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Adjusting for unrecorded consumption in survey and per capita sales data: Quantification of impact on gender- and age-specific alcohol attributable fractions for oral and pharyngeal cancers in Great Britain

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ABSTRACT

Aims: Large discrepancies are typically found between per capita alcohol consumption estimated via survey data compared to sales, excise or production figures. This may lead to significant inaccuracies when calculating levels of alcohol-attributable harms. Using British data, we demonstrate an approach to adjusting survey data to give more accurate estimates of per capita alcohol consumption.

Methods: First, sales and survey data are adjusted to account for potential biases (e.g. self-pouring, under-sampled populations) using evidence from external data sources. Second, survey and sales data are aligned using different implementations of Rehm et al.'s method (2010a). Third, the impact of our approaches is tested by using our revised survey dataset to calculate alcohol attributable fractions (AAF) for oral and pharyngeal cancers.

Results: British sales data underestimates per capita consumption by 8%, primarily due to illicit alcohol. Adjustments to survey data increase per capita consumption estimates by 35%, primarily due to under-sampling of dependent drinkers and underestimation of home-poured spirits volumes. Before aligning sales and survey data, the revised survey estimate remains 22% lower than the revised sales estimate. Revised AAFs for oral and pharyngeal cancers are substantially larger with our preferred method for aligning data sources, yielding increases in AAF from the original survey dataset of 0.47 to 0.60 (male) and 0.28 to 0.35 (female).

Conclusions: It is possible to use external data sources to adjust survey data to reduce underestimation of alcohol consumption and then account for residual underestimation using a statistical calibration technique. These revisions lead to markedly higher estimated levels of alcohol-attributable harm.

Key words: per capita consumption, survey, under-coverage, alcohol attributable fraction, methodology

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INTRODUCTION

The most reliable source of information on alcohol consumption is usually considered to be data on average per capita consumption derived from official production, sales and/or customs figures (Gmel and Rehm 2004). However, such data are population-level and can only provide aggregated per capita consumption estimates for the total adult or drinker population. The main alternative, weighted and grossed data from population surveys, is known to substantially underestimate population-level figures (Knibbe and Bloomfield 2001; Nelson et al. 2010) and the reasons for this have been discussed extensively in the survey methods literature (Duffy and Waterton 1984; Midanik 1988; Midanik 1989; Greenfield et al. 2000; Caetano 2001; Del Boca and Darkes 2003; Gmel and Rehm 2004).

Advances in survey methods research have demonstrated means to raise the coverage of survey estimates closer to population-level estimates through the use of diary surveys (Poikolainen and Karkkainen 1983; Lemmens et al. 1988; Heeb and Gmel 2005), recent recall questions (Stockwell et al. 2004; Stockwell et al. 2008) and more detailed instruments or adjustment of measures (Kuhlhorn and Leifman 1993; Casswell et al. 2002; Kerr and Greenfield 2007). However, although the impact of using alternative measures can be dramatic (e.g. Casswell et al. 2002; Stockwell et al. 2008), other approaches have produced only small improvements (Wyllie et al. 1994; Gmel and Rehm 2004). Consequently, researchers still contend with residual under-coverage and must often utilise surveys with adequate measures but potentially important biases relating to sampling methods. To date, little attention has been given to adjusting data to account for these issues.

Despite its weaknesses, survey data allows subgroup analysis of populations and their drinking patterns and also permits consumption distributions to be established for the population and subpopulations. Whilst the ability to undertake subgroup analyses of consumption data has particular importance for policy appraisals, consumption distributions are essential for calculating the proportion of an alcohol-related harm which could be avoided if the population consumed no alcohol. This proportion is known as the alcohol attributable fraction (AAF) and is a key component of burden of harm estimates (Rehm et al. 2009).

This paper reports on a proposed approach to adjusting survey data to account for under-coverage and further steps to align survey and population-level data. It aims to, firstly, derive best estimates for both aggregate per capita and survey consumption, secondly, test approaches to calibrating survey consumption to per capita estimates and, finally, test the impact of such adjustments on UK AAF estimates.

METHODS

Before describing our data sources and the details of our proposed approach, a brief overview of our method is provided. Both survey data and more accurate population-level estimates suffer from known biases; therefore, the first step of our approach is to apply adjustments to each of these estimates by drawing on alternative sources of evidence. This process yields a revised survey dataset and also a revised population-level consumption estimate. We then obtain optimally-adjusted survey datasets by aligning the revised survey to the population-level estimate using different implementations and adaptations of a method proposed by Rehm et al (2010). Finally, we test the impact of our approach and these various implementations by using the optimally-adjusted datasets to calculate gender- and age-specific AAFs for oral and pharyngeal cancers.

