

ESTIMATING LIFETIME RISK FROM SURVEY DATA

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ABSTRACT

Lifetime risk of intimate partner violence is estimated using data from Japan, collected as part of a World Health Organization Multi-Country Study of Women's Health and Intimate Partner Violence. We examine the possible bias incurred by using the Kaplan-Meier estimate of the probability of intimate partner violence at the maximum age at interview as an estimate of life-time risk. Because this is a cross-sectional study with retrospective data collection, selection bias is also possible. We show that both the use of this estimate and the selection effect lead to underestimation of the life-time risk of intimate partner violence. The effect of selection on Cox regression is also examined.

KEY WORDS: Cox regression, Kaplan-Meier, Lifetime risk, Retrospective study, Selection, Survey data.

RÉSUMÉ

Le risque à vie de subir la violence infligée par un partenaire intime est estimé en utilisant des données du Japon, recueillies par l'Enquête multi-pays sur la santé et la violence infligée par un partenaire intime chez les femmes de l'Organisation mondiale de la santé (OMS). Nous examinons la possibilité d'un biais entraîné par l'utilisation de l'estimation de Kaplan-Meier de la probabilité d'avoir subi la violence d'un partenaire intime à l'âge maximum à l'entrevue comme étant l'estimation du risque à vie. Comme il s'agit d'une enquête transversale recueillant les données de façon rétrospective, un biais de sélection est possiblement induit. Nous démontrons que l'utilisation de cette estimation combinée à l'effet de sélection mène à une sous-estimation du risque à vie de subir la violence d'un partenaire intime. L'effet de la sélection sur la régression de Cox est également étudié.

MOTS CLÉS : Données d'enquête; enquête rétrospective; Kaplan-Meier; régression de Cox; risque à vie; sélection.

1. INTRODUCTION

1.1 WHO Study

According to the World Health Organization (WHO) World Report on Violence and Health (Krug et al, 2002), intimate partner violence (IPV) is one of the most common forms of violence against women. IPV is pervasive, cutting across nationalities, religions, cultures and socio-economic strata. The proportion of women who report having experienced physical violence at the hands of an intimate male partner varies widely across countries, from 10% to almost 70%. For Canada, a 1991-2 study placed this figure at about 27% (Krug et al, 2002).

Women often experience emotional and sexual abuse in conjunction with physical abuse perpetrated by a partner. According to the WHO Report on Violence and Health (Krug et al, 2002), IPV is defined as "any behaviour within an intimate relationship that causes physical, psychological or sexual harm to those in the relationship", for instance

- slapping, hitting, kicking
- intimidation, humiliation
- sexual coercion
- restricting access to family, friends, information or assistance.

While traditionally considered a human rights issue, IPV is increasingly being viewed as a public health problem. In 1997, the World Health Organization initiated the WHO Multi-Country Study of Women's Health and Domestic Violence. The main objective of this study is to "assess the prevalence and health consequences of domestic violence against women

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using population-based sampling procedures and standardized survey instruments”(Yoshihama et al, in progress). Twelve countries have participated so far, from the continents of Asia, Africa and South America. The survey design and questionnaire were slightly modified by local experts in some countries (including Japan) to ensure relevance to the particular culture being studied.

This paper describes an analysis of the data from Japan. The study was cross-sectional, with data collected between October 2000 and January 2001. It used a stratified, multi-stage sample of women from Yokohama, the second-largest city in Japan, and was designed to be self-weighting. Both strata and clusters were geographical divisions of the city. A total of 1371 women, between the ages of 18 and 49, participated. Data were collected through face-to-face interviews, supplemented by paper-and-pencil questionnaires. Demographic information was collected, including age at interview, marital status, employment status, and education. In addition, retrospective information was collected on such variables as childhood sexual abuse, father’s violence against mother, type of IPV and age of its first occurrence, and age of sexual initiation (Yoshihama et al, in progress). Here we report results for the subset of 1287 women who had ever had an intimate relationship with a man, and focus on the physical and sexual violence components of IPV.

There are several challenges associated with this analysis, not all of which will be addressed in this paper. Although the study was designed to be self-weighting, differential non-response occurred. To adjust for non-response, post-stratified weights were constructed and used in the analysis. There are potential biases (due to misrepresentation and/or missing responses) arising from the sensitive nature of the subject matter. In addition, there is potential recall bias due to the retrospective nature of data collection (see Yoshihama and Gillespie (2002) for a discussion of recall bias and other challenges in IPV research). These issues will not be addressed in this paper.

