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Use of laboratory-based surveillance data to estimate the number of people chronically infected with hepatitis B living in Scotland

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SUMMARY

It is paramount to understand the epidemiology of chronic hepatitis B to inform national policies on vaccination and screening/testing as well as cost-effectiveness studies. However, information on the national (Scottish) prevalence of chronic hepatitis B by ethnic group is lacking. To estimate the number of people with chronic hepatitis B in Scotland in 2009 by ethnicity, gender and age, the test data from virology laboratories in the four largest cities in Scotland were combined with estimates of the ethnic distribution of the Scottish population. Ethnicity in both the test data and the Scottish population was derived using a name-based ethnicity classification software (OnoMAP; Publicprofiler Ltd, UK). For 2009, we estimated 8720 [95% confidence interval (CI) 7490–10 230] people aged $\geqslant$15 years were living with chronic hepatitis B infection in Scotland. This corresponds to 0·2% (95% CI 0·17–0·24) of the Scottish population aged $\geqslant$15 years. Although East and South Asians make up a small proportion of the Scottish population, they make up 44% of the infected population. In addition, 75% of those infected were aged 15–44 years with almost 60% male. This study quantifies for the first time on a national level the burden of chronic hepatitis B infection by ethnicity, gender and age. It confirms the importance of promoting and targeting ethnic minority groups for hepatitis B testing.

Key words: Hepatitis B, public health, surveillance.

INTRODUCTION

Worldwide, it has been estimated that about 2 billion people have been infected with hepatitis B virus (HBV). Two hundred and forty million have chronic HBV infection (CHB) and 600 000 die each year either from CHB-associated liver cirrhosis or hepatocellular carcinoma [1]. A UK prevalence of 0·3% for CHB has been reported by the Department of Health [2]. This estimate relates to data from antenatal screening tests in the West Midlands between 1983 and 1985 [3]. More recently, a higher prevalence of 0·45% has been predicted for England and Wales as a result of

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modelling data on notifications of acute HBV [4]. Generally, higher prevalences of CHB have been found in males and older people [5] and in members of certain ethnic minority groups, especially South Asians and East Asians [6, 7].

In the UK, universal infant or adolescent immunization is not considered cost-effective [8]. Instead, the Joint Committee on Vaccination and Immunization recommended that HBV immunization should be targeted at individuals at high risk of HBV exposure and at people at increased risk of complications should they acquire HBV [9].

Early diagnosis and treatment of HBV is cost-effective [10], but identification of individuals, who are often asymptomatic, is difficult. In The Netherlands and Canada, both countries with a low HBV prevalence [11], screening first-generation migrants and early treatment of those with CHB has been shown to be cost-effective [12, 13]. HBV testing has been part of the UK antenatal screening programme since 1998 [14]. Recent guidance from the National Institute for Health and Clinical Excellence (NICE) recommends testing people at increased risk of HBV infection. Those at higher risk are particularly migrants from medium- or high-prevalence countries, people who inject or have injected drugs and men who have sex with men (MSM) [15].

Until now, most studies on HBV prevalence have focused on the tested population without making comparisons with the general population. In this study, we developed an approach based on a combination of HBV laboratory test data with estimates of the Scottish population as a means to estimate, by major ethnic groups, the number of people living with CHB in Scotland. This approach is of paramount importance to guide national policy and screening strategies. Nevertheless, not being a resource-intensive approach, it has not hitherto been implemented.

METHODS

Laboratory HBV test data were used to determine the prevalence of CHB by ethnic background in (i) women undergoing an antenatal screen, and (ii) women and men tested in other primary- and secondary-care settings. The former gives information on the prevalence of CHB in females of childbearing age, while the latter gives information on differences in the prevalence of CHB by age and gender. To generate an estimate of the prevalence of CHB infection in adults living in Scotland, estimates of CHB prevalence by age, gender and ethnicity were then combined with estimates of the general Scottish population.

Laboratory data

The virology laboratories in the four largest cities in Scotland (Aberdeen, Dundee, Edinburgh, Glasgow) provided Health Protection Scotland (HPS) with data on all HBV-related diagnostic tests conducted at their laboratories from 1 January 2005 to 31 December 2009 on samples submitted from their respective health board areas. Those areas represent about 60% of the Scottish population. Information for each sample included diagnostic test results by date, patient identifiers [including full names, date of birth, gender, postcode of residence and the community health index (CHI) number when available], referral source of test (i.e. primary care, secondary care, antenatal and other), and referral source/clinic number; information on ethnicity is not routinely reported with a virology test request and therefore could not be relied on for analysis.

