MULTINOMIAL LOGISTIC REGRESSION AND GROUP-BASED TRAJECTORY MODELING FOR LONGITUDINAL DATA OF CONTRACEPTIVE METHODS AND RECOGNITION OF ABUSIVE BEHAVIORS AMONG WOMEN SEEKING FAMILY PLANNING CLINICAL CARE

by

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BS in Biology and Chemistry, University of Pittsburgh, 2016

Submitted to the Graduate Faculty of

the Department of Biostatistics

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2019

UNIVERSITY OF PITTSBURGH

GRADUATE SCHOOL OF PUBLIC HEALTH

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ABSTRACT

In the family planning study, Addressing Reproductive Coercion in Health Settings (ARCHES), an intervention to reduce intimate partner violence (IPV) and reproductive coercion (RC), was offered by healthcare providers to women seeking reproductive healthcare services. To evaluate the effect of ARCHES, three surveys were administered by the women during the one-year period of study; from the above study, the data indicated that ARCHES failed to provide extra help in reduction of IPV or RC compared to standard-of-care.

In this thesis, we were interested in the association between different birth control methods and the intervention, age, race, experiences of IPV/RC, and relationship status. Also, we were interested in recognition of abusive behaviors experienced by individual women in terms of time, unconditionally and also conditionally on whether they received the intervention or not, their ages, relationship status, IPV, RC, race and birth control methods. Thus, I demonstrated the following: (a) the application of a multinomial logistic regression model to find the association between contraceptive methods and variables of interest and we hypothesized that there should exist associations between IPV/RC and choices of contraceptive methods; and (b) the application of group-based trajectory modeling (GBTM) to delineate and describe distinct subpopulations that had similar longitudinal trajectories in recognition of abusive behaviors with and without taking

into consideration risk factors, and we hypothesized that women's individual level of recognizing abusive behaviors over time would be associated with different choices of birth control methods and experiences of IPV/RC.

Public Health Relevance:

This study proposed a method which could determine if intervention, IPV, RC and characteristics of women were associated with contraceptive methods; this study also proposed a method which could classify distinct groups of women according to the 1-year longitudinal trajectory patterns of women's recognition of abusive behaviors to find the factors that distinguish groups of women. The models built would be of great significance to determine the factors related to choices of contraceptive methods, which would help in designing a study to reduce risk for IPV/RC, and the built models would provide important information for further study of abusive behaviors.

Table of Contents

List of Tables

List of Figures

Preface

I would like to express my gratitude to Dr. Buchanich and Dr. Montano for their guidance throughout this project and their continued support to the model building, data analysis and interpretation.

I would like to thank Dr. Elizabeth Miller for providing me with the data, helping me to understand the clinical importance of the results of the study, and for assigning Dr. Kelley Jones to help me understand the background of the study.

I would also like to thank Dr. Wahed for being a member of my committee, providing me suggestions about the modelling building and for helping me throughout my career as a graduate student.

Nomenclature

ARCHES, Addressing Reproductive Coercion in Health Settings

ACASI, Audio Computer-Assisted Self Interview software

BIC, Bayesian Information Criteria

CDC, Centers for Disease Control and Prevention

CNORM, Censored Normal Model

GBTM, Group-based Trajectory Modelling

HIV, Human Immunodeficiency Virus

IPV, Intimate Partner Violence

MLE, Maximum Likelihood Estimator

RC, Reproductive Coercion

SSE, Sum of squares of residuals

SST, Total sum of squares

STI, Sexually Transmitted Infections

1.0 Introduction

1.1 Intimate partner violence & reproductive coercion

Both intimate partner violence (IPV) and reproductive coercion (RC) have major impacts on the health and well-being of women in the United States. IPV is defined by the Centers for Disease Control and Prevention (CDC) as sexual or physical violence, stalking, or psychologically aggressive behaviors which include threats, demeaning comments, control of an intimate partner *etc*, by a former or current intimate partner (not limited to spouse) (Prevention). According to the CDC, about 25% women and 10% men have experienced IPV and have reported an IPV-related event during their lifetime (Sharon G. Smith, 2018). Research on IPV has already documented its influence on women's physical and mental health. Women who have experienced IPV have more medical, gynecological and psychological (stress-related) symptoms than women who have not experienced IPV (Bonomi AE et al., 2006; Breiding MJ, Black MC, & GW., 2008; Campbell J et al., 2002; Coker AL et al., 2002 ; Sugg, 2015). It also has been shown that IPV is associated with poor reproductive and sexual health, which includes unintended pregnancy (Miller et al., 2010), human immunodeficiency virus (HIV) exposure (Hess et al., 2012) and sexually transmitted infections (STI) (Li et al., 2014). One study found that women it was four times more likely for women with unintended pregnancies to be experiencing IPV than women who intended to get pregnant (Gee RE, 2009). In 2007, the prevalence of IPV was approximately three times greater for women who sought an abortion than for women who continued their pregnancies (Bourassa D, 2007).

RC is when males force, threaten, or pressure their sex partners in reproductive decisions and reproductive willingness. RC is related to intimate partner physical and sexual violence and unintended pregnancy among women who seek reproductive health services at women's health clinics (Miller E et al., 2014). One study showed that among 75% of women who experienced IPV, these women also had a history of RC (Harris, 2010).

The Miller Lab at the Division of Adolescent and Young Adult Medicine within the Department of Pediatrics at the University Of Pittsburgh School Of Medicine has designed and tested an intervention to reduce IPV and RC. The intervention, Addressing Reproductive Coercion in Health Settings (ARCHES), trained healthcare providers to conduct assessment and education of IPV and RC for clients and to provide harm reduction strategies and methods to reduce women's risk for violent victimization and unintended pregnancy.

From the above study testing the effect of intervention, intervention did not differ from standard-of-care in reducing women's risk for IPV/RC zxMiller E et al., 2014). Since both IPV and RC have proven associations with unintended pregnancy (Miller E et al., 2014; Miller et al., 2010), we hypothesized that there should also exist some associations between IPV/RC and choices of contraceptive methods, associations which have not been addressed by previous studies. Moreover, how women's individual recognition of abusive behaviors was associated with birth control methods and IPV/RC also interested us and we hypothesized that women's individual levels of recognizing abusive behaviors over time would be associated with different choices of birth control methods and experiences of IPV/RC.

Thus, the first purpose of this thesis was to determine whether IPV/RC was associated with contraceptive methods and how experiences of IPV/RC differed in different contraceptive methods. To achieve this purpose, a multinomial logistic regression model was built in SAS®9.4

by Proc Surveylogistic with clinic set as cluster and birth control methods set as class. The second purpose of this thesis was to find whether women's individual levels of recognizing abusive behaviors were associated with birth control methods and IPV/RC. To achieve this goal, we proposed a group-based trajectory model (GBTM) for recognition of abusive behaviors – to classify distinct groups of women according to the one-year longitudinal trajectory patterns of women's recognition of abusive behaviors with and without adjustment for risk factors, and to find how contraceptive methods and IPV/RC differ among groups of women. The model was built by using a SAS macro Proc Traj, followed by examining and comparing the characteristics of women among different groups.

2.0 Method

2.1 Family planning study on women's health

Twenty-five clinics in Western Pennsylvania joined this women's health study, grouped into 17 clusters, and randomized to either ARCHES intervention or standard-of-care (the control group). Among the 17 clusters, 9 of them (11 clinics) were randomized to the intervention and the rest were set as the control. The clinicians and staff in the intervention group received a half-day ARCHES training. Family planning counselors, medical assistants, and clinicians in ARCHES intervention were trained to inform the clients about the relationship between reproductive health and IPV, to provide clients harm reduction strategies which could help in reducing risk for IPV/RC, and also to refer clients to violence victimization support services (Tancredi et al., 2015).

Women between the ages of 16 and 29 years who could speak either English or Spanish were eligible to join this study. These women were told that the aim of the study was to determine the relationships between female health and IPV/RC, but they were not informed if they were in the intervention or the control group. The clients in the intervention group received universal education about IPV/RC during their clinical visit, were encouraged to discuss situations of IPV/RC in their personal life, counseling services were provided to help reduce risk of RC and connections to local violence victim services were offered (Tancredi et al., 2015).

For the 14 clinics in the control group, usual care such as standard IPV questions and referrals was given to the clients when IPV/RC was disclosed. Clinic staff would discuss sexual health or pregnancy risk and possibly IPV with the clients, but the clinicians were not trained with any knowledge about IPV in this study (Tancredi et al., 2015).

Three surveys were conducted with the clients. The Baseline survey and the follow-up surveys were taken via Audio Computer-Assisted Self Interview software (ACASI). Answers for women who could not return to the clinics were taken by an online survey sent to their emails or by a telephone call. The first follow-up (T2) was collected around 12-20 weeks following the Baseline survey for assessing the short-term ARCHES effect. The second follow-up (T3) was taken 12 months after the Baseline survey to check the long-term ARCHES effects. Client satisfaction surveys were also taken, but those data were not used in building models in this thesis (Tancredi et al., 2015).

Table 1 shows the outcomes measures and data collection points. In the Baseline survey, RC, which includes pregnancy pressure and birth control situations, was assessed using a scale of 10 questions. (**Table 1**) Recent physical and sexual partner violence victimization was measured using 3 questions and the response contained 5 categories (Yes/NO/Don't know/Refuse to answer/Not applicable) (**Table 1**). In the T2 survey, unintended pregnancy was measured by directly asking clients how many times they were pregnant (including miscarriages and abortions) in past 12 months. To measure women's intention for pregnancy, women who reported pregnancy in the past 12 months were asked further about the timing, planning, willingness to have a baby, and how happy they were because of the pregnancy (**Table 1**). Recognition of abusive behaviors was assessed by a scale of 9 questions in the survey and the clients were required to rate the behaviors on a 4-point Likert scale from 'extremely abusive' to 'not abusive' (**Table 1**). To assess level of confidence in implementing behaviors to reduce the impact of reproductive and sexual coercion, related questions were asked, and the responses were rated on a 5-point Likert scale from 'strongly disagree' to 'strongly agree'. The effectiveness of harm reduction strategies was assessed at both T2 and T3 by asking clients whether they had used these strategies in the past 3 months;

the outcome was modeled as a summary score ranging between 0 and 6. Each type of birth control method was measured by one item and there were14 items in total measuring birth control methods (**Table 1**). To assess how well IPV services and resources were distributed, participants were asked which resources and services they had received and used in the past 3 months; the outcome was modeled as a summary score with values ranging from 0 to 5 (Tancredi et al., 2015).

2.2 Data preparation

According to our previous knowledge on the associations between contraception uses and other variables available in our dataset, and according to our interest, the covariates used for finding the associations included women's ages, races, relationship status, intention for pregnancy, ARCHES effect, IPV and RC. In multinomial regression model, the dependent variable was set as contraceptive methods and independent variables included intervention, IPV/RC, ages, races, Relationship status and intention for pregnancy. In GBTM, the dependent variable was recognition of abusive behaviors and independent variables were set as intervention, IPV/RC, ages, races, relationship status, birth control methods and intention for pregnancy.

First, the raw dataset was cleaned by relabeling variables of scale data and by creating new variables. In detail, IPV and RC, which were measured by 3 questions and 10 questions respectively with the same 5 categorical answers, were coded as 'Yes' as long as there was one 'Yes' among all the related questions answered by a woman (**Table 1**). Recognition of abusive behaviors was coded as a continuous variable by taking mean values after adding the scaled values of the 9 questions (**Table 1**). Race was coded by combining 'Alaska Native' and 'Native Hawaiian' as 'Native Americans'; 'Other', 'Refuse to answer' and 'Not applicable' as 'Other'. Race 'Asian',

‘Black’, ‘Hispanic/Latina’, ‘White’ and ‘Multiracial’ were not changed (**Table 1**). Intention to get pregnant was coded as a dichotomous variable (Yes/No). As long as one answer among the 8 items asking intention for pregnancy was positive (strongly agree, very happy, extremely agree), intention for pregnancy was coded as ‘Yes’ otherwise it was coded as ‘No’ (**Table 1**). ‘Vaginal ring’, ‘patch’, ‘Depo-Provera’ and ‘Birth control pills’ were combined in variable birth control methods, because the above contraceptive uses could work from one to several months per shot/injection (even though Depo-Provera is a long-acting reversible contraception, its effective time per shot (3 months) is relatively short compared to IUD/Implanon (> 1 year). Thus, during the one-year study, Depo-Provera was combined with vaginal ring, patch and Birth control pills). IUD and Implanon were combined because they both were long-acting contraceptive methods; other categories of birth control methods included ‘only pull out’, ‘only condoms’, ‘not using anything’ and ‘other methods’ (**Table 1**). Relationship status was coded by combining answers ‘Don’t know’, ‘Refuse to answer’ and ‘Not applicable’ as ‘Other’ (**Table 1**).