Data

Sales data

UK clearance data is produced by Her Majesty's Revenue and Customs (HMRC) and includes per capita consumption estimates for beer, wine, spirits and cider for adults (16+). Data collection methods are reported elsewhere (HMRC 2010a), but the data broadly account for all alcohol released by producers or importers for sale or consumption in the UK. This includes alcohol produced or purchased abroad for UK sale but excludes personal imports and alcohol produced in the UK for export markets. HMRC 2006/07 data are used here.

Survey data

The General Household Survey (GHS) is an annual nationally-representative cross-sectional survey of people living in around 9,000 private households in Great Britain (GB, i.e. the UK excluding Northern Ireland) (ONS 2009b). Alcohol questions are asked to all adult (16+) household members using beverage-specific quantity-frequency questions. GHS 2006 data are used here.

Table 1 shows per capita consumption estimates from the HMRC and GHS data. Coverage by GHS relative to HMRC is 61.8% and varies markedly by beverage.

[Table 1 about here]

Adjusting population-level sales data

Previous work has noted a range of potential under- and over-estimating biases with sales data (Single and Giesbrecht 1979; Smith et al. 1990; Greenfield and Kerr 2003) and Table 2 summarises those relevant to the UK. Below, we outline an approach to adjusting the sales data to account for each potential bias in turn.

[Table 2 about here]

Unrecorded alcohol

HMRC recently assessed tax loss through cross-border shopping and illicit alcohol sales for spirits and beer (HMRC 2010b). For spirits in 2006/7 HMRC estimates cross-border trade accounted for 4% and illicit sales for 9% of the total spirits market. For beer, 13% of the market was illicit and <1% was cross-border trade. An alternative source, the International Passenger Survey (IPA), estimates cross-border trade in beer to account for 1.1% of duty payable (ONS 2010b). The more precise IPA estimate for cross-border beer trade was used here. To date, HMRC has not provided estimates for wine. Alternative data sources were found to be unsuitable; therefore, it was assumed that wine has the same level of illicit and cross-border trade as spirits.

Although the European Comparative Alcohol Study found 0.9% of UK respondents have consumed home-distilled spirits three or more times in the past 12 months (Leifman 2001), no UK estimates for quantity of consumption of homemade alcohol were identified. Estimates of homemade consumption for other countries vary markedly (Macdonald et al. 1999; Nordlund and Osterberg 2000; Stockwell et al. 2008) and, again, often only relate to prevalence, as opposed to quantity, of consumption. UK industry and market research company sources felt that the market share was likely to be negligible so no adjustment was made.

Ethanol content assumptions

Beer and spirits clearances do not require ethanol content assumptions as excise duty returns to HRMC contain this information. For wine, HMRC improved their methodology for estimating wine strengths in 2010 and applied this retrospectively to sales estimates from previous years (HMRC 2008). Therefore, we attempted no further adjustments.

Spillage and wastage

Research by the Department of Environment, Food and Rural Affairs estimates 6% of alcoholic drinks bought in the off-trade are wasted (DEFRA 2010). No beverage-specific rates or corresponding on-trade data were available so we assume equal wastage for all beverages in the on- and off-trade.

Alcohol used in food

Analyses of alcohol used in food suggest alcohol content decreases by varying amounts depending on the method of food preparation (Augustin et al. 1992), with a 50% loss on average. The National Diet and Nutrition Survey shows that 1% of consumption occurs through food (ONS 2005), leaving 0.5% of total consumption lost in food preparation.

Consumption by children

For Scotland and England, estimates of average consumption by 11-15 year-olds were derived from school surveys and then multiplied by mid-year population estimates (ONS 2008; ONS 2010a) to obtain estimates of total ethanol consumption by under-16s. Separate drinking data for Wales was not available for 2006, so English estimates were used. Overall, it was estimated that 0.7% of alcohol sold in the UK is drunk by 11-15 year olds.

Tourism

Alcohol consumption by outbound UK tourists is missing from the HMRC sales figures, whilst consumption by inbound tourists is included. The IPA estimates that, in 2006, foreign tourists spent 273.4m nights in the UK, whilst UK residents spent 701.3m nights abroad (ONS 2010b). It was conservatively assumed that UK citizens abroad continue to drink the average per capita amount for 2006 (Table 1). Based on per capita consumption estimates for key source countries (BBPA 2009), inbound tourists were assumed to drink 8.5 l/ethanol per capita per annum. Annual consumption was converted to daily consumption and multiplied by tourist nights to estimate total tourist consumption.

