Outpatient Portal (OPP) Use Among Pregnant Women: Cross-Sectional, Temporal, and Cluster Analysis of Use

Thesis

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Abstract

Outpatient portal technology (OPP) can improve patient engagement. For pregnant women, this high level of engagement could have important implications for maternal and infant outcomes. There is a dearth in studies that characterize OPP use among pregnant women. Our academic medical center (AMC) implemented a system-wide OPP in 2011. The OPP includes functions that allow patients to access their personal health information (PHI), view and schedule appointments, and message their providers. Our study is among the few studies that characterizes OPP use in a historically understudied patient population.[1]

We built upon existing research using OPP server-side log files by executing a hierarchical clustering algorithm to group 7,663 pregnant women based on the proportion of use for each OPP function.[2–4] We calculated proportions of use for each OPP function a woman engaged with and used these proportions as inputs for our cluster analysis. Women who visited a Maternal Fetal Medicine (MFM) provider for pregnancy were regarded as having high pregnancy-related risk, while those who only visited an Obstetrics and Gynecology (OB/GYN) provider were considered as having normal pregnancy-related risks. Post-hoc analyses were performed using one-way ANOVA to further assess OPP use on key encounter characteristics. Use of the following OPP functions was examined within the cluster analysis: Visits (manage appointments), MyRecord (access PHI), Messaging (send/receive messages), and Billing (view bills, insurance information).

Our study sample was predominantly represented by non-Hispanic white women between the ages of 25 and 34. The most frequently used functions at the patient level were MyRecord, Visits, Messaging and Billing, with frequency of use similar between pregnancy risk groups. Median OPP function use plateaued by the third trimester for each pregnancy risk group, with

significantly more use among women with a high-risk pregnancy compared to those with a normal pregnancy. Four distinct clusters were identified among all pregnant women based on our clustering stopping rules. The "Average Users" (AUs) cluster consisted of women who primarily used the MyRecord (47%) and Visits (23%) functions. The "Schedulers" (SCs) focused on using the Visits (67%) functions. The "Intense Digital Engagers" (IDEs) primarily used the Messaging (41%) and MyRecord (33%) functions. Finally, the "Prepared Engagers" (PEs) used both the Visits (47%) and MyRecord functions (32%). The same clusters were seen among high-risk pregnancies, while SCs were absent among those with a normal pregnancy. Post-hoc analyses revealed that the IDEs cluster and MyRecord-oriented clusters engaged with the OPP less over time, while SCs engaged with the OPP the most. Movement between clusters over time, assessed using a Sankey diagram, was common, though there were women who remained in the same clusters throughout the duration of a pregnancy.

Our identification of distinct cluster groups of OPP users among pregnant women underscores the importance of avoiding the use of generalizations when describing how such patients might engage with patient-facing technologies such as an OPP. These results can be used to improve user experience and training with OPP functions, and may educate OB/GYN and MFM providers on patient engagement with the OPP.

Dedication

To those who have supported me through the peaks and valleys of this recent journey: Mary Kate, Daniel, Cynthia and Tom.

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I could not have completed this project without the help and guidance from a number of individuals, whom I would like to thank and bring special attention to:

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My parents, Cynthia and Tom, thank you for reminding me that I can achieve anything I put my mind towards. I could not have done this without your unconditional love and support.

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Fields of Study

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Biomedical Informatics

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Chapter 1: Introduction

Background

Recent advances in clinical technology (e.g., the electronic health records, EHRs) have led to new ways in which patients are able to engage with their health care providers and their own personal health information. The Health Information Technology for Economic and Clinical Health Act (HITECH) required the adoption of EHRs in the United States health care system, and utilized financial incentives to those demonstrating adoption and meaningful use (MU) of EHRs. Due to the act's MU requirements for information exchange between providers and patients, health care systems were further driven to adopt the use of patient portals as the setting for electronic health information exchange.[5] Patient portals serve as the bridge between an electronic personal health record, which are designed to be managed by patients, and the EHR that is managed by the health care system.[6,7]

Within the setting of an outpatient portal (OPP), patients are able to communicate with health care providers and actively participate in their own health care via various functions while in the outpatient setting. Actions include viewing laboratory results and visit summaries, scheduling appointment and prescription refills, and communicating with clinicians. Various studies have demonstrated that adult users of patient portals can experience positive impacts on their clinical and quality outcomes, particularly in relation to chronic conditions such as diabetes, cancer, coronary artery disease, hyperlipidemia and hypertension.[8–14] While these studies were able to demonstrate an association between use of a patient portal and benefits to health and care, they did not clarify how specific activity within a patient portal might alter a patient's engagement with their own health and health care providers.

Audit Log Files

Mining of OPP metadata presents a unique pathway to explore how patients are engaging with an OPP and, in turn, with the management of their health. Audit log files are an automatically produced, server-side documentation of user's behavior within a particular system.[15] Originally designed for monitoring purposes, these files typically include four pieces of metadata: *who* accessed *which* page at *what* time and the *action* they performed on that page.[16] While the exact granularity of the log files depends on the vendor's software, use of this information allows researchers to unobtrusively study a wide range of user activities within a system, such as an EHR or an OPP. Log files are limited by their inability to precisely indicate why actions occur. However, the scale at which this activity information exists has been harnessed to summarize sequences of activity and further identify groups of common sequential actions.[15–18]

Methods for Audit Log File Processing and Analysis

One of the biggest challenges to using audit log files has historically been processing metadata associated with audit log files generated over long periods of time. Recent studies, however, have developed, standardized and shared such methods for processing patient portal audit log files and measuring patient portal use.[2,4] These studies took particular care in documenting data sources, developing data models, and sharing data processing methods required to measure use of both inpatient and outpatient portals. In addition, they devised unique metrics to cross-sectionally assess patient portal use, which have in turn been used to further identify clusters of users according to use of specific patient portal features.[3] These studies were performed across samples of an entire health system, and did not examine how such metrics of use could be applied to patient portal use among unique patient populations. One study by Jones *et al.* was particularly

inspiring as they presented a summary of data sources, data processing methods, and metrics of use along with results from a hierarchical cluster analysis among a population of users with chronic illnesses at a large academic medical center.[19] While this study offered a valuable view of clustered OPP users, they did not address how use may change over time as users become more familiar with the OPP.

OPP Use Among Pregnant Women

Few studies have examined OPP use among pregnant women.[20] Given that pregnant women are in frequent contact with health care providers and are encouraged to actively participate in their health care, it is imperative that such time is spent efficiently improving health and health behaviors. Analysis of the log files generated from pregnant women's use of a patient portal presents a unique opportunity to leverage large scale behavioral data toward the study of an underrepresented population's interaction with an electronic care delivery technique.

While it is clear that pregnant women perceive the benefits of patient portal use [21,22], few studies have actually examined how such use varies according to the risk associated with the pregnancy or how use may change over time. One study aimed to quantify patient portal use among pregnant women, and showed that women with high-risk pregnancies were less likely to enroll in a patient portal at the time of delivery.[1] This study examined the association between certain demographic and clinical covariates and enrollment in the patient portal; however, it did not examine how interaction with the portal varied among the women with either normal or high-risk pregnancy. A stronger understanding of the behavioral interaction between pregnant mothers and the patient portal, through the use of the generated log files, could provide insight and guidance to help Obstetrics and Gynecology (OB/GYN) and Maternal Fetal Medicine (MFM) programs

improve efficiency of care, patient satisfaction, and possibly clinical outcomes associated with pregnancy.

Study Objectives

The primary objective of this study was to characterize the OPP use among pregnant women seen by the Department of Obstetrics and Gynecology and Maternal Fetal Medicine Division at the OSUWMC. We used audit log files and clinical electronic health record data to assess portal use among pregnant mothers, according to whether the pregnancy was considered to have normal or high pregnancy-related risks. Our secondary objective was to then profile the OPP user groups based on the information generated from the first objective. We used hierarchical clustering to group users based on OPP use measurements generated from the first objective.

Chapter 2: Materials and Methods

Overview

We began this study as a continuation of a larger, ongoing assessment of patient portal technology use at OSUWMC, which has been described by Huerta *et al.*, Di Tosto *et al.* and Fareed *et al.*[2–4] Huerta *et al.* first assessed inpatient portal (IPP) use at The Ohio State University Wexner Medical Center (OSUWMC), and further defined the initial data model and key metrics through which portal use could be assessed. Di Tosto *et al.* assessed OPP use across a sample of OSUWMC users and, in doing so, developed reproducible modules to process audit log file data sets for use in analysis in conjunction with individual patient demographic and clinical data. Fareed *et al.* examined the use of an IPP at OSUWMC to identify distinct clusters using a hierarchical clustering algorithm. Drawing on methods developed in these studies, we performed data processing and analysis using coded-limited data requested from the OSUWMC Information Warehouse (IW) in order to assess OPP. This study did not require approval from the institutional review board (IRB) of OSUWMC as it involved the use of a coded-limited data set reviewed and approved by the Honest Broker Committee of OSUWMC.

Study Sample

This study included data from all women seen by OB/GYN and MFM physicians at OSUWMC during the study period of January 1, 2016 to August 1, 2020. Women eligible for inclusion must have been 18 years or older and received prenatal care from OSUWMC OB/GYN or MFM providers. In the event a woman had multiple pregnancies during the study period, we only examined OPP use during the woman's first pregnancy. Our final study also excluded those

women who did not use the OPP within 280 days of their estimated delivery date in order to ensure we only assessed OPP use during a woman's pregnancy. Overall, our initial data set included 14,658 pregnant women, while our final analyses only included 7,664 women, who were considered active users of the OPP during their pregnancy if they used the OPP at least once within each trimester of pregnancy. Of these, 6,233 women had a normal pregnancy, while the remaining 1,431 women had a high-risk pregnancy. A woman was considered to have a "high-risk" pregnancy if she required a visit with a MFM provider for existing comorbidities such as multiple pregnancy, diabetes, high blood pressure, genetic conditions, premature birth history, preeclampsia, advanced maternal age, or any condition requiring high-risk care or fetal treatment.[23] A women was considered to have a "normal" pregnancy if she did not have existing comorbidities requiring a visit with a MFM provider during the study period.

Data Sources

Following approval from the Honest Broker Committee, we received two data sets: OPP audit log files from each patient and demographic data from each patient. This study was determined to be exempt from review by The Ohio State University Institutional Review Board. The audit logs files from patients seen between January 1, 2016, and August 1, 2020, were the primary data source used to assess OPP use. Pertinent data within these files included a coded patient identifier, the date and time of every action patients made within the OPP, a categorical variable for the type of action performed by each patient, and a unique session identifier. Table 2.1 shows a sample of these raw audit files. The audit log files include additional info (i.e., ext_info) for each action within the OPP, which can be used to further categorize user actions.

Additional information needed for further categorization may specifically include whether a user viewed messages, loaded a billing summary, or viewed their upcoming appointment details.

Table 2. 1 Synthetic sample of raw data from the OPP audit log files

pat_num	epi_num	act_date	act_type	ext_info	session_num
392	1	10/17/17 12:32	Messaging	reply to: ...	12345
2345	1	7/22/20 7:18	Billing Account Summary	load billing account summary~success	87623
6726	1	6/22/18 15:23	Upcoming Appointment Details	^appointment-details	235
9234	1	6/29/19 9:11	Test Results List	tests list	23456
10567	1	12/25/17 11:11	Messaging	view message ...	76554
12348	1	12/11/18 7:34	Medical Histories	pastvisits-info~success	987654

The demographic data set included patient details such as a coded patient identifier, date of birth, race, ethnicity, dates of visits with providers, counts of visits with providers, estimated delivery date, and delivery date. A categorical variable named “risk” was also included to denote the level of risk associated with the pregnancy, which include either high-risk or normal risk according to their existing comorbidities and treating physician, as mentioned previously. Trimesters were calculated for each pregnancy using the number of days prior to the estimated delivery date, according to the American College of Obstetricians and Gynecologists (ACOG).[24] The first trimester was defined as the period between 280 and 183 days prior to the estimated delivery date, which corresponds to the period from day 0 of a pregnancy to 13 weeks and 6 days. The second trimester was defined as the period between 182 and 85 days prior to the estimated delivery date, which corresponds to the period from 14 weeks to 27 weeks and 6 days. Finally, the third trimester was defined as the period between 84 days prior to estimated delivery date and the estimated delivery date, which corresponds to the period from 28 weeks to 40 weeks. We did not

use the exact delivery date to calculate trimesters as this date was not consistently provided for all patients within the demographics data set.

Data Model

Our data model for OPP use is presented in Table 2.2. We first categorized every individual action used within the portal by patients. Action types were then collapsed into various functions throughout the OPP. Sessions were defined as grouped sequences of actions that began with a patient's login and were interrupted by either a patient's manual logout or a significantly long period of inactivity between actions within the OPP. The threshold for a period of inactivity was determined by calculating the 99th percentile of the time in seconds between actions (see Module 2 in Appendix C). During a single session or period of uninterrupted OPP use, patients are able to perform multiple actions and engage with multiple functions. Over the course of a patient's pregnancy, she could use the OPP over numerous sessions, which in turn can involve her engagement with a wide variety of actions within functions.

Table 2. 2 Data Model for OPP Use

Data Aggregation Level	**Definition**
Action type	Individual action performed by the user within the OPP
Portal Function	Individual category in which actions are grouped according to different functionalities offered through the OPP
Session	Grouped, uninterrupted sequences of actions beginning with a patient's login and ending with manual logout or period of inactivity
Patient Pregnancy	Use of OPP actions or functions across the entirety of a patient's sessions during the patient's pregnancy period
First Trimester	Use of OPP actions or functions across the entirety of a patient's sessions during the period between 280 and 183 days prior to the estimated delivery date, (i.e., day 0 of a pregnancy to 13 weeks and 6 days)
Second Trimester	Use of OPP actions or functions across the entirety of a patient's sessions during the period between 182 and 85 days prior to the estimated delivery date, (i.e., 14 weeks to 27 weeks and 6 days)
Third Trimester	Use of OPP actions or functions across the entirety of a patient's sessions during the period between 84 days prior to the estimated delivery date and the estimated delivery date (i.e., 28 weeks to 40 weeks)

Using the timestamped actions (e.g., the act_date variable seen in Table 2.1) and the estimated delivery date, which serves as the standard date from which trimesters could be calculated, we were able to examine OPP use cross-sectionally at various timepoints and temporally as women progressed through pregnancy. Cross-sectional analysis of OPP use was performed at the session and patient levels, while temporal analysis took place at the patient level. Clusters of patients were later identified based on the proportion of function use at the patient level. The movement of patients between clusters was assessed temporally as women progressed through pregnancy. Finally, all measurements of OPP use were repeated to examine differences in OPP use between women with a normal pregnancy and women with a high-risk pregnancy.

The following measurements of OPP engagement, defined in recent studies [2–4], were used:

Table 2. 3 Measurements of OPP engagement

Measurement	**Measurement Construction**
Frequency of action use – session level	Count of sessions during which the OPP action was used
Frequency of function use – session level	Count of sessions during which the OPP function was used
Frequency of function use – patient level	Count of patients who used the OPP function during a pregnancy
Comprehensiveness of use – session level	Count of unique OPP functions used per session
Comprehensiveness of use – patient level	Count of unique OPP functions used by a patient during a pregnancy
Median use per trimester	Median number of sessions with at least one portal function used during each trimester of a pregnancy
Proportion of use	Sum of use of an OPP function divided by the sum of use of all OPP functions.
Sessions per pregnancy	Average number of sessions per pregnant woman
Sessions per trimester	Average number of sessions per trimester of a pregnancy
Pregnancy length	Average number of days between the start of the first trimester and the delivery date
Days to first session	Average number of days between the start of a trimester and the first session during that trimester
Days to last session	Average number of days between the start of a trimester and the last session during that trimester
Days to delivery	Average number of days between the first session and the delivery date
Days to estimated delivery	Average number of days between the first session and the estimated delivery date
MFM visit count	Average number of visits with a MFM physician

OB/GYN visit count	Average number of visits with an OB/GYN physician
Total visit count	Average number of visits with either a MFM or an OB/GYN physician
Percent change	Sum of women who are new to a cluster divided by the sum of all women in the cluster

Frequency and comprehensiveness of use were assessed at the session (N = 813,895) and patient (N = 7,664) levels, while median use per trimester was assessed at the patient (N = 7,664) level and proportion of use was assessed at the patient (N = 7,664) and cluster level. These measurements of OPP engagement were only studied among those women who were considered active users, which was defined as having at least one valid session within each trimester of pregnancy.

Data Processing

Our methods for data processing built upon existing methods which were primarily developed to assess OPP use [4] and identify distinct clusters of IPP users [3] among OSUWMC users. Our methods most notably differ from Di Tosto *et al.* according to the use of the account status information. Their study used account statuses to assess whether a user's OPP account had been activated or inactivated at the time the audit log files were pulled from the server. Activated accounts were those in regular use, while inactivated accounts had been terminated due to the death of the user, an incomplete sign-up, or an inadvertent invalidation of the account after the account had been activated. Given that there were a limited number of activated accounts among our sample of patients, we chose to define an active user according to their actual use of the OPP during each trimester, as has been defined in the previous section (see Data Model). Our definition of an active user is much more similar to Fareed *et al.*, who identified sessions according to the first presence of an IPP action that required the user to actively engage with the IPP.

A summary of the steps used for data processing are presented as a flowchart in Figure 2.1. Briefly, modules 1-7 were a continuation of the data processing methods outlined by Di Tosto *et al.*, performed with the goal of translating the audit log files into data sets from which session level OPP engagement could be calculated. In module 8, we calculated the active status of each patient by using the first session start date that falls within the specified period of a patient's pregnancy (i.e., the first, second or third trimester). Those with at least one session start date within each trimester period were considered active. Upon removal of the inactive patients, we proceeded to module 9, in which we calculated measures of OPP engagement at the patient level among each pregnancy risk group (i.e., all pregnancies, normal pregnancies, and high-risk pregnancies).

Using the patient level measurements, modules 10 and 11 were used to further assess OPP use temporally. In module 10, we calculated the sum of each patient's use of the OPP functions during each trimester, and then took the median of these summed values across all patients in module 11. The median OPP use values were then used to assess the temporal change in OPP function use across all trimesters and among each pregnancy risk group.