To determine whether variables of interest were time-stable or time-varying, differences of variables at three-time points from Baseline to T3 were tested. Differences of continuous variable (age) was tested by fitting a linear regression model of age (dependent variable) and time point (independent variable) with clinic-level clustering and P values of F test from the built model were used to determine whether the differences were significant. Differences of categorical variables were tested by building cross-tables between the outcome (birth control methods) and predictors with clinic-level clustering and the differences were determined by P values of Wald Log Linear Chi-square test.

Because Proc Traj in SAS, which is used to build GBTM, requires datasets be in a wide format, a dataset including only the variables of interest, was transposed from long format to wide

format in this thesis. Missing data could be a problem in GBTM. When data are missing at random, maximum likelihood estimators (MLE) would offer asymptotical and unbiased parameter estimates. However, when data are systematically missing, applying GBTM would be challenging. Even if issues of missing data are hard to addressed, relationship between variables of interest and the missing outcome variable could be found (**Table 3**) and effects of missingness could be evaluated by the use of GBTM (Nagin, 2005).

In order to visually observe all the trajectories within the same time period in one graph, the SAS plugin derived by Bobby L. Jones at Carnegie Mellon University was applied (Jones).

Table 1 Outcome measures and data collection points

Outcomes	Participant survey measurement points			Measures	Recoded as
	Baseline	T2	T3		
IPV	x	x	x	3 items, investigator-developed, each item has the same 5 categories	Dichotomous (Yes/No)
RC	x	x	x	10 items, investigator-developed each item has the same 5 categories	Dichotomous (Yes/No)
Recognition of abusive behaviors	x	x	x	9 items, investigator-developed, each item has the same 7 categories	Mean value
Age	x	x	x	Number	-
Race	x	x	x	1 item, 10 categories	Categorical variable with 7 categories
Intention for pregnancy	x		x	8 items, scale of 0 to 4	Dichotomous (Yes/No)
Birth control methods	x	x	x	14 items (Yes/No)	Categorical variable with 6 categories
Relationship status	x	x	x	1 item, 10 categories	Categorical variable with 6 categories

2.3 Multinomial logistic regression model

Multinomial logistic regression model is a predictive model which is frequently used in predicting probabilities of outcomes of a categorically distributed dependent variable given a set of independent variables. As an example, when Y (dependent variable) has 4 categories, the multinomial regression system contains 4 logistic models in which each category of Y is treated as a binary variable (Luís M. Grilo, 2017). In this thesis, multinomial logistic regression allowed us to compute probabilities of contraceptive methods (six categories, [0-5]). In matrix notation, let X be the matrix of the independent variables, β be the coefficients and k be the category, then we would have

$$\mathrm{P}(Y=0|X)=\frac{1}{1+\sum_{k=1}^{6}e^{X\beta_k}},\mathrm{P}(Y=1|X)=\frac{e^{X\beta_2}}{1+\sum_{k=1}^{6}e^{X\beta_k}},\ldots\ldots,\mathrm{P}(Y=5|X)=\frac{e^{X\beta_6}}{1+\sum_{1}^{6}e^{X\beta_k}}$$

The k-1=5 odds of each category of Y, the contraceptive methods, with Y=0 as reference category, are given by,

$$\frac{P(Y=1|X)}{P(Y=0|X)}=e^{X\beta_2},\qquad \frac{P(Y=2|X)}{P(Y=0|X)}=e^{X\beta_3},\frac{P(Y=3|X)}{P(Y=0|X)}=e^{X\beta_4},$$

$$\frac{P(Y=4|X)}{P(Y=0|X)}=e^{X\beta_5},\frac{P(Y=5|X)}{P(Y=0|X)}=e^{X\beta_6},$$

Thus, the odds ratios for the predictors should be the exponentiation of the coefficients, which could demonstrate how the risk of the dependent variable falling in one category compared to falling in the reference. An odds ratio greater than one could be interpreted as the probability of the dependent variable belonging to this category is higher than that belonging to the reference category, and the probability increases as the variable increases. Vice versa, when an odds ratio is less than one, the outcome is more likely to belong to the reference category, and the probability decreases as the variable increases (Murat Gunduz & Karacan, 2017).

After taking natural log of both sides of the above equations, we could obtain five ln odds of Y, relatively to the reference category,

$$ln\frac{P(Y=1|X)}{P(Y=0|X)} = X\beta_2,\ ln\frac{P(Y=2|X)}{P(Y=0|X)} = X\beta_3,\ ln\frac{P(Y=3|X)}{P(Y=0|X)} = X\beta_4,$$

$$ln\frac{P(Y=4|X)}{P(Y=0|X)} = X\beta_5, \qquad ln\frac{P(Y=5|X)}{P(Y=0|X)} = X\beta_6$$

Thus, the logit for each category over the reference category depends on values of independent variables. Multinomial logistic regression model is adjusted with the maximum likelihood method. We built a multinomial logistic regression model which would help to find associations between each category of birth control method and variables of interest.

2.4 Group-based trajectory modeling

Group-based trajectory modeling (GBTM), a statistical method which was originally derived from research on criminology by Nagin and Land with the publication "Age, Criminal Careers, and Population Heterogeneity: Specification and Estimation of a Nonparametric Mixed Poisson Model" (Bushway & Weisburd, 2006), is now popularized and applied to many other areas. For example, GBTM has been applied in clinical research to understand and evaluate the causes of psychiatric and physical disorders including caregiver psychological distress (Choi CW et al., 2012), marital happiness (Anderson, Van Ryzin, & Doherty, 2010), long-term medication adherence(Franklin JM et al., 2013), heroin addiction (Hser YI, Huang D, Chou CP, & MD., 2007), and adolescent smoking (Colder CR et al., 2001). GBTM is able to map concisely the growth and also the development of phenomena, to provide meaningful information through identifying

clusters of samples and also to assist in evaluation of samples' differences between the intervention and the control (Nagin DS & CL., 2010a).

GBTM assumes that whole samples are composed of finite distinct groups. The basic processes of GBTM are to estimate patterns of observations over time, and to group observations according to the similarity of trajectories (Nagin, 2005). In GBTM, finite mixture model (a probabilistic model for representing the presence of subpopulations with an overall population) in groups, and maximum likelihood are used to determine trajectory shapes and the number of trajectory groups (Choi CW et al., 2012).

Even though GBTM has been widely used to characterize psychiatric disorders and criminological studies, it has not been used in studying women's health.

In this thesis, GBTM of recognition of abusive behaviors was built to group women with similar trajectories over time with and without adjusting for risk factors. GBTM would help to distinguish whether women had experiences of IPV/RC and distinguish which contraceptive methods women would use based on how they recognized abusive behaviors. By comparing GBTM with and without risk factors, we would see the difference in number of groups between the two models.

To test whether there existed differences in variables of interest among women grouped by GBTM, F test in ANOVA was used to test the differences of continuous variable and Chi-square test was used to test the differences of categorical variables.

2.5 Link function of GBTM

Group-based trajectory model, based on mixture models for estimating developmental trajectories, was built via SAS® 9.4 Software in this thesis. Mixture models are useful for modeling invisible heterogeneity in a population and the appropriate model is assumed $f(\boldsymbol{y}, \lambda)$ where the longitudinal sequence of measurements on a specific subject over the X periods is denoted as $\boldsymbol{y} = (y_1, y_2, \dots\dots, y_x)$. Because there are differences in parameter values in unobserved subpopulations, the marginal density for data y can be written as

$$f(\boldsymbol{y}) = \sum_{k=1}^{K} Pr(C = k) Pr(\boldsymbol{Y} = \boldsymbol{y} | C = k) = \sum_{k=1}^{K} p_k f(\boldsymbol{y}, \boldsymbol{\lambda}_k)$$

where $p_k$is the probability of one subject belonging to group k with $\boldsymbol{\lambda}_k$ as the corresponding parameter. While $\boldsymbol{\lambda}_k$ depends on time, time stable covariates are put into the model with the assumption that they can influence the probability of one subject belonging to which group.

The time stable covariates, called risk factors were assumed as $\mathbf{Z}_i$ for specific subject I and $\boldsymbol{Z_i} = (Z_{i1}, Z_{i2}, \dots\dots, Z_{iR})$. The trajectory for subject i with repeated measurements over X periods is set as $Y_i = (Y_{i1},\ Y_{i2}, \dots\dots, Y_{iX})$, which are independent given ith group C_i (**Figure 1**). If the number of groups is set as k, the distribution of the data for subject i, conditionally on other time stable covariates and also a time varying covariate W_i, where $W_i = (w_{i1}, w_{i2}, \dots\dots, w_{iX})$, can be written as

$$f(y_i | z_i, w_i) = \sum_{k=1}^{K} Pr(C_i = k | Z_i = z_i) Pr(Y_i = y_i | C_i = k, W_i = w_i).$$

A generalized logit function is applied to test the effect of a time stable covariate on group membership with parameters θ and λ, with equation written as below:

$$Pr(C_i = k|\boldsymbol{Z}_i = \boldsymbol{z}_i) = \frac{exp(\theta_k + \boldsymbol{\lambda}_k \boldsymbol{z}_i)}{\sum_{l=1}^{K} exp(\theta_l + \boldsymbol{\lambda}_l \boldsymbol{z}_i)}$$

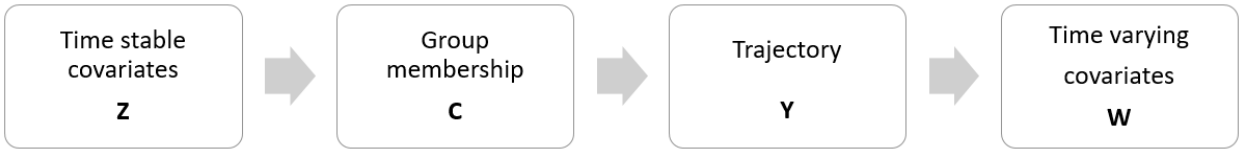

Figure 1 Acyclic graph showing the relationship of covariates in GBTM

Proc Traj in SAS offers modeling three distributions for $Pr(Y_i = y_i|C_i = k, W_i = w_i)$ to analyze either count, dichotomous or psychometric scale data. Specifically, a zero-inflated Poisson (ZIP) model is applied to model count data given that there are many zeros of group members compared to Poisson model assumption; a logistic model is used to model dichotomous data and a censored normal model (CNORM) is proper to model the conditional distribution of psychometric scale data and also continuous data which is approximately normally distributed and it allows for censoring.

The response that interested us is recognition of abusive behaviors, which was taken as the mean value of the sum of 4-points Likert scale of related questions answered by the women. In this situation, the CNORM model is appropriate to model the continuous data if its distribution is approximately normal with or without censoring. The likelihood of observing ith subject's trajectory given it belongs to group k can be written as,

$$Pr(Y_i = y_i|C_i = k, W_i = w_i)$$
$$= \prod_{y_{ij}=min} \boldsymbol{\Phi}\left(\frac{Min - \mu_{ijk}}{\sigma}\right) \prod_{Min<y_{ij}<Max} \frac{1}{\sigma}\boldsymbol{\varphi}\left(\frac{\mathbf{y_{ij}} - \boldsymbol{\mu}_{\mathbf{ijk}}}{\boldsymbol{\sigma}}\right) \prod_{\mathbf{y_{ij}=Max}} \left(\mathbf{1} - \boldsymbol{\Phi}\left(\frac{Max - \mu_{ijk}}{\sigma}\right)\right)$$

where

$$\mu_{ijk} = \beta_{0k} + age_{ij}\beta_{1k} + age_{ij}^2\beta_{2k} + \cdots + w_{ij}\delta_{k`}$$

assuming age_{ij} is the age of subject i at time period j.

To determine number of groups and polynomial terms in the GBTM, Bayesian Information Criterion (BIC) was used for model comparison with equation written as

$$BIC = log(L) - .5 * \log(n) * k$$

Where

$L = loglikehood \quad n = sample\ size \quad k = number\ of\ parameters$ (Bobby L. Jones, Daniel S. Nagin, & Rorder, 2001).

BIC, calculated by the equation above, is often used as criteria to help determine the best model by measuring improvement in model fit by adding parameters. Normally, a model with low BIC indicates a good performance in terms of the data. However, from the above equation, we could find that when fixing n (sample size) and increasing k (number of parameters) to a large number, BIC decreases, so low BIC may not indicate good fit of a model because BIC scores also decrease when too many parameters are added. Thus, since number of parameters could affect the BIC, BIC should be used carefully as criteria to determine model performance in specific situations. In this thesis, number of groups and highest polynomial order that best fit the path of each trajectory group from Baseline to T3, were tested and determined by fitting models with different group numbers and polynomial orders.