Adjusting Survey Consumption

Although much of the underestimation literature focuses on evaluating survey instruments, various additional sources of potential bias affecting survey data on alcohol consumption have been noted (Smith et al. 1990; Caetano 2001; Gmel and Rehm 2004). Table 3 lists sources we sought to explore and we particularly focus on adjusting or augmenting the data to ensure it is representative of all British adults.

[Table 3 about here]

Non-sampled populations

The GHS is a survey of private households; thus many populations, potentially containing disproportionate numbers from heavy or light drinking demographic groups (e.g. older women) or disproportionately heavy or light drinking elements of those groups (e.g. university students), are excluded from the sampling frame (Wilson 1981; Duffy and Waterton 1984). We attempted to obtain best estimates of age- and sex-specific population size and beverage-specific alcohol consumption for five such populations (homeless, military personnel, inpatient of mental health institutions, elderly people in care homes and prisoners). Full details of this process, which often involved merging data from multiple sources and making adjustments and extrapolations to account for missing or incompatible information in one of more of England, Scotland or Wales, are provided as supplementary data.

Under-sampled populations

In addition to non-sampled populations, we also investigated population suspected to be under-represented in the GHS sample after weighting.

Students

We focused on the 1.8m undergraduate students (HESA 2011) who are more likely to live in university halls of residence outside the GHS sampling frame (ONS personal communication). After weighting, GHS contains 877,000 undergraduates, just 49% of the population.

Students in the GHS consume around 20% more alcohol per year than comparable non-students of the same age and gender and this is in line with student-specific surveys (e.g. Bewick et al. 2008). We adjust the survey weights of present students so that they also represent missing students, thus assuming that alcohol consumption does not differ by missingness.

Dependent drinkers

For England, the 2004 ANARP study estimated that there were 1.1m dependent drinkers (AUDIT score >=16); 3.6% of the adult population. For Scotland, a similar study estimated 206,000 dependent drinkers, 7.2% of the adult population, with 65% being male (Drummond et al. 2005; Drummond et al. 2009). Assuming the same prevalence in Wales as in England gives 1.37m dependent drinkers in GB.

Only one UK-based estimate of dependent drinkers' consumption levels was identified (Gill et al. 2010). This used an in-treatment sample and reported annual consumption levels of 109 and 89 l/ethanol per capita for males and females respectively. AUDIT scores were not reported, thus it was not possible to assess the sample's position on the dependency spectrum. To establish whether the GHS accurately represents dependent drinkers, a lower threshold was set for dependent drinking at twice the UK health service's threshold for harmful drinking (114 g/day for men and 86 g/day for women). Even at this lower threshold, the GHS population only contains 505,000 dependent drinkers. Dependent drinkers were reweighted to account for underrepresentation and, to avoid double-counting, this was done after accounting for other non-sampled or under-sampled populations.

Proxy interviews

Proxy interviews account for 7.5% of the GHS sample, and, although core demographic data is collected, alcohol consumption is not. Proxy interviewees were particularly likely to be young and male. A two-step multiple imputation procedure was applied to first impute whether proxy respondents were abstainers or drinkers and, second, impute the consumption level of the drinkers (Gelman and Hill 2007) using the ice command in Stata 11.1 (Royston 2004). In doing so, it was assumed that, after accounting for demographic covariates, the likelihood of being a proxy respondent is not associated with alcohol consumption. Multiple imputation was performed before testing whether students and dependent drinkers are under-covered to avoid double counting.

Other biases

Assumed size of self-poured drinks

Several studies have examined whether drinkers self-pour larger drinks than is assumed by survey measures. A recent UK study around Edinburgh (Gill and Donaghy 2004) reports on asking drinkers to pour their normal measures of spirits and wine. On average participants poured 160ml of wine (approximately 2 units or 16g of ethanol) and 57ml of spirits (approximately 2.3 units). These findings have been closely replicated in other Scottish studies (Gill et al. 2007). For wine, this is consistent with GHS assumptions of 2 units for an unspecified glass of wine. However, the GHS assumption for spirits was 1 unit per drink, thus off-trade spirit consumption amongst our sample was multiplied by 2.3 and no adjustment was made for other beverages.

Fieldwork timing

Surveys continue throughout summer, Christmas and weeks containing public holidays; therefore, no adjustments are required for heavy drinking periods (ONS personal communication).

Ethanol content assumptions

In 2006, conversion factors used to convert quantity measures into units of alcohol in the GHS were updated to account for changes in beverage strengths and serving sizes, in particular for wine where glass sizes have substantially increased (Goddard 2005). Given these recent improvements and no further evidence of biases, no additional adjustment was made.

