Covariate Analysis of Multistate Life Tables: Application to Women's Contraceptive Dynamics

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Research on women's contraceptive behavior has demonstrated that women often make changes among several methods, frequently switching back and forth between methods. To investigate this switching behavior and factors related to it, previous studies used the multiple-decrement life table method and associated multinomial logistic regression models. The analysis unit in these studies was the exposure interval, which is the interval of continuous use of a method before changing to another method or to non-use. Women who switched their contraceptive methods more than once would contribute multiple records to the analysis. However, these multiple records from the same women were treated as independent, resulting in inefficient estimates of transition probabilities In addition, the multiple-decrement life table method ignores the fact that women may return to their previous contraceptive method, thus providing an incomplete picture of women's contraceptive switching behavior. Multi-state life table methods can incorporate such returns to previous methods, and also can take into account several transitions experienced by a woman. Currently multi-state life table analysis is used as a descriptive tool lacking a covariate analysis of data. The present paper fills this gap by conducting an analysis of multi-state life tables with covariates

In this paper, we parameterized the transition probabilities in multinomial logit model with dependence on time and a set of covariates. In order to take into account the dependence of several transitions for a given woman, we estimated the model using the Generalized Estimating Equations (GEE) approach. From the estimated regression model we estimated transition probabilities for each month as predicted probabilities by setting values of time and the covariates at a specified level. We then used the calculated transition probabilities to construct multi-state life tables and the summary measures. In this way we constructed multi-state life tables for each level of a specific covariate adjusted for other independent variables in the model. This approach is similar to that used in Land, Guralnik and Blazer (1994) where they used panel data to estimate active life expectancy. However Land et al. did not deal with the situation of censoring in the data and did not take into account the correlated nature of the data in estimating the model. Our approach addresses both of these problems.

Transition Probability Model

Denote $q_{ij}(t, t+u)$ as the derived transition probability that individuals transfer to contraceptive method j at time $t+u$, given that they are in contraceptive method i at time t, where $0 \leq t \leq t+u$. In this study u is taken as one month. Following Lievre et al. (2003) we parameterize the transition probabilities in the interval (t, t+1) as a multinomial logit model:

$\log \dfrac{q_{ij}(t,t+1)}{q_{ii}(t+1)} = \beta_{0ij} + \beta_{1ij}(time) + B_{ij}X$, where X represents a set of covariates.

For simplicity we consider first a model in which the set of covariates contains only four variables: race, education, and number of pregnancies at baseline as fixed covariates, and age as a time-varying covariate.. The parameter set contains regression coefficients specific for each transition type. Because one woman can contribute multiple transitions we use the GEE approach to estimate the model. We use the estimated model to obtain the predicted transition probabilities by setting time and covariates at various values. We then use these individual transition probabilities as part of the transition matrix required to construct the multi-state life tables. Let $Q(t,t+1)$ denote the matrix of transition probabilities for a specific set of covariates. Once the transition probability matrix is calculated we can complete multi-state life tables and compute summary measures. These summary measures include the state occupancy probabilities (prevalence rates), average length of use before a specified transition, and expected number switches to a particular method in a specified interval. The formula for calculation of these measures can be found in Namboodiri and Suchindran (1987) and Kuo, Suchindran and Koo (2004).

DATA AND METHODS

The data used in this paper were collected from the "Longitudinal Study of Contraceptive Choice and Use Dynamics" (Koo 1995). There were three survey interviews: baseline and two follow-up surveys spanning July 1993 to June 1997. At the baseline, the study enrolled a probability sample of women who were choosing a "new" contraceptive method (i.e., one they had not used in the previous 3 months) at public family planning and postpartum clinics in Atlanta, Georgia, and Charlotte, North Carolina. The study enrolled 2,447 women and achieved response rates in the successive rounds of 88%, 87%, and 86% of women who had not been sterilized by the previous interview. During each follow-up interview, respondents were asked to report their contraceptive use month by month since the previous interview, aided by a calendar marking pregnancies and other events important to their lives.