2.6 Data analysis

Since this study took around one year to complete and ages of women were assumed changing, statistics of women's ages was calculated at Baseline, T2 and T3. Proportion of subgroups of race and relationship status, proportion of women in ARCHES group, proportion of women who intended to get pregnant and proportion of women who experienced IPV and RC in past 3 months, were calculated for basically understanding of variables in the dataset.

Before building a multinomial logistic regression model of birth control methods, multicollinearity diagnosis of all independent variables were examined. Multicollinearity happens when two or more predictors are highly correlated in a regression model, which causes unstable and biased standard errors and inaccurate p values of predictors, and it would result in inaccurate or even incorrect interpretation (Kristina P. Vatcheva, MinJae Lee, & Rahbar, 2016). When predictors are highly correlated, the interpretation of a coefficient by changes in the expected value of the dependent variable resulting from one unit increase in one predictor holding other predictors constant, is impossible (Kutner M, Nachtsheim C, & J., 2004). Variation inflation factor (VIF) which quantifies how much variance is inflated, was used to check whether multicollinearity is an issue among independent variables, with equation

$$VIF_k = \frac{1}{1 - R_k^2}$$

where R_k^2 is the R^2 value by regressing k^{th} predictor on the remaining predictors.

$$R^2 = 1 - \frac{SSE}{SST} = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y})^2}$$

A VIF_k=1 means that there is no correlation between the k_{th} predictors and all other predictors, while if VIF_k is greater than 10, multicollinearity is very serious and requires correction.

A multinomial regression model based on survey data with clustered clinics was built after checking multicollinearity, and odds ratios with paired p values of t tests were obtained to determine differences in birth control methods used between one category and the referenced category conditionally on predictors.

When building group-based model, since we did not have a *priori* knowledge on deciding number of groups on how recognition of abusive behaviors changed over time, a step-wise method was used to find the most optimum number of groups by fitting a one group model at the beginning with all group set to a second order equation, and then fitting up to the maximum logical number of groups (Victoria Arrandale, Mieke Koehoorn, Ying MacNab, & Kennedy, 2006). However, there is no gold standard in the steps required to determine number of groups and polynomial orders with the lowest BIC. In this thesis, when modeling GBTM, number of groups (k) were continually added until BIC moved far from zero compared to the model with k-1 group. After determining the number of groups, the shapes of trajectories were selected with BICs as criteria. For each model fitting, two BICs were given in the output in which one is the BIC of overall sample size while the other one is subject sample size, and the real BIC lies between the two values (Victoria Arrandale et al., 2006).

After determining number of groups and polynomial orders with best fit, the model was built accordingly, followed by testing differences of covariates among groups.

3.0 Results

3.1 Descriptive analysis

The number of women who completed the Baseline survey was 3683(99.89%) (**Table 2**). Eighty-two percent of women completed the T2 survey and 79.25% completed all surveys from Baseline to T3 (**Table 2**). In total, 9.1% women missed two surveys, 18.8% women missed one survey in this study and 70.3% women completed all surveys from Baseline to T3. The proportion of missing data is relatively large, but this issue could be handled in GBTM by MLE if data are not missing systematically. If data are missing systematically, GBTM needs to be used carefully because it may not work to obtain correct results. Even though it is hard to determine the type of missing data in a longitudinal study and the recommended way to determine the missing type is to check with the people who collected the data, GBTM could assist in checking the patterns of missingness (Nagin DS & CL., 2010b) and whether missingness of this data was systematic was checked in **3.3 GBTM analysis**. The relationships between missing outcome and variables of interest were also tested in **3.3 GBTM analysis**.

There were 1817(49.33%) women in the intervention group at Baseline (**Table 2**). The mean age of women was 21.98(SD=3.55) at Baseline, 22.23(SD=4.06) at T2, and 22.78(SD=3.74) at T3 (**Table 2**). Women's age ($p<.0001$) was treated as time-varying variable in the GBTM since the difference was significant at three-time points. Most of women involved in this study were White (80.04%) followed by Black Americans (13.34%), Multiracial (2.99%), Hispanic or Latina (1.60%), Asian (0.76%) and Native Americans (0.57%) at Baseline (**Table 2**). Proportions of categories in race were not significantly different among three-time points from Baseline to T3 ($p=0.973$) (**Table 2**), so race was treated as a time-stable variable.

Most women taking the Baseline survey were dating one person (58.32%), followed by 32.07% women who were single, 7.03% women who were married, 1.52% women who were dating more than one person, and 0.19% who were married but had more than one sex partner (**Table 2**). At T2, proportion of women who were dating one person dropped to 44.18% (**Table 2**). The proportion of women who dated more than one person increased from 1.52% at Baseline to 18.20% at T2 and dropped down dramatically to 1.54% at T3 (**Table 2**). Relationship status was treated as time-varying variable since $p<.0001$.

Eleven percent of women indicated at Baseline that they intended to become pregnant, and this proportion increased to 24.11% at T3 (**Table 2**). Among women involved in this study, 5.74% of them showed they had experienced RC in the past 3 months before the Baseline and this proportion dropped to 2.51% at T2 and then climbed to 3.18% at T3 (**Table 2**). Twenty-three percent women in this study had experienced IPV in the past 3 months at Baseline, and this proportion decreased to 6.92% at T2 and stayed at 6.76% at T3 (**Table 2**). The differences of IPV ($P<0.0001$) and RC ($P<0.0001$) were different significantly at three time points, so IPV and RC were both treated as time-varying variables. Since the distributions of recognition of abusive behaviors from Baseline to T3 were right skewed (**Figure 2)**, log of recognition, which showed approximately normal distribution, was taken to fit GBTM (**Figure 3**).

Table 2 Demographics

Subjects' Characteristics	Overall (N=3687)			P value
	Baseline (N=3683) %(n)	T2 (N=3017) %(n)	T3 (N=2926) %(n)	
Age[a] [Mean(SD)]	21.98(3.55)	22.23(4.06)	22.78(3.74)	**<.0001***
Race[b]				0.973
Multiracial	2.99(110)	3.15(95)	3.11(91)	
White	80.04(2951)	80.12(2951)	79.99(2410)	
Hispanic or Latina	1.60(59)	1.63(49)	1.68(49)	
Black American	13.34(492)	13.54(408)	12.35(361)	
Asian	0.76(28)	0.83(25)	0.75(22)	
Native Americans	0.57(21)	0.50(15)	0.55(16)	
Other	0.60(22)	0.37(11)	0.55(16)	
Relationship status[b]				**<.0001***
Single	32.07(1181)	31.32(945)	28.13(823)	
Dating one person	58.32(2148)	44.18(1333)	59.23(1733)	
Married	7.03(259)	5.50(166)	10.46(306)	
Dating more than one person	1.52(56)	18.20(549)	1.54(45)	
Married but have one more sex partner	0.19(7)	0.10(3)	0.24(7)	
Other	0.87(32)	0.70(21)	0.41(12)	
Intervention[b]	49.33(1817)	49.12(1482)	50.79(1486)	0.372
Pregnancy intention[b]	10.78(397)	-	24.11(462)	**<.0001***
IPV[b]	23.27(390)	6.92(195)	6.76(195)	**<.0001***
RC[b]	5.74(182)	2.51(67)	3.18(88)	**<.0001***

[a] F test of linear regression model of age (dependent) with clinic level as clustering
[b] Wald Log Linear Chi-square test with clinic level as clustering
*p<.05

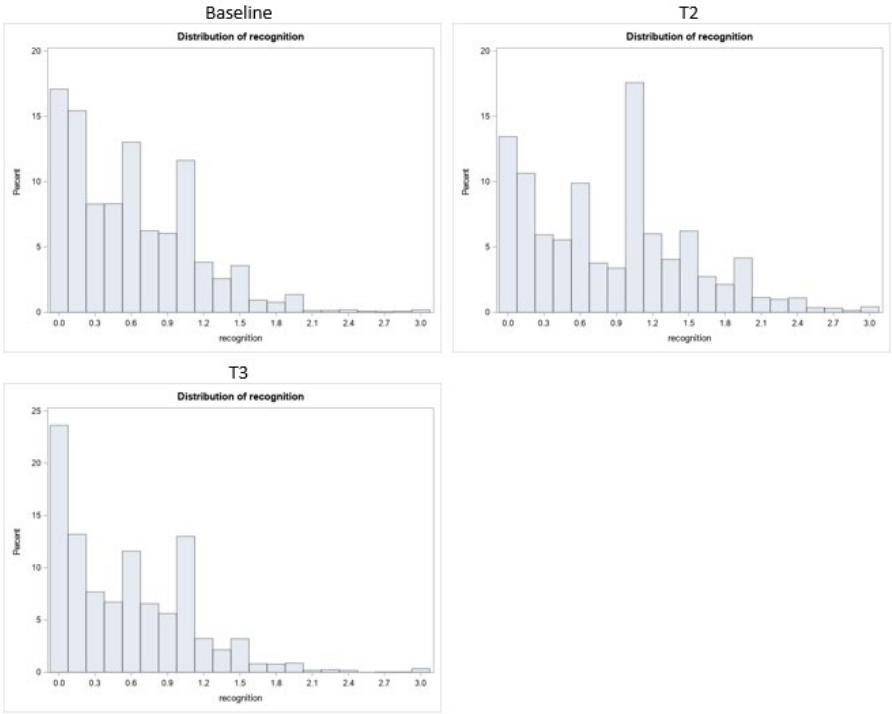

Figure 2 Distribution of recognition of abusive behaviors from Baseline to T3

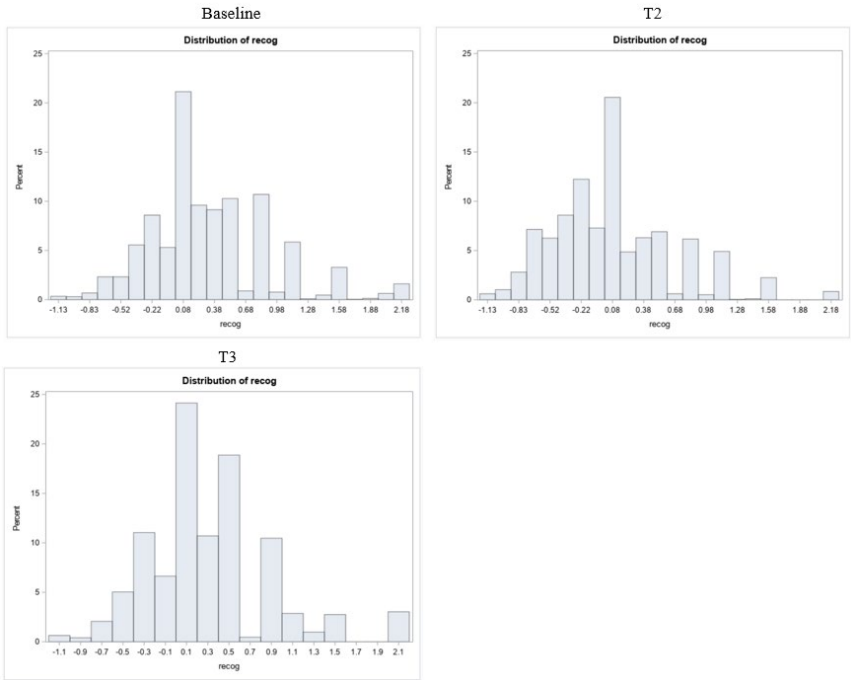

Figure 3 Distribution of log recognition of abusive from Baseline to T3

3.2 Multinomial logistic regression model analysis

The multinomial regression models were built with Baseline, T2 and T3 data separately to observe the associations between contraceptive methods and the predictors ignoring time effects. Model at T2 excluded intention for pregnancy because it was not measured at T2 (**Table 1**). The reference category of contraceptive methods was set as 'No methods'. Since, relationship status and race were categorical, dummy variables were created to fit logistic regression models. There was no multicollinearity among the predictors (**Figure 4**), so no variable was dropped from building the multinomial regression model. To avoid cells of zero value which would cause failure in computing odds ratios and P values from F test in a multinomial logistic regression model, zeros were checked in cross tables between birth control methods and the predictors. Tables with zero in cells were shown in **Figure 5**. To solve problem of zero observations in **Figure 5**, categories 'Asian', 'Hispanic/Latina', 'Native Americans' and 'Other' in Race were combined together as 'Other' and since category 'Other' in Birth control methods only took very small proportion compared to other categories in the cross table, this category was dropped in the built model. Categories of 'Dating more than one person', 'Married but have one more sex partner' and 'Other' in variable Relationship status were combined as 'Other'.

