Communication

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Posted Date: 6 December 2023

doi: 10.20944/preprints202312.0361.v1

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On Burden of Diseases, Prevention, Medical Research and Health Service Delivery: Grampian Case Study

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Abstract: Burden of diseases measured as disability-adjusted life years per 100,000 people can be mined from public domain data, when they are made available by population health surveillance systems. This can be analysed to allow insightful comparisons with the national average, and to understand differences in trends between the sexes, age groups, time periods, geographic regions and sub-regions. In this illustrative case study, we have analysed the Scottish burden of disease database to understand what ailed the population of the Grampian region before the COVID-19 pandemic. We have identified selected cancers, ischaemic heart disease, Alzheimer's disease and other dementias amongst the highest contributors to the burden; that drug use disorders and colorectal cancer are showing worsening trends and require health promotion and disease prevention measures from ages 15 and 25 respectively, especially in Aberdeen City; and that males are more vulnerable to atrial fibrillation and flutter, diabetes mellitus and oesophageal cancer, while females are to cerebrovascular disease. We demonstrate the usefulness of our analysis and methodology for the wider health system, allowing targeted medical research investments and coordinated response from public health and health service delivery. We also show the need for up-to-date surveillance data, forecasts and evidence on the impact of interventions to be made available widely.

Keywords: burden of disease; disability-adjusted life year (DALY); disease prevention; epidemiology; health policy; health service; health surveillance; medical research; public health

1. Introduction

The origin of quality of life and cost-effectiveness analyses can be traced back to a study on chronic renal disease published in 1968 [1], leading to quality-adjusted life years or QALYs being formally defined in 1976 as the output of a utility function ([2], c.f. *Acknowledgements*). This concept gained gradual acceptance over the next three decades for the economic evaluation of healthcare programmes [3], using metrics such as the incremental cost-effectiveness ratio developed at York [4], and the disability-adjusted life year (DALY) introduced in 1994 as a related term with age-weighting and discounting [3,5].

Disability-adjusted life year (DALY), the loss of equivalent of one year of full health, is a time-based measure which allows the burden of different diseases to be compared objectively [6]. DALY is a combination of years of life lost due to mortality (YLL), and years of healthy life lost due to disability or living in less than full health (YLD). DALY and DALY rate per 100,000 people in a given region can provide valuable insights to health service providers, public health departments, health economists and policy makers if data is available to compare that region (for example, Grampian in Scotland) with others and the national average – as shown in this communication. Authentic and curated sources of such data in the United Kingdom include the Fingertips for England [7], the Scottish Burden of Disease [8], etc.

 doi:10.20944/preprints202312.0361.v1

2. Methods

For this work, we have used the Scottish burden of disease [8, c.f. eight references therein], a population health surveillance system which monitors how diseases, injuries and risk factors prevent the Scottish population from living longer lives in better health. The underlying raw Scottish burden of disease data used by this communication is available as Supplementary Material S1.

3. Results and Discussions

Burden of disease expressed as DALY rate per 100,000 population was calculated for Scotland versus Grampian for the latest year for which data is available (2019), separately for females (Tables 1 and 2) and males (Tables 3 and 4).

Table 1. Disability-adjusted life year (DALY) rate per 100,000 people – **females** in Scotland versus Grampian (across time).

Disease	**Scotland**	**Grampian**				**Difference**	**CAGR** [6]
Time period →	***2019***	***2019***	***2018***	***2017***	***2016***	***2019***	***2016-19***
Alzheimer's disease [1]	1827	1693	1675	1655	1616	-134	1.6%
Ischaemic heart disease	1605	1489	1635	1639	1525	-116	-0.8%
Cerebrovascular disease	1379	1414	1391	1521	1508	**35**	-2.1%
Low back and neck pain	1452	1390	1391	1391	1370	-62	0.5%
Lung cancer	1474	1366	1287	1110	1163	-108	**5.5%**
Headache disorders	1333	1337	1337	1337	1327	4	0.3%
COPD [2]	1301	1087	952	1144	1060	-214	0.8%
Breast cancer	1027	1077	846	1092	1106	**50**	-0.9%
Depression	1215	1067	1068	1068	1044	-148	0.7%
Anxiety disorders	1045	918	919	919	898	-127	0.7%
Other cancers	1094	911	1169	1153	930	-183	-0.7%
Other cardiovascular [3]	763	850	679	865	837	**87**	0.5%
Colorectal cancer	648	726	668	681	638	**78**	**4.4%**
Drug use disorders	1003	677	522	683	553	-326	**7.0%**
Lower respiratory infections	622	528	691	800	612	-94	-4.8%
Diabetes mellitus	586	487	551	600	555	-99	-4.3%
Other musculoskeletal disorders	462	445	478	475	467	-17	-1.5%
Osteoarthritis	457	441	442	442	438	-16	0.3%
Cirrhosis [4]	510	421	429	396	445	-89	-1.8%
Chronic kidney disease	382	396	423	499	376	14	1.8%
Skin and subcutaneous diseases	406	391	407	386	364	-15	**2.5%**
Other digestive diseases	440	368	344	378	387	-72	-1.7%
Gynecological diseases	368	360	360	360	367	-8	-0.6%
Asthma	330	335	317	393	351	5	-1.5%
Self-harm [5]	399	332	291	311	289	-67	**4.8%**
Falls	380	332	287	316	277	-48	**6.1%**

