資料連結應用於道路交通事故傷害研究：一對一確定連結與一對多人工可能連結之比較

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背景：警政單位的交通事故登錄檔(交通檔)與衛生單位的死因統計登錄檔(死因檔)是交通事故傷害研究與防制計劃的重要參考訊息，但是兩個資料庫也都有一些缺點。若能將兩資料庫連結，可以提高兩者訊息的有用性。**目標**：本研究希望能建立一個連結資料庫，比過去資料庫能提供更有用訊息，並提供未來電腦機率連結程式設計基本訊息。**方法**：一九九五年交通檔與死因檔首先以身份證字號進行一對一確定連結，未被連結到的資料再以出生年月進行一對多人工可能連結。一對多可能配對再進一步以死亡證明書記錄之訊息來確認是否為正確配對。**結果**：本研究共連結3,115筆資料，確定連結與人工可能連結分別可配對到853與2,262筆資料。在交通檔警察登錄死亡的3,097個案中，有2,692(87%)可以配對到相對應的死因檔；在死因檔開具者登錄交通事故死亡的8145個案中，只有2712(33%)可以配對到相對應的交通檔。不同資料特徵(性別、年齡、事故發生地區、當事者人數、道路使用者型態)的連結率不同，人工可能連結資料與確定連結資料在重要特徵(事故發生地區與道路使用者型態)分佈上有統計顯著差異。兩個資料檔對同一筆資料的基本資料(身分證字號、出生年月)記錄不一致的主要原因是字形相近的抄錄錯誤。**結論**：由於人工可能連結在確定連結後還可多配對出近三倍的資料，因此未來若要與交通檔進行資料連結時，至少要使用人工可能連結。本研究所整理的常見抄錄錯誤，是未來電腦機率連結定義權值與部分一致規則之重要參考。(台灣衛誌 2001；**20(2)**：112-120)

關鍵詞：資料庫、資料連結、交通事故傷害、死亡率。

Record linkage for road traffic injury research:one-to-one deterministic linkage vs. one-to-many manual probable linkage

Background: The road traffic accident file (RTAF) and cause of death file (CODF) are relevant to road traffic injury research and control programs design, but both have merits as well as demerits. Linking the CODF with the RTAF may yield a dataset that makes full use of information from both files. **Objectives:** In this study we sought to establish a linked dataset which is more useful than the existing data sets and to provide information for future computerized probability record linkage (CPRL). **Methods:** The RTAF and CODF for the year 1995 were first linked with one-to-one deterministic record linkage (DRL), using ID as the identifier. The remaining unmatched records were then linked with one-to-many manual probable record linkage (MPRL), using year and month of birth as identifiers. The possible pairs linked by MPRL were then verified by the information recorded on the death certificates to determine the true matches. **Results:** The linkage process linked a total of 3,115 records; DRL and MPRL matched 853 and 2,262 records, respectively. Of the 3,097 police registered fatal cases in the RTAF, 2,692 (87%) were linked to matching CODF record. Of the 8,145 certifier registered traffic-related deaths in the CODF, only 2,712 (33%) had matching RTAF record. The linkage rate varied according to different characteristics including sex, age, place of traffic accident, number of victims involved, and type of road user. The characteristics (region of accident occurred and type of road user) of linked records obtained by MPRL differed significantly from those obtained by DRL. Most of the discrepancies between the two files in registering the same identifier information (ID or birth year and month) were due to transcription errors. **Conclusions:** Given the high yield of MPRL compared with DRL, and the differences in the distribution of characteristics between records linked by MPRL and DRL, MPRL is a necessary procedure for future record linkage with RTAF. The common discrepancies found in this study may serve as a useful reference in defining the weights and partial disagreement rules in future CPRL efforts. *(Taiwan J Public Health. 2001;20(2):112-120)*

Key words:* *factual databases, medical record linkage, traffic accidents, mortality.

INTRODUCTION

Road traffic injury is an important public health problem in Taiwan [1-7]. A relevant and reliable dataset is essential for designing an effective prevention and control program. The cause of death file (CODF), which is routinely collected by the Department of Health, and the road traffic accident file (RTAF), which is routinely collected by the Department of Police, are the two most widely used resources for road traffic injury research and policy evaluation. Each database has both advantages and disadvantages.