Hepatitis B surface antigen (HBsAg)-positive tests and HBsAg-negative tests were used to define infected and uninfected individuals, respectively. Indeterminate, weak positive or inconclusive results were excluded. In order to ensure that HBV infection included in the study was CHB, an assessment of HBV-positive individuals was performed. An HBsAg-positive individual was excluded if there was (1) a negative test within 180 days before the first positive HBsAg test or (2) a positive test for IgM antibodies to the hepatitis B core antigen at the time of the first positive HBsAg test.

Ethnicity was assigned using a name-based 'ethnicity' classification methodology (OnoMAP; Publicprofiler Ltd, UK). The OnoMAP software classifies ethnicity based on a comparison of forename and surname against a database of names sourced from public name registries from over 26 countries. In order to correct for misclassification in the assignment of ethnicity, predictive values from a recent validation study of OnoMAP have been used [16]. This study, set in the Scottish population and involving large datasets of birth registrations and the pupil census, concluded that OnoMAP was an effective methodology for categorizing populations into a variety of ethnic groups. Comparing predictions from OnoMAP to birth registrations, the study found predictive values to determine British ethnicity of 94·6%

[positive predictive value (PPV), the proportion of people determined by OnoMAP to belong to a certain ethnic group who truly belong to that ethnic group] and 74·4% [negative predictive value (NPV), the proportion of people determined by OnoMAP not to belong to a certain ethnic group who truly do not belong to that ethnic group], Chinese ethnicity of 70·9% PPV and 99·9% NPV and South Asian ethnicity of 53·6% PPV and 99·5% NPV. South Asian countries included Iran, Afghanistan, Pakistan, Tibet, Nepal, India, Bangladesh, Burma and Sri Lanka. East Asian countries included Mongolia, the People's Republic of China, Japan, North Korea, South Korea and Taiwan. In accordance with data protection requirements, after classification of ethnicity surnames were replaced by surname soundex (a consonant-only phonetic encoding) and forenames were replaced with forename initials. HPS Clinical Governance approval was obtained to assign ethnicity, using the above process.

Records for the same person were identified using (i) a combination of forename initial, soundex of surname, gender and date of birth, (ii) CHI number, or (iii) the referral source clinic-number. Age was calculated at the time of the first HBsAg test. To avoid problems from a low number of tests in children aged <15 years, analysis was restricted to the adult population (here regarded as those aged $\geqslant$15 years).

HBV prevalence in females aged 15–44 years, by ethnicity

The prevalence of HBV infection in females aged 15–44 years was estimated using test results from women living in any of the four NHS board areas and who had been tested for HBsAg as part of the universal antenatal screening programme. It was assumed that pregnant women tested as part of this programme were broadly representative of all women of childbearing age, since very few women, about 2% in Glasgow in 2004–2009 [17], opt out of antenatal screening.

In total, 154 927 HBsAg tests in the laboratory database were recognized as antenatal tests. Although it was not possible to identify all antenatal tests in the database, it was assumed that misclassification in the database was non-differential.

Prevalence was stratified according to age (15–29 and 30–44 years) and ethnic group (British/Other, South Asian, East Asian, unknown). To avoid bias from multiple testing, only the first HBsAg test for every woman during the period 2005–2009 was used in the analysis, leaving in total 129 171 tests for analysis.

HBV prevalence in females aged >44 years and males aged >14 years, by ethnicity

CHB prevalence in females aged >44 years and males aged >14 years was estimated using as a starting point the estimated prevalence generated for women aged 15–44 years (as described above). Estimates were then adjusted according to relative differences in prevalence for the former groups, as determined from examination of data on all men and women tested for HBsAg in primary and secondary healthcare settings (excluding antenatal screens).

A total of 96 763 HBsAg tests in the laboratory database had referral source identified as either primary (29 393) or secondary (67 370) healthcare provider (excluding tests from genito-urinary medicine providers, occupational health services and renal screening) and where the test was not also recognized as an antenatal screening test. Again, only the first HBsAg test for individuals was used in the analysis. For each ethnic group separately, Poisson regression was used to generate relative risks (RRs) of testing HBsAg-positive for (*a*) men compared to women, and (*b*) women aged >44 years compared to those aged 15–29 years, adjusting for NHS board and referral source. For East Asians, women aged 15–44 years were grouped together to avoid problems with small numbers in the Poisson models. Year of test (i.e. 2005, 2006, 2007, 2008, 2009) was not a significant confounder of HBsAg positivity and therefore was not included further in the regression models. Similarly, no significant interaction between age and gender was found and the interaction term was therefore not included in regression models.