Preparation for the cluster analyses began in module 12, in which we calculated the proportions of OPP function use (defined in Table 2.3). The proportion of function use was first calculated for use over the entire pregnancy period, and then for use during each trimester. The sum of each patient's use of all OPP functions during the specified time period (i.e., all trimesters or each trimester), calculated using the output from module 10, serves as the denominator for the proportion calculation, while the sum of each patient's use of a specific OPP function during the specified time period serves as the numerator. The proportions of function use produced in this module are then ready for use within the cluster analyses in module 13. The cluster analyses

performed in modules 14-15 simply require that only women with a normal pregnancy and women with a high-risk pregnancy are included, respectively.

Finally, using the coded cluster variable that is assigned to each patient during the cluster analysis, the movement of patients between clusters throughout each trimester was assessed for each pregnancy risk group using a Sankey diagram. The clusters in our diagrams are represented by the nodes seen at each trimester with the trimesters flowing left to right. The number of patients moving between each cluster are represented by the width of the bands linking each node.

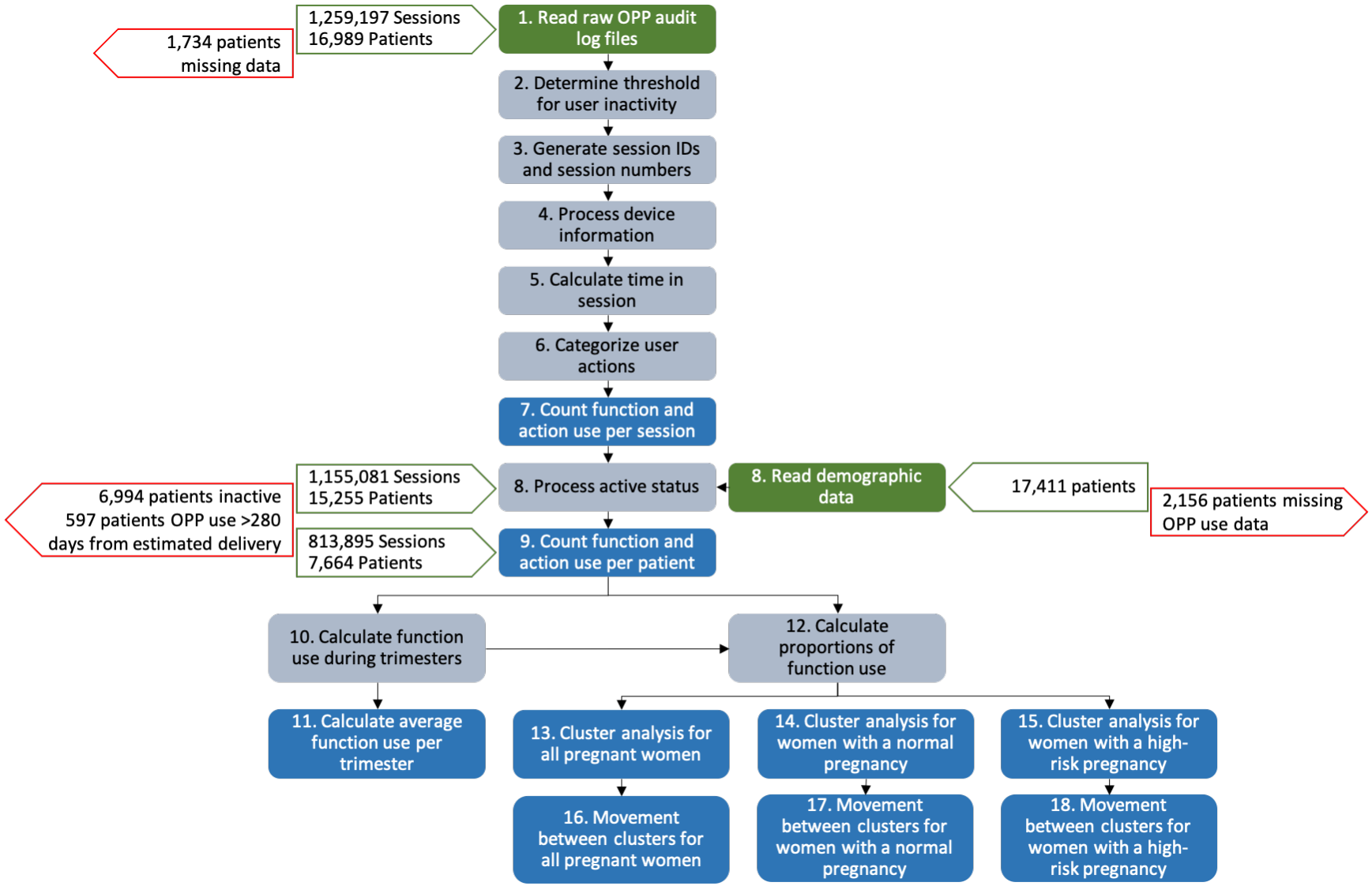


Figure 2. 1 Data processing flowchart

Data Analysis

Analyses were focused into six parts: 1) the cross-sectional descriptive summary of function use; 2) the temporal summary of median function use; 3) the cluster analyses according to proportion of function use; 4) post hoc analyses to further characterize clusters of function use; 5) the temporal summary of movement between clusters and 6) sensitivity cluster analyses examining OPP use during the COVID-19 pandemic. Descriptive statistics were calculated in order to describe the number of active users, frequency of portal action types and function use, comprehensiveness of portal function use, and the median function use per trimester. The descriptive summaries of active users, frequencies of use, and comprehensiveness of use were calculated at the session and patient, while the temporal change in median function use was only assessed at the patient level. Median use of each OPP function was calculated as the median number of sessions in which a function was used at least once, and this was repeated for each trimester according to pregnancy risk group. The median use of all functions at each trimester was similarly calculated as the median of the total number of sessions in which *any* function was used at least once during each trimester. This was repeated for each pregnancy risk group.

Hierarchical agglomerative clustering algorithms were used to group women according to proportion of OPP function use. The proportion of OPP function use calculation included use of all nine OPP functions in the denominator. To begin, each woman is first placed in her own cluster and successively joined by the two most similar clusters. Our hierarchical clustering analyses used Ward's method, which minimized within-cluster variance, as measured by the error sum of squares, across all proportion of use variables in order to determine similarity.[25] Final clusters were unique groups of women with minimized within-cluster and maximized between-cluster differences in proportion of function use. The final number of clusters was agreed upon following

review of a cluster dendrogram in conjunction with use of two cluster-analysis stopping rules, the Calinski/Harabasz pseudo-F index and Duda/Hart scores.[26,27] Hierarchical clustering was then repeated for each pregnancy risk group and at each trimester in order to assess cross-sectional and temporal differences in clustering based on proportion of OPP function use.

Additional post hoc analyses were performed to further characterize clusters and understand OPP use. We first calculated the mean value for the following metrics: number of sessions per pregnancy, pregnancy length, number of days to first session of use, number of days to last session of use, number of days to delivery, number of days to estimated delivery, number of MFM visits, number of OB/GYN visits, and number of provider visits. Race and ethnicity for each cluster group was also assessed. A chi-square test was performed to test for significant difference in proportions of active users. Kruskal-Wallis tests were performed to test for significant differences in median OPP function use across trimesters, while Wilcoxon rank-sum tests were used to test for significant differences between trimesters and between pregnancy risk groups at each trimester. Finally, to test for significant differences in mean proportions of OPP function use and mean post hoc metrics across an entire set of clusters, we performed one-way ANOVA and Kruskal–Wallis tests within each pregnancy risk group at each cross-sectional time point (i.e., the entire pregnancy period and each trimester of pregnancy). Significant differences in mean proportion of OPP use between individual clusters were assessed using Duncan's multiple range tests (DMRTs). Statistical analyses were performed using Stata 16.1, R programming language (v4.0.4), and Python programming language (v3.9). Our clustering method used the Stata cluster command with Ward's linkage and squared Euclidean distance.

Chapter 3: Results

The data processing methods listed above were applied to the OPP server-side audit log files generated from our sample of pregnant women receiving care at the OSUWMC. The following sections represent the summaries and results from our cross-sectional, temporal and cluster analyses of OPP use among these pregnant women.

OPP Active Use Status

Table 3.1 shows the classification of active and inactive OPP users among pregnant women. Following data processing (see Figure 2.1), there were 14,658 pregnant women remaining. Of these women, 7,664 (52%) were considered active users. Active use was defined as the use of the OPP once (one session) during each trimester. A greater proportion of women with a normal pregnancy (54%) were active users compared to those with a high-risk pregnancy (48%) ($p<0.001$).

Table 3. 1 Portal active status per pregnancy, by risk group

	All Pregnancies		**Normal Pregnancies**		**High-Risk Pregnancies**	
	N = 14,658		N = 11,451 (78%)		N = 3,207 (22%)	
Active Status	**n**	**%**	**n**	**%**	**n**	**%**
Active	7,664	52	6,233	54	1,431	45
Inactive	6,994	48	5,218	46	1,776	55

Patient Characteristics

Our study sample consisted primarily of non-Hispanic white (70%) women who were 30-34 years old (39%) and 25-29 years old (31%) at the time of their first visit (Table 3.2). Both

pregnancy risk groups predominantly consisted of non-Hispanic white women between the ages of 30-34 at the time of first visit. There were more non-Hispanic white women among the high-risk pregnancy group (76%) compared to those with a normal pregnancy (69%), and more women over the age of 35 among the high-risk group (26%) compared to those with a normal pregnancy (16%).

Table 3. 2 Patient characteristics, by risk group

	All Pregnancies		Normal Pregnancies		High-Risk Pregnancies	
	N = 7,664		N = 6,233		N = 1,431	
Age at First Visit	**n**	**%**	**n**	**%**	**n**	**%**
<20	110	1	95	2	15	1
20-24	809	11	675	11	134	9
25-29	2,376	31	2,000	32	376	26
30-34	2,982	39	2,450	39	532	37
35+	1,387	18	1,013	16	374	26
Race-Ethnicity						
Non-Hispanic White	5,393	70	4,326	69	1,067	75
Non-Hispanic Black	1,111	15	935	15	176	12
Hispanic	238	3	195	3	43	3
Race-Ethnicity Other	922	12	777	12	145	10

Cross-sectional Descriptive Summary of Function Use

Frequency of OPP Action Use

Table 3.3 shows the two-level taxonomy for action types and corresponding portal functions assigned to sort the raw log data from the OPP. For each action type, the count of sessions in which an action was used and the percentage of use are reported. The percentage of use is calculated as the session count/the total number of sessions (all sessions: N=813,895; normal risk: N=622,434; high-risk: N=191,461). Multiple action types and portal functions can be used during a single session. Among all sessions, the most commonly used action types were those within the Messaging, Visits, MyRecord and Billing portal functions. Women in the high-risk group used the Send New Message (5.92%) action more than those in the normal risk group (4.80%). Those in

the normal risk group used Appointment Details (19.81%), Schedule an Appointment (14.63%), Billing Account Summary (5.94%), and E-Check In (5.43%) more than those in the high-risk group (18.69%, 13.52%, 4.56%, 4.28%, respectively). Other than these noticeable differences, use by OPP actions were quite similar between the three groups.

Table 3. 3 Counts of sessions engaging with action types among active users, according to pregnancy risk group.

		All Sessions		**Normal Sessions**		**High-Risk Sessions**	
		N = 813,895		N = 622,434 (76%)		N = 191,461 (24%)	
Action Type	**Portal Function**	**n**	**%**	**n**	**%**	**n**	**%**
Message Center	Messaging	49,669	6.10	37,737	6.06	11,932	6.23
Send New Message	Messaging	41,206	5.06	29,881	4.80	11,325	5.92
Letters	Messaging	7,808	0.96	6,193	0.99	1,615	0.84
Appointment Details	Visits	159,060	19.54	123,275	19.81	35,785	18.69
Schedule An Appointment	Visits	116,963	14.37	91,072	14.63	25,891	13.52
Echeck In	Visits	42,018	5.16	33,820	5.43	8,198	4.28
Upcoming Tests	Visits	7,835	0.96	6,165	0.99	1,670	0.87
Cancel An Appointment	Visits	4,201	0.52	3,256	0.52	945	0.49
Telemedicine	Visits	1,070	0.13	785	0.13	285	0.15
Driving Directions	Visits	734	0.09	599	0.10	135	0.07
Test Results	MyRecord	172,294	21.17	130,821	21.02	41,473	21.66
Allergies	MyRecord	32,045	3.94	25,857	4.15	6,188	3.23
Current Health Issues	MyRecord	19,558	2.40	15,711	2.52	3,847	2.01
Immunizations	MyRecord	18,230	2.24	14,746	2.37	3,484	1.82
Health Summary	MyRecord	8,982	1.10	7,328	1.18	1,654	0.86
Medications	MyRecord	8,472	1.04	6,667	1.07	1,805	0.94
Preventive Care	MyRecord	4,227	0.52	3,307	0.53	920	0.48
My Conditions	MyRecord	536	0.07	225	0.04	311	0.16
Flowsheet	MyRecord	8	0.00	5	0.00	3	0.00
Consolidate Ehr	Medical tools	1,961	0.24	1,599	0.26	362	0.19
Who Accessed MyRecord	Medical tools	1,029	0.13	791	0.13	238	0.12
Research Studies	Medical tools	875	0.11	708	0.11	167	0.09
Wallet Card	Medical tools	301	0.04	244	0.04	57	0.03
Share MyRecord	Medical tools	50	0.01	37	0.01	13	0.01
Download MyRecord	Medical tools	39	0.00	36	0.01	3	0.00
Billing Account Summary	Billing	45,724	5.62	37,002	5.94	8,722	4.56
Bill Payment	Billing	34,752	4.27	27,766	4.46	6,986	3.65
Insurance Summary	Billing	24,962	3.07	20,252	3.25	4,710	2.46
Update Insurance	Billing	10,072	1.24	7,981	1.28	2,091	1.09
Estimates	Billing	4,380	0.54	3,582	0.58	798	0.42
Change Paperless Status	Billing	746	0.09	596	0.10	150	0.08

Billing Account Details	Billing	-	0.00	-	0.00	-	0.00
Terms And Conditions	Resources	-	0.00	-	0.00	-	0.00
Osuwmc Patient Education	Resources	-	0.00	-	0.00	-	0.00
Krames Patient Education	Resources	-	0.00	-	0.00	-	0.00
Locations	Resources	-	0.00	-	0.00	-	0.00
Proxyorms	Proxy	8,259	1.01	6,154	0.99	2,105	1.10
Switch Proxy Context	Proxy	2,097	0.26	1,771	0.28	326	0.17
Personalize	Proxy	1,894	0.23	1,438	0.23	456	0.24
Request Proxy Access	Proxy	401	0.05	344	0.06	57	0.03
Request Child Proxy Access	Proxy	-	0.00	-	0.00	-	0.00
Proxy Renewal Request	Proxy	-	0.00	-	0.00	-	0.00
Security Settings	Preferences	3,506	0.43	2,900	0.47	606	0.32
Notifications	Preferences	2,961	0.36	2,358	0.38	603	0.31
About Me	Preferences	-	0.00	-	0.00	-	0.00
Manage My Accounts	Preferences	-	0.00	-	0.00	-	0.00
Miscellanea	Custom	5,673	0.70	4,507	0.72	1,166	0.61

Frequency of OPP Function Use

Table 3.4 provides the frequency of OPP function use per session and per patient among active users, according to the pregnancy risk group. Frequency of function use was defined according to the taxonomy identified in Table 3.3. At the session level, a single function use was counted when any action was used at least once during a session. At the patient level, a single function use was counted when the function was used at least once across all sessions for that patient.

Table 3. 4 Frequency of portal function use per session and pregnancy among active users, according to pregnancy risk group.

	All Sessions		**Normal Sessions**		**High-Risk Sessions**		**All Pregnancies**		**Normal Pregnancies**		**High-Risk Pregnancies**	
	N = 813,895		N = 622,434		N = 191,461		N = 7,664		N = 6,233		N = 1,431	
	n	%	n	%	n	%	n	%	n	%	n	%
Visits	256,166	31.47	199,086	31.99	57,080	29.81	7,446	97.16	6,035	96.82	1,411	98.60
MyRecord	201,217	24.72	154,020	24.74	47,197	24.65	7,659	99.93	6,228	99.92	1,431	100.00
Messaging	83,378	10.24	63,076	10.13	20,302	10.60	7,087	92.47	5,737	92.04	1,350	94.34
Billing	83,133	10.21	66,931	10.75	16,202	8.46	6,827	89.08	5,565	89.28	1,262	88.19
Proxy	10,730	1.32	8,254	1.33	2,476	1.29	1,925	25.12	1,555	24.95	370	25.86
Preferences	8,107	1.00	6,491	1.04	1,616	0.84	3,387	44.19	2,764	44.34	623	43.54

Custom	5,673	0.70	4,507	0.72	1,166	0.61	2,500	32.62	1,991	31.94	509	35.57
Medical tools	3,875	0.48	3,104	0.50	771	0.40	2,254	29.41	1,810	29.04	444	31.03
Resources	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

At the session level, the most frequently used functions were Visits (31.47%), MyRecord (24.72%), Messaging (10.24%) and Billing (10.21%). These are also the most frequently used functions for both pregnancy risk groups, with use of these four functions beings relatively similar between the two groups. The most frequently used functions at the patient level were the same as those at the session level, namely MyRecord (99.93%), Visits (97.16%), Messaging (92.47%) and Billing (89.08%). Women with a high-risk pregnancy used MyRecord (100.00%), Visits (98.60%), and Messaging (94.34%) functions slightly more than those with a normal risk pregnancy (99.92%, 96.82%, and 92.04%, respectively). The Billing function was used more among women with a normal risk pregnancy (89.28%) compared to those with a high-risk pregnancy (88.19%).

Comprehensiveness of Use

Table 3.5 shows the comprehensiveness of use results at the session and patient levels, in which comprehensiveness is defined as the number of distinct functions that the patient engaged with during a session or pregnancy. Sessions in which women engaged with just one of the nine functions (46.47%) were most common, though there were also many in which no functions were used (38.61%). Sessions in which no functions were used may have occurred when a woman failed to engage with the OPP for what was deemed a significant period of time (see Data Model).

Few sessions (14.93%) involved the use of more than one portal function. There were more sessions using one function among women with a normal pregnancy (46.81%) compared to those

with a high-risk pregnancy (45.36%). The distributions of comprehensiveness among women with normal and among women with high-risk pregnancy were similar to the overall sample. At the patient level, most women used four to six functions over the duration of a pregnancy, and this is true among both pregnancy risk groups.