After solving the issue of zero observation, the multinomial regression models from Baseline to T3 were built and the results of the models were in **Table 3 – Table 5.**

Parameter Estimates							
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	Intercept	1	0.70492	0.18984	3.71	0.0002	0
age	AGE	1	0.02577	0.00628	4.10	<.0001	1.02597
racea		1	-0.02815	0.02620	-1.07	0.2828	1.04457
relstata		1	0.06511	0.02228	2.92	0.0035	1.04587
rep		1	0.02325	0.09879	0.24	0.8139	1.07712
ipv		1	0.05860	0.06520	0.90	0.3688	1.06898
intend_pregnancy		1	-0.05527	0.06663	-0.83	0.4069	1.01577
interv		1	0.00749	0.04578	0.16	0.8700	1.02007

Figure 4 Multicolinearity diagnosis

Frequency
Percent
Row Pct
Col Pct

Table of bcmethod by racea

bcmethod	racea							
	Other	Native Americans	Asian	Black American	Hispanic or Latina	White	Multiracial	Total
not use anything	5 0.17 0.96 27.78	1 0.03 0.19 7.69	4 0.14 0.76 18.18	101 3.46 19.31 27.67	10 0.34 1.91 20.00	388 13.28 74.19 16.38	14 0.48 2.68 16.67	523 17.90
Vaginal ring/patch/Depo-Provera/Birth control pills	6 0.21 0.34 33.33	12 0.41 0.68 92.31	17 0.58 0.97 77.27	141 4.83 8.04 38.63	29 0.99 1.65 58.00	1501 51.39 85.58 63.36	48 1.64 2.74 57.14	1754 60.05
IUD or implanon	1 0.03 0.67 5.56	0 0.00 0.00 0.00	0 0.00 0.00 0.00	25 0.86 16.78 6.85	2 0.07 1.34 4.00	115 3.94 77.18 4.85	6 0.21 4.03 7.14	149 5.10
only pull out	2 0.07 1.04 11.11	0 0.00 0.00 0.00	0 0.00 0.00 0.00	41 1.40 21.35 11.23	2 0.07 1.04 4.00	138 4.72 71.88 5.83	9 0.31 4.69 10.71	192 6.57
only condoms	4 0.14 1.53 22.22	0 0.00 0.00 0.00	1 0.03 0.38 4.55	54 1.85 20.69 14.79	7 0.24 2.68 14.00	190 6.50 72.80 8.02	5 0.17 1.92 5.95	261 8.94
Other methods	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 0.10 7.14 0.82	0 0.00 0.00 0.00	37 1.27 88.10 1.56	2 0.07 4.76 2.38	42 1.44
Total	18 0.62	13 0.45	22 0.75	365 12.50	50 1.71	2369 81.10	84 2.88	2921 100.00

Frequency Missing = 762

Frequency
Percent
Row Pct
Col Pct

Table of bcmethod by relstata

bcmethod	relstata						
	single	dating more than one person	dating one person	married	married but have more sex partner	other	Total
not use anything	207 7.09 39.58 25.88	7 0.24 1.34 15.91	261 8.94 49.90 14.40	37 1.27 7.07 15.74	2 0.07 0.38 40.00	9 0.31 1.72 36.00	523 17.90
Vaginal ring/patch/Depo-Provera/Birth control pills	373 12.77 21.27 46.63	23 0.79 1.31 52.27	1216 41.63 69.33 67.11	131 4.48 7.47 55.74	1 0.03 0.06 20.00	10 0.34 0.57 40.00	1754 60.05
IUD or implanon	36 1.23 24.16 4.50	4 0.14 2.68 9.09	78 2.67 52.35 4.30	30 1.03 20.13 12.77	1 0.03 0.67 20.00	0 0.00 0.00 0.00	149 5.10
only pull out	71 2.43 36.98 8.88	2 0.07 1.04 4.55	105 3.59 54.69 5.79	11 0.38 5.73 4.68	0 0.00 0.00 0.00	3 0.10 1.56 12.00	192 6.57
only condoms	106 3.63 40.61 13.25	5 0.17 1.92 11.36	132 4.52 50.57 7.28	16 0.55 6.13 6.81	0 0.00 0.00 0.00	2 0.07 0.77 8.00	261 8.94
Other methods	7 0.24 16.67 0.88	3 0.10 7.14 6.82	20 0.68 47.62 1.10	10 0.34 23.81 4.26	1 0.03 2.38 20.00	1 0.03 2.38 4.00	42 1.44
Total	800 27.39	44 1.51	1812 62.03	235 8.05	5 0.17	25 0.86	2921 100.00

Frequency Missing = 762

Figure 5 Check cells of zero observations

Table 3 Multinomial logistic regression models testing associations between contraceptive methods and age, race, pregnancy intention, intervention, relationship status, IPV and RC-baseline

Baseline Demographics	**Birth control methods[e]**				
	Vaginal ring/patch/Depo-Provera/Birth control pills	**IUD/implanon**	**Only pull out**	**Only condoms**	**Other methods**
	OR	OR	OR	OR	OR
Race[a]					
White	ref	ref	ref	ref	-
Black American	**0.36***	0.84	1.14	1.09	-
	[0.27, 0.49]	[0.50,1.39]	[0.72,1.81]	[0.74,1.61]	
Multiracial	0.89	1.45	1.81	0.73	-
	[0.51,1.54]	[0.52,4.03]	[0.84,3.89]	[0.29,1.82]	
Other[f]	0.83	0.51	0.56	1.23	-
	[0.52,1.33]	[0.19,1.32]	[0.22,1.47]	[0.78,1.92]	
Pregnancy intention[c]	**0.28***	**0.60***	1.16	0.75	1.03
	[0.19,0.41]	**[0.37,1.00]**	[0.81,1.66]	[0.42,1.32]	[0.45,2.40]
Intervention[b]	0.85	0.93	1.11	0.77	1.01
	[0.58,1.25]	[0.66,1.31]	[0.85,1.44]	[0.58,1.02]	[0.34,2.99]
IPV[c]	0.70	0.54	0.67	0.74	0.67
	[0.45,1.09]	[0.28,1.05]	[0.39,1.15]	[0.51,1.07]	[0.25,1.77]
RC[c]	**0.44***	**0.27***	0.94	**0.59***	0.24
	[0.29,0.67]	**[0.10,0.72]**	[0.50,1.76]	**[0.38,0.93]**	[0.02,2.65]
Relationship status[d]					
Single	ref	ref	ref	ref	ref
Dating one person	**2.59***	1.72	1.17	0.99	2.27
	[1.97,3.40]	[0.94,3.14]	[0.73,1.90]	[0.70,1.39]	[0.88,5.86]
Married	1.97	**4.66***	0.87	0.84	**7.99***
	[1.25,3.10]	**[2.07,10.51]**	[0.40,1.90]	[0.45,1.59]	**[3.73,17.11]**
Other[g]	1.05	1.60	0.81	0.76	**8.22***
	[0.59,1.85]	[0.62,4.11]	[0.28,1.94]	[0.30,1.94]	**[2.37,28.49]**

OR = Odds ratio
*p<.05
[a] reference is White
[b] reference is 0
[c] reference is No
[d] reference is Single
[e] reference is No methods
[f] including Asian, Hispanic/Latina, Native American and other races
[g] including dating more than one person, married but have more sex partner and others

From the result of multinomial regression model of data at Baseline, associations between contraceptive methods and intention for pregnancy, RC and relationship status were significant (**Table 3**). Compared to White women, Black women were less likely to be using vaginal ring/patch/Depo-Provera/birth control pills over not using any methods (OR=0.36, 95%CI [0.27, 0.49]) (**Table 3**). Women who intended to get pregnant were less likely using vaginal ring/patch/Depo-Provera/birth control pills than not using birth control methods (OR=0.28, 95%CI [0.19, 0.41]) and it was less likely for them to use IUD/Implanon too (OR=0.60, 95%CI [0.37, 1.00]) (**Table 3**).

Women who experienced RC were less likely to use vaginal ring/patch/Depo-Provera/birth control pills (OR=0.44, 95%CI [0.29, 0.67]), IUD/Implanon (OR=0.27, 95%CI [0.10, 0.72]), and condoms (OR=0.59, 95%CI [0.38, 0.93]), compared to no methods (**Table 3**). Women who dated one person compared to women who were single, were more likely to use vaginal ring/patch/Depo-Provera/birth control pills over using nothing (OR=2.59, 95%CI [1.97, 3.40]), which was similar to the likelihood that married women used vaginal ring/patch/Depo-Provera/birth control pills (OR=1.97, 95%CI [1.25, 3.10]) (**Table 3**). Married women were also more likely to use long-acting birth control methods than no methods (OR=4.66, 95%CI [2.07, 10.51]) (**Table 3**).

At T2, compared to White women, even though it was still less likely that Black women used vaginal ring/patch/Depo-Provera/Birth control pills over no methods, the possibility of them using condoms over nothing was higher than that of White women (OR=1.43, 95%CI [1.01, 2.03]) (**Table 4**). There was no relationship between RC and contraceptive method at T2. IPV victims were more likely to use IUD/Implanon (OR=1.87, 95%CI [1.04, 3.38]), and pulling out (OR=4.34, 95%CI [1.00, 9.43]) over no methods compared to women without IPV experience at T2 (**Table 4**). Compared to single women, women who dated one person (OR=2.65, 95%CI [1.80, 3.91]),

who were married (OR=1.71, 95%CI [1.04, 1.80]) or in other relationship status (OR=2.16, 95%CI [1.49, 3.14]) were more likely to use vaginal ring/patch/Depo-Provera/birth control pills than no methods (**Table 4**).

Table 4 Multinomial logistic regression models testing associations between contraceptive methods and age, race, pregnancy intention, intervention, relationship status, IPV and RC-T2

T2 Demographics	**Birth control methods[e]**				
	Vaginal ring/patch/Depo-Provera/Birth control pills	**IUD/implanon**	**Only pull out**	**Only condoms**	**Other methods**
	OR	OR	OR	OR	OR
Race[a]					
White	ref	ref	ref	ref	-
Black American	**0.47***	0.81	2.02	**1.43***	-
	[0.35, 0.65]	[0.57,1.14]	[0.79,5.19]	**[1.01,2.03]**	
Multiracial	0.70	1.08	1.80	1.97	-
	[0.43,2.79]	[0.42,2.79]	[0.82,3.99]	[0.60,6.45]	
Other[f]	1.03	0.76	1.44	1.16	-
	[0.67,1.59]	[0.31,1.91]	[0.46,4.47]	[0.62,2.18]	
Intervention[b]	0.83	0.71	1.14	1.01	1.63
	[0.54,1.27]	[0.45,1.13]	[0.51,2.51]	[0.67,1.52]	[0.63,4.21]
IPV[c]	1.25	**1.87***	**4.34***	1.68	2.20
	[0.84,1.87]	**[1.04,3.38]**	**[2.00,9.43]**	[0.67,4.26]	[0.65,7.46]
RC[c]	0.85	0.23	2.37	1.25	1.48
	[0.39,1.88]	[0.02,2.38]	[0.75,7.46]	[0.65,2.40]	[0.13,16.36]
Relationship status[d]					
Single	ref	ref	ref	ref	ref
Dating one person	**2.65***	2.46	1.39	1.10	**3.65***
	[1.80,3.91]	[1.49,4.05]	[0.67,2.89]	[0.69, 1.77]	**[1.33, 10.01]**
Married	**1.71***	**6.14***	1.35	0.85	4.37
	[1.04,2.80]	**[2.83,13.31]**	[0.50, 3.64]	[0.42, 1.71]	[0.98, 19.55]
Other[g]	**2.16***	**2.49***	1.56	1.13	1.41
	[1.49,3.14]	**[1.29, 4.82]**	[0.78, 3.13]	[0.62, 2.06]	[0.38, 5.17]

OR = Odds ratio
*p<.05
[a] reference is White
[b] reference is 0
[c] reference is No
[d] reference is Single
[e] reference is No methods
[f] including Asian, Hispanic/Latina, Native American and other races
[g] including dating more than one person, married but have more sex partner and others

The result of the multinomial logistic regression model using T3 data was shown in **Table 5**, in which multiracial women (OR=2.23, 95%CI [1.18, 4.23]) and other racial women (Asians or Hispanic or Latina or Native Americans) (OR=3.10, 95%CI [1.61, 5.98]) compared to White women were more likely to use pulling out as their only contraceptive methods over no methods (**Table 5**). Women seeking pregnancy were less likely to use all birth control methods except for pulling out (**Table 5**). It was more possible that women would use pulling out as the contraceptive method over not using anything if they had ever experienced IPV (OR=2.53, 95%CI [1.36, 4.72]) and they were less likely to use vaginal ring/patch/Depo-Provera/birth control pills over non contraception use if they were victims of RC (OR=0.42, 95%CI [0.24, 0.75]) (**Table 5**).