For each ethnic group, the estimated prevalence of HBsAg positivity in women aged >44 years was calculated by multiplying the prevalence in women aged 15–29 years (generated from the antenatal test data) with the RR of testing HBsAg positive for women aged >44 years compared to those aged 15–29 years (generated from primary and secondary healthcare test data). The prevalence in men was similarly estimated, applying the RR for men compared to women. For example, to estimate the prevalence in British men aged >44 years, the prevalence in British women, aged 15–29 years (0·16%, Table 1) was multiplied with the adjusted RR of British men and women aged >44 years compared to British

Table 1. *Number of women tested for HBsAg and percentage testing HBsAg positive at their first recorded antenatal screening between 2005 and 2009 in Scotland*

Age group (years)	*n*	%	HBsAg +ve	% of *n* (95% CI)
British/Other				
15–29	64397	50	103	0·16 (0·13–0·19)
30–44	55006	43	55	0·10 (0·08–0·13)
Both age groups	119403	92	158	0·13 (0·11–0·15)
South Asian				
15–29	3518	3	15	0·43 (0·24–0·70)
30–44	2117	2	18	0·85 (0·50–1·34)
Both age groups	5635	4	33	0·59 (0·40–0·82)
East Asian				
15–29	841	0·6	106	12·60 (10·44–15·04)
30–44	687	0·4	51	7·42 (5·58–9·65)
Both age groups	1528	1	157	10·27 (8·80–11·91)
Unknown				
15–29	1680	1	10	0·60 (0·29–1·09)
30–44	925	1	17	1·84 (1·07–2·93)
Both age groups	2605	2	27	1·04 (0·68–1·50)
All ethnic groups				
15–44	129171	100	375	0·29 (0·26–0·32)

CI, Confidence interval.

men and women aged 15–29 years (RR 0·3, Table 2). The resulting product (0·05%) was then multiplied with the adjusted RR of British men compared to British women (RR 1·69, Table 2) resulting in an estimated prevalence of 0·08%. In estimating the ethnic-specific CHB prevalences in older women and men, it was assumed that the RRs, as calculated from tests conducted in primary and secondary healthcare settings, were representative of differences in the general population.

Scotland's population in 2009, by ethnicity

Names, gender and age of all people registered with a general practitioner (GP) in Scotland in June 2011 ($n = 5\,800\,674$ observations) were extracted from the CHI database at Information Service Division, Scotland. The distribution of the Scottish CHI population by age slightly exceeds the number of people living in Scotland because it can include some visitors, duplicate records, people who have moved out of Scotland (and are not known to have moved) and people who have died in that year. The distribution of the Scottish populations by age (15–29, 30–44, >44 years), gender and ethnicity (British/Other, South Asian, East Asian) in 2011 was then estimated using OnoMAP. To correct for misclassification in the assignment of ethnicity, the estimated distribution was then corrected using published predicted values [16]. Finally, corrected estimates were applied to the size of the Scottish population in 2009 according to age group and gender, predicted by the General Register Office for Scotland (GRO; $n = 5\,194\,000$ [18]). In using CHI, it was therefore assumed that the ethnic distribution by age and gender in this database represented that of the general population. Estimates generated from the CHI database were compared to results from the latest (2001) census ($n = 5\,062\,000$) [19], at the time of analysis, and to published estimates for 2010 by Wohland *et al.* ($n = 4\,940\,000$) [20], who predicted the size of the Scottish population using estimates of ethnic group fertility, ethnic group mortality, internal and international migration.

