Contraceptive Switching Behavior: An Application of Multistate Life Tables

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A multistate life table, also known as the increment-decrement life table, is the advanced technique from the ordinary single-decrement life table method. The method is not new (1912, DuPasquier) and it has been continuing to appear in the literature (Fix & Neyman, 1951, Chiang, 1964). However, extensive discussion of the construction of multistate life tables using event history data is lacking in the literature. A major difficulty is in obtaining the standard error of the estimated quantities in the life table. This paper fills this gap. In recent years, studies on women's contraceptive use have collected contraceptive history data that allows us directly estimating the transition probabilities for event changes from one state to another. Two distinct features make multistate life table more powerful and flexible than ordinary single-decrement life tables in handling contraceptive switching behavior. First, there are two or more transient states that individuals can move around. Second, direction of transition among states is flexible depending on the nature of behavior that is studied. For example, in the study of contraceptive switching behavior, multistate life tables allow a women to move repeatedly among all possible reversible methods, whereas in the study of nuptiality, individual's moving process follows a certain direction such as from "never married" to "married" and then to "divorced" or widowed."

To quantify moving process among multiple states, suppose there are a finite number of states with two or more transient states that individuals can move in and out at various time points. Let $X(t)$ be a random variable that indicates the state (for example, 1= pill, 2= condom, and 3= sterilization) occupied at time t by a randomly chosen individual. A major assumption that is common to all life tables is that the dependence among the random variables, $X(0)$, $X(1)$, …, $X(t)$, …, $X(w)$, is a Markov process (Namboodiri and Suchindran, 1987; Rajulton, 1992; 2001). That is, the probability distribution of $X(t)$ depends only on the value of the $X(t-1)$. This process is governed by a set of transition probabilities. A transition probability, $q_{ij}(s, t)$, is the conditional probability that the process occupies state j at time t, given that it occupied state i at time s, where $0 \le s \le t$. The Markov process assumption implies the following relationship:

$$q_{ij}(s, t+u) = \sum_{k} q_{ik}(s, t) * q_{kj}(t, t+u) \qquad (1)$$

Denote Q (s,t) be a matrix whose (i,j)th element is $q_{ij}(s, t)$. Using the matrices **Q**(s,t) for successive time intervals, we can compute the cumulative transition probabilities over time as follows:

$$\mathbf{Q}(s, t+u) = \mathbf{Q}(s,t)\, \mathbf{Q}(t, t+u) \qquad (2)$$

Equation 2 indicates that the cumulative transition probabilities for time interval (s, t+u), which provide information of the transition probabilities between states from time s to time t+u, can be obtained from the multiplication of transition probability matrix in time interval (s, t) and the transition probability matrix in time interval (t, t+u). These cumulative probabilities measure the "state" prevalence at a given time conditional on their initial state.

To estimate the transition probability, let $n_i(s)$ denote the number of individuals who "survived" or remained in origin state i at the beginning of the time interval s and t. Let $d_{ij}(s, t)$ denote the number of transition from state i to state j between the time interval s and t. Let $c_i(s, t)$ denote the number of individuals who were censored at the origin state i between time interval s and t. Assume that censoring is uniform in the time interval s and t. The transition probability can be estimated as follows:

$$\hat{q}_{ij}(s, t) = d_{ij}(s, t) / [\, n_i(s) - 0.5 * c_i(s, t)\,] \qquad (3)$$

The variance of transition probability q_{ij} can be computed using binomial formula

$$\mathrm{Var}(\hat{q}_{ij}) = q_{ij}\,(1-q_{ij}) \,/\, [\, n_i(s) - 0.5 * c_i\,(s, t)\,] \qquad (4)$$

The covariance of between the transition probabilities q_{ij} and $q_{ij'}$ is

$$\mathrm{Cov}\,(\hat{q}_{ij},\ \hat{q}_{ij'}) = -\, q_{ij} * q_{ij'} \,/\, [\, n_i(s) - 0.5 * c_i\,(s, t)\,] \qquad (5)$$

The variance for the cumulative probabilities, as the product Q (i,j) are derived and estimated in this paper. The details of the variance calculation are not provided here.

DATA AND METHODS

The data used in this study are from two consecutive longitudinal studies “Longitudinal Study of Contraceptive Choice and Use Dynamics” and “Dynamics and Meaning of Adult Unintended Pregnancy” (Koo, 2000, 2002). There were a total of 2447 women sampled from 2 familiy planning clinincs in Charlotte and Atlanta. Data from these longitudinal studies were obtained through four panel surveys spanning on the average of 6.2 years. During each survey interview, respondents were asked about the detailed contraceptive use in each month, with a calendar provided during the interview to help the respondents recall the history correctly.

Using the month by month contraceptive data, multistate life tables can be used to compute the transitional probabilities of contraceptive methods switching among several available contraceptive methods. For illustration purpose, this paper only analyzed the transition within the first 2 years. The contraceptive methods were grouped into 5 categories, together with no use of any contraceptive method, loss to follow-up and pregnancies making a total of 8 states: (1) long acting methods, (2) pill, (3) barrier, (4) others, (5) no use of any method, (6) pregnancies, (7) female sterilization, and (8) loss to follow up. Among these, female sterilization is an absorbing state, respondents who were lost to follow-up are treated as censored, and all the other states are transient states where 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 to contraceptive practice after she gives birth or terminates of the pregnancy.

ANALYSIS

A total of 1840 women were included in the analysis after excluding women using 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 African American women. Over 75% of the respondents were less than high school or high school graduated. For the contraceptive method use, a majority of the women (66%) used non-coitus dependent methods, long acting and pill, and only 5% chose barrier method, and 3% did not use any method at all.

