Short Communication

Gender differences on the interacting effects of marital status and health insurance on long-term colon cancer survival in California, 1995–2014

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D. Campbell [a], K.M. Gorey [b,*], I.N. Luginaah [c], G. Zou [d], C. Hamm [e], E.J. Holowaty [f]

[a] School of Social Work, University of Windsor, Windsor, Ontario, Canada
[b] School of Social Work, University of Windsor, 167 Ferry Street, Windsor, Ontario N9A 0C5, Canada
[c] Department of Geography, Western University, London, Ontario, Canada
[d] Department of Epidemiology and Biostatistics and Robarts Research Institute, Western University, London, Ontario, Canada
[e] Windsor Regional Cancer Center and Department of Oncology, Division of Medical Oncology, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada
[f] Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada

health insurance adequacy and neighbourhood poverty, we have consistently found antagonistic vulnerabilities of being an unmarried and inadequately insured woman of colour, living in poverty among a cohort of colon cancer patients in California.[6,7] Here, we demonstrate the existence and importance of a five-way interaction on long-term colon cancer survival among them.

Longstanding calls for 'consilient', unified social and natural scientific knowledge of 'social life, which sets the path along which the biologic may flourish or wilt', have imagined that health and illness have multiple causes.[1,2] Such calls from pre-eminent theorists, ranging from the biologist Edward O. Wilson to the social epidemiologist Nancy Krieger, have invited the consideration of not merely statistical interactions, but of important, complex public health interactions.[2–4] So, we have been surprised that much of the historical and theoretical contexts of public health and allied interdisciplinary research, in our experience, seem still primarily comprised of the study of main effects.[5]

Therefore, we have been prompted to study complex interactions. Studying increasingly complex two-, three- and four-way interactions of gender, marital status, ethnicity,

The cohort

Six thousand three hundred people diagnosed with colon cancer between 1995 and 2000 were randomly selected from the California cancer registry that was joined to the 2000 census by census tracts and followed until 2014. The original cohort oversampled the poor by stratifying as follows: a third each from high poverty neighbourhoods where 30% or more of the households were poor, 5%–29% were poor or where less than 5% were poor. This study then secondarily analysed the survival of 3021 women and 2755 men with validly staged tumours. Primary health insurers were private (including privately supplemented Medicare), Medicare (including those with public supplementation), Medicaid or the uninsured. Marital status was married or unmarried, whether never or previously married.

* Corresponding author.
E-mail address: gorey@uwindsor.ca (K.M. Gorey).

Our developmental work led us to hypothesize an age (above or below the Medicare eligibility criterion of 65 years) by gender, by marital status, by health insurance adequacy, by neighbourhood poverty interaction. Cox regressions were used to test the five-way interaction and explore other interactions on long-term survival. Logistic regressions estimated the proportion of 10-year survival variability explainable by interaction effects.[8] Modest missing data of 8% across all variables did not confound these analyses. To describe interaction effects, 10-year survival rates were internally age and stage adjusted and reported as percentages (rates per 100). Then, standardized survival rate ratios (RR) were reported for between-group comparisons with 95% confidence intervals (CI) derived from the Mantel–Haenszel Chi-squared test. This study was reviewed and cleared by the University of Windsor research ethics board. Methodological details have been reported.[5–7]

The complex interaction

The hypothesized five-way interaction was significant. Along with main effects, it could explain 42% of the variability in long-term colon cancer survival. All of the aggregate main effects alone could only explain 10% of such survival variability. Moreover, it suggested larger disadvantages among non-Medicare-eligible people, but there was not enough power to confidently describe all of the adjusted effects across the five-way interaction's numerous strata.

The significant four-way interaction, excluding age of Medicare eligibility, was observed. It reduced to a significant three-way interaction in non-high poverty neighbourhoods and a non-significant three-way interaction in high poverty neighbourhoods where well-known main effects were predictive. The significant three-way interaction is depicted in Table 1.

The top of the table depicts findings for unmarried people. Among them, private insurance was significantly associated with survival for men (RR = 1.60), but not for women. Relatedly, there were non-significant trends of better survival among publicly or uninsured women than men (RR = 1.22) and

worse survival among privately insured women than men (RR = 0.82). Descriptive statistics enriched these findings (data not shown). Among unmarried people without private insurance, men were twice as likely to be uninsured (21.8% vs 10.7%); χ^2 (1, $n = 858$) = 18.17, $P < 0.05$. Additionally, among the unmarried who were privately insured, women lived in neighbourhoods where annual household incomes ($57,920) were typically nearly $4000 less than neighbourhood households where men lived ($61,615).

