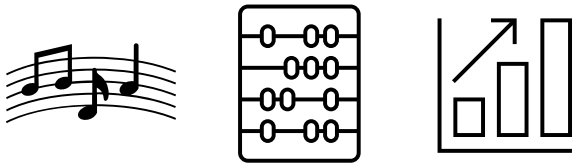
ASPHER pandemic health inequalities series – Examining the COVID-19 pandemic's unequal Burden of Disease

December 2023

How can Burden of Disease (BoD) measures that were used in the pandemic help in Examining European Health Inequalities (BoD-EEHI)?

Towards better harmonisation, better data, better analyses



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Foreword by Professor Nadav Davidovitch, Chair of ASPHER COVID-19 Task Force 2023

The ASPHER COVID-19 Task Force (now the ASPHER Public Health Emergencies Task Force) has met throughout the three years of the COVID-19 pandemic since March 2020. We have produced many papers and reviews to assess, review, support and guide our Schools of Public Health and partner European organisations. This includes two broad statements on health inequalities that highlight the vulnerabilities and disparities in how the pandemic has affected disadvantaged groups. The second statement highlighted how the pandemic has created seven long shadows that will represent a main part of the pandemic legacy for those individuals or groups who suffer long term harms.

As societies in Europe seek a return toward normality the pandemic has recently been declared by WHO to no longer represent a Public Health Emergency of International Concern (PHEIC). Work however continues towards dealing with this virus as it remains in circulation and is still damaging health, including those most vulnerable or least protected. This ASPHER review shows ongoing Burden of Disease (BoD) investigations and international collaborations in Europe and globally, that show high promise and contain many insights and pointers to future action. This work is unfinished and needs to be continued until the pandemic whole impacts are more fully understood.

This ASPHER statement/review, and its 40 recommendations, will help us in our key role in looking at and developing our future concepts and competencies. ASPHER will also advocate for better understanding of BoD studies' role in demonstrating health inequalities across Europe and how it has been particularly affecting vulnerable groups, minorities and disadvantaged communities. We would hope that BoD systems and capacity in each country will strengthen so that health losses from this pandemic and future emergency threats can be assessed in an objective and valued way to guide each country's policy makers, health professionals and also inform their wider populations in a credible and understandable way.

Report Summary

This report helps us look into several issues of importance to ASPHER. Firstly, we wished to identify which Burden of Disease (BoD) methods and metrics have been used in understanding the pandemic so far. Secondly, we wished to examine how BoD is usually measured and what are the strengths and weaknesses of the various metrics/methods. Thirdly, we also are interested in how BoD tools were applied during the COVID-19 pandemic and what initial studies tell us for European populations and vulnerable groups and how BoD evidence can inform us to help with assessing and reducing pandemic health inequalities and promoting equity. Finally, we also consider how BoD approaches might develop in future and what are ASPHER's priorities and recommendations to our members and to our partners, including further developing necessary teaching concepts and public health workforce competencies.

ASPHER has been concerned since 2020 about the pandemic's exacerbation of health inequalities and its deeper impacts on most already vulnerable population groups.[1] ASPHER recognises evidence of at least six of pandemic's 'long shadows',[2] or 'long-tails'[3] that need careful comprehensive investigation, with transparent reporting and full-scale remedial action. Much BoD emphasis initially needed to be given to the direct impacts of COVID infections such as death, hospitalisation, severity infection and residual disability of persistent (long) COVID.[4] Clearly those with persistent or 'long' covid need to receive full clinical and social support during their recoveries and rehabilitation.[5] ASPHER also advocated for the need to address the wider and indirect consequences of the pandemic including any impacts from pandemic countermeasures,[6] especially if they were applied without suitable mitigation measures.[7] Where people were required to isolate and quarantine we wish to know their resultant health and socioeconomic losses, particularly where supportive policies were not implemented to lessen the subsequent negative impacts of their income, welfare, occupation or education.

Throughout this report we ask how BoD studies can help us understand, to the fullest extent, exacerbations in health inequalities evident from this pandemic. ASPHER has concerns regarding potentially incomplete BoD assessments across Europe, particularly in regard to revealing fully the worsened population health inequalities or by underestimating or ignoring the extra burdens on already

vulnerable and disadvantaged populations. We are concerned about the unequal burdens experienced in Eastern European countries and their individual need for full BoD evaluation covering each country's population, while recognising the important supportive being conducted there by Burden-EU through its BoCO-19 Task Force.[8]

There were many known pre-pandemic inequities across Europe, but the pandemic caused geo-political shocks that have disrupted trust in health care systems as well as data collection and reporting, and ASPHER sees the potential for addressing this through open and collaborative discussions regarding learning from BoD findings.

ASPHER is concerned that the total losses and human cost of the pandemic on human health, welfare and economic development across WHO European Region may not be fully captured unless concerted and transparent international resources, expertise and public health capacity is identified to remedy this. Many European countries have been winding down pandemic specific enhanced surveillance and data collection since the autumn of 2022, despite ongoing waves of infection in 2023, along with a difficult winter with high baseline levels of infection, and Omicron variant wavelets across the winter of 2022/23. While SARS-CoV-2 related disruption continues into the summer of 2023, opportunities for comprehensive BoD assessment, including exposing health inequalities, may be lost or only taken up to a limited extent, unless a clearer plan is drawn up.

ASPHER is also concerned that, without adequate data collection and analysis, the increasing inequity of the total BoD, covering the exacerbation of health inequalities and less visible or measurable pandemic impacts on vulnerable population groups may be incompletely captured and thus missing from public policy debates, prioritisation and action programmes.

ASPHER contends that, while extensive BoD reporting is underway for some countries, and in much of EU/EEA, such high-quality work should seek to cover across all the 53 WHO Region's European countries and should be continued over the next two decades to allow cohort studies and disease registration databases to capture the long-term health impacts. Apart from the more evident severe acute infection impacts such as death or a need for intensive care, the mounting numbers of cases with persistent or 'long' COVID and its disabling sequelae will continue to add to each population's burden of disease each year.

Also, the indirect health effects of the pandemic are still being felt and need to be accounted for, such as through health impacts derived from weakened delivery of services in healthcare, social care, and public health programmes. The pandemic responses also have the ability to affect how other seasonal viruses and bacterial infections circulate. As we move towards the fourth winter of COVID-19 in Europe (February 2023) we are still concerned '*to preserve the capacities of healthcare and public health institutions as they fend off other threats*.[9]

Given the scale of the pandemic and widespread health consequences and major learning opportunities across Europe, ASPHER advocates a comprehensive, equitable programme of BoD studies: '**Burden of Disease – Examining European Health Inequalities (BoD-EEHI)'.** We see this as a key foundation, help in prioritising future pandemic policies and strategies, and central to our wider aims for evidence based pandemic policies and research-led public health practice. Ensuring public health capacity and expertise is important for supporting the many different vulnerable population groups,[1] showing how they suffer additional and multiple health insults during and arising from a pandemic. These groups need to be specifically recognised in BoD studies, as they are more commonly infected, 2-3 times more likely to die, suffer more severe direct consequences, and their personal circumstances and their wider health determinants, such as precarious income, living and working conditions have usually deteriorated.