Table 3. 5 Comprehensiveness of use per session and pregnancy among active users, according to pregnancy risk group

	All Sessions		**Normal Sessions**		**High-Risk Sessions**		**All Pregnancies**		**Normal Pregnancies**		**High-Risk Pregnancies**	
	N = 813,895		N = 622,434		N = 191,461		N = 7,664		N = 6,233		N = 1,431	
Functions used	n	%	n	%	n	%	n	%	n	%	n	%
0	314,233	38.61	236,428	37.98	77,805	40.64	2	0.03	2	0.03	0	0.00
1	378,214	46.47	291,368	46.81	86,846	45.36	9	0.12	7	0.11	2	0.14
2	94,237	11.58	73,027	11.73	21,210	11.08	98	1.28	87	1.40	11	0.77
3	23,745	2.92	18,786	3.02	4,959	2.59	512	6.68	422	6.77	90	6.29
4	3,021	0.37	2,473	0.40	548	0.29	1,894	24.71	1,554	24.93	340	23.76
5	401	0.05	318	0.05	83	0.04	2,288	29.85	1,877	30.11	411	28.72
6	41	0.01	31	0.00	10	0.01	1,864	24.32	1,476	23.68	388	27.11
7	3	0	3	0.00	0	0.00	832	10.86	683	10.96	149	10.41
8	0	0.00	0	0.00	0	0.00	165	2.15	125	2.01	40	2.80
9	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Temporal Summary of Median Function Use

Figure 3.1 shows the median number of sessions with at least one portal function used during each trimester of a pregnancy among active users, according to the pregnancy risk group. Trimesters were calculated using the estimated delivery date, according to the ACOG guidelines. Median function use increased over time for each pregnancy risk group. The increase in median use over each trimester was distinctly greater among women with a high-risk pregnancy compared to all women with a pregnancy, while the increase in median use was slightly less among those with a normal risk pregnancy compared to all women.

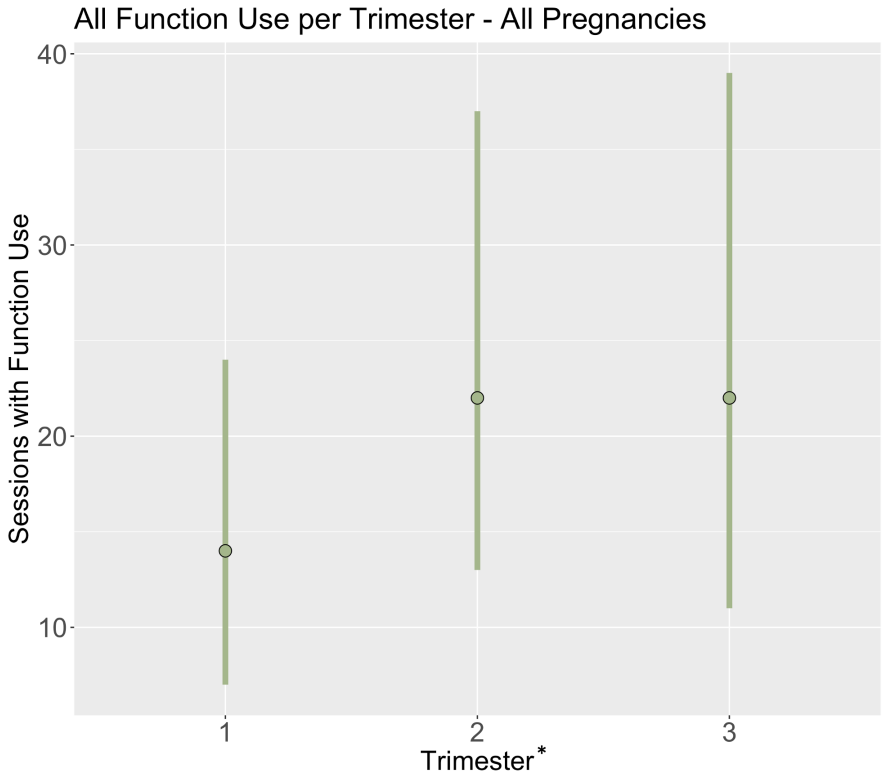


Figure 3. 1 Median function use per trimester among all women. * Median OPP function use with significant difference at $p<0.01$ level across trimesters; median OPP function use with significant different values at $p<0.05$ between trimesters 1-2 and 1-3. Error bars indicate the interquartile range equal to the 75^{th} and 25^{th} percentiles of median function use at each trimester. Kruskal–Wallis used to test for overall significant differences in median OPP function use across all trimesters. Wilcoxon rank-sum tests used to examine significant differences in median OPP function use between trimesters and pregnancy risk groups at each trimester.

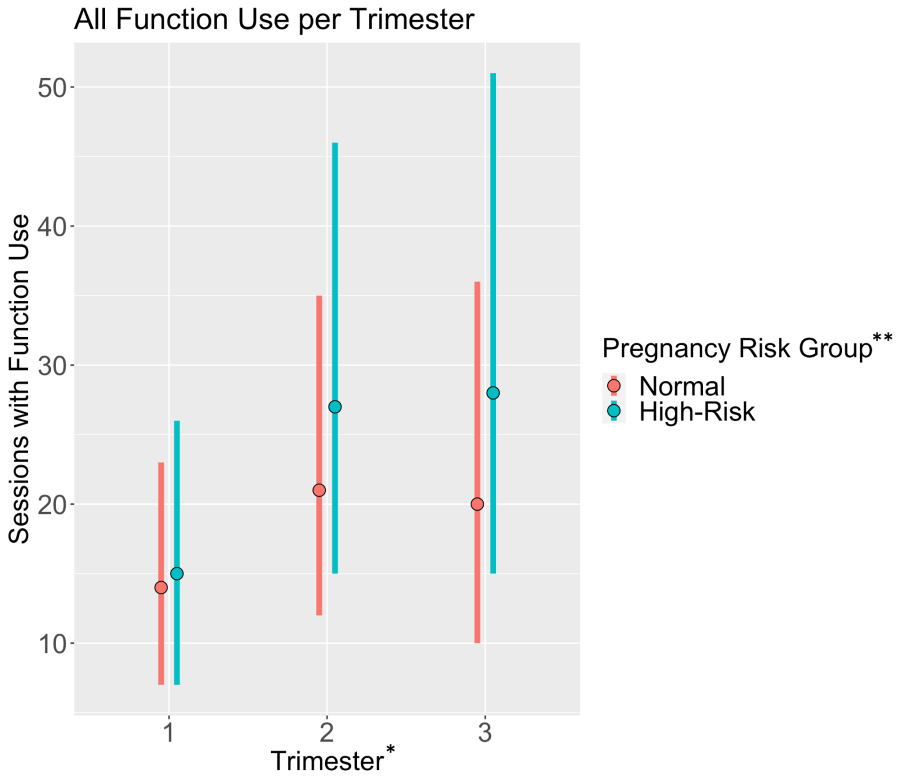


Figure 3. 2 Median function use per trimester among all women with either a normal or high-risk pregnancy. * Median OPP function use with significant difference at $p<0.01$ level across trimesters; median OPP function use with significant different values at $p<0.05$ between trimesters 1-2 and 1-3 among high-risk pregnancy group, and between all trimesters among normal pregnancy group. ** Median OPP function use with significant different values at $p<0.05$ between trimesters pregnancy risk groups at each trimester. Error bars indicate the interquartile range equal to the 75th and 25th percentiles of median function use at each trimester. Kruskal–Wallis used to test for overall significant differences in median OPP function use across all trimesters. Wilcoxon rank-sum tests used to examine significant differences in median OPP function use between trimesters and pregnancy risk groups at each trimester.

Figure 3.3 shows the median number of sessions with at least one use of the MyRecord, Visits, Messaging, or Billing function during each trimester of a pregnancy among active users, according to the pregnancy risk group. Overall, median function use increased significantly ($p<0.05$) from 14 sessions of functions use in the first trimester to 22 sessions in the second and third trimesters. The median use of each function was significantly greater among women with a high-risk pregnancy compared to women with a normal pregnancy at each trimester ($p<0.05$).

Among women with a normal pregnancy, median use of the MyRecord and Messaging functions significantly decreased between the second (7 sessions/trimester and 2 sessions/trimester, respectively) and third trimesters (6 sessions/trimester and 1 session/trimester, respectively; $p<0.05$). Among women with a high-risk pregnancy, median use of the Messaging function significantly decreased between the second (3 sessions/trimester) and third trimesters (2 sessions/trimester, $p<0.05$). Median use of the Visits function significantly increased each trimester among both pregnancy risk groups ($p<0.05$), and women with a high-risk pregnancy had significantly more sessions of use during the second and third trimesters compared to women with a normal pregnancy ($p<0.05$). There was not a significant difference in median use of the Billing function between pregnancy risk groups, though use did significantly increase for each group between the first and second trimesters ($p<0.05$).

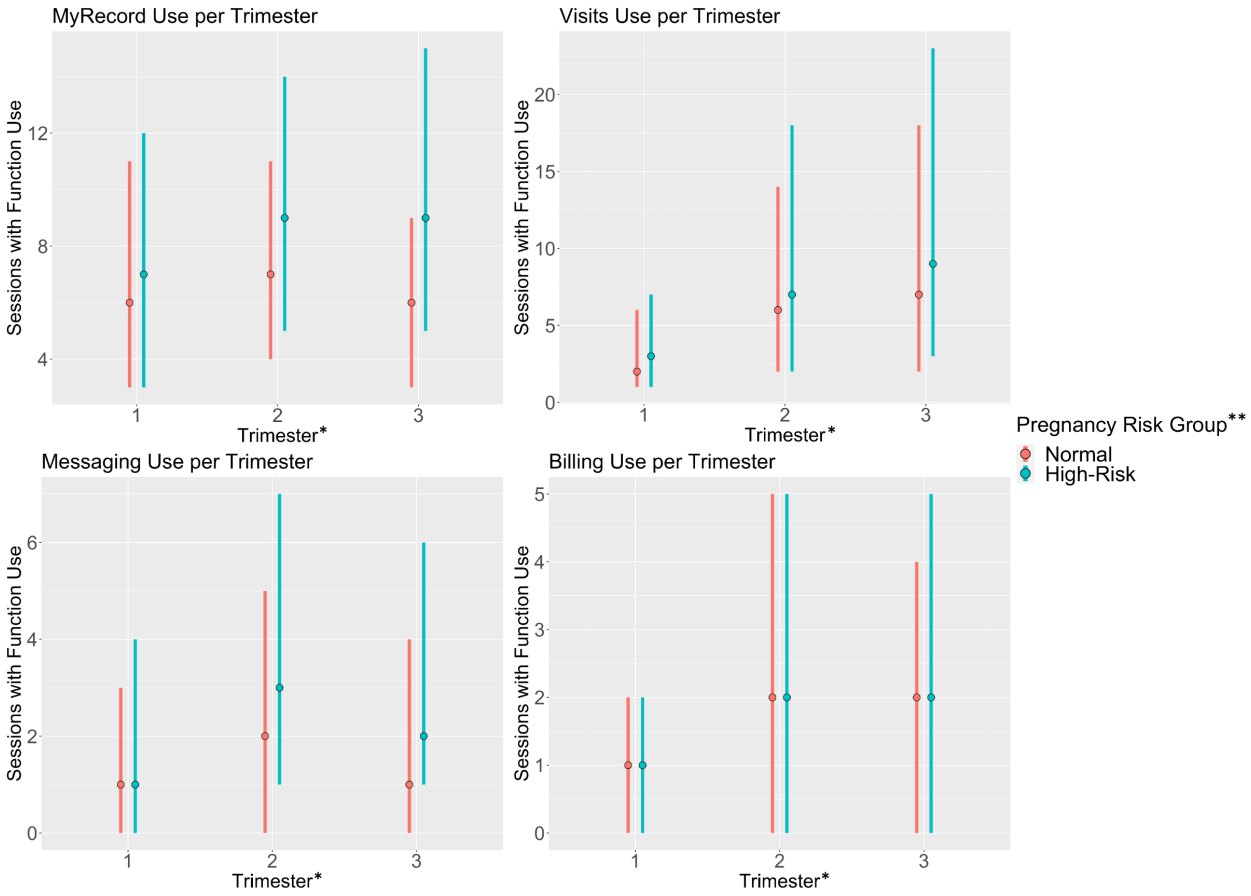


Figure 3. 3 Median (a) MyRecord, (b) Visits, (c) Messaging, and (d) Billing use per trimester among all women. * Median OPP function use with significant difference at $p<0.01$ level across trimesters for all functions in (a)-(d); among normal pregnancy group, median OPP function use with significant different values at $p<0.05$ between all trimesters for all functions in (a)-(d); among high-risk pregnancy, median OPP function use with significant different values at $p<0.05$ between all trimesters for function in (b) and between trimesters 1-2 and 1-3 for functions in (a),(c), and (d). ** Median OPP function use with significant different values at $p<0.05$ between pregnancy risk groups at all trimester for functions in (a) and (c), and at second and third trimester for function in (b). Error bars indicate the interquartile range equal to the 75th and 25th percentiles of median function use at each trimester. Kruskal–Wallis used to test for overall significant differences in median OPP function use across all trimesters. Wilcoxon rank-sum tests used to examine significant differences in median OPP function use between trimesters and pregnancy risk groups at each trimester.

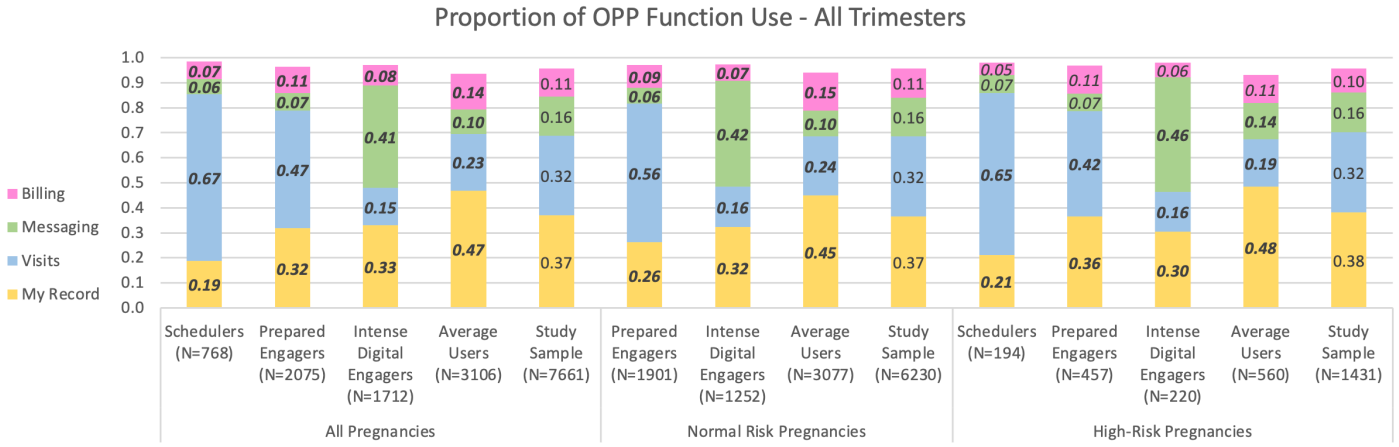
Cluster Analyses According to Proportion of Use

The following sections present results from hierarchical cluster analyses performed among each pregnancy risk group at each cross-sectional time point according to proportions of

OPP function use. In addition, we present post hoc measurements used to further characterize clusters of function use. Unless otherwise specified, all differences in OPP use and post hoc measurements across clusters and between clusters are statistically significant ($p<0.01$ and $p<0.05$, respectively). Individual p-values from one-way ANOVA tests and DMRTs are plotted in Appendix B.

All Women During Entire Pregnancy Period

Figure 3.4 shows the results from the hierarchical cluster analyses during all trimesters of a pregnancy, according to pregnancy risk groups. Review of the Calinski/Harabasz pseudo-F indexes, Duda/Hart scores, and the dendrograms for cluster analyses using the study sample of each pregnancy risk group led to the selection of five clusters to categorize all pregnant women, four clusters to categorize women with a normal risk pregnancy and five clusters to categorize women with a high-risk pregnancy. While clusters are identified according to proportions of OPP use, only the proportions for the top four OPP functions are presented in each cluster for the figures below as the remaining functions were rarely used.