The bottom of the table depicts findings for married people. Among them, private insurance was significantly associated with survival for women (RR = 1.60), but not for men. Relatedly, better survival was observed among privately insured women than men (RR = 1.16). Descriptive statistics were again informative (data not shown). Among the married people who were privately insured, women lived in neighbourhoods where annual household incomes ($70,980) were typically nearly $1000 more than neighbourhood households where men lived ($70,165). Finally, the importance of studying interaction effects was further demonstrated by the following. There was no main effect of gender on survival in this study. But comparing the two most extreme of this interaction's strata (unmarried, publicly or uninsured men vs married, privately insured women) resulted in a near two-fold between-gender survival difference (17.4% vs 32.2%, RR = 1.85; 95% CI = 1.39, 2.46).

Interpretation

Previous analyses of this California cohort of colon cancer patients focused on those who lived in poverty. We systematically replicated the fact that main effects alone, including race/ethnicity, explained well their long-term survival. The story seemed quite different, however, among the population of this study's central focus, those who did not live in profound poverty. Such diverse people are the near poor and members of the working class as well as members of the lower to upper middle classes. The predictors of their outcomes were indeed more complex, best characterized by interactions that did not differ significantly by race/ethnicity. Key among

Table 1 – Depiction of gender by marital status by health insurance interaction on 10-year survival: colon cancer patients not living in poverty in California, 1995–2014.

Primary health insurer	Women				Men				Women/men	
	No.[a]	Rate	RR[b]	95% CI	No.[a]	Rate	RR[b]	95% CI	RR[b]	95% CI
Unmarried people										
Public or uninsured	626	0.2	1.0	…	232	0.2	1.0	…	1.2	0.9, 1.6
Private	419	0.2	1.1	0.9, 1.3	218	0.3	1.6**	1.1, 2.2	0.8	0.6, 1.1
Married people										
Public or uninsured	407	0.3	1.0	…	599	0.3	1.0	…	1.0	0.8, 1.3
Private	510	0.3	1.2**	1.0, 1.5	789	0.3	1.1	0.9, 1.3	1.2*	0.9, 1.4

CI = confidence interval; RR = standardized survival rate ratio.

All survival rates were directly adjusted for age and stage using this study's combined female and male population of cases as the standard (age categories: 25–64, 65–79 and 80 years or older; stage categories: I or II, III and IV). Most (83%) of the youngest cohort were 45 years of age or older.

*$P < 0.10$, **$P < 0.05$.

[a] Number of incident colon cancer cases.

[b] A rate ratio of 1.00 is the within-gender baseline.

our interactional findings was the finding that among such near poor to upper middle class people with colon cancer, the interacting effects of marital status and health insurance adequacy were significantly modified by gender. Key vulnerable strata indicative of relatively disadvantaged survival were unmarried men who were inadequately insured and unmarried women who were privately insured. Such men were much more prevalently uninsured than their female counterparts, while such women had substantially lower neighbourhood incomes and probably household incomes, on average, than otherwise similar men.

Unmarried people seem to have fewer assets than their married counterparts, fewer unmarried men having health insurance and fewer unmarried women having adequate discretionary incomes or capital reserves.[6] So, for different reasons, they both are probably not readily able to bare the indirect or direct, covered or uncovered, costs of colon cancer care. The Patient Protection and Affordable Care Act (PPACA) alone may not be able to overcome such structural challenges. In fact, the majority of private plans purchased though the PPACA's exchanges are bronze or silver plans with high deductible, out-of-pocket costs.[9,10] In this way, many may be moving from the ranks of the uninsured to the underinsured. We think that the routine examination of complex interactions such as this study's can facilitate the identification of subpopulations at most prevalent risk.

Public health implications

Perhaps, the more diverse a population of interest, the more important it will be to study its health risk interactions. Our examination of complex interactions allowed for the inference that structural inequities related to the institutions of marriage and health care seem to affect women and men quite differently. Policy makers ought to be cognizant of such structural imbalances as future reforms of American health care are considered, while researchers should at least consider testing the most plausible and potentially public health-significant interactions in their respective fields.

Author statements

Ethical approval

This study was reviewed and cleared by the University of Windsor research ethics board.

Competing interests

None declared.

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