Despite the growing BoD literature in Europe, there is little explicit mention of the implications for public health competencies. There is scope for enhancing MPH courses in gathering learning insights and using applied methods from comprehensive BoD surveillance and research. These should be incorporated into future ASPHER public health competency frameworks or relevant supplementary guidance, and into public health academic and service-based curriculum development, thereby supporting action across our teaching and professional practices.

Addressing the 'long view', and indeed a wider view, requires deeper insights and learning from BoD models for other poverty associated diseases like HIV and TB, while Briggs and Vassal raise the need for metrics that capture how ill health, disability, stigma and poverty interact with COVID-19 could prove pivotal in efforts to overcome the disease.[10] ASPHER supports collaborative approaches to address these challenges such as data gaps, alignment of methods and recognising '*blind spots'*.[11] This work includes development and

adoption of a collaborative work programme on the Burden of COVID-19 as part of the ASPHER Health Emergencies Task Force, joint working and affiliation with the European Burden of Disease Network.[12]

Moving from earlier reliance on pre-existing measures of mortality alone, such as excess mortality and Years of Life Lost, is important. We welcome country/local levels of Disability Adjusted Life Years (DALYs) and international comparisons in studies that are already done and still being rolled out. We would encourage BoD studies to go beyond these geographical levels to focus on specific vulnerable and disadvantaged groups in each country and across countries. Where the reported population in a specific group is small, extra efforts need to be made to capture their experiences using complementary methods alongside standard BoD estimates.

We are concerned about the likely scale and severity of the BoD in countries in mid and Eastern Europe, especially given that most had made slow pre-pandemic progress in addressing inequalities, particularly during austerity policy periods.[13] Braverman in 2013 advised not to lose sight of universal health coverage in such low to mid income European countries as they seek to close their inequalities gaps with Western European higher income countries.[14] However, the COVID-19 pandemic now points to an additional major health inequality arisen between these poorer populations and geographies and much of the rest of Europe. Their pandemic phenomenon of high disease burden will need large scale long-term studies in each country to reveal the true levels. Examining the causes of their high levels of BoD requires a combination of the epidemiological methods and expertise across sub-specialties in public health, particularly, population health, health services and health systems assessment to look at underlying issues such as delayed or ineffective non-pharmaceutical policies and interventions and low vaccine coverage, particularly low in some places after the first dose. Specific attention to direct and indirect post-COVID conditions is vital so that Years Living with Disability (YLDs) and DALY estimates become more accurate, with policies and programmes to support those affected, including rehabilitation and welfare support and other measures that affect quality of life or limit social and occupational activity.

Efforts to accommodate recent and historical learning on pandemic BoD should be incorporated in our Public Health Schools curricula. Mapping the full extent of the complex risk factors and wider determinants should build upon examples from early explanatory models for tracking impacts in those groups most at risk, stigmatised and excluded.[15] Models such as the surveillance pyramid and 'iceberg of

disease' should also be updated, incorporating evidence and scholarship from across public health disciplines and for grounding clear equity principles.[16,17] Upstream factors, the causes of the causes and wider determinants, should be identified clearly, along with their day to day impact and interaction with more proximal determinants, how, in combination, they shaped the pandemic's burdens, and should be incorporated in revised public health teaching models. Pathways for differential exposure and impact should also be estimated, [18-22] and also incorporate explanations relating to integrated multi-factorial models such as Syndemic theory.[23]

This review looks at some of the methodological challenges, types of current BoD research and analysis, basic conceptual models of BoD teaching, and current findings from different European countries, while noting the need for wider health inequalities need to be fully explored and reported. Recommendations are proposed for action in Europe by Schools of Public Health, public health agencies (including European partners in WHO, EPHA and the European Observatory on Health Systems and Policies) and governmental and international policy makers in the next period 2023-2028 years.

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PART 1. BACKGROUND AND BoD TOOLS USED IN THE PANDEMIC

1. Introduction to ASPHER's interests and key questions on role of BoD studies

Since the beginning of the pandemic ASPHER has been committed to advocate for those disadvantaged or minority groups whose voices may not be fully heard, and whose health and socio-economic situations deteriorated during the pandemic.[1] ASPHER remains concerned about six enduring '*legacies'* or pandemic '*shadows'* whereby considerable health impacts are expected to be felt over this decade since 2020.[2] Various forms of disability and chronic effects were eventually shown to occur with previous influenza pandemics and evidence shows that "*Long COVID is the latest reminder that epidemics have long tails - biologically, as well as psychologically, economically and socially*"[3] We recognise the disabilities, and premature amenable deaths are all patterned by socio-economic, educational, and other characteristics such as ethnicity and social exclusion. We recognise the impact of intersectionality where different disadvantages, diseases and health problems have additive and multiplicative effects.and the need for a fuller development of intersectionality concepts and intersectional practice.

While the EU/EEA has summarised several concerns about how to understand the pandemic's impacts; these include the '*far-reaching*' impacts and '*uneven*' distribution in each pandemic wave period and in different geographies, along with their worry that morbidity data systems are not sufficient to capture the full picture.[4] There is a need to fully report each population's BoD experience across all the 53 countries in the WHO European Region, especially given that many of those less developed countries outside the EU/EEA have fewer resources and had already experienced more severe pre-pandemic mortality and morbidity profiles.

BoD studies will need to cross-reference their findings with any pandemic worsening of the five '*underlying determinants of health and prosperity'* that were shown to impact health status in Europe prior to the pandemic; - *Health Services - Income Security and Social Protection - Living Conditions - Social and Human Capital - Employment and Working Conditions*.[5] Capturing the pandemic's increased mental health burdens will also be vital,[6] particularly in children.[7] Forecasting the short, medium and long term effects of the increased

Adverse Childhood Experiences (ACEs) that were incurred during the pandemic will also be required to enrich any European BoD overview. The lifelong impact of ACEs and inequities in access to mitigations have potential long-term health impacts that will need to be tracked for austerity and pandemic-exposed child cohorts. This work should be nested within high quality longitudinal studies so that life course trajectories and the health impacts over future decades can be measured robustly.[8,9]

This ASPHER review will focus on the following eight questions:

- What is the Burden of Disease (BoD) approach and how is it useful, in pandemics such as with COVID-19?
- How is BoD usually measured and what are the strengths and weaknesses of its various metrics/methods?
- How was/is it being applied to the COVID-19 pandemic and what do initial studies tell us about European populations and vulnerable groups?
- How can BoD studies recognise encompass the growth of knowledge about a complex condition like COVID-19 that is still being researched, covering new multi-organ disease processes and evidence of chronic or persisting disease and disability?
- How can BoD evidence inform us to help with assessing and reducing pandemic health inequalities and promoting equity?
- How can BoD studies point to gaps in public health and wider governmental policy and pandemic response, including whether the health and welfare systems and social cohesion were stronger in some countries or whether weak state and social structures added to pandemic disease burdens for those populations?
- How can equity measures be incorporated into future BoD models and data collection?
- How might BoD approaches develop in future and what are ASPHER's priorities and recommendations to our members and to our partners, including on our teaching concepts and public health workforce competencies needed?