Revising GHS and HMRC consumption

After identifying the necessary adjustments above, the HMRC population-level estimate was revised by calculating the net effect of the adjustments. To revise the GHS 2006 dataset there were four sequential steps. Firstly, the consumptions for proxy interviewees were imputed. Secondly, new records were added representing the missing populations. For each country, gender and age subgroup, eleven additional records were created representing one abstainer and ten drinkers with their consumption following gamma distribution (Skog 1993; Rehm et al. 2010). Population weights were set to the missing population each added record represents. Thirdly, the weights of under-sampled populations were adjusted uniformly in line with the above estimates. Finally, underestimation of self-poured spirits was accounted for by multiplying all drinkers' off-trade spirits consumption by 2.3. An upper consumption threshold of 156 l/ethanol per year was set to exclude outliers.

As a validation, the revised GHS population of England was compared to mid-year population estimates (ONS 2010a). The overall match for the adult population improved from 89.3% to 99.9%.

Aligning GHS and HMRC data

Adjusting both population-level and individual-level consumption data does not eliminate under-estimation by survey data (see results). Therefore, we sought to use statistical calibration techniques to align the GHS to the HMRC estimate. An approach proposed by Rehm et al. (Method 1) shifts the survey consumption distribution to fit a gamma function defined by the sales data and allows for differential under-coverage rates for different observed consumption levels (Rehm et al. 2010). Further, it ensures the adjusted population consumption follows the recommended gamma distribution (Skog 1993). Method 1 is underpinned by three assumptions. Firstly, that sales data accurately reflect per capita consumption; secondly, population subgroups of interest do not have differential levels of under-estimation and, thirdly, the proportion of abstainers in the survey is accurate as only known drinkers can be adjusted. Our previous adjustments address the first assumption; however, we have no means to verify the other assumptions.

Two limitations of Method 1 are the lack of empirical evidence to indicate under-coverage is distributed as implied by the shifts necessary to fit adjusted consumption levels to the gamma distribution and that shifting the consumption to a gamma distribution can artificially reduce the distribution's long tail of heavy drinkers. Given the latter limitation, we developed a method (Method 2) of fitting a gamma function to the survey data and then, for each percentile of the distribution, calculating the percentage consumption increase between this gamma distribution and the distribution given using Method 1 and then applying these percentage shifts to the corresponding percentile of the survey data to obtain an aligned dataset. Both Method 1 and Method 2 were employed to align the GHS data with the HMRC estimate.

Method 1 is described in more detail in Rehm et al. (2010). For our purposes, calibration was performed separately for each country/gender/age subgroup and for each beverage type. All beverages were shifted by the same factor which was calculated using the population mean consumption in the revised GHS and the HMRC consumption estimate (see Table 7).

Calculating AAFs for Oral and Pharyngeal cancer

The impact of our approach to adjust and align survey and population-level data was assessed by using various base cases and implementations of Methods 1 and 2 to calculate and compare gender- and age-specific AAFs for oral and pharyngeal cancer.

The relative risk functions for oral and pharyngeal cancer mortality are taken from recent meta-analysis (Tramacere et al. 2010). We are grateful to Irene Tramacere for providing by personal communication the equation for this function (Equation 1):

$$\ln(RR) = 0.02572x - 0.00006x^2 \qquad (1)$$

Where RR is the relative risk of oral and pharyngeal cancer and x is daily alcohol consumption in grams.

Because individual-level survey data and continuous risk functions were used, the standard formula for calculating AAFs (Jones et al. 2008) was adapted by replacing pre-defined consumption groups with surveyed individuals, the relative risk estimates for consumption groups with the estimates for surveyed individuals at their consumption level and the proportion of the population exposed in each group with a proportion representing the individual survey weight as a percentage of the total weight in the population (Equation 2):

$$AAF = \frac{\sum_{i=1}^{n} p_i (RR_i - 1)}{1 + \sum_{i=1}^{n} p_i (RR_i - 1)} \quad (2)$$

Where *i* and *n* represent surveyed individuals and the total number of individuals, RR_i is the relative risk of exposure to alcohol for individual *i* given their consumption level, p_i is the proportion of the survey weight for individual *i* as a percentage of the total population weight.

AAFs were calculated under eight scenarios using different versions of the GHS dataset aligned to 70%, 80% and 90% of HMRC estimates. Aligning to 70%, 80% and 90% of the HMRC estimate, rather than 100%, is done because the risk functions underpinning AAFs are derived from survey data subject to unknown levels of underestimated consumption. Therefore, we follow recommendations to align to 90% (Rehm et al. 2010) and use other percentages as sensitivity analyses. The first two scenarios use the original GHS (S1) and the GHS revised but not aligned to HMRC data (S2). Scenarios 3-8 align the revised GHS to 70%, 80% and 90% of the revised HMRC sales estimates using Method 1 (S3-S5) and Method 2 (S6-S8).