[1] and other dementias; [2] Chronic obstructive pulmonary disease; [3] and circulatory diseases; [4] and other chronic liver diseases; [5] and interpersonal violence; [6] Compound annual growth rate in percentage. **Bold font** indicates areas of concern.

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Table 2. Disability-adjusted life year (DALY) rate per 100,000 people – **females** in Grampian 2019 (for selected diseases, age groups).

Selected diseases of concern	**Grampian 2019**						
Age groups →	***All***	***<15***	***15-24***	***25-44***	***45-64***	***65-84***	***85+***
Alzheimer's disease [1]	1693	0	0	2	72	**4489**	**36399**
Ischaemic heart disease	1489	1	1	81	**1012**	**4929**	**14448**
Cerebrovascular disease	1414	186	9	113	**913**	**3878**	**18098**
Lung cancer	1366	0	0	**73**	**1765**	**4778**	**2660**
Breast cancer	1077	0	18	**743**	**1774**	**1926**	**3218**
Other cardiovascular [2]	850	26	37	**300**	**872**	**2250**	**5948**
Colorectal cancer	726	5	7	**383**	**530**	**2271**	**3851**
Drug use disorders	677	0	**430**	**1763**	**561**	65	8

[1] and other dementias; [2] and circulatory diseases. **Bold font** indicates areas of concern.

Table 3. Disability-adjusted life year (DALY) rate per 100,000 people – **males** in Scotland versus Grampian (across time).

Disease	**Scotland**	**Grampian**				**Difference**	**CAGR [6]**
Time period →	***2019***	***2019***	***2018***	***2017***	***2016***	***2019***	***2016-19***
Ischaemic heart disease	3713	3488	3422	3495	3311	-225	1.7%
Lung cancer	1749	1605	1738	1737	1842	-144	-4.5%
Alzheimer's disease [1]	1639	1592	1578	1536	1370	-47	**5.1%**
Cerebrovascular disease	1516	1291	1763	1720	1800	-225	-10.5%
Drug use disorders	2367	1233	1308	1337	1007	-1134	**7.0%**
COPD [2]	1296	1208	1093	1385	1209	-88	0.0%
Other cancers	1295	1142	1108	1235	1259	-153	-3.2%
Depression	1277	1090	1091	1092	1059	-187	1.0%
Low back and neck pain	1075	1040	1041	1041	1029	-35	0.4%
Diabetes mellitus	923	973	935	924	816	**50**	**6.0%**
Colorectal cancer	878	960	1083	1012	808	**82**	**5.9%**
Self-harm [3]	1194	934	972	895	930	-260	0.2%
Other cardiovascular [4]	1077	925	1146	1241	1219	-152	-8.8%
Lower respiratory infections	801	774	737	884	671	-27	**4.9%**
Prostate cancer	821	758	761	830	773	-63	-0.7%
Headache disorders	617	623	623	623	619	6	0.2%
Oesophageal cancer	483	617	498	545	491	**134**	**7.9%**
Alcohol use disorders	863	607	714	720	637	-256	-1.6%
Anxiety disorders	646	552	553	553	536	-94	1.0%
Cirrhosis [5]	752	496	596	592	747	-256	-12.8%
Atrial fibrillation and flutter	430	454	412	493	447	**24**	0.5%
Chronic kidney disease	394	388	385	389	394	-6	-0.5%
Other musculoskeletal disorders	385	387	379	356	374	2	1.1%
Other digestive diseases	412	368	351	327	376	-44	-0.7%
Pancreatic cancer	372	366	436	383	285	-6	**8.7%**
Other chronic respiratory diseases	395	360	428	353	323	-35	**3.7%**
Falls	466	366	424	353	455	-100	-7.0%