The CODF is relatively complete and contains detailed information on the anatomy of injuries and reliable demographic information; nonetheless, it provides little information on the vehicles, circumstances, and causes of road traffic accidents. The RTAF, on the other hand, contains detailed information on the vehicles, circumstances, and causes of road traffic crashes, which are highly relevant in designing prevention and control programs. However, the RTAF suffers a severe underreporting rate. In 1994, for example, 7,250 people died from motor vehicle traffic injuries in Taiwan according to CODF, but the RTAF listed only 3,094 traffic-related deaths [8,9]. The reason for this discrepancy is that the police record cases as fatal only if the death occurs within 24 hours of the crash. There is no such time limitation in death certification.

One way to address the above problems is to link the CODF with the RTAF to yield a linked dataset that makes full use of information from both files. Record linkage, not new to the field of road traffic injury research [10-17], is bringing information together from two or more records that are believed to be related to the same entity (e.g., individual or household) [18]. If each entity has a unique and reliable identifier (e.g., full name or personal ID number) and this identifier is present in all files involved, the linkage is simple and straightforward. This kind of linkage is called deterministic record linkage (DRL) or all-or-none matching [19]. Sometimes, however, the only available identifiers for linkage are not unique, such as sex, date of birth, and time of the event. Even if they are uniquely identifiable, incompleteness and errors could be made when the information is recorded [20].

"Probability record linkage" is a more flexible method, using probability to determine which record pairs refer to the same entity. Weights are calculated based on these probabilities to quantify the likelihood of a pair being correctly linked (i.e., referring to the same entity). The weights for each match are based on several pre-defined rules on agreements, partial agreements, and disagreements of identifiers from two original files [18-21]. To define the partial agreement and estimate the weights for different rules, Newcombe suggested that a "manual probable record linkage" (MPRL) is needed [18].

The aims of this study were to 1) assess the differences in linkage rates between the DRL and the MPRL approaches; 2) compare the characteristics of records linked through DRL with those linked through MPRL; and 3) provide basic information (i.e., discrepancy rates of key identifiers between the CODF and RTAF) for future "computerized probability record linkage" (CPRL).

MATERIALS AND METHODS

Sources of data

The RTAF for accidents occurred during 1995, obtained from the Institute of Transportation, listed 9,683 crashes involving a total of 23,333 people. The RTAF records used in the linkage process were limited to those in which the degree of injury was fatal (3,097) or severe (6,952). Information in the RTAF that could be used as linkage identifiers included driver's license number (the same as ID number), sex, year of birth, month of birth, time of crash, and full name. In the RTAF, less than one-third (850/3,097) of the fatal cases and half (3,767/6,952) of the severely injured cases had complete ID information.

The CODF for deaths occurring from 1 January 1995 through 31 January 1996 was obtained from the Office of Statistics, Provincial Department of Health. There was a time lag of one month for those traffic accidents occurred in December 1995. There were 117,954 deaths in the year 1995 and 11,010 deaths in January 1996. Information in the CODF that could be used as

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linkage identifiers included ID number, sex, year of birth, month of birth, time of death, and full name (the name on the death certificate was not keyed into the CODF computer tape). All identifiers in the CODF were complete except for 18 deaths for which the ID number could not be determined.

Linkage process

First, we used the traditional one-to-one DRL by ID number for linkage. Then, one-to-many MPRL by year of birth and month of birth was done for those records not linked by DRL. For each case in the RTAF, we could match many cases in the CODF for which the year of birth and month of birth were the same. We further restricted the possible linked pairs to those for which the time lag between date of road traffic accident and date of death was less than one month. According to a previous study in Taiwan, the time lags were within one month for over 98% of fatal road traffic accident cases [22]. Possible linked pairs were verified manually by checking the information (e.g., name, place of residence, place of death, certifiers, and cause of death) recorded on the death certificate with the information recorded in the RTAF.