Percent of Sample	10%	27%	22%	41%		31%	20%	49%		14%	32%	15%	39%	
Sessions per Pregnancy (SD)	***111.42 (70.31)***	***129.12 (82.37)***	***61.46 (49.54)***	***79.89 (65.84)***	*92.27 (72.91)*	***119.92 (273.3)***	***58.77 (275.05)***	***76.37 (273.34)***	*86.12 (273.69)*	*147.22 (91.68)*	*152.54 (98.69)*	*88.96 (68.94)*	*93.69 (72.89)*	*119.01 (88.89)*
Pregnancy Length (days) (SD)	*272.3 (11.18)*	*272 (12.33)*	***273.67 (11.95)***	*271.94 (19.64)*	*272.4 (15.58)*	*273.3 (273.3)*	*275.05 (275.05)*	*273.34 (273.34)*	*273.69 (273.69)*	265.96 (12.46)	266.61 (13.63)	265.4 (14.91)	266.93 (19.53)	266.45 (16.25)
Days to First Session (SD)	*61.27 (15.47)*	*62.25 (15.9)*	***63.39 (15.68)***	***66.05 (15.54)***	*63.95 (15.76)*	***61.55 (273.3)***	***63.14 (275.05)***	***65.3 (273.34)***	*63.72 (273.69)*	*62.34 (16.46)*	*63.91 (17.98)*	*63.02 (17.8)*	***67.46 (17.46)***	*64.95 (17.65)*
Days to Last Session (SD)	*93.48 (5.16)*	*93.92 (4.57)*	***91.65 (7.08)***	***92.19 (6.71)***	*92.67 (6.21)*	***93.65 (273.3)***	***91.57 (275.05)***	***92.08 (273.34)***	*92.46 (273.69)*	*94.34 (4.02)*	*93.93 (5.57)*	*92.7 (5.65)*	*93.37 (5.25)*	*93.58 (5.29)*
Days to Delivery (SD)	*210.97 (19.31)*	*209.63 (20.11)*	*210.25 (18.8)*	***205.97 (24.58)***	*208.4 (21.79)*	*211.31 (273.3)*	*211.81 (275.05)*	*207.82 (273.34)*	*209.68 (273.69)*	204.49 (21.45)	204.19 (22.55)	202.99 (22.53)	200.43 (24.61)	202.56 (23.29)
Days to Estimated Delivery (SD)	*218.73 (15.47)*	*217.75 (15.9)*	***216.61 (15.68)***	***213.95 (15.54)***	*216.05 (15.76)*	***218.45 (273.3)***	***216.86 (275.05)***	***214.7 (273.34)***	*216.28 (273.69)*	*217.66 (16.46)*	*216.09 (17.98)*	*216.98 (17.8)*	***212.54 (17.46)***	*215.05 (17.65)*
MFM Visit Count (SD)	*0.9 (2.79)*	*0.96 (3.22)*	***1.55 (4.51)***	***1.27 (3.76)***	*1.21 (3.73)*	-	-	-	-	***4.72 (4.92)***	*5.84 (6.12)*	***9.17 (7.27)***	*6.56 (6.29)*	*6.48 (6.36)*
OB Visit Count (SD)	*11.6 (5.81)*	*12.34 (5.83)*	*12.32 (6.26)*	*11.78 (6.87)*	*12.03 (6.37)*	***12.49 (4.74)***	***13.79 (4.87)***	***12.92 (5.61)***	*12.96 (5.23)*	*10.24 (8.58)*	*9.53 (9.05)*	*6.33 (8.24)*	*6.61 (8.57)*	*7.99 (8.82)*
Total Visit Count (SD)	*12.5 (5.51)*	*13.3 (5.39)*	***13.87 (5.28)***	*13.05 (6.29)*	*13.25 (5.77)*	***12.49 (4.74)***	***13.79 (4.87)***	***12.92 (5.61)***	*12.96 (5.23)*	*14.96 (7.31)*	*15.36 (7.53)*	*15.5 (6.76)*	***13.16 (7.82)***	*14.47 (7.57)*
Non-Hispanic White (%)	*491 (63.93)*	*1353 (65.2)*	*1321 (77.16)*	*2226 (71.67)*	*5391 (70.37)*	*1217 (64.02)*	*962 (76.84)*	*2145 (69.71)*	*4324 (69.41)*	*128 (65.98)*	*320 (70.02)*	*181 (82.27)*	*438 (78.21)*	*1067 (74.56)*
Non-Hispanic Black (%)	*159 (20.7)*	*374 (18.02)*	*160 (9.35)*	*418 (13.46)*	*1111 (14.5)*	*384 (20.2)*	*117 (9.35)*	*434 (14.1)*	*935 (15.01)*	*39 (20.1)*	*59 (12.91)*	*23 (10.45)*	*55 (9.82)*	*176 (12.3)*
Hispanic (%)	*31 (4.04)*	*76 (3.66)*	*49 (2.86)*	*82 (2.64)*	*238 (3.11)*	*66 (3.47)*	*32 (2.56)*	*97 (3.15)*	*195 (3.13)*	*10 (5.15)*	*16 (3.5)*	*3 (1.36)*	*14 (2.5)*	*43 (3)*
Race-Ethnicity Other (%)	*87 (11.33)*	*272 (13.11)*	*182 (10.63)*	*380 (12.23)*	*921 (12.02)*	*234 (12.31)*	*141 (11.26)*	*401 (13.03)*	*776 (12.46)*	*17 (8.76)*	*62 (13.57)*	*13 (5.91)*	*53 (9.46)*	*145 (10.13)*

Figure 3. 4 Proportion of OPP use and summary statistics during all trimesters by OPP cluster types and study sample, according to pregnancy risk group. *Italicized* values indicate OPP function use or post hoc measurement with significant difference at $p<0.01$ level across clusters. **Bold** values indicate OPP function use or post hoc measurement significantly different values at $p<0.05$ for a particular cluster relative to other clusters. Total proportions do not add to 1.00 as only top four functions are shown. One-way ANOVA and Kruskal–Wallis used to test for overall significant differences across entire set of clusters among each pregnancy risk group; Duncan multiple range tests used to examine significant differences in means across individual clusters of each pregnancy risk group.

Among all pregnancies, OPP users primarily spent their time using MyRecord (37%) and Visits (32%), while using Messaging (16%) and Billing (11%) with the remainder of their time. This OPP use cluster is presented as the "Study Sample" (SS) Column in the "All Pregnancy Episodes" section of Figure 3.4, and is used as the standard for identifying the remaining clusters of OPP user groups. The "Average Users" (AUs) made up 41% of the SS and were most similar to the SS with frequent use of MyRecord (47%) and Visit (23%). The AUs demonstrated slightly more use of Billing (14%), though they used Messaging (10%) slightly less than SS (16%). The "Schedulers" (SCs) cluster made up only 10% of the SS and was comprised of those who primarily used the Visits (67%) function, occasionally used MyRecord (19%) and rarely used Billing (7%) and Messaging (6%). The "Prepared Engagers" (PEs) cluster made up 27% of the SS and consisted of those who mostly used the Visits (47%) and MyRecord (32%) functions, and rarely used Billing (11%) and Messaging (7%). Finally, the "Intense Digital Engagers" (IDEs) were 22% of the SS and split most of their use between Messaging (41%) and MyRecord (33%) and less frequently used Visits (15%) and Billing (8%).

Post hoc analyses from clusters among all pregnant women showed that the IDEs have far fewer sessions of use per pregnancy (61.46) compared to the SS (92.27), while the PEs have the most sessions per pregnancy (129.12). SCs and PEs had the least days to first session (61.27 and 62.25, respectively) and most days to last session (93.48 and 93.92, respectively), indicating that their use of the OPP began earlier and stopped later into a pregnancy compared to other clusters. Conversely, AUs started the latest (66.5) and IDEs stopped the earliest (91.65) compared to other clusters. In addition, we saw that IDEs met with their providers the most (13.87 visits) and SCs

the least (12.5) throughout a pregnancy. Finally, the SS was predominantly represented by non-Hispanic white women (70.37%), followed by non-Hispanic black women (14.5%), women of other race-ethnicity (12.02%), and Hispanic women (3.11%). The IDE cluster contained the most non-Hispanic white women (77.61%) and least non-Hispanic black women (9.35%), while the PEs and SCs had fewer non-Hispanic white women (65.2% and 63.93%, respectively) and more non-Hispanic black women (18.02% and 20.7%, respectively).

Women with Normal and High-Risk Pregnancy During Entire Pregnancy Period

Women within the SS of the normal and high-risk pregnancy groups similarly used the MyRecord and Visits functions most often, while Messaging and Billing were used less. The shared clusters between pregnancy risk groups were PEs, IDEs, and AUs. The AUs clusters are largest within both pregnancy risk groups, though more women with a normal pregnancy were AUs (49%) compared to women with a high-risk pregnancy (39%). SCs were the least common cluster among both pregnancy risk groups, as seen by the absence of SCs among women with a normal pregnancy and only 14% of users being SCs among women with a high-risk pregnancy. Lastly, more women with a normal pregnancy were IDEs (20%) compared to those with a high-risk pregnancy (15%).

Post hoc analyses demonstrated that women with a high-risk pregnancy have many more sessions (119.01) and more visits with a provider (14.47) per pregnancy compared to those with a normal pregnancy (86.12 and 13.25, respectively), though this difference was not tested for significance. Among women with a high-risk pregnancy, we saw that PEs had the most sessions per pregnancy (152.54), while IDEs had the least (88.96). Comparatively, PEs among women with

a normal pregnancy also had the most sessions per pregnancy (119.82) and IDEs had the least (58.77).

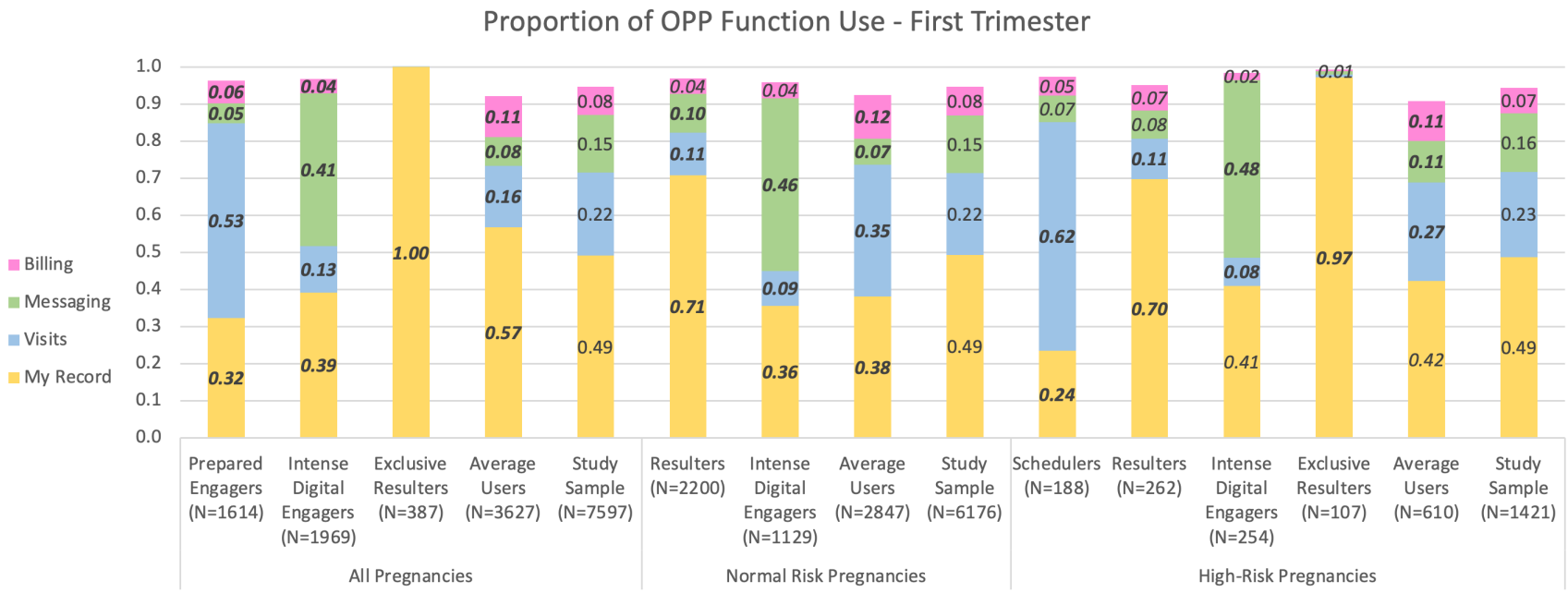
In addition, we saw that clusters that had higher use of the Visits function (PEs among normal pregnancy and SCs among high-risk pregnancy) had fewer days to first session of use (61.55 and 62.34, respectively) and more days to last session of use (93.65 and 94.34, respectively) compared to other clusters. In other words, women in these clusters began using the OPP slightly earlier and continued using it longer into their pregnancies compared to women in the SS. The AUs of these pregnancy groups were the inverse of PEs among women with a normal pregnancy and SCs among women with a high-risk pregnancy, in that they tend to start later and stop earlier compared to the SS in their respective pregnancy group. However, PEs and AUs among women with a high-risk pregnancy did not differ in their days to last use (93.93 vs 93.37, respectively).

Finally, we saw that racial and ethnic differences among clusters persisted when comparing between pregnancy risk groups. For instance, non-Hispanic white women were more common among IDEs of women with a high-risk pregnancy (82.27%) compared to those with a normal pregnancy (76.84%). Non-Hispanic black women were more common among the PEs of women with a normal pregnancy (20.2%) compared to other clusters with great use of the Visits function (PEs: 12.91%; and SCs: 20.1%) among the women with a high-risk pregnancy.

All Women During First Trimester

Within the SS of all pregnancies during the first trimester (Figure 3.5), we saw that OPP users primarily spent their time using MyRecord (49%), while they used Visits (22%), Messaging (15%) and Billing (8%) less often. The AUs made up 48% of the SS and were most similar to the SS with frequent use of MyRecord (57%), occasional use of Visits (16%) and less use of Billing

(11%) and Messaging (8%). The IDEs were 26% of the SS and split most of their use between Messaging (41%) and MyRecord (39%) and less frequently used Visits (13%) and Billing (4%). The PEs cluster made up 21% of the SS and consisted of those who mostly used the Visits (53%) and MyRecord (32%) functions, and rarely used Billing (6%) and Messaging (5%). Finally, the "Exclusive Resulters" (ERTs) cluster was a new group of women who only used the MyRecord (100%) function, and made up only 5% of the SS.



Percent of Sample	21%	26%	5%	48%		36%	18%	46%		13%	18%	18%	8%	43%	
Sessions per Trimester (SD)	***27 (22.26)***	***17.01 (18.03)***	***5.74 (5.14)***	***21.73 (19.1)***	*20.81 (19.72)*	***17.98 (16.59)***	***14.07 (13.66)***	***24.13 (21.18)***	*20.1 (18.83)*	*27.84 (23.84)*	*25.38 (23.13)*	***19.98 (20.48)***	***10.36 (9.66)***	*26.05 (24.18)*	*23.9 (22.95)*
Days to First Session (SD)	*62.13 (16.07)*	*63.01 (16.02)*	***76.32 (14.58)***	*63.58 (14.81)*	*63.77 (15.67)*	***65.01 (14.28)***	***63.78 (15.38)***	***62.31 (15.71)***	*63.54 (15.2)*	*64.87 (16.81)*	*64.33 (14.65)*	*63.01 (18.48)*	***74.53 (17.49)***	*63.95 (18.08)*	*64.77 (17.57)*
Days to Last Session (SD)	***93.78 (5.04)***	***92.39 (6.35)***	***87.45 (10.36)***	***92.98 (5.54)***	*92.71 (6.14)*	***91.55 (7.26)***	***92.07 (6.43)***	***93.44 (5.22)***	*92.52 (6.3)*	*94.22 (4.29)*	*93.55 (5.71)*	*93.16 (5.06)*	***92.09 (7.13)***	*93.81 (5.08)*	*93.57 (5.3)*
Non-Hispanic White (%)	*1025 (63.51)*	*1458 (74.05)*	*302 (78.04)*	*2565 (70.72)*	*5350 (70.42)*	*1571 (71.41)*	*842 (74.58)*	*1878 (65.96)*	*4291 (69.48)*	127 (67.55)	193 (73.66)	198 (77.95)	89 (83.18)	452 (74.1)	1059 (74.52)
Non-Hispanic Black (%)	*329 (20.38)*	*242 (12.29)*	*51 (13.18)*	*473 (13.04)*	*1095 (14.41)*	*315 (14.32)*	*122 (10.81)*	*483 (16.97)*	*920 (14.9)*	38 (20.21)	24 (9.16)	22 (8.66)	13 (12.15)	78 (12.79)	175 (12.32)
Hispanic (%)	*62 (3.84)*	*52 (2.64)*	*7 (1.81)*	*114 (3.14)*	*235 (3.09)*	*60 (2.73)*	*35 (3.1)*	*98 (3.44)*	*193 (3.12)*	8 (4.26)	11 (4.2)	9 (3.54)	0 (0)	14 (2.3)	42 (2.96)
Race-Ethnicity Other (%)	*198 (12.27)*	*217 (11.02)*	*27 (6.98)*	*475 (13.1)*	*917 (12.07)*	*254 (11.55)*	*130 (11.51)*	*388 (13.63)*	*772 (12.5)*	15 (7.98)	34 (12.98)	25 (9.84)	5 (4.67)	66 (10.82)	145 (10.2)

Figure 3. 5 Proportion of OPP use and summary statistics during first trimester by OPP cluster types and study sample, according to pregnancy risk group. *Italicized* values indicate OPP function use or post hoc measurement with significant difference at $p<0.01$ level across clusters. **Bold** values indicate OPP function use or post hoc measurement significantly different values at $p<0.05$ for a particular cluster relative to other clusters. Total proportions do not add to 1.00 as only top four functions are shown. One-way ANOVA and Kruskal–Wallis used to test for overall significant differences across entire set of clusters among each pregnancy risk group; Duncan multiple range tests used to examine significant differences in means across individual clusters of each pregnancy risk group.

Post hoc analyses from clusters among all pregnant women during the first trimester showed that the IDEs have less sessions of use per pregnancy (17.01) compared to other clusters, while the PEs have the most sessions per pregnancy (27.0). The ERT cluster had far fewer sessions per pregnancy (5.74) compared to other clusters. Through the second and third trimesters, in fact, the IDEs cluster and clusters centered on MyRecord use (i.e., RTs and ERTs) continued to have fewer sessions of use per pregnancy compared to other clusters, while the SCs continued have the most sessions per pregnancy (Tables 3.6-3.7). PEs had the least days to first session (62.1), though not significantly, and most days to last session (93.78), indicating that their use of the OPP began earlier and stopped later in the first trimester compared to other clusters. Conversely, ERTs started the latest (76.32) and stopped the earliest (87.45) compared to other clusters. Similar to PEs from the first trimester, SCs during the second and third trimesters began their use of the OPP earlier and continued using it later into a pregnancy compared to other clusters. However, this only holds true among women with a normal pregnancy as days to the last session of OPP use did not significantly differ among clusters of women with a high-risk pregnancy during the third trimester. Clusters centered on MyRecord use during the second and third trimesters also started the latest and stopped the earliest compared to other clusters.

Regarding the racial and ethnic differences among all women during the first trimester, the SS was predominantly represented by non-Hispanic white women (70.42%), followed by non-Hispanic black women (14.41%), women of other race-ethnicity (12.07%), and Hispanic women (3.09%). The ERT and IDE clusters contained the most non-Hispanic white women (78.04% and 74.05%, respectively) and few non-Hispanic black women (13.18% and 12.29%, respectively), while the PEs had the least non-Hispanic white women (63.51%) and most non-

Hispanic black women (20.38%). The increased prevalence of non-Hispanic white women among the RTs, ERTs, and IDEs clusters compared to the clusters centered on use of the Visits function (i.e., SCs and PEs) continued among all women during the second and third trimesters as well (Tables 3.6-3.7).