Table 5 Multinomial logistic regression models testing associations between contraceptive methods and age, race, pregnancy intention, intervention, relationship status, IPV and RC-T3

T3 Demographics	**Birth control methods[e]**				
	Vaginal ring/patch/Depo-Provera/Birth control pills	**IUD/implanon**	**Only pull out**	**Only condoms**	**Other methods**
	OR	OR	OR	OR	OR
Race[a]					
White	Ref	Ref	Ref	Ref	-
Black American	**0.55***	1.05	1.03	0.95	-
	[0.43, 0.71]	[0.73,1.53]	[0.68,1.57]	[0.50,1.81]	
Multiracial	0.96	1.14	**2.23***	1.19	-
	[0.58,1.59]	[0.49,2.68]	**[1.18,4.23]**	[0.55,2.58]	
Other[f]	0.68	0.86	**3.10***	1.04	-
	[0.43,1.08]	[0.37,1.99]	**[1.61,5.98]**	[0.42,2.58]	
Pregnancy intention[c]	**0.27***	**0.42***	0.87	**0.57***	**0.29***
	[0.22,0.34]	**[0.28,0.63]**	[0.63,1.20]	**[0.37,0.88]**	**[0.11,0.74]**
Intervention[b]	0.83	0.87	1.07	1.06	0.82
	[0.63,1.09]	[0.62,1.24]	[0.67,1.72]	[0.70,1.60]	[0.37,1.83]
IPV[c]	1.15	1.49	**2.53***	1.13	0.99
	[0.76,1.73]	[0.90,2.47]	**[1.36,4.72]**	[0.72,1.77]	[0.31,3.21]
RC[c]	**0.42***	0.57	0.87	0.73	1.21
	[0.24,0.75]	[0.24,1.36]	[0.35,2.14]	[0.32,1.67]	[0.20,7.38]
Relationship status[d]					
Single	Ref	Ref	Ref	Ref	Ref
Dating one person	**3.65***	**2.73***	**2.91***	**1.83***	**6.77***
	[2.82,4.72]	**[1.43,5.24]**	**[1.77,4.77]**	**[1.13,2.96]**	**[2.43,18.88]**
Married	**2.00***	**3.42***	**2.43***	1.39	**11.88***
	[1.33,3.00]	**[1.56,7.49]**	**[1.27,4.63]**	[0.61,3.18]	**[5.20,27.17]**
Other[g]	**2.48***	**3.36***	3.00	**4.01***	**16.55***
	[1.41,4.35]	**[1.11,10.18]**	[0.84,10.43]	**[1.95,8.26]**	**[3.38,81.00]**

OR = Odds ratio
*p<.05
[a] reference is White
[b] reference is 0
[c] reference is No
[d] reference is Single
[e] reference is No methods
[f] including Asian, Hispanic/Latina, Native American and other races
[g] including dating more than one person, married but have more sex partner and others

3.3 GBTM analysis

Before building GBTM, relationships between variables of interest and missing recognition of abusive behaviors were tested. The result showed that differences of Intervention and Relationship status were significant in missingness of recognition of abusive behaviors among three time points and for the other variables, there were no associations between them and Recognition of abusive behaviors at three time point (**Table 6**). The above analysis of missing outcome assisted in learning about missingness of recognition of abusive behaviors.

During modeling recognition of abusive behaviors without risk factors, the minimum value and the maximum value of the response were checked which were -1.098 and 2.197 respectively (**Figure 6**). Thus, the minimum was set as -1.1 and the maximum was set as 2.2 in the CNORM model of GBTM. Then number of groups and polynomial orders were determined by the following process.

Statistics of log recognition of abusive behaviors

The MEANS Procedure

Analysis Variable : recog				
N	Mean	Std Dev	Minimum	Maximum
7532	0.4620826	0.7911549	-1.0986123	2.1972246

Figure 6 Statistics of log recognition of abusive behaviors

BICs moved close to zero as number of groups increased from 1 to 7 and then BICs moved far from zero as number of groups reached 8. However, when number of groups reached 7, numbers of observations of some groups were less than 5% of the whole sample size. To satisfy the condition that the sample size of each group was greater than 5%, number of groups

was determined as 6. Then polynomial orders that would fit best the model were tested (**Table 7**). The model with polynomial orders with one group equaling to 1 and with the rest groups equaling to 2, was found the lowest BIC compared to the others (**Table 7**), which also satisfied the condition that sample size of each group was not less than 5% of the whole sample size (**Figure 7**). Thus, the final model was determined as a six-group model, with polynomial orders 1, 2, 2, 2, 2, 2 for Group 1 to Group 6.

Table 6 Demographics of variables of interest for missing outcome

Subjects' Characteristics	**Number of missing outcome (N=441)**			**P value**
	Baseline (N=158) %(n)	**T2 (N=206) %(n)**	**T3 (N=77) %(n)**	
Age[a] [Mean(SD)]	20.68(3.62)	20.86(3.65)	21.38(3.55)	0.346
Race[b]				0.571
Multiracial	5.06(8)	2.91(6)	2.60(2)	
White	74.05(117)	77.67(160)	72.73(56)	
Black American	16.46(26)	16.50(34)	23.38(18)	
Other	4.43(7)	2.91(6)	1.30(1)	
Relationship status[b]				**<.0001***
Single	44.30(70)	38.35(79)	41.56(32)	
Dating one person	50.00(79)	24.76(51)	51.95(40)	
Married	3.80(6)	1.94(4)	3.90(3)	
Other	1.90(3)	34.95(72)	2.60(2)	
Intervention[b]	50.63(80)	36.81(82)	62.34(48)	**0.003***
Pregnancy intention[b]	5.70(9)	0(0)	3.08(2)	0.421
IPV	38.46(5)	0(0)	2.78(1)	-
RC	0(0)	1.00(1)	0(0)	-

[a] F test of linear regression model of age (dependent) with clinic level as clustering
[b] Wald Log Linear Chi-square test with clinic level as clustering
*p<.05

Table 7 Model selection results for recognition of abusive behavior model-without adjustment

Number of groups	Polynomial order	$BIC_{complex}$ (N=3314)	BIC_{null} (N=6663)
1	2	-7805.78	-7807.18
2	2, 2	-7496.68	-7499.47
3	2, 2, 2	-7291.67	-7295.86
4	2, 2, 2, 2	-7217.35	-7222.93
5	2, 2, 2, 2, 2	-7140.31	-7147.30
6	2, 2, 2, 2, 2, 2	-7127.54	-7135.92
7	2, 2, 2, 2, 2, 2, 2	-7065.58	-7075.36
8	2, 2, 2, 2, 2, 2, 2, 2	-7075.54	-7086.71
6	**1, 2, 2, 2, 2, 2**	**-7122.66**	**-7130.70**
6	1, 1, 2, 2, 2, 2	-7124.45	-7132.14

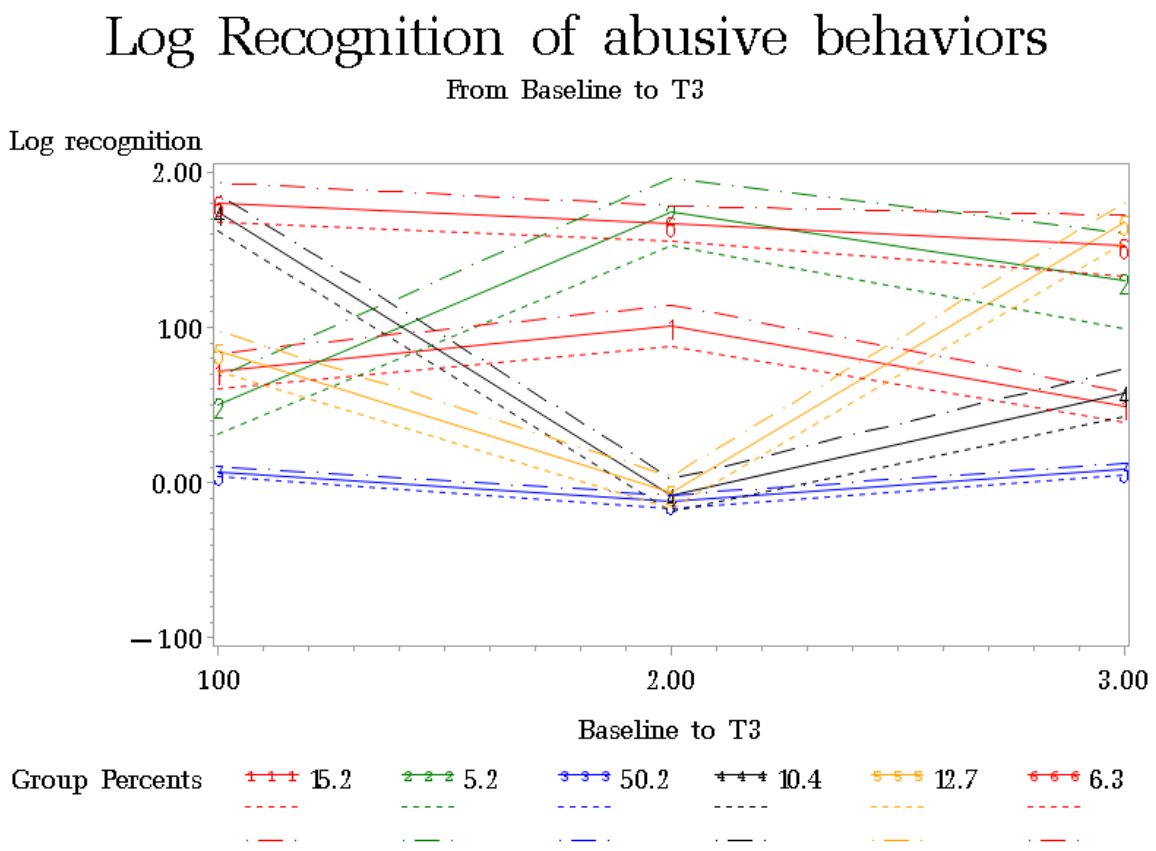

Figure 7 Trajectory group for log recognition of abusive behavior over Baseline to T3 without adjustment, with percentage membership for each trajectory group

The y-axis represents log recognition of abusive behaviors values. Short-dash lines represent lower end of the 95% CI. Long-dash lines represents upper end of the 95% CI.

Table 8 Check missingness among groups of women

GBTM without adjustment	Group percent	Missing proportion
Group 1	15.2	22.7
Group 2	5.2	22.8
Group 3	50.2	22.9
Group 4	10.4	5.6
Group 5	12.7	0
Group 6	6.3	9.6

To check how missingness of the independent variables among groups of women influence the trajectories of women, a method provided by Daniel Nagin (Nagin DS & CL., 2010b) was applied. In detail, proportions of women who did not complete the whole study were calculated to check whether completing this study was associated with recognition of abusive behaviors. **Table 8** showed the missing proportions (proportions of women who did not complete 3 surveys) of six-group women during the one-year study. While women in Group 6 showed the highest recognizing level (**Figure 7**), proportion of Group-6 women not taking the whole surveys from Baseline to T3 was not high (9.6%) (**Table 8**). Proportions of women who did not complete all the surveys in Group 1 (22.7%), Group 2 (22.8%) and Group 3 (22.9%) were almost the same (**Table 8)**, but their levels of recognition of abusive behaviors differed (**Figure 7**). Thus, patterns of missing surveys from women at three-time points should not associate with recognition of abusive behaviors, which meant that missingness of independent variable did not affect building GBTM of recognition of abusive behaviors.

After the model was built, Chi-square test and F test in ANOVA were used to test the differences among proportions of categories of variables in each group after checking assumptions of each test. First, from the patterns of trajectories shown in **Figure 7**, women (50.2%) grouped in Group 3 had lower recognition of abusive behaviors throughout the whole study, compared to

other women. 15.2% women (Group 1) had moderate recognition of abusive behaviors from Baseline to T3 and 6.3% women (Group 6) owned high level of recognition of abusive behaviors throughout the study. Five percent women (Group 2) recognized abusive behaviors at a moderate level at Baseline, but their level of recognition climbed up to a higher level at T2, which then dropped down slightly from T2 to T3. About 12.7% women (Group 5) started at a moderate level recognizing abusive behaviors and ended with a high level of recognition at T3 after reaching the bottom level at T2. Ten percent women (Group 4) started with a high level of recognition and their level of recognition decreased dramatically from Baseline to T2; even though the level ascended from T2 to T3, women in this group still failed to reach back the level of recognizing abusive behaviors at Baseline and ended with a moderate recognizing level of abusive behaviors. (**Figure 7**)

The differences of variables that interested us among the above 6 groups of women were shown in **Table 9** – **Table 11**, from which we could conclude that age at Baseline (p=0.039), race at Baseline (p=0.011), intervention at Baseline (p=0.033), RC at Baseline (p=0.012), relationship status from Baseline (p=0.003) to T3 (p=0.012), contraceptive methods at Baseline (p=0.003) were significantly different among the 6 groups of women. Since this model was built without adjustment, we could not determine which characteristic was significant in individual trajectory.