RESULTS

Revised HMRC sales estimates

The impact of adjustments made to the aggregate-level consumption figures are shown in Table 4. Several adjustments have only minor effects. None of cross-border purchases, alcohol used in food or children's consumption influenced per capita estimates by more than 2%. In contrast, tourism (+2.9%), spillage (-6.7%) and illicit alcohol (+9.3%) have larger, but partly off-setting, impacts. The net effect of these adjustments influences beer and spirits in particular, while the estimate for wine is largely unchanged. The final consumption estimate of 12.3 l/ethanol per capita is 7.6% higher than the original HMRC figure.

[Table 4 about here]

Revised survey consumption

The gender and age breakdown and average consumption for each subgroup of the non-sampled population and the original GHS 2006 data, are provided in Table 5. In total, 861,000 people were estimated to be outside the GHS sampling frame, including 230,000 homeless people (mean consumption 23.8 l/ethanol per person per annum), 110,000 military personnel (9.6 l/ethanol), 35,000 psychiatric inpatients (4.4 l/ethanol), 400,000 care home residents (3.2 l/ethanol) and 86,000 prisoners (1.7 l/ethanol). The weighted average annual consumption of these populations was estimated as 9.5 l/ethanol per person. Although this is 35% higher than the GHS average of 7.0 l/ethanol, the new cases represent only 2% of the population and thus increase per capita consumption by just 0.04 l/ethanol.

[Table 5 about here]

The 1,513 proxy interviewees were disproportionately young and male with a predicted average consumption of 9.0 l/ethanol, thus increasing the total GHS estimate by 0.20 l/ethanol. Reweighting for the missing half of GB undergraduates contributed only a small increase (0.03l/ethanol); however, the missing majority of dependent drinkers substantially increased the GHS estimate by 1.01 l/ethanol. Adjusting for home serving sizes of spirits also had a marked effect, increasing the GHS estimate by 1.19 l/ethanol.

After carrying out all adjustments the per capita consumption estimate in the revised GHS increased by 2.47 l/ethanol or 35.1% (Table 6).

[Table 6]

Aligning GHS survey data to HMRC population-level estimates

Table 7 shows the revised survey estimates and shifting factors obtained under scenarios S1-S8. As Methods 1 and 2 only affect the shape and not the mean of the aligned consumption distribution, the revised estimates are identical for some scenarios. Aligning to 70%, 80% and 90% of the revised HMRC estimate increases our revised GHS survey estimate by a further 22%, 39% and 57% respectively, suggesting considerable residual under-estimation remained even after our initial adjustments.

[Table 7 about here]

Comparison of AAFs for oral and pharyngeal cancer

Table 8 summarizes gender- and age-specific AAFs for GB oral and pharyngeal cancer mortality under 8 scenarios. The comparison shows that AAF estimates are highest in S8 when the revised survey data are shifted to 90% of the revised HMRC sales data using Method 2. The AAFs in S8 are 0.60 for men and 0.35 for women compared with 0.47 and 0.28 respectively in S1 when the original survey data was used. As one would expect, S1 gives the lowest AAFs suggesting underestimation of consumption in surveys leads to underestimation of alcohol-attributable harm. In general, Method 2, which preserves the long tail of the consumption distribution, yields higher AAFs compared with Method 1 which shifts to a continuous gamma distribution. The decision of whether to calibrate to 70%, 80% or 90% of the HMRC data also has a significant impact on the AAFs. The AAFs increased from 0.54 (male) and 0.28 (female) at 70% to 0.60 and 0.35 at 90%.

[Table 8 about here]

DISCUSSION

This paper has three major findings, which have relevance to the British case through the specific results and for alcohol research more broadly through the methodological developments. Firstly, it was estimated that per capita consumption in Britain for 2006/7 was 12.3 l/ethanol per year; 7.6% more than the original HMRC estimate. Some potential biases had only a small impact, whilst the more important factors somewhat offset one another. Accounting for spillage reduced the total amount drunk (-6.7%) but this was outweighed by tourism (+2.9%) and illicit alcohol (+9.3%). The findings provide some support for those who have queried the accuracy of per capita data although, in Britain at least, the overall impact is modest due to counteracting biases. Many of the adjustments are, however, based on weak or incomplete evidence and it would be informative to similarly assess the net effect of biases in other countries with different data sources.