2. What areas of pandemic health impacts can BoD studies assist in explaining?

Eleven main themes of health data assessment are needed to explain variations in BoD impacts during the pandemic period.

I. Assessing loss of life or periods of disability (usually as Disability Adjusted Life years or 'DALYs') or by measuring lower quality of life due directly to COVID-19 infection and its various resulting illness.

II. Assessing losses from indirect social and economic impacts/losses of the pandemic, including worsening of pre-existing diseases, although there is a significant challenge to agree on and gather suitable datasets to allow this.

III. Showing the full burden and how under-ascertainment and under-reporting of deaths and disabilities are manifest in different countries' surveillance systems.

IV. Estimating loss of life or disability via indirect impacts, from other causes (including specific disease groups and unexpressed need) that have been worsened due to impacts of the pandemic on health and care systems, such as via delayed and disrupted reporting of those health problems or disrupted care management of existing, new non-covid illness or disabilities.

V. Estimating health losses for health problems that could have been avoided, through routine prevention, early intervention, chronic disease management and rehabilitation. This could include estimating increases in preventable outcomes, such as avoidable hospital admissions or ambulatory care sensitive hospital admissions, or late diagnosis (e.g., population cancer screening, missed sexual and reproductive healthcare, or other regular follow-ups).

VI. Demonstrating the pandemic's socio-economic impact on underlying wider determinants of health, with a need to measure health inequalities and underlying inequities in access to societal goods, including healthcare, welfare, and social support, building upon earlier health inequity profiles.[10]

VII. Highlighting impacts on BoD from **variations in adoption and implementation of pandemic-specific policies and strategies** such as for income protection, SARSCoV2 testing, social distancing, other non-pharmaceutical interventions (NPIs), and also removal of protections and equity support measures.

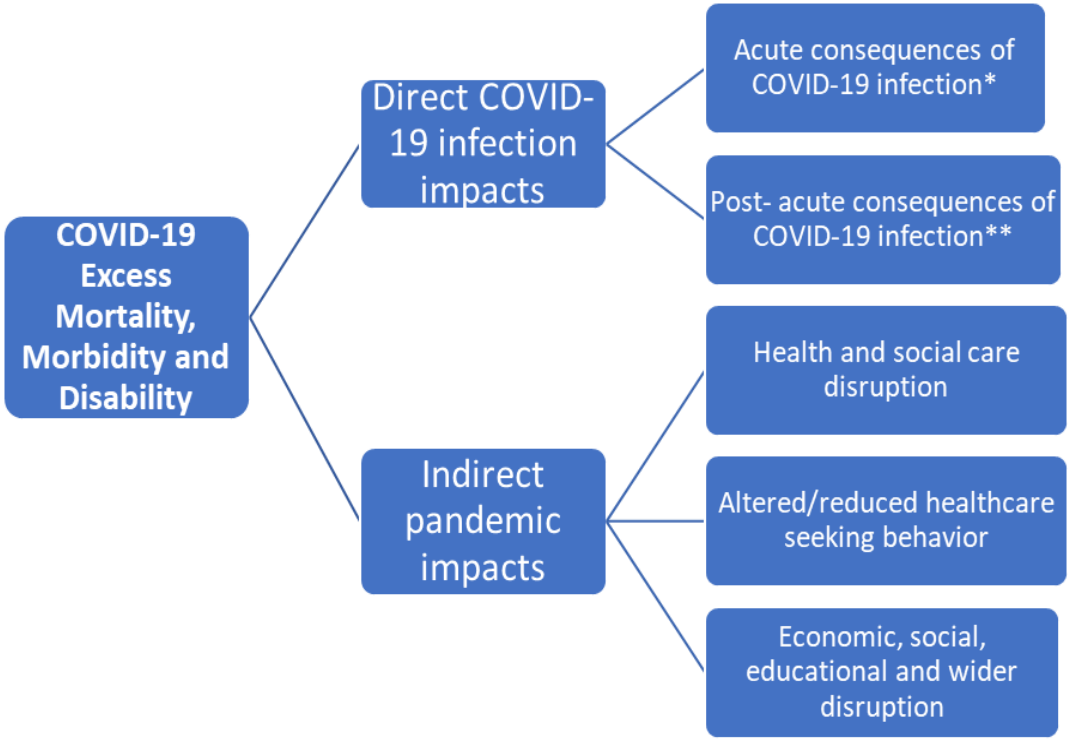
VIII. Helping to assess impacts from **vaccination programmes** and also access to COVID-19 specific medicines.

IX. Assisting in interpreting results to allow for **other co-temporal factors** such as conflicts, other epidemics, and disasters as well as pre-existing failure to address inequity and avoidable harm from austerity policies.[11]

X. Using BoD studies, particularly with DALYs, to allow researchers **to attach a monetary value,** to each DALY lost, and providing some broad estimates of costs, including health economic estimates, for comparing cost-effectiveness of pandemic public health interventions across populations. This could be used both for direct losses from COVID-19 illnesses and/or for the indirect impacts of the pandemic. It would also allow wider pandemic losses to be compared with those from other diseases or public health emergencies.

XI. Helping to stratify analysis of excess morbidity and mortality for different populations and particular groups in order **to understand the differential indirect disruptive impact of the pandemic era evident with the increases** in YLL and YLD in new diagnoses, hospital admissions and deaths and other health measures such as quality of life.[12]

Figure 1. Overview of pandemic health impacts of the Pandemic of COVID-19 infection



* Acute illness and hospitalization (including indirect effect of acute illness – economic, psychological etc); death

** Post-acute consequences (Post COVID Conditions or Long COVID) as defined for those who do have recovered fully after 3 months following their COVID-19 infection. For instance, COVID-19 itself can lead to immune disruption and predisposition to other acute and long term illnesses. We recognise there is still much to learn and that better awareness and recognition, research and improved responses and rehabilitation for these conditions needs to be a Euro-wide priority.

https://www.who.int/europe/activities/increasing-recognition-research-and-rehabilitation-for-post-covid-19-condition-long-covid

3. What do we mean by typical Burden of Disease (BoD) studies? Key metrics

In order to compare across countries or regions or population groups the BoD studies typically used *five summary measures* that each help explain the broad and accumulating pandemic related health burdens. These are standard metrics that help each country or population to understand and count their health losses from a chronic disease, and also for endemic infectious diseases or outbreaks/epidemics or other emergencies or disasters.