Approximately 15% of the 1287 women who had been in an intimate relationship reported that they had experienced IPV before the time of interview. Thus, 15% (95% confidence interval: (13%, 17%)) is an estimate of the prevalence of IPV. Here, “prevalence” indicates the percentage of women *in the population at the time of interview* (roughly January 2001) who had experienced IPV at some point during their lives. Rather than focusing on prevalence estimates, whose properties are well known, we concentrate on estimates of life-time risk of IPV. By “lifetime risk” of an event, we mean the probability that a newborn will experience the event of interest during his/her lifetime.

The estimation of lifetime risk is complicated by the presence of censoring. Women who have not experienced IPV at the time of interview are considered censored, in that the age of first IPV experience is unknown. Censoring is a common feature of survival data, and methodologies have been developed which take censoring into account (e.g. Kaplan-Meier estimates and Cox regression). In section 2, we discuss the Kaplan-Meier estimate of life-time risk in a heterogeneous population, using survey data.

Another challenging feature of these data is the possible presence of selection bias. This bias arises from the cross-sectional nature of the study design, combined with the collection of retrospective data. Only subjects that survive to the time of interview can participate in the survey. This phenomenon has been termed “selection by virtue of survival”, for instance by Hoem (1985), and can introduce bias, as discussed in section 3 below.

Finally, we are interested in characterizing the relationship between first occurrence of IPV and explanatory variables such as childhood sexual abuse, father’s violence against mother and age of sexual initiation. This can be done using the Cox regression model. Again, we are interested in the effect of selection on the estimates, which is briefly explored in section 4.

2. SURVIVAL ANALYSIS

The study of lifetime risk falls under the purview of life history or survival analysis, where the goal is to estimate the distribution of the time to an event and to determine important covariates that affect this distribution. Here the event is the first occurrence of IPV, and the time scale is age, i.e. years since birth. Age is the relevant time scale here, as an important objective of this research is to inform public health policy with respect to targeting interventions to age groups of women at highest risk of IPV.

At the time of interview 15% of women in the sample had experienced IPV. It is possible that some of the remaining 85% of women would experience IPV at a later point in their lives. Thus these women contribute censored observations to the

analysis. For these women the age of first occurrence of IPV, if it occurs at all, must be greater than the age of interview. Special techniques are necessary to deal with censored data, such as Kaplan-Meier estimates and Cox regression.

2.1 Kaplan-Meier Estimate of the Failure Function

A quantity that is often of interest in survival analysis is the survival function $S(t)$, which can be interpreted as the probability that the event of interest occurs after time t . However, studies of domestic violence usually report the failure function, $F(t) = 1 - S(t)$ (Yoshihama & Gillespie, 2002). In our context this quantity estimates the probability that a woman in the sampled population experiences IPV before age t . Figure 1 shows the Kaplan-Meier estimate of $F(t)$ made using the `survfit` function in `Surv`, incorporating post-stratified weights.

Of course, the sampled population is heterogeneous, including women from different birth cohorts and socio-economic strata, over which the failure function might be expected to vary. To a limited extent, this heterogeneity is accounted for through the stratified design and weighted estimation. However there are likely many variables that affect IPV that vary within strata, and so heterogeneity remains. Thus, we cannot interpret the failure function $F(t)$ as an individual level function, but rather a population-averaged quantity. While not a useful measure for individuals, this quantity is of interest to policy makers, giving an estimate of the proportion of individuals in the population that experience IPV before age t . This information can be used, for instance, to target prevention programs to specific age-groups. If inference were to be made at the individual level, it would be important to condition on relevant covariates, using, for instance, Cox regression as in section 3.

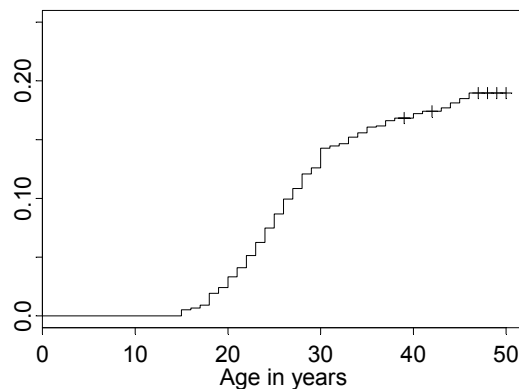
2.2 Kaplan-Meier Estimate of Lifetime Risk

The maximum age at interview for this dataset was 50 years. The Kaplan-Meier estimate of the probability of IPV by age 50 is 0.19. This is an intuitively appealing estimate of life-time risk. As can be discerned in Figure 1, there are no new cases of IPV after age 46. However, it is possible that a woman in the population could experience IPV for the first time after age 46, although this would likely be a rare event. Thus, we could claim 19% as a possibly conservative estimate of lifetime IPV.