Secondly, a new survey-based estimate of average consumption was produced that corrected for a number of potential biases and raised survey consumption by 35%, but still left residual underestimation. Some biases had smaller effects than expected; notably, accounting for the consumption of around 860,000 people not living in private households increased per capita consumption by just 0.6%, mainly because of counteracting adjustment and most of the added populations being fairly small. However, these missing populations represent many of society's heaviest and lightest drinkers and accounting for them may have substantial effects on AAFs and thus estimated levels of alcohol-related harm. Adjusting for other sampling biases had a larger effect, particularly under-sampling of dependent drinkers which increased average consumption by 14.4% and we recommend further research to improve prevalence and consumption estimates for this group. Accounting for under-estimation of self-poured off-trade spirits (16.9% increase) was also important and highlights the importance of surveys using robust instruments. Casswell et al. (2002) have demonstrated that underestimation is not a given with survey instruments, although their method is unfeasibly time-consuming for some surveys. Greenfield et al. (2010) have achieved high coverage rates with a less intensive calibrated graduated frequency approach and further methodological developments which lead to robust and efficient survey instruments would be welcome.

Finally, adjusting survey consumption has a significant impact on estimates of AAFs for oral and pharyngeal cancer. As expected, using adjusted survey data and further aligning it to population-level sales data gives higher AAF estimates than using unadjusted survey data. This strongly suggests estimated levels of alcohol-related harm based on population surveys may contain sizeable underestimates of true levels of harm. Aligning to sales data by calibrating the survey consumption distribution to a gamma distribution of the sales data is seen to artificially reduce the long tail of heavy consumption and thus results in lower AAFs than our adapted approach which preserves the empirical consumption distribution. Thus, we believe our adapted method to be the preferable approach. Those using harm estimates based on survey data should be aware of the potential biases which are demonstrated by our results. However, it should be noted that the estimates within some studies, such as the WHO Global Burden of Disease studies, do already adjust survey data with reference to sales or excise records (Rehm et al. 2007).

Limitations

For several adjustments, there was substantial uncertainty due to a lack of robust evidence; for example, drinking by tourists and wastage estimates for the on-trade sector. For survey estimates, this uncertainty affected the most important biases such as off-trade spirits servings and the prevalence and consumption levels of dependent drinkers. Further research should focus on obtaining robust estimates in these areas.

Due to limited data availability and the scale and complexity of this study, we have not performed a comprehensive sensitivity analysis to address the uncertainty of our revised consumption estimates. Ideally we would obtain a range of revised estimates using different data sources and assumptions and obtain confidence intervals where possible. However, the importance of this is reduced as, unless the uncertainty and confidence intervals are large, their impact on our findings should be limited given we are aligning survey consumption to 70% to 90% of the revised HMRC and this uncertainty will dominate other uncertainties. That said, uncertainty regarding individual-level GHS adjustments will impact on subgroup level AAF estimates where adjustments relate to specific population subgroups such as dependent drinkers or students.

Further limitations include assuming constant under-coverage when adjusting survey consumption in different subpopulations or for different beverages for many of the considered biases. It should also be noted that, although we address under-sampling of dependent drinkers, we assume harmful drinkers are adequately represented.

CONCLUSION

Of the biases investigated, we find those impacting most on consumption estimates are under-sampling of dependent drinkers and under-estimation of home-poured spirits volumes. We demonstrate a method for adjusting both sales and survey data to obtain revised consumption estimates and present a means for aligning survey data to population-level data to account for residual under-estimation. We also highlight the importance of retaining the long tail of the consumption distribution. Overall, we demonstrate that practicable and evidence-based methods for accounting for underestimation of alcohol consumption lead to substantially increased estimates of the proportion of given harms attributed to alcohol and thus increased estimated levels of alcohol-related harm.

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Tables

Table 1: Beverage-specific consumption and coverage estimates by data source

	HMRC 2006 per capita	GHS 2006 per capita	Coverage (%)
All alcohol	11.39	7.04	61.8
Beer & Cider	5.56	3.05	54.9
Wine	3.48	2.80	80.5
Spirits	2.35	1.18	50.2

Note: Per capita consumption is expressed as litres of ethanol (l/ethanol) per year.