Scotland's CHB population in 2009, by ethnicity

Scotland's CHB population in 2009 was estimated as the product of the estimated CHB prevalence and the estimated size of the population in 2009 by gender, age group and ethnicity. Confidence intervals (CIs) for these estimates were derived by replacing the following three parameters with distributions and then

Table 2. *Relative risks of testing HBsAg positive in men and women aged >15 years tested for HBsAg in primary- and secondary-care settings (excluding all antenatal tests) in Scotland during 2005–2009, stratified by ethnicity*

Variable	Level	*n*	%	HBsAg positive	% of *N*	Relative risk (95% CI) Unadjusted	Adjusted*
(a) British/Other							
Source	Secondary care	53 957	68	271	0·50		
	Primary care	25 768	32	226	0·88	1·75 (1·46–2·08)	1·57 (1·31–1·88)
Gender	Female	36 546	46	166	0·45		
	Male	43 179	54	331	0·77	1·69 (1·4–2·03)	1·69 (1·40–2·04)
Age group	15–29 yr	15 533	19	160	1·03		
	30–44 yr	24 359	31	219	0·90	0·87 (0·71–1·07)	0·83 (0·68–1·02)
	>44 yr	39 833	50	118	0·30	0·29 (0·23–0·36)	0·30 (0·24–0·39)
NHS board	GG&C	30 762	39	248	0·81		
	Other	48 963	61	249	0·51	0·63 (0·53–0·75)	0·66 (0·55–0·79)
(b) South Asian							
Referral	Secondary care	1431	44	30	2·10		
Source	Primary care	1830	56	83	4·54	2·16 (1·43–3·28)	2·05 (1·34–3·13)
Gender	Female	1159	36	25	2·16		
	Male	2102	64	88	4·19	1·94 (1·24–3·03)	1·81 (1·16–2·83)
Age group	15–29 yr	1127	35	33	2·93		
	30–44 yr	1287	39	50	3·89	1·33 (0·85–2·06)	1·25 (0·81–1·95)
	>44 yr	847	26	30	3·54	1·21 (0·74–1·98)	1·25 (0·76–2·06)
NHS board	GG&C	2056	63	75	3·65		
	Other	1205	37	38	3·15	0·86 (0·59–1·28)	0·95 (0·64–1·40)
(c) East Asian							
Referral	Secondary care	503	45	101	20·08		
Source	Primary care	627	55	146	23·29	1·16 (0·90–1·49)	1·22 (0·94–1·57)
Gender	Female	551	49	110	19·96		
	Male	579	51	137	23·66	1·19 (0·92–1·52)	1·13 (0·88–1·46)
Age group	15–44 yr	887	78	198	22·32		
	>44 yr	243	22	49	20·16	0·90 (0·66–1·23)	0·91 (0·66–1·24)
NHS board	GG&C	489	43	134	27·40		
	Other	641	57	113	17·63	0·64 (0·50–0·83)	0·63 (0·49–0·82)

CI, Confidence interval; GG&C, Greater Glasgow & Clyde.
* Adjusted for source, gender, age and NHS board.

repeatedly (10 000 iterations) randomly sampling from those distributions: (i) the prevalence of CHB in the antenatal population, (ii) the log of the adjusted RR of testing HBsAg positive in women aged >44 years compared to those aged 15–29 years and men compared to women and (iii) the predictive values for OnoMAP classification. For each ethnic group separately, parameters were replaced with the following distributions: (i) the prevalence of CHB in the antenatal population was replaced with a binomial distribution with n equal to the number of women tested in antenatal tests and p equal to the proportion of n who tested positive; (ii) the log of the adjusted RRs was replaced with a normal distribution with mean of the log of the adjusted RR and the standard error (S.E.) as estimated from the Poisson models; (iii) the predictive values for OnoMAP classification was replaced with a normal distribution with mean and S.E. as published by Lakha *et al.* [16]. In generalizing results to the Scottish population, it was assumed that the ethnicity, gender and age-specific CHB prevalence estimates for the four largest Scottish NHS boards were representative of the Scottish population.

Data processing and analysis

PostgreSQL version 9.0.1 (PostgreSQL Global Development Group) was used for data storage and data linkage. R statistical package version 2.13.1 (R Foundation for Statistical Computing, Austria) and @RISK version 5 (Palisade Corporation, USA) were used for statistical analysis and modelling.

Table 3. *Distribution (percentage) of the Scottish population by ethnicity, sex and age group*

	(*a*) CHI database (2009)*		(*b*) ETHPOP estimate (2010)		(*c*) Census (2001)	
Age group (yr)	Females	Males	Females	Males	Females	Males
British/Other						
15–29	11·17	11·54	10·94	11·41	11·22	11·10
30–44	12·10	11·26	11·89	11·18	14·22	13·34
>44	27·87	23·85	28·52	24·29	26·59	22·26
South Asian						
15–29	0·24	0·36	0·18	0·19	0·19	0·20
30–44	0·23	0·34	0·18	0·19	0·15	0·17
>44	0·15	0·20	0·17	0·19	0·11	0·13
East Asian						
15–44	0·28	0·26	0·25	0·25	0·12	0·12
>44	0·07	0·08	0·10	0·09	0·04	0·04

CHI, Community health index.
* Adjusted for positive predictive value and negative predictive value of name classification using OnoMAP and for the predicted size of the population.