These are:

i. Excess mortality

ii. Life Expectancy (LE)

iii. Years of Life Lost (YLL)

iv. Years (of life lost through) Living with Disability (YLD)

v. Disability Adjusted Life years (DALY) = (YLD+YLL)

All such measures are open to scientific critique of their conceptual basis, their underlying data and analytical quality, their timeliness in early/late reporting, and the scope of the health problems covered. Methodological assumptions need to be specified but overall, there is a growing and credible evidence base.

i. Excess deaths and excess mortality rates:

The simplest calculation is by counting extra deaths and expressing those as a crude rate, e.g., per 100,000 population, in pandemic periods from 2020 onwards, are compared with a chosen pre-COVID reference period. The main focus should be on 'all causes' (including ill-defined causes of death given incomplete recording of COVID-19 on death certificates that varies from country to country. This excess mortality method has the advantage of using in-country historical figures for that population to compare with subsequent pandemic era rates. Other measures, such as LE and YLL described below, draw upon European Region survival table data mainly, or

OECD or other global life expectancy and survival tables for comparison. A recent EU-wide analysis of excess mortality (to December 2022, with data extracted 13/01/2023) showed four major peaks of deaths between March 2020 and October 2022, with the last major peak in November 2021.[13] Interpreting such a three-year period of the pandemic can be difficult due to other problems arising that may cause extra deaths, such as heatwaves or other emergencies.

Four summative death/mortality metrics in this excess mortality category were estimated in a recent WHO global analysis, albeit all such estimates used assumptions and incomplete data from nearly half of the 194 countries.[14] While these estimates for Europe were linked to Eurostat data, other data sources were used in the global context. These estimates used were, (i) the raw excess deaths count, (ii) the excess mortality rate (per 100,000 of population), (iii) the P-score, which is the ratio of the observed excess to the expected, compared to pre-pandemic chosen periods (iv) the ratio of the excess mortality to the reported COVID-19 deaths, the latter probably highlighting undercounting of COVID-19 deaths e.g. due to lack of testing or other under-reporting or under-counting reasons.

WHO guidance on rapid mortality reporting and technical methods was updated in 2020 and 2022. Going forward, this should help countries and international collaborations to standardise processes and improve confidence in reporting.[15,16]

Another possible analysis, of high significance for early to late pandemic health inequalities analyses, is to compare numbers/rates of excess deaths across social groups or geographical localities in a time period, comparing with the social group/locality with the most favourable deprivation rates. In England, a recent report (June 2022) compared the ten deciles of multiple deprivation using the Index of Multiple Deprivation.[17] This example highlighted "*In 2020, the first year of the COVID-19 pandemic, the number of excess deaths associated with area deprivation increased to nearly 152,000. That was nearly 28,000 more than the average for the five years 2015-19".* Also, this was likely to be an underestimate, as the least deprived populations usually have older age profiles and given the known age-related gradient in COVID-19 case fatality rates. Pre-pandemic studies show that deprivation and other socioeconomic factors influence earlier age of onset for multimorbidity and associated life expectancy[18] that need to be considered in pandemic BoD assessments.

Reliance on the all-causes excess deaths and mortality statistics above, however valuable, on their own, underestimates the eventual population disease burdens. Excess mortality estimates will continue to contribute to cross-country profiles and to our understanding of any countries or geographies that may have more significant problems or successes with pandemic countermeasures or protecting those more vulnerable. The pre-pandemic period versus the pandemic period continues to get news headlines. As we moved further through the winter of 2022/23, the resurgence of other respiratory viruses/pathogens, including influenza, has also become a key seasonal driver of excess mortality following the general relaxation of pandemic countermeasures.[19] Within a pandemic period the respiratory pathogen picture becomes more complex as other respiratory viruses and bacteria rebound, as population social mixing and more crowded indoor settings are back closer to pre-pandemic levels. Increased mortality in children from invasive Group A Streptococcal (iGAS) infection has been a concern in 2022/23. Such 'rebound' of severe infections can make all causes excess mortality less useful as time progresses.

ii. Life Expectancy (LE):

LE measures rely on data from death certification/registration systems and population estimates and survival tables for each age (year) and sex (M/F) group that are available in most of Europe's (WHO(E) 53 countries. Life Expectancy (LE) at birth is a useful BoD measure but this normally changes slowly in each country unless it is abruptly affected by major such as pandemics or disasters. Pre-pandemic stalls and falls in Life Expectancy and Health Life Expectancy were observed in Scotland during the 2011-2019 period.[20,21]

Overall, the significant changes in life expectancy during the COVID-19 pandemic's worst mortality years in 2020 and 2021 was probably the second most useful early BoD indicator available for the early pandemic impact, after excess mortality. Scholey and colleagues reported differences in age distribution of Covid deaths in some countries between 2020 versus 2021, that also recognised that the *"the inconsistent registration of deaths due to COVID-19 across countries complicates any cause-of-death attribution analysis, including ours".*[22] Their analysis highlighted largest LE decreases in East/Mid European countries such as Bulgaria, Slovakia, Poland, Lithuania, Hungary, Estonia, Czech Republic and Croatia with reductions of over 20 months to life expectancy across the period 2020 and 2021, compared to the most recent previous estimates.

Other useful LE sub-analyses are possible such as that the pandemic related reductions in life expectancy in Italy were not cushioned by lower levels of environmental exposure (e.g. air pollution) or road accidents.[23] However, later years from 2022 onwards, if still showing some reduction in life expectancy, will also need to seek to look at changes in non-Covid causes of death more closely. Many countries in Europe already have relatively low life expectancy that link to their inequalities in amenable mortality, including cardiovascular disease, diabetes, respiratory, and cancer deaths. Late presentation to health care is a potential major pandemic issue, and there is a need to assess how such causes have been worsened by the wider and indirect impacts of the pandemic on each population's health and the health system.

iii. (Potential) Years of Life Lost (PYLL or YLL):

Overall and potential years of life lost can be estimated by summing the number of years lost by each individual who died below a selected older age, e.g., 75 or 85, that is chosen to represent a reasonable life expectancy.[24]

For more detailed YLL analysis the life expectancy tables for each country can be used across all age groups. Pifarre and colleagues [25] assessed 81 countries, where "Country life expectancies are from the life tables in the World Population Prospects for the period 2015-2020". Country life expectancies are published regularly by the United Nations, Department of Economic and Social Affairs Division, albeit there may be assumptions and data quality issues that may have to be acknowledged.[26]

A study of Hungarian data looked at an alternative method that reduced standard YLL estimates somewhat to take account of the prevalence of co-morbidities in many of the COVID-19 deaths.[27] However this could distort standard international comparisons and diminish understanding of inequities given the number (11) of comorbidities measured.[28] Whichever methodology is used it appears that death certification of COVID-19 illness is too variable across countries and that the 'all-causes mortality' based YLL figures are probably best fit during a pandemic period to account for observed changes in LE and YLL. Also, given there are indirect pandemic impacts on mortality the All Causes Mortality (ACM) , the YLL metric will pick up such impacts. Changes to avoidable or amenable mortality will need to be taken into account also.