Table 2: Potential biases on UK population-level consumption estimates from HMRC sales data

Underestimating Influences	Unclear direction	Overestimating Influences
Unrecorded alcohol including illicit and homebrewed alcohol and cross-border purchases	Incorrect ethanol content assumptions	Spillage and wastage before and after sale
Alcohol consumed by UK tourists abroad		Alcohol used in food
		Consumption by children aged under 16
		Alcohol consumed in the UK by tourists

Table 3: Potential biases on UK consumption estimates from the GHS survey data

Unsampled populations	Under-sampled populations	Other biases
Homeless people	Students	Assumed size of self-poured drinks
Military personnel not living in private accommodation	Dependent drinkers	Ethanol content assumptions
Inpatients of psychiatric institutions	Other possible survey non-respondents	Fieldwork timing in relation to high consumption periods
Elderly living in care homes		
Prisoners		

Table 4: Quantification of underestimating and overestimating effects on UK per capita data

	Estimated effect (l/ethanol)			
	Beer	**Wine**	**Spirits**	**Total**
Previous HMRC estimates for 2006/7	**5.56**	**3.48**	**2.35**	**11.39**
Effect of Adjustments				
Cross-border purchases	0.05	0.03	0.10	0.17
Illicit alcohol	0.71	0.15	0.23	1.06
Ethanol content assumptions	0.00	0.00	0.00	0.00
Spillage and wastage	-0.33	-0.21	-0.16	-0.76
Alcohol used in food	(-0.03)	(-0.02)	(-0.01)	-0.06
Consumption by children	(-0.04)	(-0.02)	(-0.02)	-0.08
Tourism (inbound/outbound net effect)	(0.16)	(0.10)	(0.07)	0.33
Total effect of adjustments	0.57	0.04	0.25	0.86
(%)	10.3%	1.1%	10.6%	7.6%
Revised HMRC estimates	**6.13**	**3.52**	**2.60**	**12.25**

Note: Data represent effects in l/ethanol per person per annum. Figures in brackets were not available in beverage-specific form, and have been assigned to beverage types based on the HMRC sales split.
[1] The total alcohol net effect is made up of alcohol sold in UK but consumed by visiting tourists (-0.12 l/ethanol) and alcohol drunk by UK citizens whilst abroad (+0.45 l/ethanol).

Table 5: Age and sex distribution, and estimated annual per capita consumption (l/ethanol) for missing populations

	Male		Female		Total	
	N	Mean l/ethanol	N	Mean l/ethanol	N	Mean l/ethanol
Homeless						
Under 18	12,146	12.4	8,261	4.6	20,407	9.2
18-24	27,402	23.0	12,240	5.1	39,642	17.5
25-34	45,823	26.7	14,068	6.2	59,890	21.8
35-44	43,355	23.0	11,923	12.9	55,278	20.8
45-54	23,350	36.7	9,059	46.3	32,410	39.4
55-64	15,809	47.7	3,519	3.2	19,328	39.6
65-74	3,029	36.9	401	2.2	3,430	32.9
75+	1,670	23.3	333	1.6	2,003	19.8
Total	172,584	27.6	59,804	12.9	232,388	23.8
Military personnel not living in private households						
18-24	15,773	7.6	1,753	4.7	17,525	7.3
25-34	38,849	11.0	4,317	5.8	43,166	10.5
35-44	30,963	10.2	3,440	5.3	34,403	9.7
45-54	11,782	10.2	1,309	5.2	13,090	9.7
Total	97,366	10.1	10,819	5.4	108,185	9.6
Inpatients of mental health institutions						
18-24	1,645	12.1	1,346	5.8	2,991	9.3
25-34	3,654	3.3	2,990	3.3	6,644	3.3
35-44	3,363	6.3	2,751	1.7	6,114	4.2
45-54	2,751	5.7	2,251	1.4	5,002	3.8
55-64	2,649	13.0	2,168	0.4	4,817	7.3
65-74	3,261	6.4	2,668	0.3	5,929	3.7
75+	3,057	3.2	2,501	0.1	5,558	1.8
Total	20,380	6.6	16,674	1.6	37,054	4.4
Elderly living in care homes						
55-64	5,170	11.0	5,170	4.6	10,340	7.8
65-74	15,907	8.3	27,838	3.2	43,746	5.0
75+	78,344	5.3	265,257	2.1	343,602	2.8
Total	99,422	6.1	298,265	2.2	397,687	3.2
Prisoners						
16-17	2,565	1.75	107	1.16	2,672	1.73
18-24	21,450	1.75	1,336	1.16	22,787	1.72
25-34	27,547	1.75	1,730	1.16	29,277	1.72
35-44	19,363	1.75	1,038	1.16	20,401	1.72
45-54	7,230	1.75	310	1.16	7,540	1.73
55-64	2,374	1.75	72	1.16	2,446	1.73
65-74	823	1.75	0	1.16	823	1.75
75+	0		0		0	
Total	81,352	1.75	4,593	1.16	85,945	1.72
Total added records					**861,259**	**9.47**
Original GHS						
16-17	393,757	6.85	345,969	4.69	739,725	5.84
18-24	1,860,788	10.97	2,190,406	5.83	4,051,195	8.19
25-34	3,137,187	10.19	3,517,133	5.30	6,654,319	7.61
35-44	3,919,879	10.20	4,357,863	5.18	8,277,742	7.56
45-54	3,255,828	10.67	3,790,034	5.47	7,045,861	7.87
55-64	3,194,160	10.94	3,305,257	4.63	6,499,417	7.73
65-74	2,230,197	8.23	2,482,076	3.18	4,712,273	5.57
75+	1,606,019	5.30	2,428,465	2.07	4,034,484	3.36
Total	19,597,815	9.78	22,417,202	4.66	42,015,017	7.04

