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A multi-centre prospective case-control study of campylobacter infection in persons aged 5 years and older in Australia

To the Editor:

I write in response to the article by Stafford and colleagues [1] who provide results from a case-control study examining risk factors for sporadic *Campylobacter* infections in Australia. In their article they report consumption of undercooked chicken to be significantly associated with illness. This is in keeping with findings reported in other case-control studies [2, 3]. However the risk of illness from consumption of undercooked chicken is likely to be overstated due to the effects of information bias, particularly differential misclassification. A number of factors, including interview and questionnaire design, the characteristics of cooked poultry meat, consumer perceptions on thoroughness of cooking and the physiology of *Campylobacter* organisms all require consideration before the significance of a relationship between consumption of chicken labelled as being undercooked and illness can be established.

To begin with it would be helpful to know how questions on undercooked chicken were phrased. Some studies attempt to qualify the use of the term undercooking by providing a definition, for example, eating 'chicken that was pink on the inside' [3]. Obviously, in large case-control studies that examine scores of variables, it is difficult to cover all bases in published material. However, the means of elucidating such information is particularly relevant to this study because eating undercooked chicken was identified as the principal independent risk factor (aOR 4·7).

Myoglobin, a protein found in muscle, is the pigment most responsible for the colour of meat [4]. A number of factors including pH levels, meat source, packaging conditions, freezing history, fat content, and preservation treatments contribute to the phenomenon known as 'pink defect' seen in well-cooked white meats [4, 5]. Meat pinking and red or bloody poultry parts are critical for consumer rejection as they directly relate to an undercooked appearance of the product [6], with most consumers assessing cooking status by the colour of the meat or its juice [4].

However, from a food safety perspective, a food thermometer is recommended to ensure cooked meats have reached a temperature that will ensure destruction of pathogenic organisms [7]. However, it has only been in the last few years that food safety authorities have moved away from promoting messages such as cooking meat 'until the inside is no longer pink and the juices run clear', as well as specifying temperature and time rules and use of food thermometers. The United States Department of Agriculture (USDA) and Food Safety Inspection Service (FSIS) have updated their recommendations for cooking poultry using an extensive health promotion campaign to highlight the inappropriateness of visual assessment and the need to use a food thermometer. Such practices have important implications, with evidence showing colour is not a reliable indicator that organisms have been destroyed or that meat is cooked. On this basis, there can be no confidence in visually inspecting a meat product to ascertain if it is safely cooked, and use of a food thermometer is the most reliable method for guaranteeing the inactivation of foodborne pathogens in cooked meat [4].

The temperature at which different bacteria are destroyed varies, as does the temperature at which different meat and poultry types are deemed to be thoroughly cooked. *Campylobacter* are generally regarded as being less robust than many other pathogenic bacteria [8], demonstrating particular sensitivity

to heat [9]. Given *Campylobacter* has a *D* value of less than 1 min at 60 °C [10] it becomes possible that chicken not cooked to a recommended temperature will still have been exposed to sufficient heat to destroy or inactivate any *Campylobacter* present. This view is supported by a number of risk-based assessments [8, 11]. If true, the relevance of undercooking should be reconsidered and greater emphasis instead placed on examining the relationship between human infection and cross-contamination and poor hand hygiene, as suggested by the authors in their conclusion.

It is recognized that *Campylobacter* contamination levels in commercial kitchens are particularly high [12]. In this study and others [2] consumers of undercooked chicken have been shown to have a higher rate of eating chicken in restaurants, and eating in restaurants *per se*. Because both activities have been associated with increased risk of *Campylobacter* infection it is possible that reports of undercooking are being confounded by eating at restaurants where it is biologically plausible that cross-contamination is occurring.

In summary the use of a questionnaire or interviews collecting self-reported data on undercooked chicken, while practical, is inappropriate to answer the question of whether consumption of undercooked chicken is a significant risk factor for campylobacteriosis. Evidence shows use of a food thermometer is the only method that can reliably determine thoroughness of cooking. Determining whether meat is cooked based on colour is no longer recommended in the United States, although mixed messages continue from government food authorities in Australia. To label or define undercooked chicken as being 'pink on the inside' is also misleading, especially given that 'meat pinking' and 'bone darkening', are not uncommon in cooked poultry meat. Physiological attributes of the *Campylobacter* organism may also contribute to undercooking being a less likely explanation of illness. Given the impracticality of direct observation, the inclusion of a subjective assessment of subjects' food handling and food hygiene practices into epidemiological studies examining risk factors may allow a better understanding of the magnitude that undercooking and cross-contamination play in disease transmission.