Transparent and collaborative international models that also take account of the dimensions of health inequalities and differential severity distribution across and within countries are essential.[29,30]

iv. Years Living with Disability (YLD):

Given the disabling nature of many chronic conditions, YLD estimates the impact of disability incurred as a direct result of health states on the burden of disease. YLD for diseases is calculated from three main parameters - number of cases, the duration of the disability (until recovery or death) and the disability weight (DW). Data sources may vary in how they recognise shorter periods of disability in a time period. Disability weights represent the effect of the condition on a person's health in terms of impairment or reduction in health, as measured on a scale with 0 representing no impact and 1 death. It is extracted from specific burden of disease studies and assigned according to the severity level of the condition. Ultimately, YLD estimates the years of life lost due to impaired health or disability. Such studies may be expensive and need additional funding. Also YLD estimates could consider estimating impacts of environmental and welfare improvements made to minimise the impact of acute and chronic conditions on quality of life as well as years living with disability or years in poor health. Useful tools for assessing limitations in activities of daily living and altered wellbeing, such as the EQ5D, have been validated in Europe and translated into many languages.

Philosophically, we measure YLD not because lives lived in disability are of less value but that we expect governments and civil society to act to mitigate any pandemic's impact, by designing in pandemic related measures that enable optimal quality of life and potential contribution of all populations to society to be optimised.

The YLD measure allows assessment of the disability burden for those impacted but alive, and that have a level of disability during the chosen time period e.g., calendar year. This measure during a pandemic could include disabilities caused directly by COVID-19 infection or disabilities arising from indirect pandemic impacts. It may require multiple data sources to be compiled. Measuring YLD may require surveys of samples of the population to report their disabilities or chronic illnesses that limit their daily activities. This YLD measure is combined with YLL measures to become the most summative BOD metric; see DALY section v. below. It will also be vital to capture symptoms that have not presented to the health service, therefore are not captured in usual electronic health records. Many countries

do not readily capture primary care presentations that can comprise 95% of routine population care or emergency presentations that do not have a definitive diagnosis. Many countries have household studies that capture disability and illness (surveys or panel studies) but there is also a need to undertake specialist cohort studies and bring together academic and national studies, including of multimorbidity.

For any new or emerging infectious disease, a 'disability weight' needs to be applied to estimate the typical disabling effect for each individual diseased person in that period or year.[31] The initial COVID-19 YLD calculations in Europe relied mostly on attaching a disability weight to different disease states (levels of COVID-19 severity) based on a European Consensus Model,[32] (*also see Table 1 below)*. YLD also contributes to calculation of wider global measures, "*Not only is YLD a key input to estimates of DALYs, it also contributes to estimates of healthy life expectancy*".[33] The early COVID-19 DW values (Table 1) are open to continued review for varied reasons, such as them being largely based on extrapolating from (pre-COVID) Lower Respiratory Tract Infection DWs, before subsequent scientific appreciation of COVID-19 as a wider often multi-organ disease with many clinical manifestations.[30] Comprehensive assessment is needed of the impact of post-COVID conditions, particularly for those with long term physical sequelae and with mental health syndromes. Further work is progressing to define better how disability weights could be applied to post-covid conditions, such as comparisons with weightings for different levels of severity of anaemias.[34]

Table 1. COVID-19 health states and disability weights (DW)

From Burden of disease of COVID-19 PROTOCOL FOR COUNTRY *STUDIES*[33]

Type	Name	Description	Data input proxy	Disability weight (95% uncertainty interval)
Acute infectious disease	Asymptomatic	Has infection but experiences no symptoms	Estimates of suspected asymptomatic community cases	Nil
	Mild-Moderate	Has a fever and aches, and feels weak, which causes some difficulty with daily activities	Positive (and/or suspected) cases community cases	0.051 (0.032-0.074)

	Severe	Has a high fever and pain, and feels very weak, which causes great difficulty with daily activities	Positive (and/or suspected) requiring a non-intensive care hospitalisation	0.133 (0.088-0.190)
	Intensive care	Intensive care unit admission	Positive (and/or suspected) requiring intensive care hospitalisation	0.655 (0.579-0.727)
Chronic, infectious disease	Post-acute consequences (fatigue, emotional lability insomnia)	Is always tired and easily upset. The person feels pain all over the body and is depressed.	Not estimated	0.219 (0.148-0.308)

v. Disability Adjusted Life Years (DALYs):

The DALY metric helps epidemiologists to examine both death and disability estimates by combining YLL and YLD. The DALY BoD metric tool helps global and national policy makers to identify priorities for prevention strategies (primary, secondary, tertiary) by showing relative impact of different contributing conditions on overall population, by combining YLL+YLD in countries and regions. The DALY is the most widely used and comprehensive of the global summary BoD metrics, as it is an indicator that allows enduring morbidity and disability to be encompassed in the BoD reports. We should remember that disability can be seen as a socially negative or stigma associated label, and BoD investigators will need to acknowledge this and use their work to empower those affected.[35]

The ease of estimating DALYs in each of the 53 European (WHO Region) may vary. A useful COVID-19 study of DALYs in five small countries (Cyprus, Iceland, Luxembourg, Malta and Montenegro) showed that data sources and methodologies can be improved, while recognising a need for networked collaboration internationally.[36]

An early study of 16 countries (for period 27 January 2020 to 15 November 2020) offered further insights but acknowledged its reliance on a pre-covid DW derived from other Lower Respiratory Infections,[37] which will need updating as further disability studies on COVID-19 emerge. We need greater understanding of our about the longer-term impact of infection on physical and mental health beyond the presenting organ, such as lungs, heart or brain.

DALY and YLD measures historically were particularly used to include estimates of levels of chronic disabling non-communicable diseases, given "*the DALY is the key element of the BoD approach: a framework for integrating all available information on fatal and non-fatal health outcomes to provide an overview of the causes of health loss*".[38] There is also a good case for their use in many communicable diseases including COVID-19, given that SARS-CoV-2 infection, often led to post-COVID conditions, with longer-term patient-reported symptoms but also verifiable persisting clinical features with measurable disabilities that require follow up and rehabiliation.[39] WHO guidance on post-COVID conditions needs to be widely adopted across Europe so that cases are well recognised in health data systems.[40] Also, given that the pandemic's wider direct impacts can exacerbate or cause new disabling physical and mental health problems, there is a strong need to recognise all these parameters. Earlier in the pandemic Wyper and colleagues (March 2021) advocated a standardised and complimentary data collection methodology and recognition of the value of using DALYs to capture COVID-19 mortality and morbidity more comprehensively, albeit with caveats about the need for timely and accurate data.[41]

The European Burden of Disease Network also recognise the uncertainties around Post Covid Conditions and the need to review and revise methods as new knowledge accumulates, *"It is however too early to assess the full spectrum and burden of long-term sequelae associated with COVID-19, so new knowledge on type, duration and disability weight of COVID-19 sequelae will need to be incorporated as more solid evidence becomes available*".[41] In addition they suggest the pandemic's BoD would be examined in two separated models, "*We however recommend to not include these indirect effects in the COVID-19 disease model, and to make an explicit distinction between COVID-19 as a disease, and the COVID-19 crisis as a risk factor for ill-health*.[41] This suggestion would probably enable more rapid development of models and overall assessment of the direct impact of COVID-19 infection while models assessing the indirect effects and contribution towards overall population BoD are built up more steadily.