RESULTS

HBV prevalence in females aged 15–44 years, by ethnicity

A total of 375 women tested HBsAg positive in 129 171 antenatal screening tests in Scotland during 2005–2009 (Table 1). This corresponds to a prevalence of 0·29% (95% CI 0·26–0·32%). The majority of women for whom an ethnic group could be determined were of British/Other ethnicity (94%). The prevalence in this group was 0·13%. Higher proportions of women in the South Asian (0·59%) and East Asian (10·3%) ethnic groups were found to be HBsAg positive. Of South Asian women, the prevalence was higher for those aged 30–44 years compared to 15–29 years, whereas in women with East Asian and British/Other ethnicity the prevalence of HBsAg was higher for women aged 15–29 years.

HBV prevalence in females aged >44 years and males aged >14 years, by ethnicity

Compared to females of South Asian and British/Other ethnicity, males had a 1·7–1·8 times higher risk of testing HBsAg positive (Table 2). No significant gender difference in risk was observed for East Asian ethnicity. Compared to the 15–29 years age group, those aged $\geqslant$44 years of British/Other ethnicity had a significantly lower risk of testing HBsAg positive (RR 0·3, 95% CI 0·2–0·4). No significant difference in risk by age was observed for those of South or East Asian ethnicity. Compared to women and men tested in secondary care, those tested in primary care had a higher risk of testing positive. This pattern was observed for all ethnic groups and age groups (these differences were not tested for statistical significance).

Multiplying the adjusted RR estimates for each ethnic group (Table 2) with the prevalences of HBsAg positivity in women aged 15–29 years (Table 1), estimates of the prevalence of CHB were generated (Table 4*a*). Estimates for the prevalence of CHB in men ranged from 0·08% in those of British/Other ethnicity aged >44 years to 11·6% in those of East Asian ethnicity aged 15–44 years. Estimates for the prevalence of CHB in women aged >44 years ranged from 0·05% in those of British/Other ethnicity to 9·3% in those of East Asian ethnicity.

Scotland's population in 2009, by ethnicity

Through the approach of applying OnoMAP to the CHI database it was estimated that 1·5% and 0·7% of the Scottish population aged $\geqslant$15 years in 2009 were of South Asian and East Asian ethnicity, respectively (Table 3). For South Asians, the estimate was higher than that reported from the 2001 Scottish Census (1·0%) and from Wohland *et al.* [20] for 2010 (1·1%). For East Asians, it was higher than that reported from the 2001 census (0·3%), but comparable to the estimate from [20] (0·7%).

Table 4. *Stratum-specific predicted prevalence (%) and number (n) of HBsAg-positive adults in Scotland, 2009*

	(*a*) CHB prevalence, % (95% CI)		(*b*) Prevalent number with CHB, *N* (95% CI)*†		
Age group (yr)	Females	Males	Females	Males	Total
British/Other					
15–29	0·16 (0·13–0·19)	0·27 (0·20–0·35)	780 (630–930)	1350 (1020–1760)	2130 (1670–2650)
30–44	0·10 (0·08–0·13)	0·17 (0·12–0·23)	530 (390–670)	830 (580–1120)	1350 (990–1770)
>44	0·05 (0·04–0·07)	0·08 (0·06–0·12)	590 (430–800)	850 (590–1220)	1440 (1040–2000)
All ages			1890 (1580–2250)	3030 (2330–3910)	4920 (3970–6050)
South Asian					
15–29	0·43 (0·24–0·70)	0·78 (0·36–1·43)	50 (20–70)	120 (60–230)	170 (80–290)
30–44	0·85 (0·50–1·34)	1·54 (0·74–2·78)	80 (50–130)	230 (110–410)	310 (160–530)
>44	0·54 (0·24–1·06)	0·97 (0·38–2·16)	30 (20–70)	80 (30–180)	120 (50–250)
All ages			160 (110–230)	430 (240–750)	600 (360–960)
East Asian					
15–44	10·27 (8·80–11·91)	11·64 (8·62–15·60)	1240 (980–1510)	1330 (950–1840)	2570 (1990–3280)
>44	9·31 (6·52–13·00)	10·55 (6·85–16·04)	290 (200–420)	350 (220–540)	640 (420–940)
All ages			1520 (1200–1880)	1680 (1190–2330)	3200 (2460–4120)
All ethnicities					
15–44			2670 (2340–3020)	3860 (3210–4670)	6530 (5630–7580)
>44			910 (730–1160)	1280 (980–1710)	2200 (1720–2850)
All ages			3580 (3120–4080)	5140 (4260–6280)	8720 (7490–10 230)