Analyses

Chi-square tests were used to assess differences in linkage rate between the DRL and MPRL approaches. The differences in characteristics (age, sex, place of accident, type of vehicle, and driver vs. passenger or pedestrian) of records linked through MPRL and those linked through DRL were also assessed by chi-square test. We then examined the discrepancies in key identifiers such as ID number, sex, year of birth, and month of birth registered in the RTAF and CODF.

RESULTS

Linkage results

The DRL and MPRL yielded 853 and 2,262 matched records, respectively. On an average, the possible linked pairs were 1:4 during the MPRL process with a maximum of 1:29 (i.e., for one record in RTAF we could find 29 possible candidates in CODF for which the identifier information were the same). The number of possible linked pairs increased with age, 1:1.6, 1:2.1, 1:3.3, 1:8.0, 1:14.1 for age groups 0-19, 20-29, 30-49, 50-69, 70 and over, respectively.

The possible outcomes after linkage according to different subsets in the original datasets are illustrated in Figure 1. We expected that all police registered fatal cases in the RTAF could be linked to records in the CODF. However, only 2,692 (87%) of the 3,097 police registered fatal cases in the RTAF could be linked to a matching CODF record (Table 1). The variation of linkage rate in sex and age were statistically insignificant. For accidents occurred in Northern Taiwan or on a city road, the linkage rates were significantly lower than for those occurred in other regions or on other types of road. Bicyclists and pedestrians also had significantly lower linkage rates than other types of road users, such as those involved in motorcycle, automobile, truck, or bus accidents.

Of the 8,145 certifier registered traffic-related deaths recorded in the CODF, only 2,712 (33%) had a matching RTAF record (Table 2). The linkage rates varied among different age groups, from 39% for victims of 30-49 years old to 25% for victims of 20-29 years old. Records with a place of residence in Eastern Taiwan had a significantly higher linkage rate than those in other regions. The linkage rate of deaths certified by physicians was significantly lower than that of deaths certified by a coroner or an examiner.

Characteristics of linked records

Comparisons of the characteristics of records linked with the two linkage methods are shown in Table 3. The characteristics of the deceased differed with MRPL and DRL: MRPL yielded higher percentages of records of females, victims aged 0-19 years, bicyclists, pedestrians, passengers, and victims of accidents involving more than 2 fatalities.

In order to assess the similarity between the linked records and fatal cases registered in RTAF, the characteristics of the two groups were compared. The distributions of characteristics did not show statistically significant differences (data not shown).

Discrepancies between the RTAF and CODF

Establishing the common types of error and frequencies of discrepancies in the same identifiers between the two original datasets is important for defining the weights and rules for partial agreement in CPRL. Among the 853 records linked by DRL (the same ID), the discrepancy rates between the RTAF and the CODF were 0.1% (1/853) for sex, 2.7% (23/853) for year of birth, and 3.4% (29/853) for month of birth. There were 15 records for which the difference in the registration of year of birth was within 5 years. Among the 2,262 PRL records, which had the same year of birth and month of birth, only 79 had ID information completely registered in the RTAF. More than two-thirds (54/79) of these cases had ID information in the RTAF that was not consistent with that registered in the CODF. Most of these discrepancies appeared to be transcription errors. The registers often committed errors in recording the numbers or letters with similar forms (i.e., those look alike)-for example 6≒4, 2≒8, 11≒7, 12≒3, 5≒8, 9≒8, 6≒8, 3≒5, 7≒9, 3≒8, P≒F, V≒U, V≒N, N≒M, R≒K. We also noted that among the 3,115 linked records, the original death certificates did not register in 403 cases that the death was 'traffic-related'.