<u>Other BoD tools and methods to estimate losses in vulnerable groups:</u>

There are various other standard population metrics or tools that have been adapted for demonstrating the burden from the pandemic, for instance Years of Life Gained (YLGs) and Quality Adjusted Life Years QALYs). This report cannot summarise the wider catalogues of measures but recognises that alternative metrics can be developed further and may add to our overall evidence base. Given the number

and types of indirect health impacts during the pandemic this poses a formidable challenge to BoD investigators to recognise and capture such burdens. Examples of these complex relationships were highlighted in 2020 by ASPHER.[42]

Examples of population subgroups that are highly vulnerable and need special attention in BoD strategies are given below.

BoD in children: Health of child populations have been severely impacted and this could be overlooked or under-recognised using the standard BoD tools. Measuring Adverse Childhood Experiences (ACEs) is also important as the pandemic-exposure will have increased the number of ACEs and thereby lead to increased risk of long-term health problems over subsequent decades.[7-9] Children could be affected by death or disability of a parent from COVID-19 illness, or from impacts of lockdown such as increased exposure to abuse, neglect, poor living conditions combined with limited access to support and loss of access to care and wider unmet childcare needs.

Cancer Screening and Cancer Care: For instance, those who have cancer are a particular focus for BoD studies. Investigators are still seeking to evaluate these pandemic damages whether through delayed or disrupted diagnoses and medical care or from disrupted cancer screening programmes. This could be looking at YLL or changes in cancer survival rates and other measures including end stage quality of life.

Mental Health Care. Other examples include mental health impacts from disrupted care that are still being evaluated in different countries.[43-45]

People with Learning disabilities. There will be similar needs to study additional Burden of Disease for those with learning disabilities

Apart from the five summary BoD metrics that are covered in i-v above there is a variety of other tools for measuring quality of life, such as Quality Adjusted Life Years (QALYs).

QALYs measures and COVID-19 mortality and morbidity:

Historically, epidemiological indices such as the presence/absence of disease and/or death (e.g., morbidity and mortality) have been used to assess population health. During the past two *decades, QALYs were extensively used as a comprehensive measure of health*

outcomes that integrates morbidity (years lived with a non-fatal outcome) and mortality (years of life lost due to premature mortality) into a single indicator. To simplify, QALYs is the number of years lived in perfect health of a person and is measured in terms of ''utility'' (considering a direct association between a particular health condition and utility). The quality of life and the utility associated with it is represented numerically. Thereby, an individual living in perfect health for one year has had in that period equivalent to 1 QALY i.e., 1 year of life*1 utility = 1 QALY. Similarly, a person lived in perfect health, but for only half that year is measured as having had 0.5 years of life*1 utility = 0.5 QALY. Also, for an individual who lived one year of life but with 0.5 utility, QALYs are 0.5 (1 year of life*0.5 utility).[46,47]

QALYs play a major role in cost-utility analysis, a specific economic analysis method employed in the field of healthcare. Also, the application of QALYs extends to evaluating the cost-effectiveness of various treatments, serving as a valuable metric in healthcare decision-making. Further, it facilitates the comparison of intervention effectiveness and cost-effectiveness (cost-utility) between two different health conditions.[46]

Although, QALYs are an integral part of the economic evaluation to inform health policy, during COVID-19 little emphasis was placed on the significance of incorporating measures to account for the impact on health-related quality of life. A study on data from Poland revealed that for the year 2020, the average number of QALYs (quality-adjusted life years) lost due to COVID-19 death was 6.76 per person. The QALYs lost due to COVID-19 morbidity and mortality were 2% and 98% respectively. The study findings also showed that the QALYs loss was higher among men (42%) compared to women (31%) and 38% of QALYL was attributed to people aged 65 or younger.[48] Similarly, according to findings from a study conducted in the Netherlands, the loss of QALYs per person due to COVID-19 mortality was reported to be 3.73 average.[49]

Researchers have predicted the potential consequences of delays in the diagnosis and treatment of certain health conditions during the pandemic, which were assumed to be caused by the excess number of deaths during the initial surge of the pandemic that would not have occurred under regular conditions. A nationwide population-based modelling study in the UK on the economic impact of avoidable cancer deaths due to diagnostic delays of Breast, Bowel, Lung, and Oesophagus cancers was estimated to be 103.8million GBP(£) over five years and the QALYs loss due to excess cancer deaths would be more than 30,000.[50]

In health technology assessment (HTA), different economic evaluation methods are employed, including cost-utility analysis (CUA). CUA is a form of cost-effectiveness analysis that evaluates the value of interventions by considering the incremental cost per quality-adjusted life-year.[51] QALYs (Quality-Adjusted Life Years) aid health policymakers in making well-informed choices concerning the allocation of resources and prioritization of healthcare interventions. This signifies further research opportunities highlighting the impact of QALYs at the pan-European level, for COVID-19 and other infections.

Future and more harmonised BoD methodologies: Strengthening international collaboration for COVID-19 BOD studies

European BoD Network researchers recognised quickly that collaborative and '*harmonised efforts and methodologies'* were needed, using standard tools, such as the DALY, which can help measure 'indirect impacts' from unmitigated lockdowns or other interventions.[33] Lack of progress in BoD estimation in a country could be due to gaps in public health professional education leading to blind spots, lack of political will, or limited resources to collect data/embed in systems/ clean data rapidly. There is a need to engage public and professionals in BoD data enrichment - ASPHER can help support this with partners

Future modelling needs also to look systematically at numbers of *DALYs averted* through vaccination programmes, or via other pandemic countermeasures, or by measures to address wider health determinants. Gaps in vaccination programmes and inequitable access to anti-viral medicines could also be assessed.

ASPHER recognise the vital continuing development work of the European Burden of Disease Network (burden-eu) established in 2019 that offered a technical platform for collaborative work, and is linked into the scientific network "BoCO-19 -The Burden of Disease due to COVID-19" that was launched in May 2021.[52] A protocol on methodologies and methods has been issued for country level investigators.[53] It could be argued that the COVID-19 pandemic has accelerated BoD collaboration and country level development of improved reporting systems. ASPHER and its Schools of Public Health should continue to support this progress, both to understand the full BoD from this pandemic, and also to prepare for future pandemics or disasters.