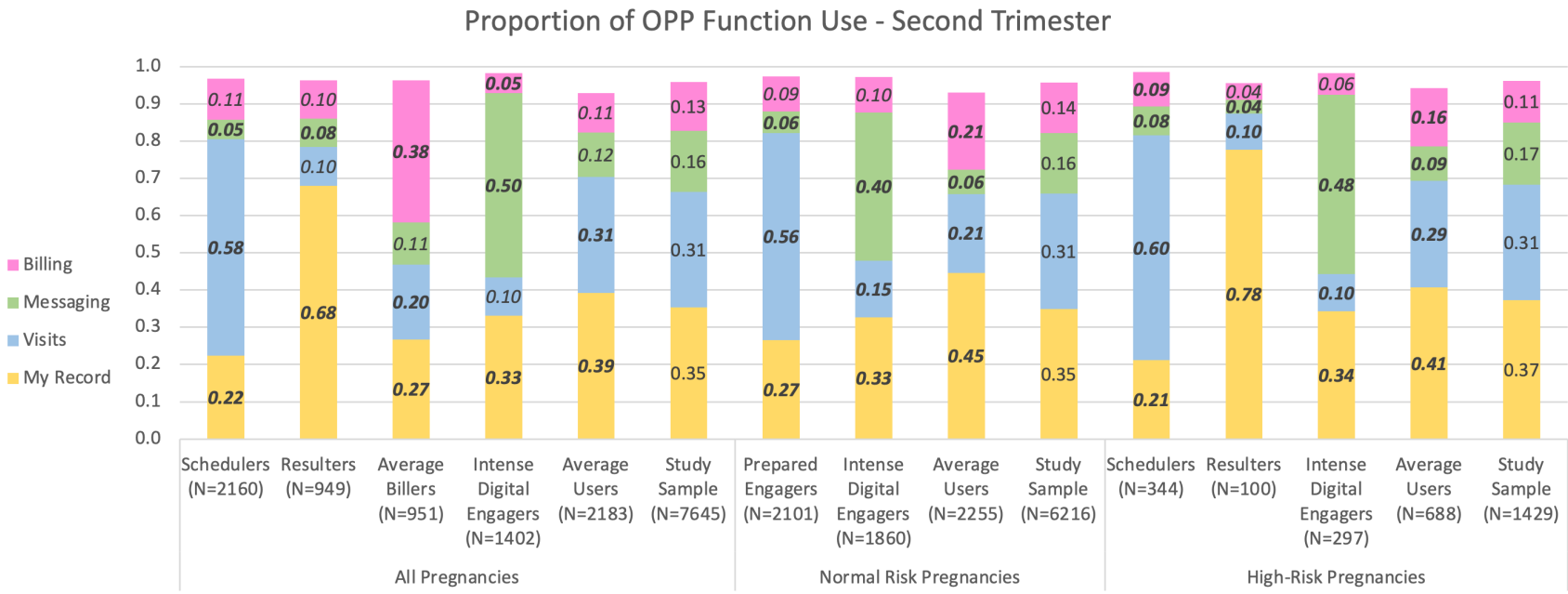
Women with Normal and High-Risk Pregnancy During First Trimester

During the first trimester, the MyRecord function was used most often according to the SS of the normal and high-risk pregnancy groups, while Visits, Messaging and Billing were used less. The "Resulters" (RTs) cluster was new to both pregnancy risk groups and was composed of women who primarily used MyRecord (70% in each group). The shared clusters between pregnancy risk groups were RTs, IDEs, and AUs. Similar to all pregnant women during the first trimester, the AUs are the largest cluster among both pregnancy risk groups.

Our post hoc analyses again showed that women with a high-risk pregnancy tend to have more sessions (23.9) per trimester compared to those with a normal pregnancy (20.1), whereas they have a similar number of days to first and last sessions, though these this were not tested for significance. Of note, we expected there to be many days to first session during the first trimester as women have not yet begun meeting with providers for pregnancy-related care. The gap between the average number of sessions for each pregnancy risk group continued to increase through the second (43.97 vs 32.2, respectively) and third (51.48 vs 34.21, respectively) trimesters (Tables 3.6-3.7). Finally, we continued to see a greater prevalence of non-Hispanic white women among the RTs, ERTs, and IDEs clusters in both pregnancy risk groups when compared to the clusters centered on use of the Visits function (i.e., SCs and PEs). These racial and ethnic differences between clusters in each pregnancy risk group persisted through each trimester.

All Women During Second Trimester

The study sample of all pregnancies during the second trimester (Figure 3.6) was similarly composed of OPP users who primarily spent their time using MyRecord (35%) and Visits (31%). Compared to the previous trimester, MyRecord use decreased while Visits use increased among the SS. The sample was composed of AUs (29%), SCs (28%), IDEs (18%), RTs (12%) and "Average Billers" (ABs: 12%). The ABs cluster was a new cluster consisting of those who used the Billing (38%), MyRecord (27%), and Visits (20%) functions most often, and occasionally used Messaging (11%).

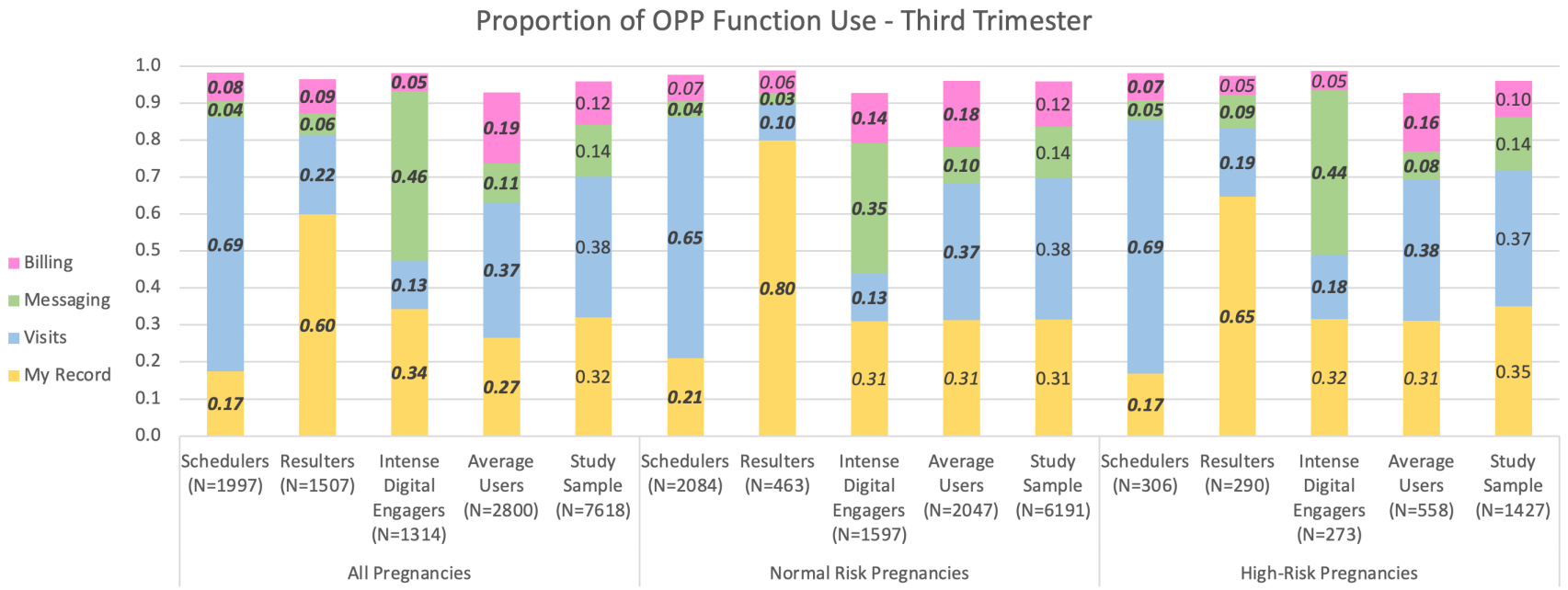


Percent of Sample	28%	12%	12%	18%	29%		34%	30%	36%		24%	7%	21%	48%	
Sessions per Trimester (SD)	***44.1 (32.76)***	*22.6 (22.16)*	***30.72 (26)***	*22.6 (20.61)*	***39.13 (30.69)***	*34.4 (29.53)*	***42.99 (29.79)***	***24.46 (20.36)***	***28.55 (25.79)***	*32.2 (26.97)*	***55.68 (46.16)***	*28.49 (25.15)*	***31.58 (28.66)***	*45.7 (34.78)*	*43.97 (37.3)*
Days to First Session (SD)	***4.4 (8.47)***	***9.51 (15.72)***	*5.57 (9.93)*	***6.84 (11.01)***	*5.59 (10.24)*	*5.97 (10.85)*	***4.18 (8.01)***	***6.7 (10.88)***	***7.51 (13.52)***	*6.14 (11.2)*	*4.58 (8.42)*	***8.74 (13.66)***	*5.39 (8.31)*	*4.9 (8.9)*	*5.19 (9.14)*
Days to Last Session (SD)	***92.31 (9.11)***	***87.16 (15.1)***	***89.94 (11.98)***	***88.69 (12.91)***	***91.41 (9.69)***	*90.46 (11.41)*	***92.49 (8.5)***	*89.17 (12.01)*	*88.69 (13.33)*	*90.12 (11.62)*	*93.58 (6.82)*	***87.92 (17.88)***	*90.86 (10.28)*	*92.11 (10.11)*	*91.91 (10.32)*
Non-Hispanic White (%)	*1405 (65.05)*	*692 (72.92)*	*708 (74.45)*	*1101 (78.53)*	*1475 (67.57)*	*5381 (70.39)*	*1320 (62.83)*	*1386 (74.52)*	*1608 (71.31)*	*4314 (69.4)*	239 (69.48)	80 (80)	237 (79.8)	511 (74.27)	1067 (74.67)
Non-Hispanic Black (%)	*414 (19.17)*	*119 (12.54)*	*61 (6.41)*	*134 (9.56)*	*379 (17.36)*	*1107 (14.48)*	*445 (21.18)*	*204 (10.97)*	*284 (12.59)*	*933 (15.01)*	55 (15.99)	6 (6)	32 (10.77)	81 (11.77)	174 (12.18)
Hispanic (%)	*82 (3.8)*	*22 (2.32)*	*22 (2.31)*	*40 (2.85)*	*72 (3.3)*	*238 (3.11)*	*79 (3.76)*	*50 (2.69)*	*66 (2.93)*	*195 (3.14)*	13 (3.78)	1 (1)	7 (2.36)	22 (3.2)	43 (3.01)
Race-Ethnicity Other (%)	*259 (11.99)*	*116 (12.22)*	*160 (16.82)*	*127 (9.06)*	*257 (11.77)*	*919 (12.02)*	*257 (12.23)*	*220 (11.83)*	*297 (13.17)*	*774 (12.45)*	37 (10.76)	13 (13)	21 (7.07)	74 (10.76)	145 (10.15)

Figure 3. 6 Proportion of OPP use and summary statistics during second trimester by OPP cluster types and study sample, according to pregnancy risk group. *Italicized* values indicate OPP function use or post hoc measurement with significant difference at $p<0.01$ level across clusters. **Bold** values indicate OPP function use or post hoc measurement significantly different values at $p<0.05$ for a particular cluster relative to other clusters. Total proportions do not add to 1.00 as only top four functions are shown. One-way ANOVA and Kruskal–Wallis used to test for overall significant differences across entire set of clusters among each pregnancy risk group; Duncan multiple range tests used to examine significant differences in means across individual clusters of each pregnancy risk group.

Women with Normal and High-Risk Pregnancy During Second Trimester

MyRecord and Visits functions were used most often during the second trimester according to the study sample of the normal and high-risk pregnancy groups, while Messaging and Billing were used less. The shared clusters between pregnancy risk groups were IDEs and AUs, while the high-risk group had SCs and RTs clusters and the normal pregnancy group had a PEs cluster. The AU clusters are largest within both pregnancy risk groups (36% normal, 48% high-risk). IDEs (30%) were the least common cluster among women with a normal pregnancy, while RTs (7%) were the least common cluster among women with a high-risk pregnancy.



	All Pregnancies					Normal Risk Pregnancies					High-Risk Pregnancies				
Percent of Sample	26%	20%	17%	37%		34%	7%	26%	33%		21%	20%	19%	39%	
Sessions per Trimester (SD)	***49.77 (37.84)***	***30.02 (26.63)***	***23.35 (23.97)***	***39.28 (37.71)***	*37.45 (34.97)*	***44.81 (34.21)***	*19.75 (20.46)*	*21.2 (25.82)*	***36.85 (30.24)***	*34.21 (31.6)*	*63.5 (47.22)*	*37.48 (29.55)*	*38.15 (32.77)*	*58.7 (49.87)*	*51.48 (44.22)*
Days to First Session (SD)	***3.66 (6.74)***	*6.78 (11.67)*	*6.97 (10.94)*	***6.07 (10.92)***	*5.73 (10.24)*	*4.25 (7.9)*	***11.13 (16.69)***	***8.56 (13.13)***	*4.96 (8.4)*	*6.11 (10.7)*	*2.87 (5.48)*	*5.25 (9.41)*	*4.49 (7.95)*	*3.97 (7.61)*	*4.09 (7.73)*
Days to Last Session (SD)	*71.7 (17.99)*	***68.29 (17.49)***	***70.06 (13.96)***	*72.12 (15.64)*	*70.9 (16.46)*	***71.8 (18.09)***	***64.59 (20.86)***	***69.96 (15.14)***	***73.91 (13.38)***	*71.48 (16.34)*	69.17 (18.19)	66.93 (15.82)	67.23 (15.63)	69.21 (16.9)	68.36 (16.75)
Non-Hispanic White (%)	*1325 (66.35)*	*1083 (71.86)*	*1017 (77.4)*	*1936 (69.14)*	*5361 (70.37)*	*1351 (64.83)*	*337 (72.79)*	*1171 (73.32)*	*1437 (70.2)*	*4296 (69.39)*	207 (67.65)	229 (78.97)	222 (81.32)	407 (72.94)	1065 (74.63)
Non-Hispanic Black (%)	*343 (17.18)*	*224 (14.86)*	*136 (10.35)*	*399 (14.25)*	*1102 (14.47)*	*396 (19)*	*68 (14.69)*	*185 (11.58)*	*279 (13.63)*	*928 (14.99)*	51 (16.67)	24 (8.28)	22 (8.06)	77 (13.8)	174 (12.19)
Hispanic (%)	*71 (3.56)*	*51 (3.38)*	*30 (2.28)*	*84 (3)*	*236 (3.1)*	*69 (3.31)*	*14 (3.02)*	*43 (2.69)*	*67 (3.27)*	*193 (3.12)*	11 (3.59)	10 (3.45)	5 (1.83)	17 (3.05)	43 (3.01)
Race-Ethnicity Other (%)	*258 (12.92)*	*149 (9.89)*	*131 (9.97)*	*381 (13.61)*	*919 (12.06)*	*268 (12.86)*	*44 (9.5)*	*198 (12.4)*	*264 (12.9)*	*774 (12.5)*	37 (12.09)	27 (9.31)	24 (8.79)	57 (10.22)	145 (10.16)

Figure 3. 7 Proportion of OPP use and summary statistics during third trimester by OPP cluster types and study sample, according to pregnancy risk group. *Italicized* values indicate OPP function use or post hoc measurement with significant difference at $p<0.01$ level across clusters. **Bold** values indicate OPP function use or post hoc measurement significantly different values at $p<0.05$ for a particular cluster relative to other clusters. Total proportions do not add to 1.00 as only top four functions are shown. One-way ANOVA and Kruskal–Wallis used to test for overall significant differences across entire set of clusters among each pregnancy risk group; Duncan multiple range tests used to examine significant differences in means across individual clusters of each pregnancy risk group.

All Women During Third Trimester

Within the SS of all pregnancies during the third trimester (Figure 3.7), OPP users primarily spent their time using Visits (38%) and MyRecord (32%), while using Messaging (14%) and Billing (12%) less often. This marks the first period in which the SS uses the Visits function more than MyRecord. The sample was composed of AUs (37%), SCs (26%), RTs (20%), and IDEs (17%).

Women with Normal and High-Risk Pregnancy During Third Trimester

During the final trimester, Visits and MyRecord functions were still used most often within the SS of the normal and high-risk pregnancy groups, while Messaging and Billing were used less. Pregnancy risk groups consisted of the same clusters: SCs, RTs, IDEs, and AUs. The AUs were most common among women with a high-risk pregnancy (39%), while SCcs were most common among those with a normal pregnancy (34%). IDEs (19%) were the least common cluster among women with a high-risk pregnancy, while RTs (7%) were the least common cluster among women with a normal pregnancy.

Temporal Summary of Movement Between Clusters

Figure 3.8 depicts the flow of all pregnant women between clusters throughout all trimesters of their pregnancy. Women in clusters were not entirely stagnant over time. Though the AUs clusters were consistently one of the largest clusters at each trimester, the majority of AUs subsequently moved to new clusters at the onset of a new trimester. Comparatively, many women remained IDEs over time, with many second trimester IDEs coming from first trimester AUs and leaving for third trimester AUs. PEs and ERTs ceased to exist after the first trimester, with most

PEs becoming SCs or AUs and ERTs primarily moving to RTs and AUs. During the second trimester, ABs and RTs were primarily composed of those who were AUs during the first trimester. The incoming clusters for third trimester AUs and RTs were well distributed, whereas third trimester SCs and IDEs saw great carryover from the second trimester. Non-users (NUs) are those who have logged a session in the OPP during a trimester, but did not engage with any of the functions listed. Few NUs persist over two trimesters, though there were no women who were NUs across all trimesters.