Table 6. Survey adjustments: Effects on per capita consumption

		Estimated effect size l/ethanol per capita
Previous GHS per capita estimate		**7.04**
Missing populations		
	Homeless	*+0.080*
	Military	*+0.006*
	Mental health institutions	*-0.003*
	Care homes	*-0.034*
	Prisons	*-0.010*
	Total	+0.04
Under-coverage		
	Students	*+0.03*
	Dependent drinkers	*+1.01*
	Proxy interviewees	*+0.20*
	Total	+1.24
Self-pouring (adjustment for off-trade spirits)		+1.19
Fieldwork timing		0
Ethanol content assumptions		0
Total effect		**+2.47**
New GHS annual per capita estimate		**9.51**

Table 7. Mean annual per capita consumption (l/ethanol) for the 8 scenarios and shifting factors

	Annual per capita consumption						Shift factor[1]		
	S1: Basecase GHS 2006	S2: Revised GHS 2006	Revised HMRC 2006	S3,S6: HMRC 2006 revised (70%)	S4,S7: HMRC 2006 revised (80%)	S5,S8: HMRC 2006 revised (90%)	S3,S6	S4,S7	S5,S8
Beer/cider	3.05	3.88	6.13	4.29	4.90	5.52	1.11	1.26	1.42
Wine	2.81	3.04	3.52	2.46	2.82	3.17	0.81	0.93	1.04
Spirits	1.18	2.60	2.60	1.82	2.08	2.34	0.70	0.80	0.90
Total	7.04	9.49	12.25	8.58	9.80	11.03	0.90	1.03	1.16

[1] *These figures are used for the shifting for beer/cider, wine and spirits respectively in the relevant scenario*

Table 8: Comparison of gender/age specific AAFs of oral and pharyngeal cancers for the UK population in 8 difference scenarios

		16-17	18-24	25-34	35-44	45-54	55-64	65-74	75+	Total
S1: Original GHS	Male	0.35	0.51	0.48	0.48	0.50	0.51	0.42	0.30	0.47
	Female	0.31	0.33	0.30	0.30	0.31	0.28	0.20	0.13	0.28
S2:Revised GHS	Male	0.42	0.60	0.55	0.54	0.58	0.60	0.52	0.39	0.55
	Female	0.33	0.39	0.36	0.36	0.37	0.34	0.26	0.18	0.34
S3: Revised GHS aligned to 70% HMRC (Method 1)	Male	0.45	0.60	0.56	0.54	0.58	0.58	0.49	0.32	0.55
	Female	0.27	0.32	0.29	0.29	0.31	0.26	0.19	0.13	0.27
S4: Revised GHS aligned to 80% HMRC (Method 1)	Male	0.49	0.63	0.60	0.58	0.62	0.63	0.53	0.36	0.59
	Female	0.30	0.36	0.33	0.33	0.34	0.30	0.22	0.15	0.30
S5: Revised GHS aligned to 90% HMRC (Method 1)	Male	0.52	0.66	0.63	0.61	0.65	0.66	0.57	0.39	0.62
	Female	0.33	0.40	0.37	0.36	0.38	0.33	0.24	0.16	0.34
S6: Revised GHS aligned to 70% HMRC (Method 2)	Male	0.41	0.58	0.55	0.53	0.57	0.58	0.49	0.34	0.54
	Female	0.28	0.34	0.31	0.31	0.31	0.28	0.21	0.14	0.28
S7: Revised GHS aligned to 80% HMRC (Method 2)	Male	0.44	0.62	0.58	0.57	0.60	0.61	0.52	0.38	0.57
	Female	0.31	0.37	0.35	0.34	0.35	0.31	0.23	0.16	0.32
S8: Revised GHS aligned to 90% HMRC (Method 2)	Male	0.47	0.64	0.61	0.60	0.62	0.63	0.55	0.41	0.60
	Female	0.34	0.40	0.38	0.37	0.38	0.34	0.26	0.18	0.35

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