Table 9 Characteristics for each reocognition of abusive behaviors trajectory subgroup without adjustment

Subjects' characteristics	Trajectory groups						P value
	Group1 (N=474)	**Group 2 (N=101)**	**Group3 (N=2220)**	**Group 4 (N=408)**	**Group 5 (N=367)**	**Group 6 (N=113)**	
Age[a] at baseline, mean(SD)	21.86 (3.73)	20.89 (5.53)	20.05 (3.57)	21.90 (3.31)	22.10 (3.46)	22.13 (3.50)	0.380
Race[b]							**0.011***
White	80.38 (381)	82.18 (83)	78.87 (1751)	83.82 (342)	82.29 (302)	81.42 (92)	
Black American	12.24 (58)	14.85 (15)	15.05 (334)	10.05 (41)	9.26 (34)	8.85 (10)	
Multiracial	4.43 (21)	1.98 (2)	2.61 (58)	3.19 (13)	3.54 (13)	2.65 (3)	
Other	2.95 (14)	0.99 (1)	3.47 (77)	2.94 (12)	4.90 (18)	7.08 (8)	
Intervention[b]	44.30 (210)	46.53 (47)	51.40 (1141)	47.79 (195)	48.23 (177)	41.59 (47)	**0.033***
Pregnancy intention[b]	10.36 (49)	13.86 (14)	11.49 (255)	6.86 (28)	11.72 (43)	7.08 (8)	0.058
IPV							
Baseline[b]	20.60 (48)	23.40 (11)	23.55 (228)	26.24 (53)	21.59 (38)	24.00 (12)	0.812
T2[b]	9.14 (37)	6.12 (6)	6.75 (110)	7.24 (22)	5.43 (15)	4.85 (5)	0.425
T3[b]	7.71 (30)	6.02 (5)	6.58 (111)	7.89 (24)	6.37 (20)	4.72 (5)	0.832
RC[c]							
Baseline[b]	6.46 (27)	8.99 (8)	6.42 (121)	3.23 (12)	4.43 (14)	0 (0)	**0.012***
T2[b]	3.50 (13)	2.35 (2)	2.64 (41)	1.35 (4)	1.86 (5)	2.06 (2)	0.580
T3[b]	4.28 (16)	3.66 (3)	3.61 (58)	2.71 (8)	0.97 (3)	0 (0)	0.051

[a] F test to test the differences of mean of ages among the groups
[b] Chi-square tests
[c] Group 6 was dropped in Chi-square test due to zero values
*p<.05

Table 10 Relationship status for each recognition of abusive behaviors trajectory subgroup without adjustment

Time point	Relationship status	Trajectory group						P value[a]
		Group1 (N=474)	Group 2 (N=101)	Group3 (N=2220)	Group 4 (N=408)	Group 5 (N=367)	Group 6 (N=113)	
Baseline								**0.003***
	Single	32.70 (155)	40.59 (41)	33.20 (737)	26.72 (109)	28.07 (103)	31.86 (36)	
	Dating one person	59.70 (283)	55.45 (56)	56.31 (1250)	65.69 (268)	60.49 (222)	61.06 (69)	
	Married	4.43 (21)	0.99 (1)	7.66 (170)	6.37 (26)	9.54 (35)	5.31 (6)	
	Other	3.16 (15)	2.97 (3)	2.84 (63)	1.23 (5)	1.91 (7)	1.77 (2)	
T2								**<.0001***
	Single	30.05 (125)	36.73 (36)	32.56 (578)	26.15 (85)	28.52 (85)	34.29 (36)	
	Dating one person	57.45 (239)	56.12 (56)	41.52 (737)	38.46 (125)	39.93 (119)	55.24 (58)	
	Married	5.29 (22)	2.04 (2)	6.08 (108)	4.62 (15)	3.36 (10)	8.57 (9)	
	Other	7.21 (30)	5.10 (5)	19.83 (352)	30.77 (100)	28.19 (84)	1.90 (2)	
T3								**0.012***
	Single	27.62 (108)	28.92 (24)	29.52 (509)	28.76 (88)	19.62 (62)	30.19 (32)	
	Dating one person	62.92 (246)	60.24 (50)	56.67 (977)	61.44 (188)	66.14 (209)	59.43 (63)	
	Married	7.93 (31)	6.02 (5)	11.66 (201)	8.50 (26)	10.76 (34)	8.49 (9)	
	Other	1.53 (6)	4.82 (4)	2.15 (37)	1.31 (4)	3.48 (11)	1.89 (2)	

[a] Chi-square tests

*p<.05

Table 11 Birth control methods for each recognition of abusive behaviors trajectory subgroup without adjustment

Time point	Birth control method	Trajectory group						P value [a]
		Group1 (N=474)	Group 2 (N=101)	Group3 (N=2220)	Group 4 (N=408)	Group 5 (N=367)	Group 6 (N=113)	
Baseline								**0.003***
	Not use anything	17.94 (68)	18.52 (15)	18.76 (328)	14.45 (49)	19.52 (57)	7.32 (6)	
	Vaginal ring/patch/ Depo-Provera/Birth control pills	60.95 (231)	64.20 (52)	57.55 (1006)	65.78 (223)	61.64 (180)	75.61 (62)	
	IUD or Implanon	2.90 (11)	2.47 (2)	4.98 (87)	8.55 (29)	5.48 (16)	4.88 (4)	
	only pull out	6.60 (25)	3.70(3)	7.67 (134)	2.65 (9)	6.16 (18)	3.66 (3)	
	only condoms	10.29 (39)	9.88 (8)	9.55 (167)	6.78 (23)	6.16 (18)	7.32 (6)	
	Other methods	1.32 (5)	1.23 (1)	1.49 (26)	1.77 (6)	1.03 (3)	1.22 (1)	
T2								0.221
	Not use anything	14.37 (51)	15.85 (13)	22.07 (326)	20.35 (58)	21.96 (56)	12.09 (11)	
	Vaginal ring/patch/ Depo-Provera/Birth control pills	68.45 (243)	68.29 (56)	61.21 (904)	63.86 (182)	59.61 (152)	73.63 (67)	
	IUD or Implanon	5.63 (20)	2.44 (2)	6.36 (94)	7.37 (21)	7.06 (18)	7.69 (7)	
	only pull out	4.51 (16)	3.66 (3)	3.25 (48)	1.75 (5)	3.53 (9)	2.20 (2)	
	only condoms	5.63 (20)	8.54 (7)	6.03 (89)	5.26 (15)	7.45 (19)	4.40 (4)	
	Other methods	1.41 (5)	1.22 (1)	1.08 (16)	1.40 (4)	0.39 (1)	0 (0)	

Table 11 Continued								
T3								0.697
	Not use anything	25.00 (94)	27.85 (22)	28.19 (446)	25.26 (72)	26.25 (79)	21.43 (21)	
	Vaginal ring/patch/ Depo-Provera/Birth control pills	55.59 (209)	58.23 (46)	52.28 (827)	54.04 (154)	52.82 (159)	54.08 (53)	
	IUD or Implanon	6.12 (23)	2.53 (2)	7.02 (111)	7.72 (22)	5.98 (18)	9.18 (9)	
	only pull out	3.72 (14)	5.06 (4)	4.74 (75)	4.21 (12)	4.65 (14)	5.10 (5)	
	only condoms	6.12 (23)	5.06 (4)	6.19 (98)	6.67 (19)	7.31 (22)	10.20 (10)	
	Other methods	3.46 (13)	1.27 (1)	1.58 (25)	2.11 (6)	2.99 (9)	0 (0)	

[a] Chi-square tests
*p<.05

Thus, another model was built with race and intervention as time-stable risk factors; birth control methods, age, relationship status, RC and IPV as time-varying factors. First step was to find the number of groups and then polynomial orders of each group, which was the same as building the above GBTM without adjustment. The result showed that a three-group model with polynomial orders 1, 2, 2 had the lowest BIC values (**Table 12**).

Table 12 Model selection results for recognition of abusive behavior model with adjustment

Number of groups	Polynomial order	$BIC_{complex}$ (N=2189)	BIC_{null} (N=3697.34)
1	2	-3695.61	-3697.34
2	2, 2	-3544.73	-3548.59
3	2, 2, 2	-3521.99	-3527.96
4	2, 2, 2, 2	-3526.62	-3534.71
3	**1, 2, 2**	**-3520.10**	**-3525.87**
3	1, 1, 2	-3535.15	-3540.74
3	1, 2, 3	-3540.12	-3546.09

After adding risk factors, number of groups decreased to three. In detail, Group Steady Low (81.7% women, Group 1) started at a low level of recognition of abusive behaviors and maintained at this level from Baseline to T3 (**Figure 8**). Women in both Group Middle (Group 2) and Group Relatively High (Group 3) started with a moderate level of recognizing abusive behaviors and at T3 ended with the same level at the Baseline (**Figure 8**). The level of recognition of women in Group Relatively High increased to a high level and reached the peak at T2 then dropped down, while in Group Middle women's ability in recognizing abusive behaviors reached the bottom at T2 (almost the same level of women in Group Steay Low at T2) before climbing up from T2 to T3 (**Figure 8**). The difference between women in Group Middle and Group Relatively High in levels of recognition at T2 was discussed in **4.0 Discussion**.

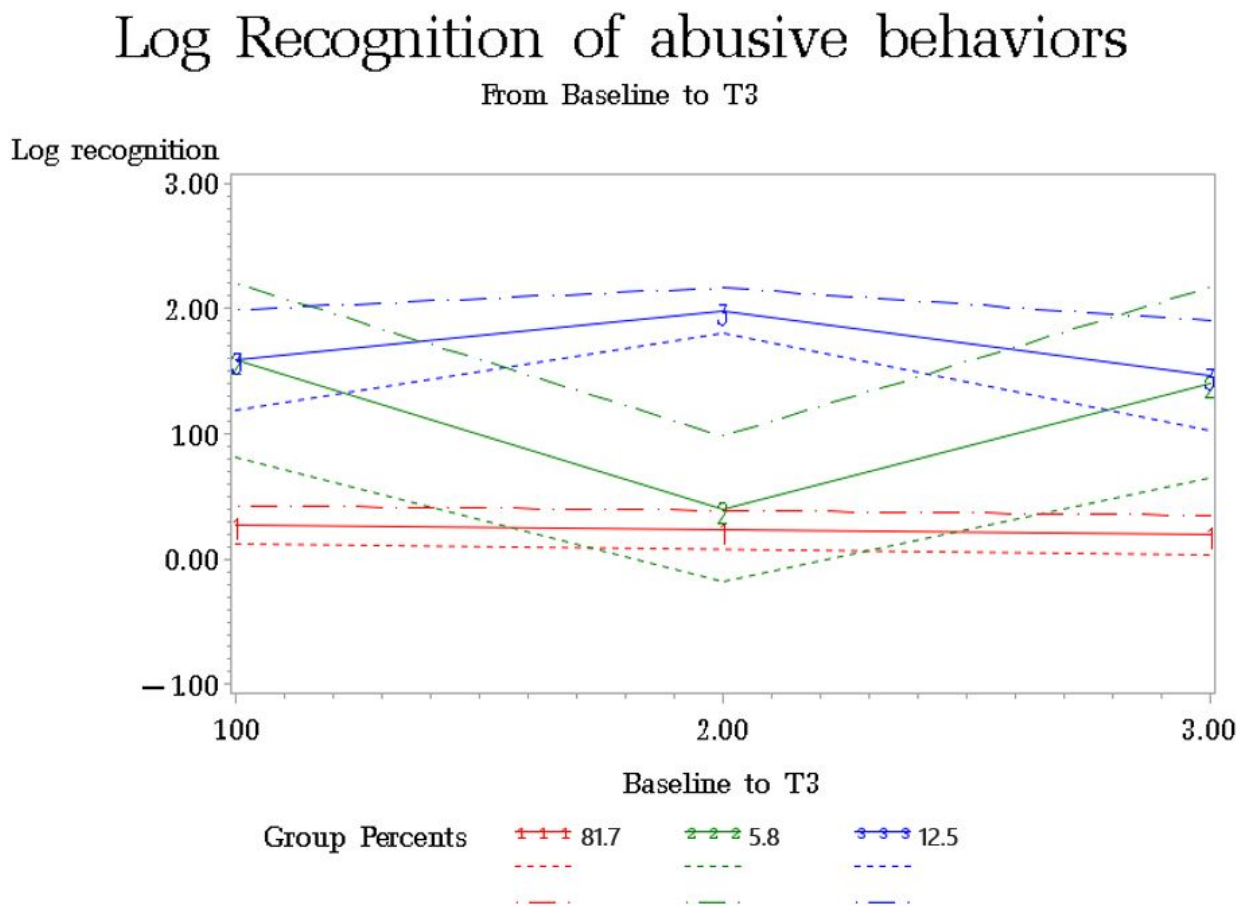

Figure 8 Trajectory group for log recognition of abusive behavior over Baseline to T3 with percentage membership for each trajectory group

The y-axis represents log recognition of abusive behaviors values. Three trajectory groups were identified. Short-dash lines represent lower end of the 95% CI. Long-dash lines represents upper end of the 95% CI.