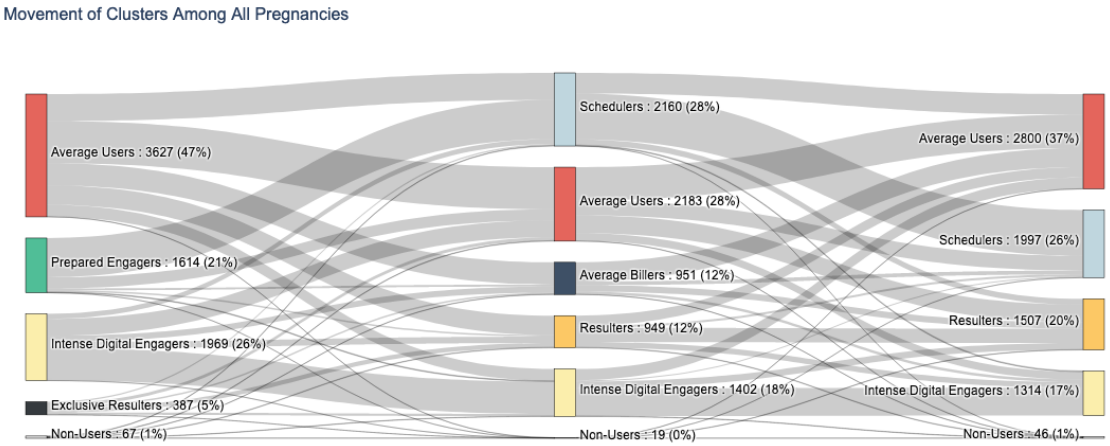


Figure 3. 8 Movement of clusters among all pregnancies, during the first, second and third trimester. Cluster names are listed with number of women and percent of total sample in each cluster.

Figure 3.9 depicts the flow of all women with a normal pregnancy between clusters throughout all trimesters of their pregnancy. Here, we see fewer overall clusters, and slightly less movement between clusters compared to all pregnancies in Figure 3.7. While AUs and IDEs endure through all trimesters, all RTs disappear as they flow into other clusters during the second

trimester only to return during the third trimester, albeit with far fewer women in the cluster. IDEs persist with great carryover through all trimesters. PEs appear only during the second trimester, consisting of mostly AUs and RTs. They eventually disappear in the third trimester as most move into SCs and AUs. SCs only appear during the third trimester, receiving many women from PEs and AUs.

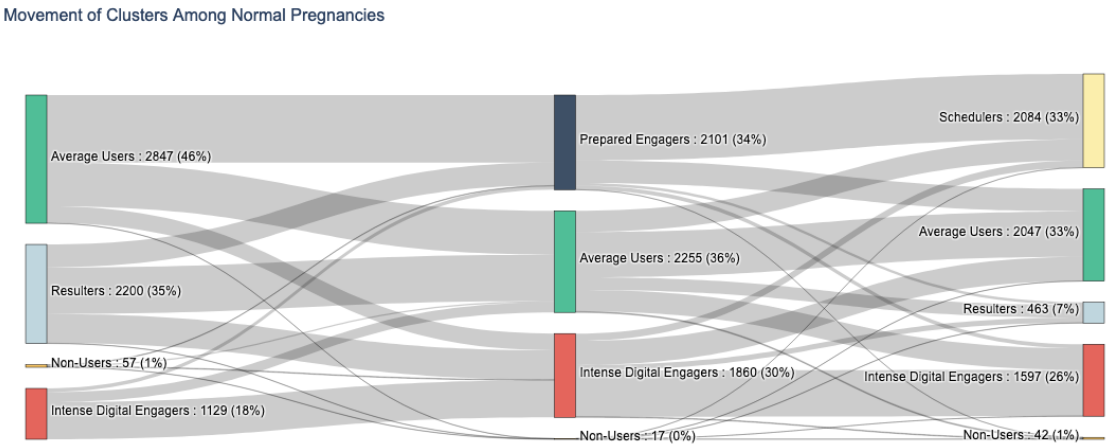


Figure 3. 9 Movement of clusters among normal pregnancies, during the first, second and third trimester. Cluster names are listed with number of women and percent of total sample in each cluster.

Lastly, Figure 3.10 depicts the flow of all women with a high-risk pregnancy between clusters throughout all trimesters of their pregnancy. Similar to Figure 3.7, which depicts all pregnant women, we saw movement between many clusters. AUs, SCs, and IDEs persist with a large amount of carryover through all trimesters. Such carryover has been especially common among IDEs in all pregnancy groups. Most first trimester RTs become second trimester AUs, with

little carryover into second trimester RTs. ERTs cease to exist after the first trimester, with most becoming AUs.

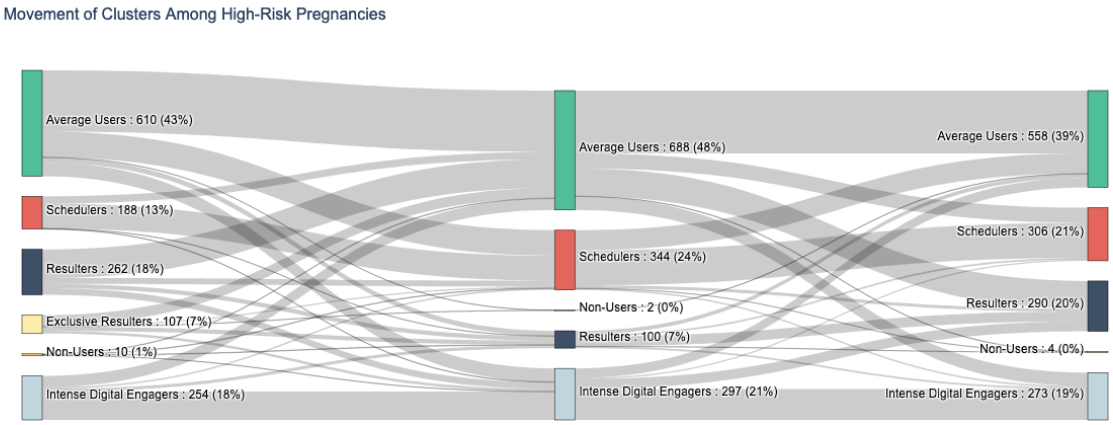


Figure 3. 10 Movement of clusters among high-risk pregnancies during the first, second and third trimester. Cluster names are listed with number of women and percent of total sample in each cluster.

Tables 3.6 and 3.7 show the percentage of women who are new to each cluster during the second and third trimesters, respectively. From the first to the second trimester, we saw that the IDEs cluster had the lowest percentage of women change clusters among all pregnancy risk groups (31.9% among all, 55.7% normal, and 45.1% high-risk). The AUs cluster was also consistently ranked with the second lowest percent change between the first and second trimesters (43.2% among all, 56.9% normal, and 48.5% high-risk). Among all pregnant women and women with a high-risk pregnancy, the RTs cluster had a high percentage of new women (100.0% and 75.0%, respectively). As explained earlier, there were entirely new clusters that arose during the second trimester, meaning 100% of the women in these clusters were in a different cluster during the first

trimester. However, not all clusters with 100% change were new during the second trimester, as the NUs cluster among women with a high-risk pregnancy was present during the first and second trimesters.

We saw similar patterns of percent change between the second and third trimesters when compared to the first and second trimesters. For instance, the IDEs cluster still had a low percent change among all pregnancy risk groups. The AUs cluster still had relatively little change among women with normal (50.9%) and high-risk (34.8%) pregnancies when compared to other clusters. While the SCs cluster changed least among all women and women with a high-risk pregnancy (32.4% and 34.0%, respectively), the lack of an SCs cluster during the second trimester among women with a normal pregnancy resulted in 100% change between the second and third trimesters, with most of these women coming from the IDEs during the second trimester.

Table 3. 6 Percent change in clusters between first and second trimesters.

All Pregnancies – Second Trimester		**Normal Pregnancies – Second Trimester**		**High-Risk Pregnancies – Second Trimester**	
Cluster	**Percent Change**	**Cluster**	**Percent Change**	**Cluster**	**Percent Change**
Intense Digital Engagers	31.9%	Intense Digital Engagers	55.7%	Intense Digital Engagers	45.1%
Average Users	43.2%	Average Users	56.9%	Average Users	48.5%
Non-Users	68.4%	Non-Users	64.7%	Schedulers	58.1%
Average Billers	100.0%	Prepared Engagers	100.0%	Resulters	75.0%
Resulters	100.0%			Non-Users	100.0%
Schedulers	100.0%				

Second trimester clusters are listed along with the percentage of women who are new to the second trimester cluster based on their proportions of function use during the second trimester.

Table 3. 7 Percent change in clusters between second and third trimesters.

All Pregnancies – Third Trimester		**Normal Pregnancies – Third Trimester**		**High-Risk Pregnancies – Third Trimester**	
Cluster	**Percent Change**	**Cluster**	**Percent Change**	**Cluster**	**Percent Change**
Schedulers	32.4%	Intense Digital Engagers	35.7%	Schedulers	34.0%
Intense Digital Engagers	37.1%	Average Users	50.9%	Intense Digital Engagers	34.8%

Average Users	64.8%	Non-Users	90.5%	Average Users	35.1%
Resulters	72.2%	Resulters	100.0%	Non-Users	75.0%
Non-Users	91.3%	Schedulers	100.0%	Resulters	80.3%

Third trimester clusters are listed along with the percentage of women who are new to the third trimester cluster based on their proportions of function use during the third trimester.

Sensitivity Analysis: OPP Use During the COVID-19 Pandemic

A final cluster analysis was performed among a subsample of women who only used the OPP between January 1, 2020, and August 1, 2020, in order to determine if clusters of OPP use varied during the COVID-19 pandemic compared to our original sample. Appendix A contains tables with the proportions of OPP use among this subsample of women, listed by pregnancy risk group and trimesters. Table A.1 demonstrates that the Visits function was used approximately two times more frequently than the MyRecord function (55% vs 27%, respectively) among the entire population of pregnant women. This disparity in use between Visits and MyRecord is very different from what we saw in the original sample of women, who engaged with the two functions relatively evenly (32% and 37%, respectively). In addition, the Proxy function was occasionally used among clusters, and has been included with the top four functions from the original sample. Finally, use of the Messaging function was rarer among these women, resulting in the loss of the IDEs cluster entirely.

The specific clusters among all women in this subsample were different from the original sample as well. While there was still an SCs cluster, which made up 42% of women in this SS, there were two new, small clusters among all women. The "Proxy Users" (PUs) cluster made up only 4% of the SS, but uniquely consisted of women who frequently used the Proxy function (31%) in addition to Visits (35%) and MyRecord (21%). The "Result Schedulers" (RSCs) made up 8% of the SS and consisted of women who predominantly used MyRecord (48%) and Visits (33%)

and rarely used Messaging (6%), Billing (10%), or Proxy (1%). The AUs remained a reflection of the larger SS, consisting of women who primarily used Visits (51%) and MyRecord (30%).

Throughout all trimesters for all women within this subsample, the SCs and AUs clusters remained the largest, while the PUs cluster and MyRecord oriented clusters (i.e., RTs, RSCs, and ERTs) remained the smallest. These trends continue, though not as clearly, when examining clusters among women with a normal pregnancy and women with a high-risk pregnancy. For instance, SCs and AUs are most common during the first and third trimesters among women with a normal pregnancy, whereas they are most common during the second and third trimesters among women with a high-risk pregnancy. The PUs cluster was still the smallest cluster among both pregnancy risk groups; however, PUs did not frequently appear among clusters at the trimester periods.

Chapter 4: Discussion

In this study, we performed cross-sectional and temporal analyses in order to characterize OPP use among pregnant women and identify profiles of OPP user groups based on the characteristics of OPP use. Furthermore, we intended to discover differences in the characteristics and clusters of OPP use between women with normal and high pregnancy-related risks in order to discern how different patient populations engage with the OPP.

Regarding the characterization of OPP use, we discovered that pregnant women in our study predominantly used only four OPP functions: MyRecord, Visits, Messaging, and Billing. These women spent 56.2% of their sessions either checking PHI using MyRecord or managing appointments using Visits, while 20.5% of sessions were spent either contacting providers using Messaging or managing payments for care using Billing (Table 3.4). Such engagement happened in short bursts though, as women rarely engaged with more than one function per session, which suggests that they may be goal-oriented when using the OPP to monitor their health and health care. Over the course of an entire pregnancy, women typically only used five of the nine available OPP functions. Lastly, the average number of sessions during which a woman used an OPP function increased each trimester among all pregnant women, suggesting that they were becoming more comfortable engaging with the OPP over time. In comparison to Di Tosto *et al.*, the patients in our overall sample primarily used the same four OPP functions, though use of the Messaging function was far less common in our study.[4] For instance, the message center action (i.e., the most frequently used action type within the Messaging function) was used in roughly 32% of the sessions in their sample, while this was used in only 6% of our sessions. It is yet to be determined why these samples differ so greatly in their usage of the Messaging function, though this could

hypothetically be driven by the difference in providers that these patient samples communicate with.

With respect to the second objective of our study, we were able to identify four unique clusters of OPP users (SCs, PEs, IDEs, and AUs), though these were not entirely consistent across trimesters. In fact, we learned that change amongst the proportions of function use over time was not uncommon, as every cluster experienced at least a 30% change in its sample of patients during the second and third trimesters (Tables 3.6-3.7). It was quite common for women in the largest clusters (i.e., the AUs clusters) to move to new clusters over time. For instance, nearly 43% of AUs during the second trimester came from a different first trimester cluster, and nearly 65% of third trimester AUs came from a different cluster. This shows that women in our largest clusters were engaging with a variety of different OPP functions over time. It should be also noted that the classification of AUs appeared to have relatively minor changes in average proportions of use in order to reflect the study sample at each trimester. Women in the IDEs cluster were among the most consistent OPP users in terms of proportions of use, as the IDEs frequently saw the least percent change within their sample of patients. The SCs also saw low turnover between the second and third trimesters. While the RTs cluster was quite common among the cluster types, it was more rare for women to stay within this cluster throughout an entire pregnancy.

Amidst this cluster movement, there were notable consistencies among certain clusters with regards to sessions of OPP use per pregnancy and race-ethnicity of pregnant women. Across all trimesters, the IDEs cluster and clusters centered on MyRecord use (i.e., RTs and ERTs) had a low number of sessions per pregnancy, while the clusters centered on use of the Visits function (i.e., SCs and PEs) had many sessions per pregnancy (Figures 3.4-3.7). Furthermore, these clusters with few sessions per pregnancy also had a higher percentage of non-Hispanic white women, and

decreased percentage of non-Hispanic black women compared to the clusters that typically had many sessions of OPP use per pregnancy. Therefore, there appears to be a relationship between a pregnant woman's race-ethnicity and her use of the OPP, such that a non-Hispanic black woman may use the OPP frequently in order to schedule and monitor in-person appointments with her provider while a non-Hispanic white woman may use the OPP sparingly in order to check lab results and digitally message with her provider, when compared to the average pregnant user. These results support previous research that demonstrated African American/black users look at their results in a patient portal less often compared to white users.[28] Future work could determine whether these racial disparities in OPP use are driven by the health literacy of individuals in these clusters, which would add to research examining a digital divide among pregnant users of patient portals.[29]

In comparison to previous studies utilizing a hierarchical clustering algorithm to identify groups of patient portal users, our study identified only four clusters among the entire sample while Jones *et al.* profiled eight electronic patient portal users and Fareed *et al.* identified five clusters of IPP users.[3,19] All studies were able to identify clusters of users who primarily used functions related to monitoring schedules and results, though the remaining clusters were quite different. For instance, since Fareed *et al.* defined clusters based on IPP use, the remaining clusters were defined by use of functions that were not available in the OPP. While the clusters identified by Jones *et al.* were based on use of an electronic patient portal that allowed users to perform similar functions (e.g., review labs, secure messaging, and manage appointments), their clustering methods incorporated measures of use (i.e., frequency, consistency, duration and intensity of use) for what we considered actions (e.g., reviewing specific lab results, reviewing message inbox, or reviewing details of a visit) compared to our methods of using proportions of function use.

Unexpectedly, frequency and comprehensiveness of portal function use were quite similar among women with normal and high-risk pregnancy episodes (Tables 3.4-3.5). However, this supports previous research that found no difference in likelihood of engaging with a secure messaging portal when comparing women with and without a high-risk pregnancy, which was defined using various clinical characteristics.[1] In regards to our temporal analysis of OPP use, women with a high-risk pregnancy demonstrated a significantly greater median OPP function use per trimester when compared to women with a normal pregnancy (Figure 3.2). This difference was especially apparent when examining MyRecord use, as women with a normal pregnancy actually used this function less after the second trimester (Figure 3.3). Additionally, we found that even though median use of the Visits function significantly increased between the second and third trimesters for both pregnancy risk groups, the median use of the Visits function was still significantly higher among women with a high-risk pregnancy compared to those with a normal pregnancy during these trimesters. Finally, we found that the median use of the Messaging function was greater among women with a high-risk pregnancy compared to those with a normal pregnancy during the second and third trimesters, even though use decreased during these trimesters. In contrast to the findings from Ukoha *et al.*, these results suggest that women with a high-risk pregnancy may engage with the results-, scheduling-, and messaging-oriented functions of an OPP more than their counterparts with a normal pregnancy over time. Furthermore, we have demonstrated that the Messaging function is not the primary function of choice among users (Tables 3.3-3.4), therefore it may be better to consider use of multiple OPP functions when examining differences between pregnancy risk groups rather than looking at use of a messaging-oriented function alone.

While the clusters of the two pregnancy risk groups were the same during the third trimester (Figure 3.7), there were numerous differences in the clusters between groups during the first and second trimesters (Figures 3.5-3.6). The common difference across all trimesters being that there were typically more clusters of OPP users among women with a high-risk pregnancy. Another notable difference between groups is the lack of an SCs cluster during the first and second trimesters of women with a normal pregnancy; however, PEs are present during the second trimester, and they are similar to SCs in their focus on use of the Visits function. Lastly, outside of the AUs, there is no cluster with an emphasis on the use of the MyRecord function (e.g., RTs or ERTs) among women with a normal pregnancy during the second trimester. These cluster omissions align with the larger differences in median MyRecord and Visits use per trimester between pregnancy risk groups, which we previously identified. In comparison to women with a normal pregnancy, those with a high-risk pregnancy may be more inquisitive in their use of the OPP in that they engage with and explore the OPP in a wider variety of ways, while also using the portal more frequently according to median use per trimester. We have yet to determine why women with a high-risk pregnancy may use an OPP in a more explorative manner, though previous research indicates that the complexity of their pregnancy care may hypothetically intensify their inclination to engage with their health care using the OPP and diminish their perception of barriers to OPP use.[30]

Building upon our temporal analysis of median function use per trimester, our post hoc analyses also demonstrated that women with a high-risk pregnancy averaged many more sessions of OPP use per pregnancy compared to those with a normal pregnancy (Figures 3.4-3.7). A review of the differences in sessions per trimester between the same clusters of each pregnancy risk group (e.g. SCs among normal risk pregnancies and SCs among high-risk pregnancies) revealed that

these differences continued to grow over time in that clusters among women with a high-risk pregnancy engaged with the OPP at a greater rate of sessions per trimester. Similar to results among all pregnant women, the IDEs cluster and clusters centered on MyRecord use continued to have a low average of sessions per trimester among both pregnancy risk groups, while the clusters centered on Visits use continued to have the highest sessions per trimester among both pregnancy risk groups. With these differences in sessions of function use per trimester growing at each trimester, it appears that women are increasingly engaging with respective OPP function over time. Furthermore, women in the IDEs cluster and clusters centered on MyRecord use continued to start OPP use later and stop OPP use earlier at each trimester among both pregnancy risk groups, while the clusters centered on Visits use among both pregnancy risk groups continuously started their OPP use early and stopped OPP use later. As a result, there may be a spectrum of engagement with the OPP, in which women with a high-risk pregnancy in a scheduling-oriented cluster engage with their preferred OPP function the most, while women with a normal pregnancy in an IDEs cluster or a results-oriented cluster engaged with their preferred OPP function the least. Women who are AUs or are in less common clusters may exist at the center of this spectrum in terms of their preference to continuously engage with the OPP.