[1] and other dementias; [2] Chronic obstructive pulmonary disease; [3] and interpersonal violence; [4] and circulatory diseases; [5] and other chronic liver diseases [6] Compound annual growth rate in percentage. **Bold font** indicates areas of concern.

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Table 4. Disability-adjusted life year (DALY) rate per 100,000 people – **males** in Grampian 2019 (for selected diseases, age groups).

Selected diseases of concern	Grampian 2019						
Age groups →	*All*	*<15*	*15-24*	*25-44*	*45-64*	*65-84*	*85+*
Ischaemic heart disease	3488	1	3	**391**	**3577**	**11196**	**21317**
Lung cancer	1605	0	0	**141**	**1574**	**5874**	**6083**
Alzheimer's disease [1]	1592	0	0	1	204	**4632**	**29994**
Drug use disorders	1233	0	**884**	**2671**	**1564**	21	193
Diabetes mellitus	973	19	62	**286**	**1266**	**2802**	**3015**
Colorectal cancer	960	6	11	**94**	**872**	**3327**	**5437**
Oesophageal cancer	617	0	1	**70**	**734**	**2235**	**954**
Atrial fibrillation and flutter	454	0	3	20	**229**	**1601**	**4630**

[1] and other dementias. **Bold font** indicates areas of concern.

It is seen from Tables 1 and 3 that by and large the top 25 diseases for Grampian are also important for Scotland, however their exact order may vary. Ischaemic heart disease, lung cancer, Alzheimer's disease and other dementias significantly affect both Grampian and Scotland (c.f. Figure 1), so it is important to focus on these national priorities.

We are able to identify those diseases where Grampian's DALY rate exceeds the Scottish average as local priorities for the region. These include atrial fibrillation and flutter, diabetes and oesophageal cancer for males; breast cancer, cerebrovascular disease, and other cardiovascular and circulatory diseases for females; colorectal cancer and drug use disorders affecting both sexes with worsening trends since 2016 (c.f. Tables 1 and 3). Tables 2 and 4 identify the age groups for these diseases of concern where the burden is especially high. It is important to address these unmet needs through a combination of public health measures (e.g. health promotion, disease prevention) and interventions arising from life sciences, health and medical research and innovation.

The latter is very important as demonstrated by recent reviews of Australia's hugely important Medical Research Future Fund [9,10], in which it was found that 231 grants were awarded during 2016-19 with a total value of AU$ 574.5 million [10], but when mapped against 17 disease groups in the Australian burden of disease study 2015 [11], only a weak association was observed with DALY (r^2 = 0.4359) and no association was observed with disability burden YLD (r^2 = 0.0009) [10]. Any life sciences, health and medical research and innovation investments into Grampian by public, private or non-profit sectors should take these considerations into account. Realistic medicine approaches [12] and regional investments should target the local burden of diseases, lest there could be higher opportunity costs and unintentional widening of inequalities. For the Grampian region, disease priorities are summarized under the mnemonic "CICADAS" (Table 5), with the worst-affected age groups identified from Tables 2 and 4.

Table 5. Selected disease conditions of concern to Grampian and age groups worst affected.

Acronym	Disease condition(s) of concern	Age groups worst affected
C	**C**ancer – Breast, Colorectal, Lung, Oesophageal (especially amongst males)	**25+**
I	**I**schaemic heart disease; Other cardiovascular and circulatory diseases	**25+**
C	**C**erebrovascular disease (especially amongst females)	**45+**
A	**A**lzheimer's disease and other dementias	**65+**
D	**D**rug use disorders	**15-64**
A	**A**trial fibrillation and flutter (especially amongst males)	**45+**
S	**S**ugar (Diabetes mellitus, especially amongst males)	**25+**