DISCUSSION

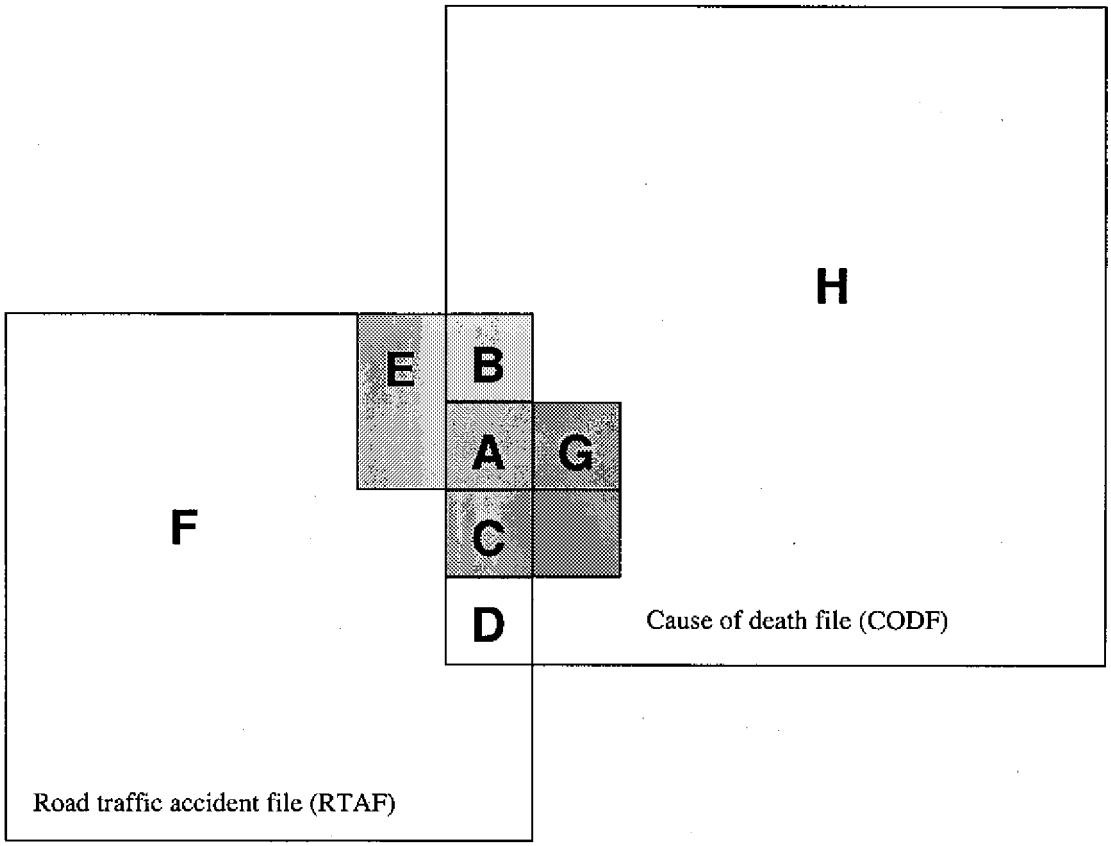
Our findings showed that the MPRL linked a significantly higher percentage of records than the DRL (2,262 versus 853). The linkage rates varied with certain characteristics including sex, age, place of traffic accident, number of victims involved, and type of the road user. The characteristics of records linked by MPRL differed significantly from those linked by DRL. Common discrepancies in the information registration were often due to transcription errors.

Linkage rates

The MPRL used in this study could link more records than the DRL, largely because a high percentage of records in the RTAF had incomplete or missing ID number information (75.6% for fatal cases, 45.5% for severe injury cases), which rendered DRL by ID a very low linkage rate. For records in the RTAF without ID information, we could still make full use of other identifier information to increase the linkage rate. Nevertheless, the MPRL assumed that the information on year and month of birth was complete and correct.

Most previous studies of road traffic injury-related record linkage have linked hospital admission data [11-13] or emergency room data [14,15] with police road accident data; only two studies linked cause of death data [16,17] with police road accident data. Using health-related data (e.g., cause of death data, hospital discharge data, or emergency data) as the denominator in calculating the linkage rate, the rates ranged from 51% to 93% in various studies [11-17]. In our study, only 33% of 8,145 traffic related deaths in the CODF could be linked to the RTAF. The reasons for the low linkage rate includ: 1) some traffic accidents involving fatalities or severe injuries might not have been reported to the police; 2) errors in registration of identifier information; 3) certifiers did not mention traffic-related information on the death certificates; 4) limitations of MPRL. There was one assumption in MPRL that the information on year of birth and month of birth should be complete and correct. There was also the possibility of human errors in the process of matching.