Our results add to the foundation of research that suggests OPP use is highly heterogenous.[3,19] We were able to identify unique clusters of OPP users among our population of pregnant women, based upon differences in proportions of OPP function use, median OPP use per trimester and patient characteristics such as race and ethnicity. Future studies might benefit from our work if they intend to explore whether such patterns of OPP use could influence patient quality and clinical outcomes. For instance, it could be helpful to know if OB/GYN or MFM teams are retaining women who primarily use the Visits function more than women in other clusters. In

addition, providers might be interested in whether medication adherence is greater among women with a high-risk pregnancy who frequently track their lab results using the MyRecord function compared to those who check these infrequently. Such knowledge could influence health care teams and centers to provide further training on OPP use for both providers and patients. It would also be beneficial for future work to examine whether there are qualitative themes of OPP use, rather than quantitative alone, that might help expand our understanding of OPPs as a beneficial tool in the effort to improve quality and possibly clinical outcomes. For instance, Fareed et al. has identified that prior exposure to an OPP influences a patient's use of an IPP, which demonstrates that familiarity with health information technology should be considered when examining the impact of OPP use on outcomes.[31] Such information could help identify needed improvements to portal design that might allow for improved quantitative assessment of OPP engagement and use.

Our study is not without limitations. First, the generalizability of our study in somewhat limited given that it was preformed using data from users of single OPP portal at a single academic medical center. Nevertheless, our work adds to the larger picture of OPP use among pregnant women. Next, a portion of our study timeframe overlapped with the COVID-19 pandemic, which forced our academic medical center to rapidly transition the majority of their care to the outpatient setting with the understanding that the OPP would be used more frequently to engage with patients. We performed a final cluster analysis among women who only used the OPP between January 1, 2020, and August 1, 2020, in order to determine how clusters of OPP use during the COVID-19 pandemic differed from those in our original sample. Second, we only utilized one clustering algorithm (i.e., hierarchical clustering) to identify groups of OPP users. While *k*-means clustering is a commonly employed algorithm, we were not able to use this method given our lack of *a priori*

information regarding types of OPP users within this patient population. Our next steps could include starting a clustering algorithm with the clusters we have previously identified, and forcing these clusters to exist during each trimester in order to better examine changes in proportions of use and clusters over time. Our current use of hierarchical clustering at different points in time assumed that clusters with the same label demonstrated equal proportions of use throughout, and forcing these clusters to exist over time would help to address this assumption. Given the clusters we have now identified, future research could explore the optimal clustering algorithm for use on this data set.

In conclusion, characterizing OPP use and identifying profiles of OPP user groups among pregnant women demonstrates how specific patient populations might engage with their health. We were able to identify distinct cluster groups of OPP users among pregnancy groups, which underscores the importance of avoiding the use of generalizations when describing how patients in this population of pregnant women might engage with patient-facing technologies such as an OPP. These results can be used to improve user experience and training with OPP functions, and may educate OB/GYN and MFM providers on patient engagement with the OPP.

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Appendix A. Supplemental Tables and Figures

Sensitivity Analysis: OPP Use During the COVID-19 Pandemic

The following tables show the proportion of OPP function use among the pregnancy risk groups (i.e., all women, women with a normal pregnancy and women with a high-risk pregnancy) during the entire pregnancy period and at each trimester.

Table A. 1 Cluster Analysis - All women during entire pregnancy period

	Schedulers (N=392)	Result Schedulers (N=74)	Proxy Users (N=35)	Average Users (N=370)	Study Sample (N=871)
	42%	8%	4%	45%	
Messaging	0.058	0.058	0.039	0.066	0.061
Visits	0.660	0.332	0.351	0.506	0.554
MyRecord	0.198	0.476	0.211	0.303	0.267
Billing	0.068	0.097	0.068	0.097	0.083
Proxy	0.003	0.006	0.312	0.006	0.017

Table A. 2 Cluster Analysis - All women during first trimester

	Schedulers (N=248)	Resulters (N=154)	Result Schedulers (N=197)	Average Users (N=270)	Study Sample (N=869)
	29%	18%	23%	31%	
Messaging	0.069	0.054	0.094	0.040	0.063
Visits	0.666	0.205	0.323	0.506	0.457
MyRecord	0.218	0.642	0.413	0.328	0.371
Billing	0.035	0.060	0.079	0.085	0.065
Proxy	0.002	0.007	0.047	0.011	0.016

Table A. 3 Cluster Analysis - All women during second trimester

	Schedulers (N=287)	Result Schedulers (N=98)	Prepared Engagers (N=256)	Proxy Users (N=22)	Average Users (N=207)	Study Sample (N=870)
	33%	11%	29%	3%	24%	
Messaging	5.6%	5.1%	8.7%	3.2%	4.9%	6.2%
Visits	70.6%	41.4%	44.7%	28.2%	59.6%	56.0%
MyRecord	14.8%	44.6%	23.3%	16.2%	28.3%	23.9%

Billing	7.7%	6.9%	18.5%	6.2%	5.6%	10.2%
Proxy	0.2%	0.4%	1.3%	44.4%	0.3%	1.7%

Table A. 4 Cluster Analysis - All women during third trimester

	Schedulers (N=352)	**Result Schedulers (N=83)**	**Exclusive Resulters (N=31)**	**Proxy Users (N=19)**	**Average Users (N=382)**	**Study Sample (N=867)**
	44%	10%	2%	41%	4%	
Messaging	0.035	0.043	0.000	0.029	0.075	0.052
Visits	0.741	0.341	1.000	0.294	0.552	0.619
MyRecord	0.152	0.541	0.000	0.125	0.232	0.218
Billing	0.056	0.049	0.000	0.029	0.109	0.076
Proxy	0.002	0.006	0.000	0.517	0.009	0.017

Table A. 5 Cluster Analysis - Women with a normal pregnancy during all trimesters

	Schedulers (N=324)	**Result Schedulers (N=73)**	**Proxy Users (N=18)**	**Average Users (N=282)**	**Study Sample (N=697)**
	46%	10%	3%	40%	
Messaging	0.055	0.067	0.032	0.062	0.058
Visits	0.656	0.338	0.300	0.511	0.555
MyRecord	0.205	0.437	0.204	0.299	0.267
Billing	0.066	0.126	0.069	0.096	0.085
Proxy	0.003	0.004	0.372	0.010	0.015

Table A. 6 Cluster Analysis - Women with a normal pregnancy during first trimester

	Schedulers (N=348)	**Resulters (N=185)**	**Average Users (N=162)**	**Study Sample (N=695)**
	50%	27%	23%	
Messaging	0.064	0.056	0.056	0.060
Visits	0.598	0.254	0.374	0.454
MyRecord	0.272	0.596	0.350	0.376
Billing	0.048	0.057	0.118	0.067
Proxy	0.003	0.006	0.053	0.015

Table A. 7 Cluster Analysis - Women with a normal pregnancy during second trimester

	Schedulers (N=127)	Prepared Engagers (N=174)	Average Users (N=395)	Study Sample (N=696)
	18%	57%	25%	
Messaging	0.041	0.053	0.068	0.059
Visits	0.744	0.387	0.577	0.560
MyRecord	0.151	0.363	0.213	0.239
Billing	0.053	0.122	0.115	0.105
Proxy	0.002	0.045	0.007	0.016

Table A. 8 Cluster Analysis - Women with a normal pregnancy during third trimester

	Schedulers (N=199)	Result Schedulers (N=103)	Prepared Engagers (N=105)	Average Users (N=287)	Study Sample (N=694)
	29%	41%	15%	15%	
Messaging	0.019	0.077	0.030	0.067	0.049
Visits	0.806	0.324	0.571	0.629	0.626
MyRecord	0.140	0.363	0.334	0.168	0.214
Billing	0.029	0.112	0.044	0.108	0.076
Proxy	0.001	0.078	0.003	0.007	0.015

Table A. 9 Cluster Analysis - Women with a high-risk pregnancy during all trimesters

	Schedulers (N=36)	Result Schedulers (N=47)	Prepared Engagers (N=40)	Proxy Users (N=9)	Average Users (N=42)	Study Sample (N=174)
	27%	24%	5%	23%	21%	
Messaging	0.089	0.052	0.041	0.044	0.109	0.071
Visits	0.722	0.442	0.635	0.312	0.501	0.552
MyRecord	0.147	0.402	0.266	0.244	0.212	0.264
Billing	0.035	0.073	0.042	0.058	0.149	0.076
Proxy	0.001	0.007	0.002	0.335	0.007	0.022

Table A. 10 Cluster Analysis - Women with a high-risk pregnancy during first trimester

	Schedulers (N=44)	Resulters (N=56)	Prepared Engagers (N=22)	Average Users (N=52)	Study Sample (N=174)
	13%	30%	25%	32%	
Messaging	0.037	0.080	0.022	0.118	0.073
Visits	0.707	0.245	0.533	0.483	0.469
MyRecord	0.230	0.524	0.423	0.240	0.352

Billing	0.019	0.043	0.011	0.128	0.058
Proxy	0.002	0.052	0.001	0.007	0.019

Table A. 11 Cluster Analysis - Women with a high-risk pregnancy during second trimester

	Schedulers (N=47)	**Result Schedulers (N=29)**	**Prepared Engagers (N=25)**	**Proxy Users (N=8)**	**Average Users (N=65)**	**Study Sample (N=174)**
	17%	5%	37%	14%	27%	
Messaging	0.078	0.072	0.019	0.037	0.099	0.075
Visits	0.743	0.393	0.609	0.269	0.518	0.560
MyRecord	0.143	0.409	0.321	0.207	0.202	0.238
Billing	0.030	0.095	0.030	0.078	0.158	0.091
Proxy	0.001	0.011	0.003	0.402	0.005	0.023

Table A. 12 Cluster Analysis - Women with a high-risk pregnancy during third trimester

	Schedulers (N=81)	**Result Schedulers (N=24)**	**Average Users (N=68)**	**Study Sample (N=173)**
	39%	14%	47%	
Messaging	0.062	0.050	0.070	0.063
Visits	0.737	0.352	0.498	0.590
MyRecord	0.145	0.511	0.246	0.236
Billing	0.048	0.051	0.115	0.075
Proxy	0.002	0.018	0.051	0.024

Appendix B. ANOVA and Duncan's Multiple Range Test Results

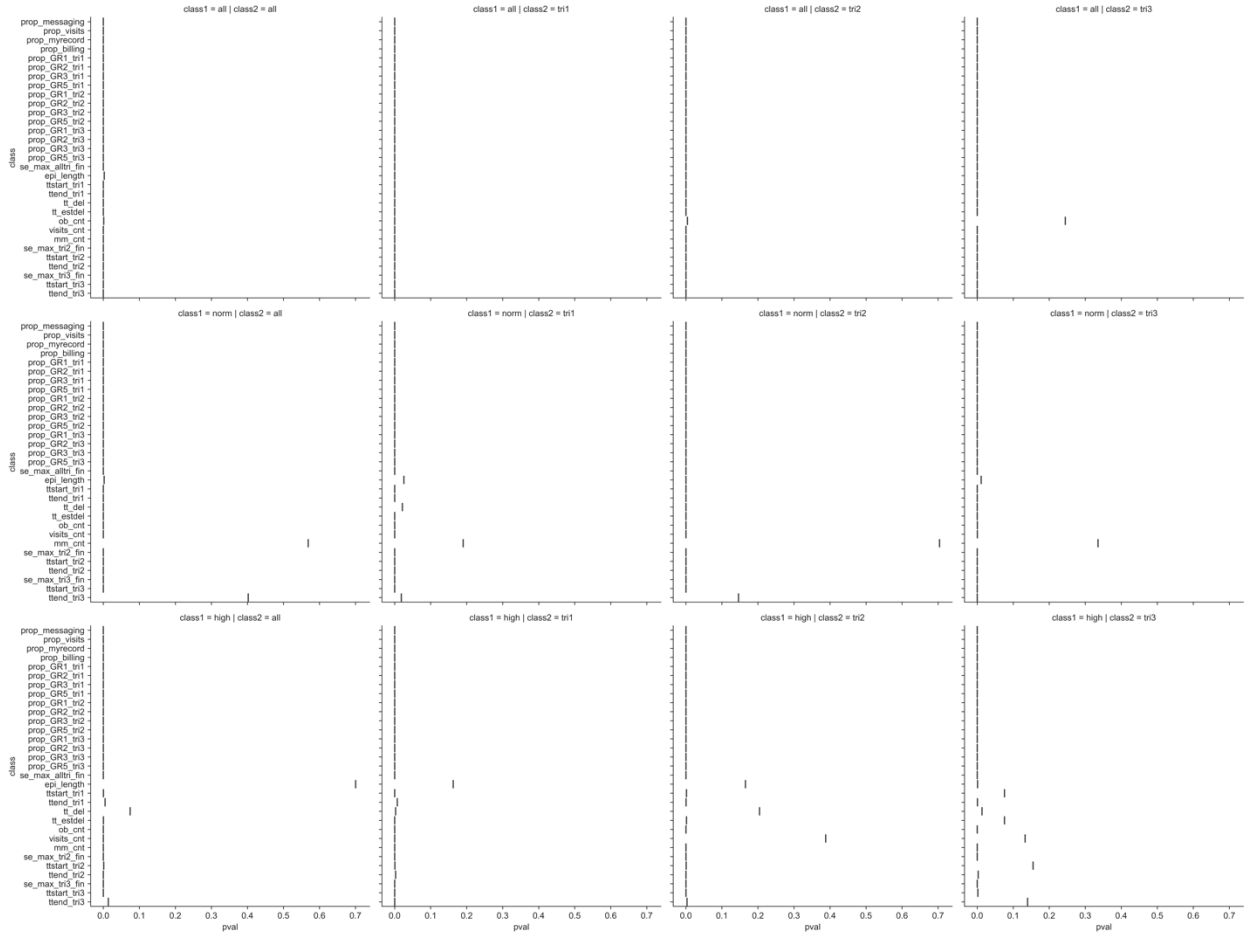
Table B. 1 Codebook and key for Figures B.1-B.2

Variable Name	Variable Label	Relevant Plots
prop_messaging	Proportion of Messaging Use – All Trimesters	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
prop_visits	Proportion of Visits Use – All Trimesters	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
prop_myrecord	Proportion of MyRecord Use – All Trimesters	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
prop_billing	Proportion of Billing Use – All Trimesters	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
prop_GR1_tri1	Proportion of Messaging Use – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
prop_GR2_tri1	Proportion of Visits Use – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
prop_GR3_tri1	Proportion of MyRecord Use – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
prop_GR5_tri1	Proportion of Billing Use – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
prop_GR1_tri2	Proportion of Messaging Use – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
prop_GR2_tri2	Proportion of Visits Use – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
prop_GR3_tri2	Proportion of MyRecord Use – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
prop_GR5_tri2	Proportion of Billing Use – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
prop_GR1_tri3	Proportion of Messaging Use – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
prop_GR2_tri3	Proportion of Visits Use – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
prop_GR3_tri3	Proportion of MyRecord Use – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
prop_GR5_tri3	Proportion of Billing Use – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
se_max_alltri_fin	Sessions per Pregnancy – All Trimesters	class1 = all | class 2 = all class1 = norm | class 2 = all

		class1 = high | class 2 = all
se_max_tri1_fin	Sessions per Trimester – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
se_max_tri2_fin	Sessions per Trimester – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
se_max_tri3_fin	Sessions per Trimester – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
epi_length	Pregnancy Length	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
ttstart_tri1	Days to First Session – First Trimester	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
ttstart_tri2	Days to First Session – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
ttstart_tri3	Days to First Session – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
ttend_tri1	Days to Last Session – First Trimester	class1 = all | class 2 = tri1 class1 = norm | class 2 = tri1 class1 = high | class 2 = tri1
ttend_tri2	Days to Last Session – Second Trimester	class1 = all | class 2 = tri2 class1 = norm | class 2 = tri2 class1 = high | class 2 = tri2
ttend_tri3	Days to Last Session – Third Trimester	class1 = all | class 2 = tri3 class1 = norm | class 2 = tri3 class1 = high | class 2 = tri3
tt_del	Days to Delivery	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
tt_estdel	Days to Estimated Delivery	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
mm_cnt	MFM Visit Count	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
ob_cnt	OB Visit Count	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
visits_cnt	Total Visit Count	class1 = all | class 2 = all class1 = norm | class 2 = all class1 = high | class 2 = all
class1 = all	All Pregnant Women	
class1 = norm	All Women with a Normal Pregnancy	
class1 = high	All Women with a High-Risk Pregnancy	
class2 = tri1	First Trimester	

