.19]
Age 25-29	1.11
	[1.10,1.13]
Age 30-34	1.06
	[1.05,1.07]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.14
	[1.08,1.20]
White	1.09
	[1.05,1.12]
Latino	1.18
	[1.14,1.22]
Multiracial	1.11
	[1.07,1.15]
Other Race	1.06
	[0.96,1.17]
Black	1.00
	[1.00,1.00]
PCOS	1.32
	[1.30,1.34]

Hormone Irregularity	1.18
	[1.17,1.20]
Obesity	1.11
	[1.10,1.13]
Diabetes	1.19
	[1.14,1.26]
Thyroid Dysfunction	1.07
	[1.04,1.10]
Pregnant Last 12 Months	1.04
	[0.94,1.16]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(8) Alternative measure of cycle irregularity #2:
within person variance in cycle length >=7 Days

Age 18-24	1.34
	[1.32,1.36]
Age 25-29	1.23
	[1.22,1.25]
Age 30-34	1.12
	[1.11,1.14]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.19
	[1.13,1.25]
White	1.11
	[1.08,1.15]
Latino	1.22
	[1.17,1.26]
Multiracial	1.13
	[1.09,1.17]
Other Race	1.11
	[1.00,1.22]
Black	1.00
	[1.00,1.00]

PCOS	1.36
	[1.34,1.39]
Hormone Irregularity	1.20
	[1.19,1.22]
Obesity	1.21
	[1.18,1.23]
Diabetes	1.17
	[1.10,1.24]
Thyroid Dysfunction	1.07
	[1.04,1.10]
Pregnant Last 12 Months	1.10
	[1.00,1.20]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.

(9) Alternative measure of cycle irregularity #3
Within-person median cycle length differences >=9 (see Li et al. 2020)

Age 18-24	2.30
	[2.21,2.41]
Age 25-29	1.90
	[1.82,1.98]
Age 30-34	1.42
	[1.36,1.47]
Age 35-39	1.00
	[1.00,1.00]
Asian	1.23
	[1.06,1.44]
White	1.14
	[1.04,1.24]
Latino	1.50
	[1.36,1.65]
Multiracial	1.26
	[1.15,1.38]
Other Race	1.35
	[1.04,1.75]
Black	1.00
	[1.00,1.00]

PCOS	2.21
	[2.12,2.31]
Hormone Irregularity	1.63
	[1.58,1.69]
Obesity	1.55
	[1.45,1.66]
Diabetes	1.50
	[1.29,1.76]
Thyroid Dysfunction	1.12
	[1.03,1.21]
Pregnant Last 12 Months	1.07
	[0.86,1.33]

Note: Relative risks from 8 separate regressions predicting cycle irregularity. 95% confidence intervals in brackets. All regressions include controls for age, frequency of app use, trying to conceive, and birth control use. Estimates are weighted with post-stratification weights to better approximate the U.S. reproductive-age population.