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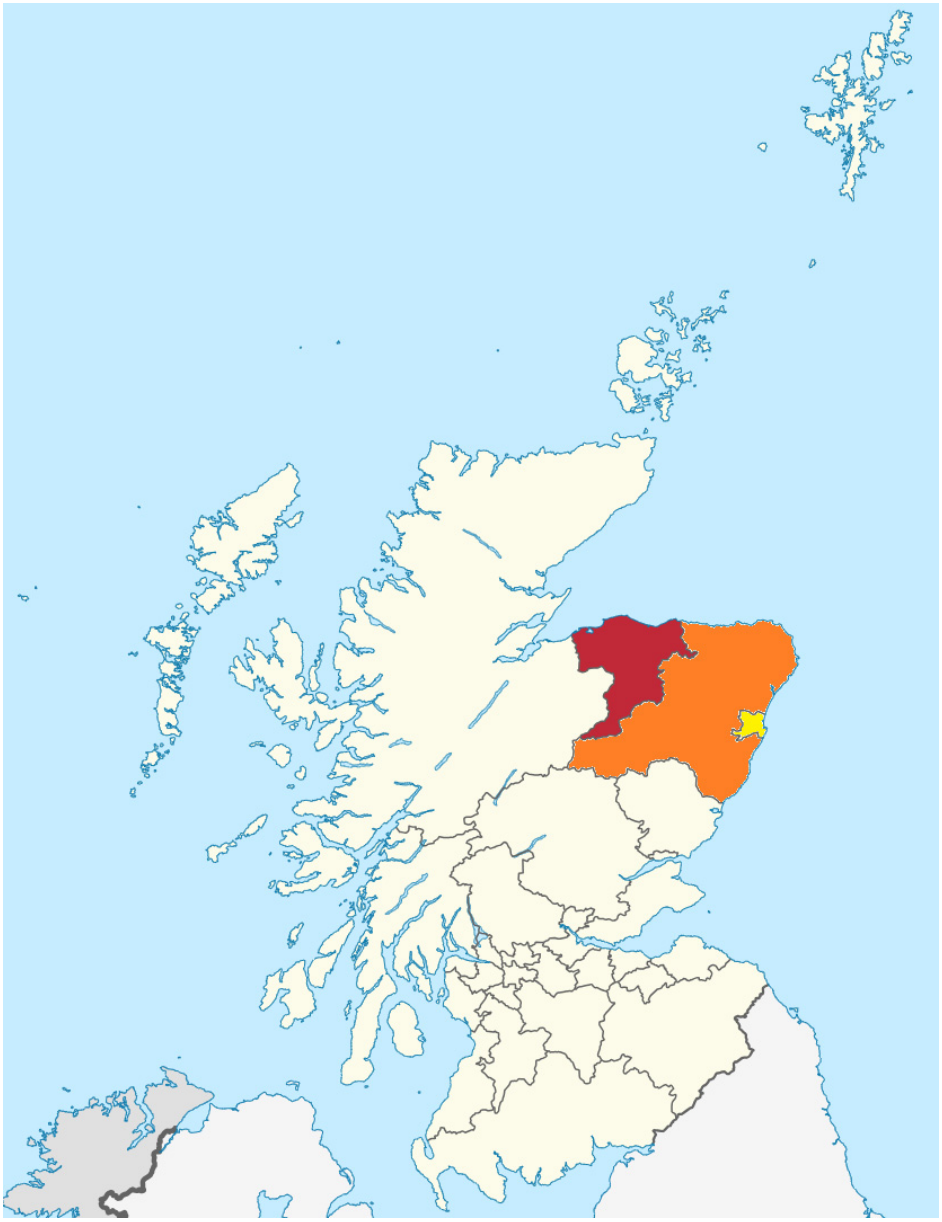

Figure 1. Grampian is a region in Scotland, and its constituent Health & Social Care Partnerships are shown in yellow (Aberdeen City), amber (Aberdeenshire) and red (Moray). Remixed image from Wikipedia released under the GNU Free Documentation License, highlighted for clarity.

As shown in Figure 1, the Grampian region is in turn comprised of three Health & Social Care Partnerships (viz. Aberdeen City, Aberdeenshire and Moray), so it will be instructive to see if there are any sub-regional variations that these partnerships should be made aware of. From Table 6, it is seen that Aberdeenshire is close to the Grampian average for diseases in females listed under Table 2 (except perhaps breast cancer); Aberdeen City has higher DALY rate than Grampian for Alzheimer's disease and other dementias, lung and colorectal cancers and drug use disorders; while Aberdeenshire has higher DALY rate than Grampian for ischaemic heart disease, cerebrovascular disease and other cardiovascular and circulatory diseases.