Characteristics of the deceased also influenced linkage rates. In Barancik and Fife's study [14], the linkage rate increased as the age of the deceased increased, and automobile drivers had a higher linkage rate than other types of road user. Rosman and Knuiman [12] showed that sex, ethnicity, type of road user, and severity of injury significantly affected linkage rates. Our study did not show any gradient of difference in linkage rates with respect to age or type of road user. Differences in the percentage of victims carrying ID cards during travel may partially explain this discrepancy. Our study also showed regional differences in linkage rates, which has not been reported in previous studies. This might have been due to differences in reporting rates or transcription error rates among different regions [23,24]. The finding that the characteristics of DRL-linked records differed significantly from those linked by MPRL (Table 3) indicates a bias of representativity in DRL-linked records.



Note:

1. Light gray area in RTAF indicates police registered fatal cases and other area in RTAF indicates severely injured cases.
2. Heavy gray area in CODF indicates certifier registered traffic-related deaths and other area in CODF indicates deaths from other causes.
3. Areas A, B, C, D, E, F, G, H were defined according to the status in the original files and the results of linkage; the number of cases in each area was listed as follow:

		Status registered in RTAF		Status registered in CODF	
Area	Number	Fatal cases	Severely injured cases	Traffic related	Other causes of death
			Linked records		
A	2,655	+		+	
B	37	+			+
C	57		+	+	
D	366		+		+
			Unlinked records		
E	405	+			
F	6,529		+		
G	5,433			+	
H	120,416				+
Number		3,097	6,952	8,145	120,819

Figure 1 Possible outcomes of linkage process according to the subsets of the original datasets

Table 1 Percentage of fatal cases registered in the Road Traffic Accident File (N=3097) that could be linked to the Cause of Death File by characteristics

Characteristics	Linkage rate (%)
Total (n=3097)	86.9
Sex	
Male (n=2296)	86.4
Female (n=801)	88.4
Age	
0-19 (n=537)	88.1
20-29 (n=707)	89.8
30-49 (n=813)	89.3
50-69 (n=643)	90.2
≧70 (n=320)	86.6
Place of crash by region ***	
Northern Taiwan (N=1050)	83.1
Central Taiwan (n=797)	90.2
Southern Taiwan (n=974)	87.8
Estern Taiwan (n=276)	88.8
Type of road ***	
National (n=192)	90.6
Provincial (n=1051)	89.0
County (n=616)	89.9
Municipal (n=719)	79.3
Hsiagn (n=330)	88.2
Others (n=188)	89.4
Type of road user ***	
Truck of bus (n=253)	92.9
Automobile (n=830)	87.8
Heavy motorcycle (n=884)	90.3
Light motorcycle (n=442)	88.2
Bicycle (n=184)	79.4
Pedestrian (n=496)	79.0

*** $p < 0.001$ for χ^2 test

Table 2 Percentage of certifier registered traffic-related cases in the Cause of Death File (N=8145) that could be linked to the Road Traffic Accident File by characteristics

Characteristics	Linkage rate (%)
Total (n=8145)	33.3
Sex	
Male (n=6156)	32.5
Female (n=1989)	35.9
Age	
0-19 (n=1418)	32.0
20-29 (n=1550)	24.5
30-49 (n=2130)	38.7
50-69 (n=2060)	36.5
≧70 (n=987)	30.7
Place of residence by region ***	
Northern Taiwan (N=2531)	34.7
Central Taiwan (n=2302)	31.0
Southern Taiwan (n=2749)	32.1
Estern Taiwan (n=563)	41.2
Certifier ***	
Coroner or examiner (n=7664)	34.0
Physicin (n=481)	22.5

*** $p < 0.001$ for χ^2 test

Table 3 Comparison of characteristics of records linked using manual probable record linkage (MPRL) versus deterministic record linkage (DRL)