CHB, Chronic HBV infection; CI, confidence interval.
* Rounded to nearest 10.
† Confidence intervals generated through bootstrapping.

Scotland's CHB population in 2009, by ethnicity

By applying the CHB prevalence estimates (Table 4*a*) to the estimates of the adult Scottish population by ethnicity, gender and age group (as in Table 3*a*) it was estimated that about 8720 (95% CI 7490–10230) people aged ⩾15 years infected with CHB were living in Scotland in 2009; this represents a population prevalence in people aged ⩾15 years of 0·2% (95% CI 0·17–0·24). Of these 8720, 56% (4920, CI 3970–6050) were predicted to have British/Other ethnicity, 37% (3200, 95% CI 2460–4120) to have East Asian ethnicity and 7% (600, 95% CI 360–960) to have South Asian ethnicity. Seventy-five per cent (6530, 95% CI 5630–7580) were predicted to be aged between 15 and 44 years and 59% (5140, 95% CI 4260–6280) to be male.

DISCUSSION

This is the first time a CHB prevalence of 0·2% for all Scotland has been predicted based on a combination of laboratory data and population demographics. This prevalence was slightly lower than the generally accepted figure of 0·3% for the UK population [2] and less than half of the most recently published prevalence of 0·45% in England and Wales [4]. These differences in predictions could be explained by differences in the ethnic composition of the Scottish population (98% 'White' in the 2001 census) compared to the English population (91% 'White' in the 2001 census). Additionally, these differences may be explained by different assumptions made about the prevalence of CHB in men compared to women. In the study with 0·3% CHB [2] it was assumed that compared to women, men had a twofold higher risk, while our study indicated that gender differences in CHB prevalence were modified by ethnicity.

Different CHB rates by ethnicity are probably caused by different modes of transmission – gender-neutral vertical transmission in the Chinese population and male-dominated horizontal transmission in the British/Other group. However, the increased risk for South Asian males compared to females of the same ethnicity was unexpected. Similarly, different CHB rates by NHS board are probably related to different modes of transmission – higher proportions of MSM and people who inject drugs live in the NHS board area of Greater Glasgow and Clyde.

Additional information on exposure risks through enhanced surveillance with local NHS boards – responsible for following up new cases and contact tracing – is needed to explain these results.

Given the high prevalence of CHB in ethnic minority groups, estimates of the ethnic composition of the general population are crucial but rarely available. In this study we present a novel approach to estimate the proportion of East Asians and South Asians in the Scottish population using a name-based ethnicity classification software applied to data on all people registered with a GP in Scotland (CHI database). We aim to extend this to other ethnic groups (in particular East Europeans and Africans) once data from the 2011 Scottish census become available. Indeed, once detailed predictions of the number of people living in England, Wales and Northern Ireland in 2011 by age group, sex and ethnicity become available, the number of people with CHB could be calculated for the whole of the UK. Since the prevalence of CHB in ethnic minority groups is changing and heterogenous, such calculations should not be based on the Scottish rates presented in this study but rather be re-calculated using a similar approach.

About 3200 CHB-infected people aged $\geqslant$15 years with East Asian ethnicity were predicted to be living in Scotland in 2009, almost 40% of the total predicted CHB-positive population. The high number of infected people was due to the high prevalence of CHB in this population (e.g. 10% of women having had an antenatal test), while population estimates indicated that the proportion of adult East Asians in the Scottish population was low at 0·7%. Estimates of the large proportion of East Asians in the CHB-infected population is supported by results from an (unpublished) Scotland-wide survey of hepatitis B specialist services during 2009 which showed that approximately 50% of CHB patients at clinics were of Chinese ethnicity (G. Hawkings, personal communication).