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Table 6. Disability-adjusted life year (DALY) rate per 100,000 people – **females** (2019, for selected diseases in Table 2, sub-regions).

Selected diseases of concern	Grampian	Aberdeen	Aberdeenshire	Moray
Alzheimer's disease [1]	1693	**1821**	1660	1526
Ischaemic heart disease	1489	1460	1477	**1597**
Cerebrovascular disease	1414	1493	1252	**1683**
Lung cancer	1366	**1603**	1207	1334
Breast cancer	1077	1068	1113	1012
Other cardiovascular [2]	850	797	850	**874**
Colorectal cancer	726	**960**	674	438
Drug use disorders	677	**830**	638	449

[1] and other dementias; [2] and circulatory diseases. **Bold font** indicates areas of concern.

From Table 7, it is seen that Aberdeenshire is again tracking the Grampian average for diseases in males listed under Table 4 (except perhaps colorectal cancer, atrial fibrillation and flutter); Moray has higher DALY rate than Grampian for lung cancer, atrial fibrillation and flutter; while Aberdeen has higher DALY rate than Grampian for all but atrial fibrillation and flutter. Thus we notice that while some trends are the same for both sexes, there are significant differences too, so we need a nuanced approach.

Table 7. Disability-adjusted life year (DALY) rate per 100,000 people – **males** (2019, for selected diseases in Table 4, sub-regions).

Selected diseases of concern	Grampian	Aberdeen	Aberdeenshire	Moray
Ischaemic heart disease	3488	**4166**	3109	3231
Lung cancer	1605	**1910**	1287	**1898**
Alzheimer's disease [1]	1592	**1732**	1556	1440
Drug use disorders	1233	**1665**	949	1153
Diabetes mellitus	973	**1153**	869	930
Colorectal cancer	960	**1103**	980	682
Oesophageal cancer	617	**823**	538	449
Atrial fibrillation and flutter	454	399	478	**503**

[1] and other dementias. **Bold font** indicates areas of concern.

4. Conclusions, limitation and future work

With health services under increasing pressure across the world, it is important to ensure better alignment between the long-term plans for population health, integrated health and social care. In many developed countries, we have health surveillance data on the public domain. These, especially on burden of diseases, can be mined and analysed by health service providers to serve their populations more effectively and in a targeted manner, as shown in this communication with the Grampian region case study. For example, we were able to identify which diseases have the highest DALY rate burden, which ones are of particular concern to Grampian, and those that are showing a worsening trend. We were also able to gain a nuanced understanding in terms of differences between males and females, age groups, and the three sub-regions that make up Grampian. This will allow targeted medical research investments and coordinated response from public health and health service delivery. The public domain Scottish burden of disease data ends at 2019, and we acknowledge this limitation. However, this communication does provide a useful pre-pandemic baseline for future comparisons, and our methodology and case study will still be very useful across the UK and internationally. We also demonstrate the importance of up-to-date surveillance data being available to health service providers, as well as the need for predictive trends and evidence on the impact of interventions, and it is heartening to note that such forecasting could soon be made available "*to offer insights into future public health challenges in Scotland*" [8].

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1: Scottish burden of disease underlying dataset.

Author Contributions: Conceptualization, S.S.V. and N.F.; methodology, S.S.V.; software, S.S.V.; validation, S.S.V.; formal analysis, S.S.V.; investigation, S.S.V.; resources, N.F.; data curation, S.S.V.; writing—original draft preparation, S.S.V.; writing—review and editing, S.S.V. and N.F.; visualization, S.S.V.; supervision, N.F.; project administration, S.S.V.; funding acquisition, N.F. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data supporting reported results can be downloaded from the Scottish burden of disease [8] or Supplementary Material.

Acknowledgments: S.S.V. is grateful for discussions with his past collaborator and co-author Professor Donald S. Shepard of Brandeis University (see for instance [13] and [14]) on QALYs versus DALYs. Donald preferred the term QALY to quality-adjusted citizen years as the latter acronym was felt to be *quacky* and *fowl usage*. The authors thank their colleague Professor Shantini Paranjothy for her comments.

Conflicts of Interest: The authors declare no conflict of interest.

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