To check missingness of surveys-taken (independent variable) among the three-groups women, proportions of women who did not complete the whole study were calculated and the result was shown in **Table 13**. While women in Group Relatively High showed the highest recognizing level, the proportion of them not completing the whole surveys (22.7%) was almost the same as that of Group Middle (22.9%) but the levels of recognition of abusive behaviors between Group Relatively High and Group Middle differed at T2 apparently (**Figure 8, Table 13**). Thus, after adjusting for risk factors, the missing survey-taken of women was not associated with

recognition of abusive behaviors either, so missingness of the independent variable did not affect the GBTM with adjustment for risk factors in our thesis.

Table 13 Check missingness among groups of women

GBTM with adjustment	Group percent	Missing proportion
Group Steady Low	81.7	20.4
Group Middle	5.8	22.9
Group Relatively High	12.5	22.7

From F test and Chi-square test, we concluded that intervention (p=0.016) and IPV at T2 (p=0.038) were the only two variables with significant different proportions among the three groups of women (**Table 14 – Table 16**). The SAS output showed that intervention was significant (p=0.044) in the trajectory of women in Group Relatively High. As shown in **Table 14**, the proportion of women in Group Middle who experienced IPV in past 3 months before T2 was 3.8%, while that of women in Group Relatively High was 9.63%; RC of Group Middle at T2 was 0.66% while that of Group Relatively High was 4.45%.

Table 14 Characteristics for each reocognition of abusive behaviors trajectory subgroup with adjustment

Subjects' characteristics	Trajectory group			P value
	Group Steady Low (N=3008)	**Group Middle (N=214)**	**Group Relatively High (N=461)**	
Age[a], mean(SD)	22.00(3.54)	21.80(3.54)	21.99(3.62)	0.734
Race[b]				0.338
White	79.82(2401)	82.24(176)	81.13(374)	
Black American	13.86(417)	9.35(20)	11.93(55)	
Multiracial	2.89(87)	4.67(10)	2.82(13)	
Other	3.42(103)	3.74(8)	4.12(19)	
Intervention [b]	50.10(1507)	51.87(111)	43.17(199)	**0.016***
Pregnancy intention [b]	10.61(319)	14.49(31)	10.20(47)	0.191
IPV[b]				
Baseline	23.03(316)	22.58(21)	25.12(53)	0.790
T2	6.74(155)	3.80(6)	9.63(34)	**0.038***
T3	6.86(162)	6.75(11)	5.92(21)	0.804
RC[b]				
Baseline	5.78(149)	7.78(14)	4.62(19)	0.311
T2	2.34(51)	0.66(1)	4.45(15)	**0.023***
T3	3.28(74)	3.18(5)	2.58(9)	0.787

[a] baseline, F test to test the differences of mean of ages among the groups
[b] Chi-square tests
*p<.05

Table 15 Relationship status for each recognition of abusive behaviors trajectory subgroup with adjustment

Time point	Relationship status	Trajectory group			P value[a]
		Group Steady Low (N=3008)	Group Middle (N=214)	Group Relatively High (N=461)	
Baseline					0.071
	Single	32.68(983)	26.17(56)	30.80(142)	
	Dating one person	57.71(1736)	64.02(137)	59.65(275)	
	Married	6.78(204)	9.35(20)	7.59(35)	
	Other	2.83(85)	0.47(1)	1.95(9)	
T2					0.991
	Single	31.43(775)	29.41(50)	31.83(120)	
	Dating one person	44.08(1087)	44.71(76)	44.56(168)	
	Married	5.39(133)	5.88(10)	5.84(22)	
	Other	19.10(471)	20.00(34)	17.77(67)	
T3					0.978
	Single	28.35(680)	27.44(45)	27.30(98)	
	Dating one person	59.07(1417)	59.76(98)	59.89(215)	
	Married	10.34(248)	11.59(19)	10.58(38)	
	Other	2.25(54)	1.22(2)	2.23(8)	

[a] Chi-square tests
*p<.05

Table 16 Birth control methods for each recognition of abusive behaviors trajectory subgroup with adjustment

Time point	Birth control method	Trajectory group			P value[a]
		Group Low (N=3008)	Group Middle (N=214)	Group Relatively High (N=461)	
Baseline					0.341
	Not use anything	17.82(423)	13.10(22)	20.58(78)	
	Vaginal ring/patch/Depo-Provera/Birth control pills	59.69(1417)	66.67(112)	59.37(225)	
	IUD or Implanon	5.35(127)	4.76(8)	3.69(14)	
	only pull out	6.53(155)	4.17(7)	7.92(30)	
	only condoms	9.14(217)	10.12(17)	7.12(27)	
	Other methods	1.47(35)	1.19(2)	1.32(5)	
T2					0.894
	Not use anything	20.07(415)	23.24(33)	20.24(67)	
	Vaginal ring/patch/Depo-Provera/Birth control pills	62.77(1298)	65.49(93)	63.44(210)	
	IUD or Implanon	6.58(136)	3.52(5)	6.34(21)	
	only pull out	3.34(69)	1.41(2)	3.32(11)	
	only condoms	6.19(128)	4.93(7)	5.74(19)	
	Other methods	1.06(22)	1.41(2)	0.91(3)	

Table 16 Continued

T3					0.713
	Not use anything	27.05(601)	24.68(38)	27.86(95)	
	Vaginal ring/patch/Depo-Provera/Birth control pills	52.79(1173)	57.79(89)	53.67(183)	
	IUD or Implanon	7.16(159)	4.55(7)	5.57(19)	
	only pull out	4.68(104)	1.95(3)	4.69(16)	
	only condoms	6.39(142)	8.44(13)	6.16(21)	
	Other methods	1.94(43)	2.60(4)	2.05(7)	

[a] Chi-square tests
*p<.05

Even though contraceptive methods used at three time points among the three groups of women was not different (**Table 16**), from GBTM, we were able to characterize consistent and inconsistent contraceptive methods among three-group women. Vaginal ring/patch/Depo-Provera/birth control pills and IUD/Implanon were relatively used consistently because among the three groups, most of women who used the above methods at Baseline did not switch to the others (**Figure 9- Figure 11**). Birth control methods 'only pull out' and 'only condoms' were inconsistent contraceptive methods because switching rates of 'only pull out' and 'only condoms' among the three-group women were high (**Figure 9- Figure 11**). In all, among the three-group women from Baseline to T3, vaginal ring/patch/Depo-Provera/birth control pills and IUD/Implanon were consistent contraceptive methods while pulling out and condoms were inconsistent contraceptive methods.

Frequency Percent Row Pct Col Pct	Table of bcmethod1 by bcmethod3						
	bcmethod3						
bcmethod1	not use anything	Vaginal ring/patch/Depo-Provera/Birth control pills	IUD or implanon	only pull out	only condoms	Other methods	Total
not use anything	13 8.55 61.90 35.14	5 3.29 23.81 6.02	1 0.66 4.76 11.11	0 0.00 0.00 0.00	1 0.66 4.76 10.00	1 0.66 4.76 16.67	21 13.82
Vaginal ring/patch/Depo-Provera/Birth control pills	13 8.55 12.87 35.14	70 46.05 69.31 84.34	4 2.63 3.96 44.44	5 3.29 4.95 71.43	5 3.29 4.95 50.00	4 2.63 3.96 66.67	101 66.45
IUD or implanon	2 1.32 28.57 5.41	1 0.66 14.29 1.20	3 1.97 42.86 33.33	0 0.00 0.00 0.00	1 0.66 14.29 10.00	0 0.00 0.00 0.00	7 4.61
only pull out	3 1.97 37.50 8.11	2 1.32 25.00 2.41	1 0.66 12.50 11.11	2 1.32 25.00 28.57	0 0.00 0.00 0.00	0 0.00 0.00 0.00	8 5.26
only condoms	6 3.95 46.15 16.22	4 2.63 30.77 4.82	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 1.97 23.08 30.00	0 0.00 0.00 0.00	13 8.55
Other methods	0 0.00 0.00 0.00	1 0.66 50.00 1.20	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.66 50.00 16.67	2 1.32

Figure 9 Birth control methods used at baseline and T3 for Group Steady Low

Frequency Percent Row Pct Col Pct	Table of bcmethod1 by bcmethod3						
	bcmethod3						
bcmethod1	not use anything	Vaginal ring/patch/Depo-Provera/Birth control pills	IUD or implanon	only pull out	only condoms	Other methods	Total
not use anything	131 7.52 43.52 31.80	108 6.20 35.88 11.00	18 1.03 5.98 13.74	19 1.09 6.31 24.36	22 1.26 7.31 20.56	3 0.17 1.00 9.09	301 17.27
Vaginal ring/patch/Depo-Provera/Birth control pills	195 11.19 17.89 47.33	766 43.95 70.28 78.00	41 2.35 3.76 31.30	30 1.72 2.75 38.46	43 2.47 3.94 40.19	15 0.86 1.38 45.45	1090 62.54
IUD or implanon	14 0.80 15.38 3.40	11 0.63 12.09 1.12	61 3.50 67.03 46.56	0 0.00 0.00 0.00	4 0.23 4.40 3.74	1 0.06 1.10 3.03	91 5.22
only pull out	24 1.38 26.09 5.83	26 1.49 28.26 2.65	6 0.34 6.52 4.58	25 1.43 27.17 32.05	9 0.52 9.78 8.41	2 0.11 2.17 6.06	92 5.28
only condoms	42 2.41 28.97 10.19	65 3.73 44.83 6.62	3 0.17 2.07 2.29	4 0.23 2.76 5.13	28 1.61 19.31 26.17	3 0.17 2.07 9.09	145 8.32
Other methods	6 0.34 25.00 1.46	6 0.34 25.00 0.61	2 0.11 8.33 1.53	0 0.00 0.00 0.00	1 0.06 4.17 0.93	9 0.52 37.50 27.27	24 1.38

Figure 10 Birth control methods used at baseline and T3 for Group Middle

Frequency Percent Row Pct Col Pct	Table of bcmethod1 by bcmethod3						
	bcmethod3						
bcmethod1	not use anything	Vaginal ring/patch/Depo-Provera/Birth control pills	IUD or implanon	only pull out	only condoms	Other methods	Total
not use anything	16 5.44 34.78 24.24	18 6.12 39.13 10.65	5 1.70 10.87 27.78	2 0.68 4.35 16.67	2 0.68 4.35 10.53	3 1.02 6.52 30.00	46 15.65
Vaginal ring/patch/Depo-Provera/Birth control pills	37 12.59 19.89 56.06	130 44.22 69.89 76.92	3 1.02 1.61 16.67	4 1.36 2.15 33.33	10 3.40 5.38 52.63	2 0.68 1.08 20.00	186 63.27
IUD or implanon	3 1.02 23.08 4.55	0 0.00 0.00 0.00	8 2.72 61.54 44.44	1 0.34 7.69 8.33	0 0.00 0.00 0.00	1 0.34 7.69 10.00	13 4.42
only pull out	7 2.38 31.82 10.61	8 2.72 36.36 4.73	0 0.00 0.00 0.00	3 1.02 13.64 25.00	3 1.02 13.64 15.79	1 0.34 4.55 10.00	22 7.48
only condoms	3 1.02 13.64 4.55	12 4.08 54.55 7.10	2 0.68 9.09 11.11	2 0.68 9.09 16.67	3 1.02 13.64 15.79	0 0.00 0.00 0.00	22 7.48
Other methods	0 0.00 0.00 0.00	1 0.34 20.00 0.59	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.34 20.00 5.26	3 1.02 60.00 30.00	5 1.70

Figure 11 Birth control methods used at baseline and T3 for Group Relatively High

4.0 Discussion

In this thesis, we hypothesized that there should exist some associations between IPV/RC and choices of contraceptive methods. And we also hypothesized women's individual level of recognizing abusive behaviors over time would be associated with different choices of birth control methods and experiences of IPV/RC.

Our first hypothesis was supported by results of multinomial logistic regression model, which showed that there existed associations between birth control methods and IPV/RC. Our second hypothesis was also supported by the significant differences of IPV/RC among groups of women who were grouped by GBTM of recognition of abusive behaviors.