Efforts to target the Chinese population and other ethnic minority groups for HBV testing and immunization are already under way in Scotland (A. Bathgate, personal communication), the rest of the UK [21] and in other European countries [22, 23]. Without such initiatives to diagnose CHB-infected individuals (particularly males, as they are not covered through antenatal screening) cases go undiagnosed until symptoms develop.

Our study has several limitations. While we give 95% CIs for our prevalence estimates, we could only take account of the statistical uncertainty in the estimated prevalence of (i) CHB in the antenatal population, (ii) the RR of testing HBsAg positive in women aged >44 years compared to those aged 15–29 years and men compared to women; and (iii) the predictive values for OnoMAP classification.

In order to estimate the prevalence of CHB in men and in women aged >44 years, it was assumed that the RRs, as calculated from HBV tests conducted in primary and secondary healthcare settings, were representative of differences in the general population. This assumption is supported by a comparison of CHB prevalences between women aged 15–29 years and those aged 30–44 years in antenatal tests and in primary and secondary care. In antenatal tests of British/Other women, those aged 15–29 years had a 1·6 times higher prevalence compared to those aged 30–44 years. In tests taken in primary and secondary care the rate between the two age groups was similar at 1·3. In antenatal tests of South Asian women, those aged 15–29 years had a 0·5 times lower prevalence compared to those aged 30–44 years. In tests taken in primary and secondary care the rate between the two age groups was similar at 0·8. However, it is possible that the estimated RRs are confounded by different indications for testing in the different age and gender strata. Reasons for HBV testing are not routinely recorded with the laboratory surveillance data and could therefore not be included in the analysis.

We relied on estimates for the PPV and NPV from Lakha *et al.* [16] to adjust for misclassification of OnoMAP in generating estimates of Scotland's population by ethnicity in 2009. The distribution of the Scottish population derived through this process was similar to that reported by Wohland *et al.* [20]. Slightly higher estimates of the proportion of South Asian males in the latter study would have little effect on the predicted prevalence of CHB in Scotland, a reduction of 0·008%.

In our analysis, people from low HBV-prevalence countries (e.g. the UK and Northern Europe) were grouped together with people from medium- and high-prevalence countries (e.g. Eastern and Southern Europe, Africa) due to the sub-optimal performance of OnoMAP to accurately classify names relating to the latter ethnic groups [16]. The prevalence observed from antenatal tests in the British/Other stratum (0·13%) was therefore higher than in British women alone (0·06%); the observed higher prevalence in those aged 15–29 years compared to 30–44 years in

British/Other ethnicity could be due to a higher proportion of the younger group originating from medium- and high-prevalence countries. Further work is therefore needed to accurately predict the numbers of people with CHB within ethnic minority groups, other than East and South Asians.

Name-based 'ethnicity' classification is routinely used by Public Health England to assign ethnicity to laboratory test data [24]. In the absence of information on ethnic background of people tested for CHB in various settings, use of full names was here the only way to attribute ethnicity and calculate reliable estimates of national prevalence. Consent from the thousands of individuals undergoing a HBV test, to generate ethnicity data based on their records, was not retrospectively sought; however, permission to use these personal data for this purpose was granted by the HPS Clinical Governance Committee, as the public health gain from this exercise far outweighed the negligible risk to the individual. Name-based 'ethnicity' classification was not available for tests conducted in sexual health clinics or occupational health in Scotland, because these usually do not share personal identifiers without explicit permission.

In conclusion, this study has estimated that in Scotland in 2009 about 8700 people aged >14 years (0·2% of this population) were infected with CHB. Slightly less than half of the infected population belong to ethnic minority groups. There is a need to identify the undiagnosed population and thereby prevent disease progression into liver cirrhosis and liver cancer and to prevent spread of disease into the non-infected population. To this end, novel strategies should be developed to promote and offer testing to people at increased risk of CHB. Indeed, the Scottish Government's Sexual Health and Blood-borne Virus Framework aims to 'reduce the health inequalities gap' and ensure 'people affected by blood borne viruses lead longer healthier lives' through targeted testing, earlier diagnosis, effective treatment and care, and active monitoring thereof [25]. Our study has also demonstrated that even without access to population sizes from census statistics, the size of the infected population in a nation can be estimated.

SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper visit http://dx.doi.org/10.1017/S0950268813003105.

DECLARATION OF INTEREST

None.

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