Key aims of continuing and future BoD research

In summary, there are many ways to look into BoD with standard metrics and with additional tools that could be suited to the disease or population groups affected. Studies of BoD during and after COVID-19 could help us to:

1. Identify areas and disease groups where prevention or healthcare efforts should be prioritised
2. Understand direct impacts of COVID-19 infection in health as well as indirect impacts due to changes in social organisation, and in individual behaviour and in altered healthcare
3. Understand what groups have been more affected in term of DALYs or other suitable measures to demonstrate health inequalities leading to an analytical framework against which to measure health losses and also identify missing data or data deserts.
4. Look at the health impacts of shifts in proximal and wider determinants during and after a pandemic.
5. Go beyond excess mortality and have a clearer quantification of morbidity, disability, and quality of life to show an overall profile of the health impacts of COVID-19 infection and also the wider pandemic health impacts.
6. Burden of Disease studies could also feed into country level inquiries into the handling of the pandemic, as a comprehensive way of showing the true burdens and losses for those societies.

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PART 2. FINDINGS FROM EUROPEAN BOD STUDIES – with comments on if and how they revealed health inequalities

What we tried to do

We focussed largely on ASPHER's main geographical orientation covering the 53 countries that are within the remit of the European Region of the World Health Organization. We sought to report single country BoD studies and also findings where European Countries were included in more global analyses. A literature review was conducted in December 2022, supplemented by lists of sources sent by colleagues in the European Burden of Disease Network. Studies identified were used to extract only brief illustrative excerpts that are shown in the tables below with limited commentary on key points. A systematic review or meta-analysis was not attempted due to shortage of capacity and also the temporal and methodological heterogeneity of the studies found. Our main goal was to know what was being said about inequalities in BoD studies and any other pointers to concepts of BoD and competencies needs by public health professionals. By collating as many European sources as we could in this time period, we hoped to summarise some of the lessons being learned, identify gaps and priorities that ASPHER could recognise and use. We accept that this report will have limitations and there may be a need for further reviews or supplementation as pandemic-related BoD studies continue to report, and hopefully add to a stronger and wider cumulative picture across Europe.

4. Findings from comparative and single country studies of European Region Countries

Early cross-country BoD comparisons began using 2020 varied data and metrics to cover the first two pandemic waves, leading to a growing research literature since then, allowing greater insights and completeness. However, all studies can be seen as limited and

open to in-depth critical review that is beyond this paper. Most studies acknowledge their assumptions and limitations. Commentary on illustrative results from the five different summative BoD methods as given below (i-v).

i. Excess mortality: *COVID reported excess deaths are an important rapid metric but are not the full story. Excess all-cause mortality (ACM) became a key feature in quickly gaining a truer picture in the early months.*

A variety of investigators looked at early pandemic excess mortality in their countries that were helpful in raising awareness of the need to monitor and report on this as a rapid public health metric. All the studies used assumptions and databases that are open to discussion or conflicting arguments in their interpretation. Nevertheless, the necessary public health urgency and rapidity of reporting probably balances to some degree the methodological shortcomings or critic reservations, particularly where the investigators acknowledged and carefully interpret limitations.

In some instances, the direct cause of death associated to COVID-19 may in fact be underlined by chronic disease. Patients with chronic diseases are more sensitive to the severe course of COVID-19 disease, die directly in the course of infection but also with associated delay after recovered from infection, due to exacerbation of underlying conditions. The BoD and other analyses should be focused on this aspect while drawing lessons for future pandemics. For public health programs it is crucial to reveal and confirm that the populations we had assumed that were vulnerable, truly should be protected in future pandemics. Therefore, Burden of Disease associated with COVID-19 infection should focus on differentiation of patients whose health outcomes related directly to severe or moderate infections in distinction from those who might have adverse outcomes due to other disease, despite an apparently mild or moderate COVID-19 infection. Cancer patients were vulnerable in the sense that they might more easily die from the infection itself. But also, they might die because of prolongations and delays in the cancer care pathway, associated with either an individual being exposed to COVID-19 or healthcare system delays. Both scenarios should be captured to create policies for the future.

These analyses may take account of four main phenomena (4Ds) that can affect the time series and attribution of excess mortality:

Delay phenomenon: in certifying or registering deaths, including regulatory factors such as those deaths needing coroners or forensic attention. This can lead to under-ascertainment.

Displacement phenomenon: some deaths that might have been expected in a typical seasonal pre-pandemic period, may occur earlier or later; earlier for instance due to uncontrolled virus spread, or alternatively occur later, due to effect of enhanced protection from social distancing countermeasures and other NPIs, or better access to COVID-19 vaccines or antiviral medicines than other populations.

Disaster phenomenon: Countries that experience disasters like armed conflict and heatwaves may wish to smooth these impacts out from usual baselines. Also, the heatwave in Europe in 2021 had a disaster effect that needed to be distinguished from pandemic impacts, by leaving out those summer excess deaths.

Documentation phenomenon: Countries need to consider ill-defined causes of death and missing data, such as place of death. This could include undocumented migrants, refugees asylum seekers, precarious workers whose deaths are not captured, or homeless people. Deaths of people in institutions may not be captured in some countries. There is a need to make clear how death data is handled so that BoD systems can allow for issues of attribution as well as broader under-ascertainment.

Box 1. Technical problems that emerged - some examples

Data accuracy and under ascertainment this is particularly where covid-19 specific deaths reported heavily underestimated the overall excess mortality in those populations infected.

Data systems - some countries or intra-country regions were unable to report regularly using electronic links.

Data timeliness - delays may occur in registering deaths, validating data, collation and reporting of deaths data