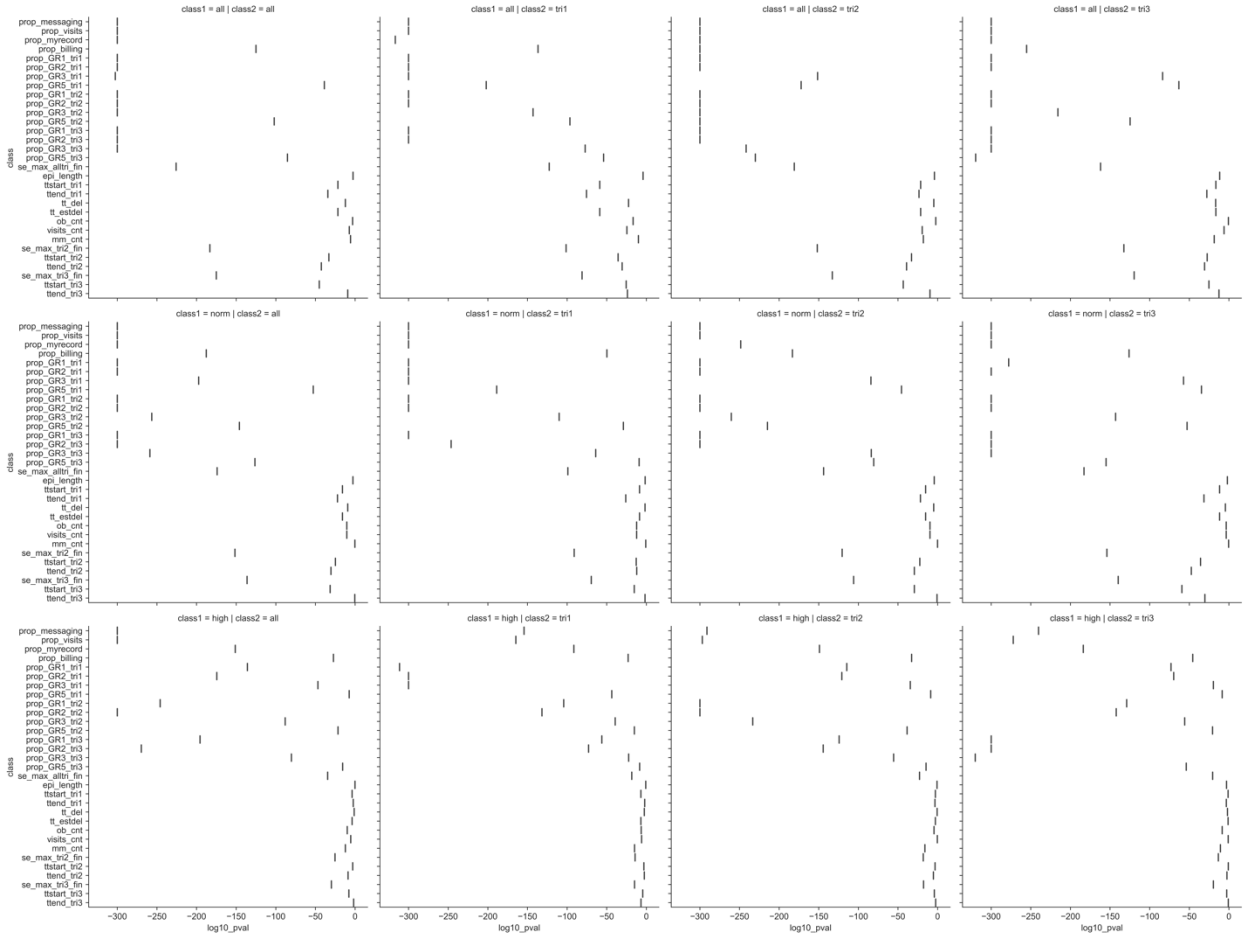
class2 = tri2	Second Trimester
class2 = tri3	Third Trimester

Figure B. 1 P-values from ANOVA tests



Legend: P-values produced from ANOVA tests across clusters of each pregnancy risk group at each cross-sectional time point.

Figure B. 2 Log(p-values) from ANOVA tests



Legend: Log of P-values produced from ANOVA tests across clusters of each pregnancy risk group at each cross-sectional time point.

Table B. 2 Codebook and key for Figures B.3-B.5

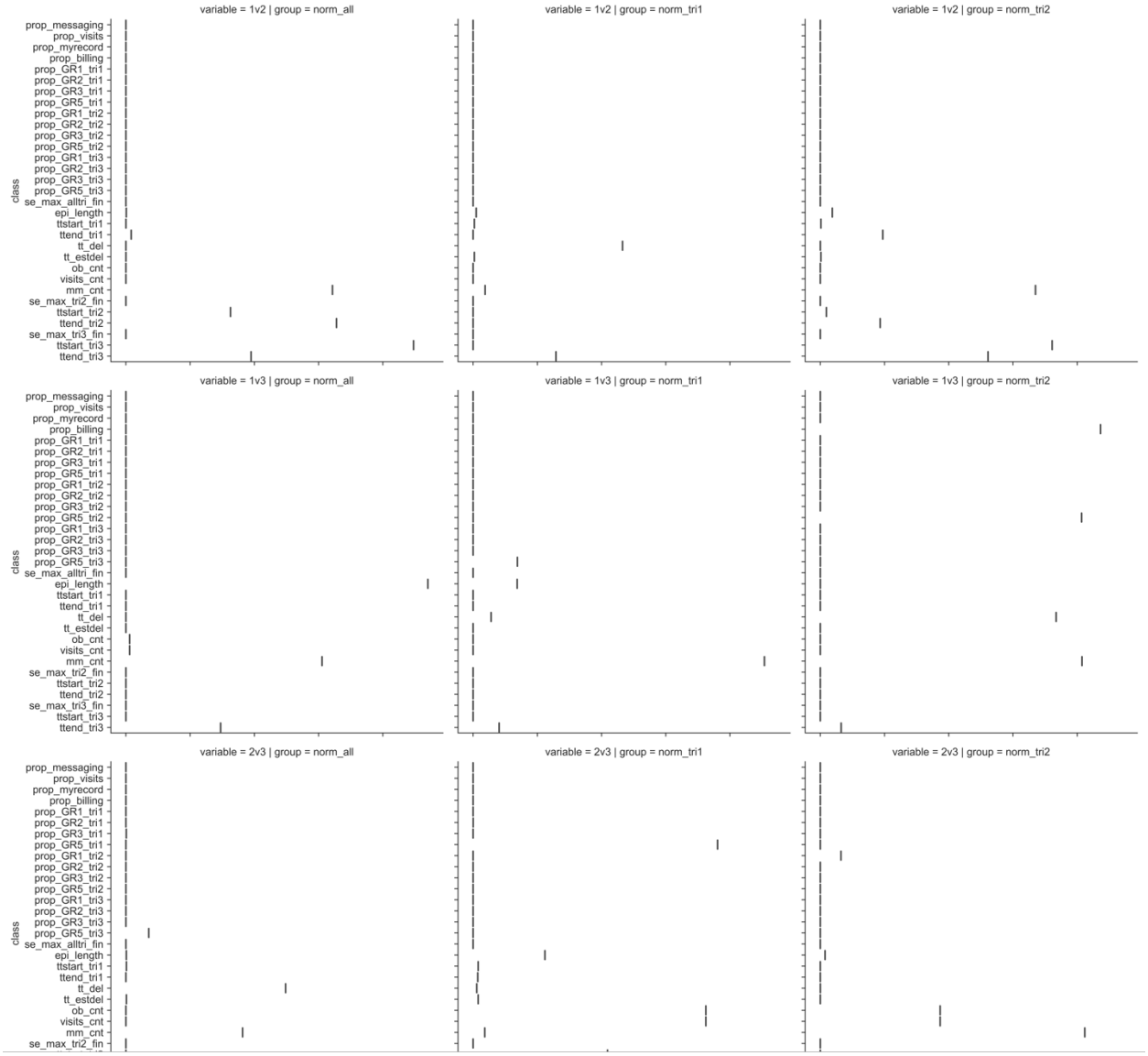
Variable Name	**Variable Label**	**Relevant Plots**
prop_messaging	Proportion of Messaging Use – All Trimesters	group = all_all group = norm_all group = high_all
prop_visits	Proportion of Visits Use – All Trimesters	group = all_all group = norm_all group = high_all
prop_myrecord	Proportion of MyRecord Use – All Trimesters	group = all_all group = norm_all group = high_all
prop_billing	Proportion of Billing Use – All Trimesters	group = all_all group = norm_all group = high_all
prop_GR1_tri1	Proportion of Messaging Use – First Trimester	group = all_tri1

		group = norm_tri1 group = high_tri1
prop_GR2_tri1	Proportion of Visits Use – First Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
prop_GR3_tri1	Proportion of MyRecord Use – First Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
prop_GR5_tri1	Proportion of Billing Use – First Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
prop_GR1_tri2	Proportion of Messaging Use – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
prop_GR2_tri2	Proportion of Visits Use – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
prop_GR3_tri2	Proportion of MyRecord Use – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
prop_GR5_tri2	Proportion of Billing Use – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
prop_GR1_tri3	Proportion of Messaging Use – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
prop_GR2_tri3	Proportion of Visits Use – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
prop_GR3_tri3	Proportion of MyRecord Use – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
prop_GR5_tri3	Proportion of Billing Use – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
se_max_alltri_fin	Sessions per Pregnancy – All Trimesters	group = all_all group = norm_all group = high_all
se_max_tri1_fin	Sessions per Trimester – First Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
se_max_tri2_fin	Sessions per Trimester – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
se_max_tri3_fin	Sessions per Trimester – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
epi_length	Pregnancy Length	group = all_all group = norm_all group = high_all
ttstart_tri1	Days to First Session – First Trimester	group = all_all group = norm_all group = high_all group = all_tri1 group = norm_tri1 group = high_tri1

ttstart_tri2	Days to First Session – Second Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
ttstart_tri3	Days to First Session – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
ttend_tri1	Days to Last Session – First Trimester	group = all_tri1 group = norm_tri1 group = high_tri1
ttend_tri2	Days to Last Session – Second Trimester	group = all_tri2 group = norm_tri2 group = high_tri2
ttend_tri3	Days to Last Session – Third Trimester	group = all_tri3 group = norm_tri3 group = high_tri3
tt_del	Days to Delivery	group = all_all group = norm_all group = high_all
tt_estdel	Days to Estimated Delivery	group = all_all group = norm_all group = high_all
mm_cnt	MFM Visit Count	group = all_all group = norm_all group = high_all
ob_cnt	OB Visit Count	group = all_all group = norm_all group = high_all
visits_cnt	Total Visit Count	group = all_all group = norm_all group = high_all
group = all_all	All Pregnant Women during All Trimesters	
variable = 1	Average Users	
variable = 2	Intense Digital Engagers	
variable = 3	Prepared Engagers	
variable = 4	Schedulers	
group = norm_all	Women with a Normal Pregnancy during All Trimesters	
variable = 1	Average Users	
variable = 2	Intense Digital Engagers	
variable = 3	Prepared Engagers	
group = high_all	Women with a High-Risk Pregnancy during All Trimesters	
variable = 1	Prepared Engagers	
variable = 2	Schedulers	
variable = 3	Average Users	
variable = 4	Intense Digital Engagers	
group = all_tri1	All Pregnant Women during First Trimester	
variable = 1	Prepared Engagers	
variable = 2	Intense Digital Engagers	
variable = 3	Average Users	
variable = 4	Exclusive Resulters	
group = norm_tri1	Women with a Normal Pregnancy during First Trimester	
variable = 1	Average Users	
variable = 2	Intense Digital Engagers	

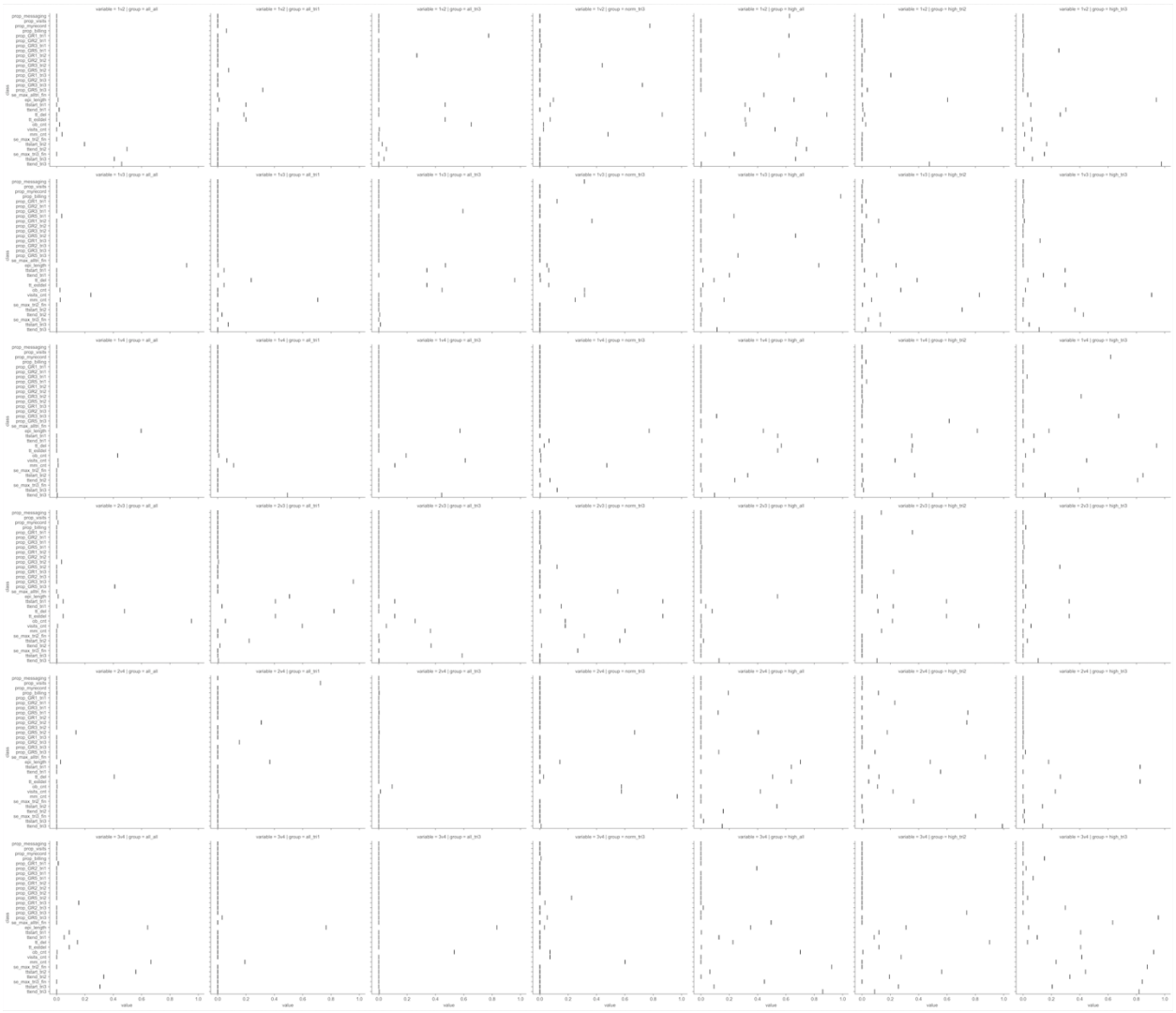
variable = 3	Resulters
group = high_tri1	Women with a High-Risk Pregnancy during First Trimester
variable = 1	Average Users
variable = 2	Schedulers
variable = 3	Intense Digital Engagers
variable = 4	Exclusive Resulters
variable = 5	Resulters
group = all_tri2	All Pregnant Women during Second Trimester
variable = 1	Average Users
variable = 2	Average Billers
variable = 3	Resulters
variable = 4	Intense Digital Engagers
variable = 5	Schedulers
group = norm_tri2	Women with a Normal Pregnancy during Second Trimester
variable = 1	Intense Digital Engagers
variable = 2	Average Users
variable = 3	Prepared Engagers
group = high_tri2	Women with a High-Risk Pregnancy during Second Trimester
variable = 1	Schedulers
variable = 2	Resulters
variable = 3	Average Users
variable = 4	Intense Digital Engagers
group = all_tri3	All Pregnant Women during Third Trimester
variable = 1	Average Users
variable = 2	Resulters
variable = 3	Intense Digital Engagers
variable = 4	Schedulers
group = norm_tri3	Women with a Normal Pregnancy during Third Trimester
variable = 1	Average Users
variable = 2	Intense Digital Engagers
variable = 3	Resulters
variable = 4	Schedulers
group = high_tri3	Women with a High-Risk Pregnancy during Third Trimester
variable = 1	Average Users
variable = 2	Schedulers
variable = 3	Resulters
variable = 4	Intense Digital Engagers

Figure B. 3 P-values from Duncan's multiple range tests among clusters of three



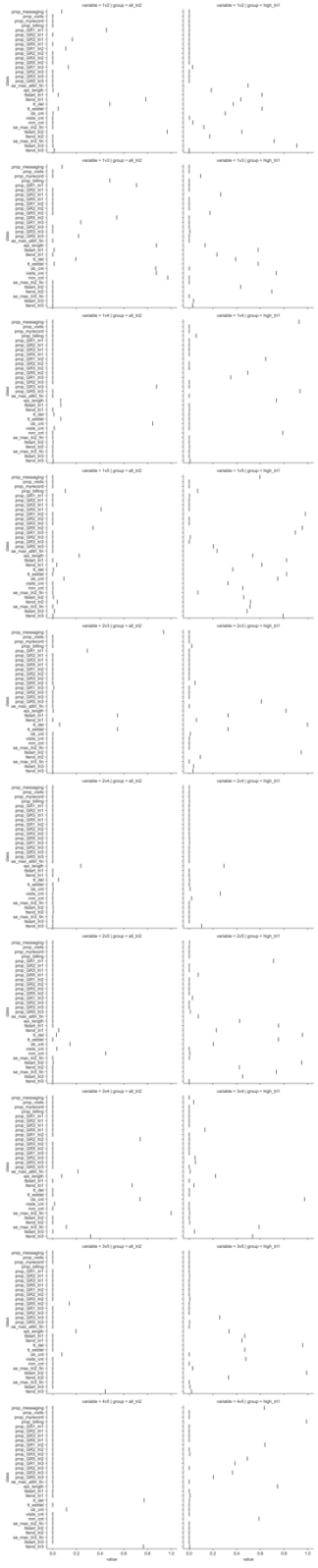
Legend: P-values produced from Duncan's multiple range tests between clusters of pregnancy risk groups at cross-sectional time points that contain only three clusters.

Figure B. 4 P-values from Duncan's multiple range tests among clusters of four



Legend: P-values produced from Duncan's multiple range tests between clusters of pregnancy risk groups at cross-sectional time points that contain only four clusters.

Figure B. 5 P-values from Duncan's multiple range tests among clusters of five



Legend: P-values produced from Duncan's multiple range tests between clusters of pregnancy risk groups at cross-sectional time points that contain only four clusters.

Appendix C. Programming Code for Data Processing

See supplementary files.