We defined transition states to include two groups of reversible contraceptive methods, non-use, female sterilization, and pregnancy. Specifically, these five states are (1) hormonal contraceptive methods (Norplant, Depo-Provera, and oral contraceptives); (2) non-hormonal methods (IUD, condoms, cervical cap, diaphragm, sponge, withdrawal, calendar method, and spermicides used alone); (3) no use of any method (including no methods and abstinence for birth control); (4) pregnancies; and (5) female sterilization. We only considered the most effective contraceptive method in a given month if a woman used more than one method that month.

Among these five states, female sterilization is an absorbing state and all the other states are transient states, which women can enter and exit repeatedly. Pregnancies are considered as a transient state because when a pregnancy occurs, a woman normally stops using any contraceptive method but resumes contraceptive practice (or non-use) after her pregnancy ends. Data of respondents who were lost to follow-up in the survey are treated as censored.

We used these monthly data to perform multimonial logit models to obtain transition probabilities. Each model was conditioned on beginning with each of the non-absorbing states. As mentioned before, the initial model contained, besides time, four covariates: race, education, and number of pregnancies at baseline and age as a time-dependent covariate.

The transition probabilities for each time interval from month 0 to month 24 were computed. (For illustrative purposes, this paper analyzed only transitions among methods within the first 24 months after enrollment in the study. The technique could also be applied to any duration of data.) Using these transition probabilities we computed the summary measures of the expected number of visits and the expected length of use for each contraceptive method, for Black versus White women, women with less than high school education versus those with high school education or more, for women with zero, one, and two pregnancies at baseline, and women younger than 20 versus those older than 20 at the time when a change in state occurred.

ANALYSIS

A total of 1840 women were included in the analysis after excluding women choosing female sterilization at the beginning of the study and those who were lost to follow-up. Overall, the majority of the respondents were young, unmarried women. Eighty-five percent of them were Black and 15% were White. Forty-three percent of the respondents had less than high school education and 57% of them were high school graduates or had more than a high school education.

At enrollment, a majority of the women (89.3%) used hormonal methods, 6.6% used non-hormonal methods, 3.8% did not use any method, and 0.3% was pregnant at the beginning of the study.

Table 1 shows the odds ratio and 95% confidence intervals of race and education from multinomial logit models. Black women were significantly more likely to switch from non-hormonal methods to no use than White women were. Blacks were also more likely to become pregnant after using non-hormonal methods. Compared to better educated women, women who had not completed high school were less likely to switch from non-hormonal methods to hormonal methods, and they were also more likely to become pregnant after using non-hormonal methods.

Table 1. Odds Ratio (95% CI) of Race and Education for Multinomial Logit Models[a] by Each Origin Method

Origin Method	Destination Method				
	Hormonal vs No Change	**Non Hormonal vs No Change**	**No method vs No Change**	**Pregnancy vs No Change**	**F. Sterilization Vs No Change**
Hormonal					
Black[b]	_	1.01 (0.83 − 1.23)	1.09 (0.89 − 1.33)	1.30 (0.98 − 1.72)	0.94 (0.68 − 1.31)
Less than HS[c]		1.17 (0.98 − 1.39)	1.07 (.90 − 1.28)	1.41 (1.13 − 1.76)**	1.10 (0.84 − 1.44)
Non Hormonal					
Black	0.88 (0.67 − 1.16)	_	1.51 (1.15 − 1.97)**	1.45 (1.09 − 1.94)*	1.50 (0.80 − 2.81)
Less than HS	0.64 (0.49 − 0.84)**		1.03 (0.86 − 1.23)	1.18 (0.96 − 1.46)	0.76 (0.48 − 1.21)
No method					
Black	1.05 (0.76 − 1.44)	1.41 (1.04 −1.91)*	_	1.17 (0.88 − 1.54)	1.35 (0.71 − 2.56)
Less than HS	0.81 (0.62 − 1.04)	1.11 (0.89 − 1.37)		1.72 (1.39−2.13)***	0.65 (0.37 − 1.13)
Pregnancy					
Black	1.10 (0.92 − 1.31)	0.94 (0.66 − 1.35)	1.25 (0.94 − 1.65)	_	1.06 (0.75 − 1.49)
Less than HS	1.07 (0.92 − 1.25)	0.97 (0.73 − 1.28)	0.95 (0.79 − 1.14)		0.98 (0.77 − 1.24)