3. SELECTION

The estimates reported so far essentially assume a two state model. Individuals are in State 1 while free of IPV and enter State 2 once they have experienced IPV for the first time. We are interested in the distribution of time of transition from State 1 to State 2, which can be characterized using either the failure function $F(t)$ (as in the previous sections) or the hazard function. In this section, we use the notation $\lambda_{12}(t)$ to represent the rate of transition from State 1 to State 2 at time t . This can be thought of as the instantaneous risk of IPV.

Figure 1 – Kaplan-Meier estimate of probability of IPV before age t



However this is not the whole story. In fact, as shown in Figure 2, there is, implicitly, a third state representing death. Of course, only individuals who are alive at the time of interview are capable of providing data, resulting in a selection effect. This has been called “selection by virtue of survival” by Hoem (1985). Note that there is no information in the data set on death times of women in the sample, or on any characteristics of women who died before the study was completed.

Transitions into the death state, that is from State 1 to State 3, and from State 2 to State 3, are thus not observed, and hence are shown as dotted lines in Figure 2. However we will now attempt to gain some insight into the effect of mortality on the estimate of $\lambda_{12}(t)$.

Intuitively, if $\lambda_{13}(t) = \lambda_{23}(t)$ at all times t , then women are removed by mortality from state 1 and state 2 at the same rate, and the estimate of $\lambda_{12}(t)$ is not affected. However suppose that, as we suspect, death rates are uniformly higher for those who have experienced IPV, i.e. $\lambda_{23}(t) > \lambda_{13}(t)$ at all times t . In that case, relatively more individuals leave state 2 before we get a chance to observe them. Thus we underestimate the relative number of people in state 2 at any given time, and so we underestimate the rate of moving from state 1 to state 2, namely $\lambda_{12}(t)$.

We now present a more stringent analysis, following Hoem (1985), assuming a continuous-time, three-state Markov chain model. Let $P_{ij}(t,t')$ equal the probability that an individual is in state j at time t' , given that she was in state i at time t , where $t' > t$. This means that the individual made the transition from state i to state j some time in the interval (t,t') . Now let A represent a set of states, and let $P_{iA}(t,t')$ be the probability that an individual is in one of the states in A at time t' , given that she was in state i at time t . Consider a woman who has never experienced IPV at age x . The probability that she will experience IPV by age y , given that she survives to interview time I , equals

$$\frac{P_{12}(x,y) P_{22}(y,I)}{P_{1A}(x,I)}$$

where $A=\{1,2\}$, and where $x < y < I$. Taking the limit as $y \downarrow x$ gives

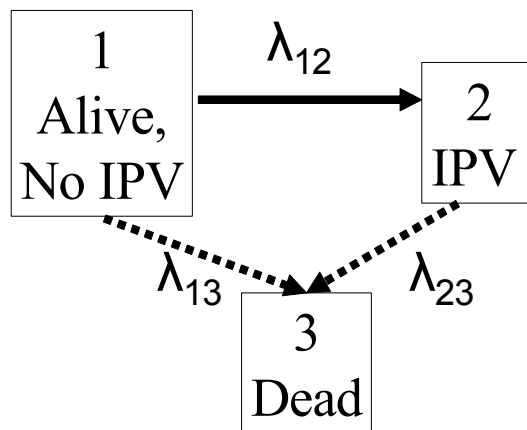
$$\frac{\lambda_{12}(x) P_{22}(x,I)}{P_{1A}(x,I)}$$

where $\lambda_{12}(x)$ is the hazard at age x . Thus the object of inference, $\lambda_{12}(x)$, is distorted by a factor of

$$D(x) = \frac{P_{22}(x,I)}{P_{1A}(x,I)} = \frac{1-P_{23}(x,I)}{1-P_{13}(x,I)}$$

Note that the last equality is true since, if an individual is in state 2 at age x , then at a later time she can only be in state 2 or state 3, so $P_{22}(x,I) + P_{23}(x,I) = 1$. Similarly, if an individual is in state 1 at age x , then at a later time she can be in set A (state 1 or 2) or state 3; hence $P_{1A}(x,I) + P_{13}(x,I) = 1$.

Figure 2 – Three State Model



Clearly, if $P_{13}(x,I)$ equals $P_{23}(x,I)$, then the distortion factor is 1 and the estimates of the hazard and failure functions given above are not affected by selection. This condition is satisfied if the age-specific mortality rates are equal for women with and without IPV, and if the age distribution is the same in both these populations. However if $P_{13}(x,I)$ does not equal

$P_{23}(x,I)$, then the estimate of $\lambda_{12}(x)$ based on women who are alive at interview will be biased. Similarly, the Kaplan-Meier estimate of the failure function $F(x)$, described above, will be biased.