In this study, for women conditionally on one factor (age, race, intention for pregnancy, IPV, RC, intervention), the probability of choosing one contraceptive method over another was obtained. From Baseline to T3, Black women were less likely to use vaginal ring/patch/Depo-Provera/Birth control pills as birth control methods than White women and for women with pregnancy intention, they were less likely to use birth control methods over not using any methods.

Using GBTM, our second objective, finding whether women's individual level of recognizing abusive behaviors was associated with birth control methods and IPV/RC was achieved. From GBTM, distinct patterns of recognition of abusive behaviors were identified, which were reflective of variations in women's age, race, relationship status, whether receiving intervention, intention for pregnancy, experiences of IPV/RC over a one-year time period. Comparisons of the shapes of each trajectory in the models were made. To our knowledge, this is

the first use of GBTM in women's health data to reflect patterns of recognition of abusive behaviors.

Six distinct subgroups of women by patterns of recognition of abusive behaviors were identified by GBTM of recognition of abusive behaviors without adjustment, that included: Group 3 in which women's recognition of abusive behaviors stayed steadily low throughout the study, Group 6 in which women recognized abusive behaviors to a high extend from Baseline to T3, Group 1 in which women somewhat were able to recognize abusive behaviors, Group 2 with a convex-shape trajectory, Group 4 and Group 5, the trajectories of which showed concave shapes. In detail, Group 4 and Group 5 showed big drops from Baseline to T2 followed by big jumps from T2 to T3. What interested us was that why women recognized abusive behaviors dropped down rapidly in a short period of 12 to 20 weeks from Baseline.

Assuming no data errors, it could be very interesting to explore why there existed drops of recognition of abusive behaviors for women in Group 4 and Group 5 at T2, who in total made up 14.6% of women in the dataset (**Figure 7**). At T2, both Group-4 and Group-5 women who dated one person dropped from around 60% at Baseline to 40% at T2 and then increased back to about 60% at T3. Opposite to women who dated one person, proportions of Group-4 and Group-5 women who were in other relationship status (dating more than one partners, married but have more than one sex partner and other) increased from around 2% at Baseline to 30% at T2 and then dropping to around 2% at T3 (**Table 10**). Thus, I considered being in a serious relationship (eg, dating one person) might help women to recognize sexually abusive behaviors. This was the first time applying GBTM to model recognition of abusive behaviors among women without adjusting for any factors so we did not find any studies that showed the same conclusion that a serious relationship might help women to recognize sexually abusive behaviors. However, there

were some studies showing similar results. One similar result found that risk for partner violence for women in serious relationship was less than women not in a healthy relationship (Miller et al., 2010).One study showed that partner violence was higher among women who had been in several marriages and the behavioral and social traits of women were associated with sexual violence (Salam A, Alim A, & T., 2006). Another study found that among adolescents who were in dating relationship, 60% of them experienced abusive acts (Symons PY, Groër MW, Kepler-Youngblood P, & V., 1994), but dating relationship was not categorized in this study and we would not be able to tell the difference in abusive behaviors between healthy dating relationship and unhealthy dating relationship.

Three distinct subgroups of women by patterns of recognition of abusive behaviors were identified by GBTM with adjustment that included: Group Steady Low in which women's recognition of abusive behaviors stayed steadily low throughout the study, Group Relatively High with a convex-shape trajectory, Group Middle, the trajectory of which showed a concave shape. Group Middle and Group Relatively High showed opposite trends from Baseline to T3. After analyzing from the statistics of demographic characteristics, the great difference between Group Middle and Group Relatively High should result from IPV and RC at T2. This is because IPV and RC were the only two factors that differed significantly at T2 among the three groups of women (**Table 13**). Intervention was significantly different among three-group women (**Table 13**) but it was a time-stable variable which meant its effect worked from Baseline to T3 instead of only at T2. If intervention caused the difference between Group Middle and Group Relatively High at T2, it should also cause the same difference between the two groups at T3. However, recognition level of Group Middle and Group Relatively High was the same at T3 (**Figure 8**). Except for IPV/RC and intervention, all other variables did not differ significantly among the three-group women

throughout the study, so these variables were not able to make the difference between Group Middle and Group Relatively High at T2. Thus, experiencing IPV and RC might stimulate women's sensitivity in recognizing abusive behaviors happening around them. However, one published study showed that high-school girls who reported RC were less likely to have high recognition of abusive behaviors (Northridge JL, Silver, Talib HJ, & SM., 2017), which conflicts with our conclusion. Since women in Northridge study were high-school girls while women in our study were not limited to school and also how IPV was associated with recognition of abusive behaviors was not analyzed, the results of the two studies might not be comparable. So, it would be interesting to study whether experiences of IPV/RC stimulate high-school girls' recognition of abusive behaviors and then do the comparison with Northridge study. Whether IPV/RC stimulate recognition of abusive behaviors would help healthcare providers and clinicians to design an effective method to reduce women's risk for being victims of abusive behaviors.

4.1 Limitation

Like all other data analysis, the data analysis in this thesis is not free from limitations. First of all, since questions of birth control methods listed in the surveys were dichotomous (answers Yes/No), women could choose more than one 'Yes' which meant that they used more than one birth control methods in the past 30 days, it is impossible to create one variable which showed exactly the methods individual women chose without losing information. In this thesis, birth control methods vaginal ring, patch, Depo-Provera and birth control pills could be grouped together because the above were all birth control methods that could work for one to several months per injection or shot. IUD and Implanon were grouped together since they both could

work for several years and other subgroups were not re-grouped including 'No methods', 'Only pull out', 'Only condoms' and 'Other methods'. Thus, if a woman used IUD along with another method during the past 30 days, she would be grouped into category of IUD/Implanon instead of category of 'Other methods'. The rate of women who switched birth control methods during the one-year study was 17.30% after creating the variable of birth control methods, which meant that actual switch rate should be higher due to information loss by combination of categories. For example, without recreating birth control methods, one woman who switched from vaginal ring at Baseline to birth control pills at T2 would be counted as people who switched birth control methods. However, after recreating the variable, woman would not be counted as people that switched birth control methods. Thus, some information might be lost when building the multinomial logistic regression model. Variables for relationship status and race were combined for some categories to prevent zero cells, which might cause inaccurate statistics and incorrect interpretation. However, it was necessary to perform the modeling.

Similar to birth control methods, the variable for recognition of abusive behaviors was created from a series of questions which asked women to choose a value (0: extremely abusive to 3:not abusive) from the 4 points Likert scale to demonstrate how abusive these women thought about in specific situations. In detail, the values of all questions were added up and mean values were taken as the response to build the GBTM. Since the distribution of the mean values was extremely right-skewed, negative log values were taken to build the model. Thus, the original discrete variables related to recognition of abusive behaviors were transferred to one continuous variable and built by a CNORM within GBTM. Because the response variable was taken logarithmically, differences between any two values of the response became closer, which might result in two women whose responses to the recognition of abusive behaviors were different being

grouped together in the GBTM. As an example, a woman with the mean value of recognition of abusive behaviors equaling to 3 (not abusive) would end with the response value -0.478 while a woman whose mean value of recognition of abusive behaviors as 2 (a little abusive) would have the final value as -0.301, and from the GBTM plot, the two women should have been grouped together in group Middle (**Figure 7**), which means that the result we obtained might be imprecise.

Fisher test should be applied to the sample with small sample size with any cell having less than 5 observations; the situation happened in our dataset. However, due to Fisher test taking a long time to calculate in SAS, Chi-square test was applied as the alternative method. Since Fisher is more conservative than Chi-square, any rejection made by Chi-square test would be rejected by Fisher.

Despite the potential limitations mentioned above, there are major strengths by applying multinomial logistic regression and GBTM in this study. The multinomial logistic regression helped us better understand birth control methods. The use of GBTM helped to show the patterns of women in different trajectories and what characteristics mattered in distinguishing differences among women in different groups.

In conclusion, GBTM of recognition of abusive behaviors in women who looked for help in clinics allows for identification of women into subgroups and patterns. Combining with the Chi-squared test and F test, the GBTM also helped to identify the characteristics and other factors that influenced the responses of women's recognition of abusive behaviors. From the three-group GBTM, we concluded that experiences of IPV/RC stimulate women's recognition of abusive behaviors and from the six-group GBTM, we concluded that being in a serious relationship might help women to recognize sexually abusive behaviors. To support the above conclusions, further studies are needed to be carried out.

Also, further studies to qualify the way to create the response variables and clarify the accuracy of the dataset are needed to determine how the women should be accurately grouped to test which factors are associated with specific groups. Comparison of the GBTM without adjustment and the GBTM with adjustment can be made in future studies to look for more interesting finding and to understand the mechanism of how samples were grouped in GBTM.

Appendix SAS Output for the Model of Log Recognition of Abusive Behaviors

Appendix A SAS Output for the Model of Log Recognition of Abusive Behaviors without Adjustment

Maximum Likelihood Estimates
Model: Censored Normal (cnorm)

Group	Parameter	Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
1	Intercept	-0.37536	0.20165	-1.861	0.0627
	Linear	1.50075	0.24156	6.213	0.0000
	Quadratic	-0.40423	0.06095	-6.632	0.0000
2	Intercept	-2.57764	0.39111	-6.591	0.0000
	Linear	3.96744	0.45717	8.678	0.0000
	Quadratic	-0.89145	0.11880	-7.504	0.0000
3	Intercept	0.67155	0.06867	9.780	0.0000
	Linear	-0.80521	0.08111	-9.928	0.0000
	Quadratic	0.20310	0.02041	9.952	0.0000
4	Intercept	6.19131	0.21182	29.229	0.0000
	Linear	-5.67236	0.25673	-22.094	0.0000
	Quadratic	1.26710	0.06833	18.543	0.0000
5	Intercept	4.44329	0.27674	16.056	0.0000
	Linear	-4.93815	0.29184	-16.921	0.0000
	Quadratic	1.34214	0.06897	19.458	0.0000
6	Intercept	2.02509	0.09409	21.522	0.0000
	Linear	-0.16111	0.04935	-3.265	0.0011
	Sigma	0.45800	0.00551	83.134	0.0000
Group membership					
1	(%)	15.15880	1.32932	11.403	0.0000
2	(%)	5.22867	0.97361	5.370	0.0000
3	(%)	50.23491	1.50333	33.416	0.0000
4	(%)	10.37509	1.02947	10.078	0.0000
5	(%)	12.73212	1.10263	11.547	0.0000
6	(%)	6.27041	0.73901	8.485	0.0000

BIC= -7130.70 (N=6663) BIC= -7122.66 (N=3314) AIC= -7052.45 L= -7029.45

Appendix B SAS Output for the Model of Log Recognition of Abusive Behaviors with Adjustment

Maximum Likelihood Estimates
Model: Censored Normal (cnorm)

Group	Parameter	Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
1	Intercept	0.31321	0.07915	3.957	0.0001
	Linear	-0.04055	0.01580	-2.566	0.0103
	bcmethod101	0.00715	0.01061	0.674	0.5004
	age101	-0.00416	0.00316	-1.314	0.1890
	relstatb101	0.02419	0.01281	1.889	0.0590
	rep101	-0.08594	0.05866	-1.465	0.1430
	ipv101	-0.03078	0.03673	-0.838	0.4021
2	Intercept	5.07792	0.49282	10.304	0.0000
	Linear	-4.57405	0.44077	-10.377	0.0000
	Quadratic	1.11812	0.10918	10.241	0.0000
	bcmethod102	0.04742	0.03477	1.364	0.1727
	age102	0.00225	0.01262	0.179	0.8583
	relstatb102	0.05929	0.04000	1.482	0.1384
	rep102	-0.41399	0.20920	-1.979	0.0479
	ipv102	-0.22527	0.10391	-2.168	0.0302
3	Intercept	-0.16504	0.23082	-0.715	0.4747
	Linear	2.40349	0.22651	10.611	0.0000
	Quadratic	-0.61834	0.05738	-10.776	0.0000
	bcmethod103	-0.01641	0.02558	-0.642	0.5212
	age103	-0.02049	0.00625	-3.280	0.0011
	relstatb103	-0.03793	0.03358	-1.130	0.2587
	rep103	-0.63405	0.14091	-4.500	0.0000
	ipv103	0.06710	0.12873	0.521	0.6022
	Sigma	0.49909	0.00859	58.086	0.0000
Group membership					
1	Baseline	(0.00000)	.	.	.
2	Constant	-2.11993	0.45741	-4.635	0.0000
	interv102	0.02209	0.18441	0.120	0.9046
	raceb102	0.30535	0.22021	1.387	0.1657
3	Constant	-1.06614	0.31448	-3.390	0.0007
	interv103	-0.30230	0.14996	-2.016	0.0439
	raceb103	0.09011	0.15917	0.566	0.5714

BIC= -3525.87 (N=3213) BIC= -3520.10 (N=2186) AIC= -3434.75 L= -3404.75

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