a: age and number of pregnancy at baseline were also included in the models
b: reference category is White
c: reference category is women with high school education or more
* p<.05 ; ** p<.01; *** p<.001

Following the estimation of transition probabilities using the multinomial logit models, we constructed multistate life tables and computed the summary measures. Table 2 shows the expected number of contraceptive transitions among 1,000 women of a synthetic cohort who begin with each origin state. The results suggest that, with the effects of the other three covariates taken into account, Black women tended to have more transitions than White women during the first 24 months. The biggest difference occurred among women who started with non-hormonal methods: Black women made a total of 2,903 transitions (2.9 per woman), whereas this number was 2,537 for White women (2.5 per woman). However, White women made more switches from non-hormonal to hormonal methods (676 vs. 610 for Blacks) and from pregnancy to hormonal methods (708 vs. 680). Table 3 indicates that Black women who started with non-hormonal methods tended to subsequently spend a longer time pregnant than White women did (3.4 versus 2.8 months) during the first 24 months.

We also computed summary measures comparing the two education groups (data not shown) and found that, controlling for race, age and number of pregnancies, women with less than a high school education tended to have more transitions and experience more pregnancies during the first 24 months than better educated women. Although not included here, the full paper presents results by the number of pregnancies at baseline and age at the time of the change in state.

DISCUSSION

This study demonstrated an approach to conducting multivariate analysis of multi-state life tables: using multinomial logit models to estimate predicted monthly transition probabilities and then using these probabilities to construct multistate life tables and associated summary measures. Our approach differs from previous studies by controlling for the correlated-data that a woman may contribute to the analysis if she switches her contraceptive method multiple times.

The parameterization assumes that the transition probabilities are linear functions of time. So far we have not attempted to include the standard errors of the predicted probabilities to estimate the standard errors of the summary measures. Calculation of the standard errors of summary measures is cumbersome and is beyond the scope of this paper.

Table 2. Expected Number of Visits to Each Contraceptive Method during the First 24 Months for 1,000 Women Who Begin with Each Origin State, by Race

Origin State	Destination State					
	Hormonal	Non Hormonal	No method	Pregnancy	F. Ster.	Total
Black Women						
Hormonal	281	631	590	345	149	1930
Non Hormonal	646	641	986	583	202	2903
No method	678	1014	675	597	198	2996
Pregnancy	726	627	677	297	210	2426
White women						
Hormonal	271	550	474	271	140	1706
Non Hormonal	676	483	750	464	164	2537
No method	692	830	483	512	168	2685
Pregnancy	708	549	534	231	197	2219

Table 3. Expected Months of Contraceptive Use of Each Method, by Beginning Method, during 24 Months, by Race

Origin State	Destination State				
	Hormonal	Non Hormonal	No method	Pregnancy	F. Ster.

Origin State	Destination State				
	Hormonal	**Non Hormonal**	**No method**	**Pregnancy**	**F. Ster.**
Black Women					
Hormonal	15.5	2.8	2.2	1.8	1.8
Non Hormonal	5.9	8.2	3.8	3.4	2.8
No method	6.3	4.8	6.7	3.5	2.7
Pregnancy	6.9	2.8	2.5	8.9	2.9
White Women					
Hormonal	15.8	2.9	2.0	1.5	1.7
Non Hormonal	6.4	9.2	3.4	2.8	2.2
No method	6.6	4.8	7.3	3.2	2.2
Pregnancy	6.8	2.9	2.4	9.2	2.7