The bias could be corrected if estimates of $P_{13}(x,I)$ and $P_{23}(x,I)$ were available. Currently, there is little hard evidence on differential mortality rates among those women who have experienced IPV and those who have not. Evidence is accruing that shows increased mortality, morbidity, smoking rates, and drug and alcohol abuse among victims of IPV, compared to the general population. A recent study in Victoria, Australia found that IPV is a leading contributor to death, disability and illness in women aged 15–44, with more of the disease burden being attributable to IPV than to high blood pressure, smoking or obesity (Victoria Department of Human Services, 2004). Thus we have reason to believe that death rates will be higher among women who have experienced IPV, and that the reported estimate of lifetime risk is in fact an underestimate.

4. COX REGRESSION

A further objective of this study was to assess whether the probability of experiencing IPV varied by exposure to abuse during childhood and by age of sexual initiation. For this purpose a Cox regression model was fit to the data from the 1287 women who had ever had a sexual relationship. The results are summarized in Table 1, which shows hazard ratios, standard errors, p-values and 95% confidence intervals (CI). The differential effects of types of childhood sexual abuse before the age of 15 (CSA) were examined. The probability of experiencing IPV was higher among women who had experienced CSA by known perpetrators, and those who had experienced CSA multiple times. In addition, IPV was higher among women who reported observing, during their childhood years, violent acts perpetrated by their father against their mother. Finally, the probability of experiencing IPV was higher if the woman had experienced intercourse at age 20 or before.

Again, we must consider the effects of selection. To fix ideas, consider a simple model with a single covariate, u , at two levels (0 and 1). The Cox regression model can be written as

$$\lambda_{12}(x) = \lambda_0(x) \exp(\beta u),$$

where $\lambda_{12}(x)$ is the risk or hazard of IPV at age x and $\lambda_0(x)$ is the baseline hazard of IPV for individuals with $u=0$. Under this model, the hazard ratio comparing individuals with $u=1$ versus those with $u=0$ is:

$$\exp(\beta) = \frac{\lambda_{12}(x|u=1)}{\lambda_{12}(x|u=0)}.$$

But the hazard ratio estimated from the survey data under the possible effect of selection is

$$\exp(\beta) = \frac{\lambda_{12}(x|u=1) D(x|u=1)}{\lambda_{12}(x|u=0) D(x|u=0)},$$

where $D(x|u)$ is the distortion factor for individuals with covariate value u . Clearly if $D(x|u=1) = D(x|u=0)$, the distortion factors will cancel. In general, if the distortion factors are equal across the groups of individuals formed by the levels of a covariate, then the estimated hazard ratio will not be affected by selection. While this is not likely to be true exactly, we may hope that it is true approximately.

5. DISCUSSION AND FUTURE WORK

The Kaplan-Meier estimate of the failure function $F(t)$ at the maximum age at interview is an intuitively appealing estimate of lifetime risk. However, as discussed above, it may be an underestimate since some individuals may experience the event of interest at a later age. When designing future studies to estimate lifetime risk, it may be wise to include women of older ages in the sample.

Table 1 – Cox Regression Output

Variable	Hazard Ratio	s.e.	p-value	95% CI	
Childhood Sexual Abuse	stranger	1.21	0.47	0.606	(0.57, 2.57)
	known	2.39	0.85	0.015	(1.19, 4.82)
	multiple	2.31	0.75	0.010	(1.23, 4.35)
Father's violence	1.83	0.32	0.000	(1.31, 2.58)	
Sexual Initiation ≤ 20	1.75	0.29	0.001	(1.26, 2.43)	

Selection due to differential mortality can also cause bias in the estimates of the failure function, the hazard function and lifetime risk. For this application, where we expect higher mortality among those who have experienced IPV, the effect of selection is to cause the lifetime risk of IPV to be underestimated. Thus, both sources of bias investigated here may lead to underestimation of the lifetime risk of IPV.

Selection effects are also possible in a Cox regression analysis. However if the distortion factor is the same for groups of individuals formed by different levels of the covariates, then the regression parameters will not be affected.

In future, we will undertake a sensitivity analysis to examine the extent of bias due to selection in this population. Note that, in addition to mortality, the forces of immigration and emigration should be considered, as differential net migration could also cause bias in the estimates of $F(t)$, $\lambda_{12}(t)$ and lifetime risk. While a cohort or longitudinal study would allow us to collect information on mortality, i.e. transitions from state 1 to state 3 and from state 2 to state 3, cohort studies are very expensive and are rarely used in IPV research.

Finally, methods for constructing confidence intervals for the Kaplan-Meier estimate of the failure function in a heterogeneous survey population will be investigated.

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