Transition probabilities were computed to describe the probabilities of method change from each of the initial methods to other methods at any two consecutive time points within 2 years. For example, transition probabilities of method switching during the first month of observation was shown in Table 1. The rows in the table represent the origin states and the columns represent the destination states. Note that each row of the matrix of transition probabilities sum to unity. During the first month, 99.6% of the respondents who started with long acting methods stayed in the same method, while only 0.2% of the respondents switched to barrier method and another 0.2% switched to not using any method. Similarly, 93.3% of pill users stayed in the same contraceptive method during the first month, and 2.1% became pregnant. For barrier users, 30% of women who started with barrier method switched to another method during the first month.

For women who did not use any method at the beginning of the study, 55% of them remained not using any method during the first month, and another 45% switched to using some kind of method. Finally, because female sterilization method is an absorbing state, the transition probability is always 100%.

Table 1. Transition Probabilities in (0,1) Months

Origin state	Destination State						
	Long acting	Pill	Barrier	Others	Nouse	Preg	F. Ster.
Long acting	0.9959	0	0.0021	0	0.0021	0	0
Pill	0.0060	0.9330	0.0193	0	0.0179	0.0208	0.0030
Barrier	0.0417	0.1250	0.7000	0.0167	0.0750	0.0333	0.0083
Others	0	0	0.5000	0.5000	0	0	0
Nouse	0.0571	0.2714	0.0571	0	0.5571	0.0429	0.0143
Preg	0	0	0	0	0	1.0000	0
F. Ster.	0	0	0	0	0	0	1.0000

The cumulative transition probabilities (can be considered as prevalence rates), estimating the probability of contraceptive switching from beginning use of an initial method to the destination method after a certain period of time. For example, after starting using barrier method for 12 months, 14% of the women switched to long acting method, 17% switched to pill, and 26% were in the same method as the initial method (Table 2). For women using long acting method at the beginning, 61% of them were in the same method as their initial method, whereas 9% switched to pill method, 12.3% switched to barrier method, and another 9% switched to no method. As shown in Table 2, except for the long acting method, after 12 months of use, less than 50% of the women were in the same method as the initial method that they started with. As compared the prevalence rates for all initial methods, it seems that no matter what contraceptive method that a woman used at the beginning of the study, the probabilities of using the same method over a certain time decreased over time. That is, the probabilities of switching to a different method as the initial method increased as the interval of use increased.

Table 2. Cumulative Transition Probabilities (Prevalence Rate) from Beginning to the 12th Month

Origin state	Destination state						
	Longact	Pill	Barrier	Other	Nouse	Preg	F. Ster.
Longact	0.6096856	0.0919288	0.1234779	0.0081001	0.0916229	0.0640233	0.0108218
Pill	0.0971366	0.424985	0.1803812	0.0103408	0.1270352	0.1481769	0.011264
Barrier	0.1402724	0.1671582	0.2602653	0.0184142	0.1712193	0.2202009	0.0213306
Other	0.1166819	0.1326362	0.2166499	0.0334994	0.1524202	0.3338561	0.0127781
Nouse	0.1440237	0.2175289	0.214039	0.0126201	0.1762399	0.2019021	0.0326975
Preg	0.1227719	0.1305411	0.1273374	0.0067123	0.1167108	0.4829131	0.011138
F. Ster.	0	0	0	0	0	0	1

Variance-covariance matrices for the transition probabilities can also be computed. Each transition probability matrix has 7 rows and 7 columns, and each row generated a 7 by 7 variance-covariance matrix. Therefore a 49 by 49 variance-covariance matrix could be generated for a transition probability matrix. In addition, the variance-covariance matrix for cumulative transition probabilities for a set of initial condition was computed. Using the method, we computed the variance-covariance for the cumulative transition probabilities over time for women who used pill at the beginning of the study (data not shown in this abstract).

Given the rich and detailed information that produced by the multistate life table method, a summary measure is useful to synthesize these information. One commonly used summary measure is the expected length of staying in state *j* within a time interval *(s, t)*, given occupancy of state *i* at time *s*. For example, we estimated the length of each contraceptive method that a woman used before she reached the state of unintended pregnancy. This information could be very useful when we try to understand the relationship between method used and the occurrence of unintended pregnancies (Data not shown in this abstract).

DISCUSSION

This study demonstrated the application of multistate life table method to understand American women's contraceptive switching behavior. Overall, the results indicated that a high proportion of women switched their contraceptive methods within two-year of use. This study also demonstrated that Multistate life table method generates very rich and detailed information about transition process. Furthermore, the method is well suited for studying contraceptive dynamics because of two reasons: multistate life tables method allows women to re-enter previously occupied states and it handles the changes among all states simultaneously.

However, the method also has few limitations. First, the cumulative probabilities at a given time, although provide the transition probabilities from the initial state to the destination state, the method fails to reveal the specific states between the time interval from which that individuals reach the destination state. Second, the multistate life tables assume that transition follows Markov process. Although many have expressed their doubt regarding whether any social process obeys the Markov assumption (Hoem, 1982; Heckman and Singer, 1982). Other studies have also pointed out that the results of using more complex framework are not much different from those obtained from the Markovian framework (Barthlomew, 1967; Howard, 1971).

In summary, multistate life table method provides us with an excellent tool to describe the dynamics of contraceptive switching behavior. The results generated from multistate life tables can also be combined with other statistical method to better understand the study behavior. For example, combining with multivariate models will help us better understand contraceptive switching by controlling for factors such as women's preference toward specific contraception, health concerns, change of couples' life circumstances, relationship between couples, etc. In addition, the variance-covariance matrices can be applied to provide statistical comparison among different demographic groups. This information is importance from family planning services point of view to be able to identify populations for their "unsafe" contraceptive practice.