Declaration of Interest

None.

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The author replies:

In his letter, Moffatt raises a valid concern about the possibility of information bias leading to an inflated association between illness and eating undercooked

chicken; a limitation acknowledged in our paper and common to all case-control studies. Our definition of undercooked chicken meat used that of Friedman and colleages [1] and asked participants 'did any of this meat appear pink on the inside when you ate it'. Information collected on undercooked meat may be highly subjective and exposure difficult to measure within a case-control design so significant associations need to be interpreted with caution. However, undercooked chicken meat has been repeatedly reported as a potential risk factor for *Campylobacter* infection in previous case-control studies necessitating its inclusion in our study [1–4].

It is unclear whether there are differential information biases between cases and controls in the reporting of undercooked chicken meat. Indeed, it may be that consumption of undercooked chicken is also systematically under-reported by cases. Moreover, we assume that other case-control studies which have identified an association with the consumption of chicken or poultry are, in fact, actually reporting consumption of undercooked chicken as a potential risk factor for *Campylobacter* infection (assuming all cooked chicken is safe to eat) in addition to transmission by cross-contamination [5–9]. The main concern with our study, therefore, lies in the accuracy of the estimate effect size and subsequent population attributable risk (PAR) estimate. Our PAR estimate for 'undercooked' chicken meat was 8·1%, similar to that reported elsewhere (3–11%) [1–3].

No other types of 'undercooked' meat that were measured in our study (e.g. pork, lamb and beef) were significantly associated with *Campylobacter* infection. If differential bias was strongly affecting the association with undercooked chicken then such bias is likely to have applied to these other meats.

Campylobacter are fastidious organisms and are relatively sensitive to the effects of environmental stress such as heat. However, it is reasonable to assume that not all chicken meat that is consumed is cooked thoroughly. For example, in recent years we have investigated several outbreaks of campylobacteriosis associated with the consumption of chicken kebabs from takeaway stores, where frozen rolled chicken meat was partially thawed then cooked on a vertical rotating spit slowly over several hours (OzFoodNet, unpublished data). The investigations revealed that during periods of high demand, the risk of serving undercooked meat increases, due to insufficient time to enable thorough cooking of the meat internally. Given the low infectious dose required to infect humans, the high frequency of raw chicken meat colonized with *Campylobacter*, and contamination levels often in excess of $>10^5$ organisms/carcass, it is not surprising then that such outbreaks due to undercooked chicken occur [10–14]. The use of thermometers to ensure that meats are cooked thoroughly is desirable, but probably does not happen very often.

Investigators have commonly examined food handling and hygiene practices in epidemiological studies of *Campylobacter* infection, but interpretation is problematic. We included several food hygiene and handling questions in our study but the results were not reported as the questions were poorly answered and the response rates were low. As with 'undercooked' chicken, an assessment of food hygiene and handling practices in the home kitchen can be quite difficult to measure accurately as most people, in general, are very reluctant to disclose unhygienic practices [1, 8, 15].

So while the characteristics of cooked poultry meat, consumer perceptions on thoroughness of cooking and the physiology of *Campylobacter* organisms are all important factors for consideration, the consistency of findings in the literature suggest that consumption of undercooked chicken is one of the most important risk factors for infection. Given the high prevalence of chicken consumption in the community (81% during the 7-day period prior to interview among our study controls), we would expect to see eating undercooked chicken as a risk factor despite the low reported frequency of exposure.

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Editorial Comment

This is a very well thought out commentary on the problem of ascertaining reliable histories of undercooking of chicken by way of a questionnaire. I think it adds a great deal of important information to the general discussion of how we conduct case-control studies of sporadic foodborne infections.

The issue of undercooking of meats, particularly chicken, does seem to be closely tied to consumption in restaurants. There has never (to date) been a following for consumption of undercooked poultry in a manner similar to the taste for undercooked beef.

In the United States, a series of FoodNET case control studies have had similar findings. One puzzling element from my perspective is why a history of eating undercooked chicken emerges in the context of studies looking at consumption of chicken-related organisms. For example, if cross-contamination in a restaurant is the issue, why would chicken consumption *per se* be important. Someone ordering a beef-containing dish may equally be served a salad that was previously contaminated by raw chicken. Either the history of eating chicken is a surrogate for the general menu choices available at the restaurant, or there is some cross-contamination occurring in proximity to that particular dish being prepared and served.

Both may be possible, and should entail further study.

CRAIG HEDBERG

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