	MPRL	DRL
	No. (%)	No. (%)
Total linked records	2262 (100)	853 (100)
Sex		
Male	1544 (68.3)	752 (88.2)
Female	718 (31.7)	101 (11.8)
Age, yr		
0-19	516 (22.8)	64 (7.5)
20-29	425 (18.8)	276 (32.4)
30-49	500 (22.1)	320 (37.5)
50-69	547 (24.2)	161 (18.9)
70+	274 (12.1)	32 (3.8)
Place of crash by region*		
Northern Taiwan	635 (28.0)	371 (43.5)
Central Taiwan	610 (27.0)	220 (25.8)
Southern Taiwan	791 (35.0)	219 (25.7)
Eastern Taiwan	226 (10.0)	43 (5.0)
Number of persons involved		
1	507 (22.4)	420 (49.2)
2	1093 (48.3)	415 (48.7)
≧3	662 (29.3)	18 (2.1)
Type of road user*		
Truck or bus	158 (7.0)	86 (10.1)
Car	521 (23.0)	287 (33.7)
Heavy motorcycle	617 (27.3)	321 (37.6)
Light motorcycle	353 (15.6)	142 (16.7)
Bicycle	163 (7.2)	3 (0.4)
Pedestrian	450 (19.9)	14 (1.6)
Driver or passenger		
Driver of car	192 (8.5)	287 (33.7)
Passenger of car	329 (14.5)	0 (0.0)
Driver of motorcycle	779 (34.4)	462 (54.2)
Passenger of motorcycle	173 (7.7)	1 (0.1)
Others	789 (34.9)	103 (12.0)

* $p < 0.001$, χ^2 test

Though the number of fatal cases registered in RTAF was underestimated (because the police registered only those died within 24 hours), the characteristics of police registered fatal cases were similar to linked fatal cases. This implies that if the resources for performing MPRL or CPRL are limited, the description of characteristics of fatal cases registered in RTAF can provide a good substitute of MPRL linked records.

Limitations of record linkage

A linked traffic-related injury database would allow more economical and efficient use of existing official data. In addition to better defining the nature and extent of road injuries, linkage of these data sources will enable research to be carried out that would otherwise require in-depth data collection at the scene of the crash. However, Rosman [10] noted that the linked database was not without limitations. There are many problems associated with the use of data derived from routinely collected mass data, whether from police or health service sources. Not only the variables restricted by the coding system imposed by the collecting agency, but the data integrity is always a concern.

With regard to the discrepancies of identifiers registration among files on the same individual, Gill and Baldwin [19] summarize that there are four basic groups of errors in registration. Firstly, 'transcription or substitution errors', in which one or more correct digits are replaced by incorrect characters through mishearing, misreading, or miskeying. This type of error is by far the most common, and from the

Oxford Record Linkage Study (ORLS), accounts for about 86 percent of errors in the recording of numbers but applies to less than one percent of all records. A common cause is poor definition of hand written and printed digits, such as confusion between 1 and 7 or 3 and 8. Secondly, there are 'transposition errors' in which two correct digits are transposed in adjacent positions (single transposition) or across an intervening correct digit (double transposition). In the ORLS, the former contribute approximately eight percent of all errors and the latter one percent. Thirdly, shift errors occur when a whole number is moved one digit position or more to the left or right by the addition or omission of consecutive zeros. These tend to account for less than one percent of error in most number systems. Finally, there are several other types of errors which fit none of these categories and together constitute less than five percent of all data preparation errors in ORLS.

For road traffic injury research, a study in Australia [17] found that the discrepancy rates in registration of demographic variables were 0.5% (15/2,947) for sex and 18% for age-higher than that in our study. The researchers concluded that most of the errors in the registration of age were due to transcription errors. We also found that most of the transcription error pairs had 'similar form'. This information may provide important guidance in defining the weights and rules of partial agreements in CPRL. For example, previous studies [15,17, 20] defined age differences within 5 years as partial agreement. The results of this study did not show the same picture: both files registered year of birth and month of birth instead of age per se as previous studies did. Most of the recording errors in Taiwan were due to transcription errors rather than memory errors, so partial agreements should be determined according to 'similar form'.

Conclusion

Given the high yields of MPRL as compared to DRL and the great difference in the distribution of characteristics between records linked by MPRL and DRL, we conclude that MPRL is a necessary procedure for future record linkage with the RTAF. The common discrepancies found in this study may serve as a useful reference in designing a CPRL program.

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