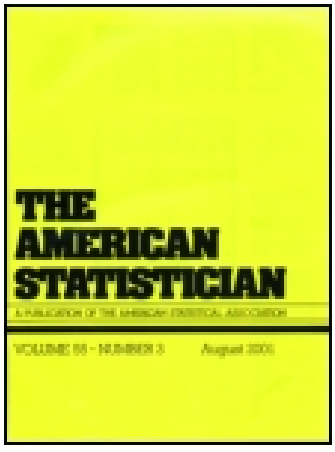

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Ignoring a Covariate: An Example of Simpson's Paradox

David R. Appleton [a], Joyce M. French [b] & Mark P. J. Vanderpump [c]
[a] Department of Medical Statistics, University of Newcastle, Tyne, NE2 4HH, UK
[b] Medical Statistics, University of Newcastle, Tyne, NE2 4HH, UK
[c] Endocrinology and Diabetes, North Staffs Royal Infirmary, Stoke on Trent, ST4 7LN, UK
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Ignoring a Covariate: An Example of Simpson's Paradox

David R. APPLETON, Joyce M. FRENCH, and Mark P. J. VANDERPUMP

The possibility that the apparent direction of an association will be reversed when covariates are taken into account is well known, but many examples of this effect are rather contrived. A real example from an epidemiological survey is presented.

KEY WORDS: Covariate; Simpson's paradox; Smoking.

1. INTRODUCTION

All statisticians know of the dangers of ignoring a covariate that is correlated to an outcome variable and an explanatory one (Simpson 1951). Simple but convincing examples based on real data are, however, in rather short supply. We present one here in which a naive analysis suggests a beneficial effect of cigarette smoking.

In 1972–1974 a one-in-six survey of the electoral roll, largely concerned with thyroid disease and heart disease, was carried out in Whickham, a mixed urban and rural district near Newcastle upon Tyne, United Kingdom (Tunbridge et al. 1977). Twenty years later a follow-up study was conducted (Vanderpump et al. 1995). Some of the results make interesting teaching material, and we present here those dealing with smoking habits as reported at the original survey, and whether or not the individual survived until the second survey. For the sake of simplicity we have restricted ourselves to women, and within them to the 1,314 who were classified either as current smokers or as never having smoked; there were relatively few women at the first survey (162) who had smoked but stopped, and only 18 whose smoking habits were not recorded. The 20-year survival status was determined for *all* the women in the original survey.

Table 1. Relationship Between Smoking Habits and 20-Year Survival in 1314 Women

	Smoker		
	Yes	*No*	*Total*
Dead	139	230	369
Alive	443	502	945
	582	732	1,314

$\chi^2 = 9.12$ on 1 df; $P = .0025$.
Odds ratio = .68 (95% confidence limits .53–.88).

2. RESULTS

Results are shown in Table 1. They imply a significant protective effect of smoking because only 24% of smokers died compared to 31% of nonsmokers. Can this be the correct interpretation? No, it cannot, and Table 2 shows one variable that is strongly related to both smoking and survival—namely age. Few of the older women (over 65 at the original survey) were smokers, but many of them had died by the time of follow-up.

3. DISCUSSION

We do not wish to give too much consideration here to the proper analysis of these data. However, it is clear that any sensible weighted average of the odds ratios for the different age groups will have a value of greater than unity. For example, Woolf's test applied to the first six two-by-two tables gives an overall odds ratio of 1.53 with 95% confidence limits of 1.08 and 2.16. This should be enough to indicate that we do indeed have an example of Simpson's paradox. However we do not intend to suggest that such an analysis would be totally satisfactory: it does not take the ordering of the categories into account. Alternatives could involve the use of standardized mortality ratios (SMR's) for smokers and nonsmokers, or the application of logistic

David R. Appleton is Head, Department of Medical Statistics, and Joyce M. French is Honorary Research Associate in Medical Statistics, University of Newcastle upon Tyne, NE2 4HH, UK. Mark P. J. Vanderpump is Senior Registrar in Endocrinology and Diabetes, North Staffs Royal Infirmary, Stoke on Trent, ST4 7LN, UK. The authors thank Dr. Michael Tunbridge, the principal investigator in the original survey, for permission to use his data. MPJV was principal investigator in the follow-up study, JMF ascertained whether the subjects had survived or not, and DRA performed the analyses.

Table 2. Numbers of Women Smokers and Nonsmokers in Different Age Groups, Showing their 20-Year Survival Status

	Age group													
	18–24		25–34		35–44		45–54		55–64		65–74		75+	
	Smoker		Smoker		Smoker		Smoker		Smoker		Smoker		Smoker	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−
Dead	2	1	3	5	14	7	27	12	51	40	29	101	13	64
Alive	53	61	121	152	95	114	103	66	64	81	7	28	0	0
$\hat{\psi}$	2.30		0.75		2.40		1.44		1.61		1.15		—	

NOTE: For each age group the odds ratio ($\hat{\psi}$) is given for a smoker dying relative to a nonsmoker.

regression. The latter has the advantage of not categorizing the age variable, but is complicated by a quadratic term in age being required. Also, this approach is less useful if particular causes of death are to be considered.

The actual effect of smoking will be underestimated from these data, as the population seen in the original survey was already subject to selection: the small proportion of the older women smoking is likely to be due not only to a low proportion in that cohort being smokers, but also to those who had smoked being less likely to survive to be seen in the original study. But this example is not intended to show the extent to which smoking affects survival; it is meant merely to provide a convenient vehicle for the discussion of problems of analysis and interpretation of data.

The data we have presented are capable of making other teaching points to suit the purposes of particular classes, and are available from the first author (david.appleton@newcastle.ac.uk).

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