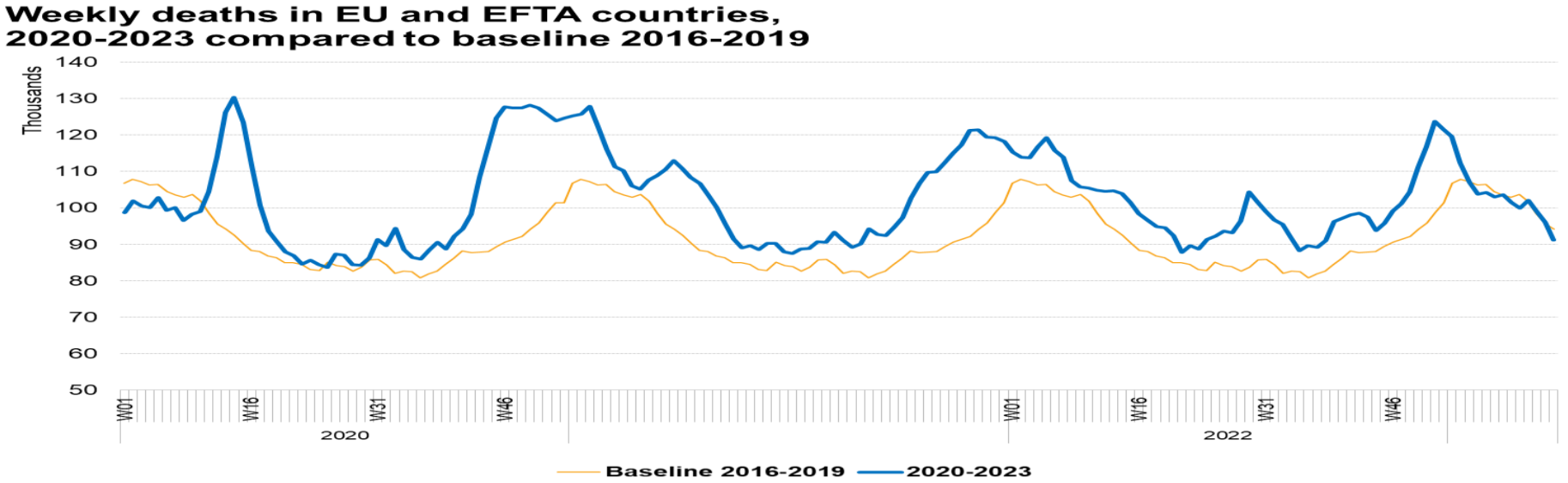
Study Periods shown– these may be from daily, weekly, monthly and annual or multi-year, Epidemic wave periods less than a 12-month timescale may be used where there are interests in particular waves or a wish to highlight the initial mortality shocks.

Baseline comparative period – selection of which previous years or periods may vary but usually cover several pre-pandemic years from 2015 onwards.

Varying modelling ,analysis or interpretation - country level investigators may produce alternative excess mortality data for their country and challenge the cross-country results that multi-country analysts used. Transparency of methods, assumptions and source of funding/conflict of interest is vital - particularly where models/assumptions are used instead of available data

The pivotal issue of not fully capturing covid-19 deaths was illustrated, for instance in Portugal. Under ascertainment happened, even in a country that had initial strong countermeasures, where there was an overall 14% excess in the months following their first COVID-19 death, and where "*The excess mortality occurred mostly in people aged 75+. Forty-nine percent (49%) of the estimated excess deaths were registered as due to COVID-19, the other 51% registered as other natural causes".*[1] Such rapid reports points to an initial key under ascertainment message with official COVID-19 death registrations, leading to serious underestimates, where using only certified COVID-19 deaths, whatever the potential underlying reasons such as limited access to testing, or the deceased not accessing healthcare facilities. This 2020 under ascertainment phenomenon in Portugal was also evident in other countries as comparative estimates emerged.[2] Each country should have routine cause of death review processes in pandemic times. During a pandemic disruption and overload of such systems can alter cause of death reporting if for instance there are concerns on the potential risk of autopsy or a limited supply of forensic pathologists. Also some deaths early in the pandemic could not be fully attributed during the period before more recently developed organ specific tests became available. Future pandemic preparedness should consider how death registration and review data systems could be protected and reinforced to cope with additional workload. Whole year data and whole pandemic period cumulative accounts will be most useful to help aggregate the population whole experience but weekly excess mortality also help us understand the seasonal and other epidemic curve dynamics. Figure 1 shows Eurostat weekly excess deaths chart combined for EU and EFTA countries that indicates the persistent weekly excess mortality between early 2020 and early 2023, as compared to a baseline average across 2016-2019. Within countries there was much disparity between provinces/regions within these weekly calculations, with, for instance, differences between the first and second wave in terms of '*hardest hit regions*'.[3] Such disparities in Burden of Disease reports will be a challenge to explain and evaluate for national public health bodies, and for their local regional services and their respective local academic advisers.

Figure 1. Eurostat weekly statistics[3]



Coverage: 27 EU Member States and 4 EFTA countries
Data for 2020-2023 are provisional
Source: Eurostat (online data code: demo_r_mwk_ts)

Taking whole year assessments across several countries offers a more complete picture, particularly as the pandemic rolled out later in 2020 and 2021 in several European countries. Major variations across European countries were reported for 2020 and 2021. Age standardised rates generally showed higher levels in males than females, and a rise with advancing age, particularly from over age 65 years, although some countries or some population groups already had high mortality rates in men under 65. The 26 European countries that featured in a 29-country analysis of 2020 excess deaths (versus the 2016-2019 period) gave some comparative levels with the other three countries (USA, New Zealand and South Korea).[2] They noted this included 'avoided deaths' with reduced mortality in children in some countries. Displaced deaths that are delayed slightly temporarily were also noted as a methodological consideration. A first look at ACM in subnational regions for five European countries highlighted the initial higher levels linked to transit hubs *"…the*

highest number of excess deaths during the first wave was observed in the areas affected first, i.e., big transit hubs like London, Madrid, Lombardia and Ticino, and Geneva."[4]

The European Commission's State of Health in the EU report (2022) noted that excess all causes mortality (ACM) was a better measure than COVID specific death reports, particularly in the first two pandemic calendar years.[5] Central and Eastern European countries had the highest cumulative excess mortality rates, while Nordic countries had the lowest, with Norway the only country having '*negative excess mortality'* in those two years.

Preliminary global, regional and country level estimates of 2020 excess mortality were highlighted by WHO in 2021.[6] The scale of under-reporting was becoming apparent. *"By 31 December 2020, this figure stood at 1 813 188. Yet preliminary estimates suggest the total number of global deaths attributable to the COVID-19 pandemic in 2020 is at least 3 million, representing 1.2 million more deaths than officially reported."*[6]

A global collaborative group studied international excess mortality for 2020 and 2021 while acknowledging several limitations.[7] They noted '*negative excess mortality*' in several countries including Iceland and Norway, along with high losses in Eastern Europe for the 24 months across 2020 and 2021, while noting Russia's excess deaths estimated at 1.07 million. They calculated "*the ratio of excess mortality rate to reported COVID-19 mortality rate as a measurement of undercounting of the true mortality impact*" and found very high ratios in some countries.[7]

The above global analysis also generated significant post-publication correspondence that highlighted geographical and other disagreements with those global calculations and other wider criticisms. Scholey et al argue of *'implausible estimates'* in several European countries, and queried the baseline period assumptions used.[8] Donzelli argued that the global analysis attributes 95,059 more 2020+2021 year ACM deaths than estimates from data of the Italian National Institute of Statistics and that the numbers are *'implausible'*.[9] Bager et al advised of conflicting estimates for several European countries, such as Denmark, and suggest instead to use EuroMOMO excess mortality estimates that include *"include both surplus and deficit mortality."*[10] O'Neill highlights limitations of their analysis by missing commentary on vulnerable older age groups and high levels of deaths in nursing homes, such as in Ireland and

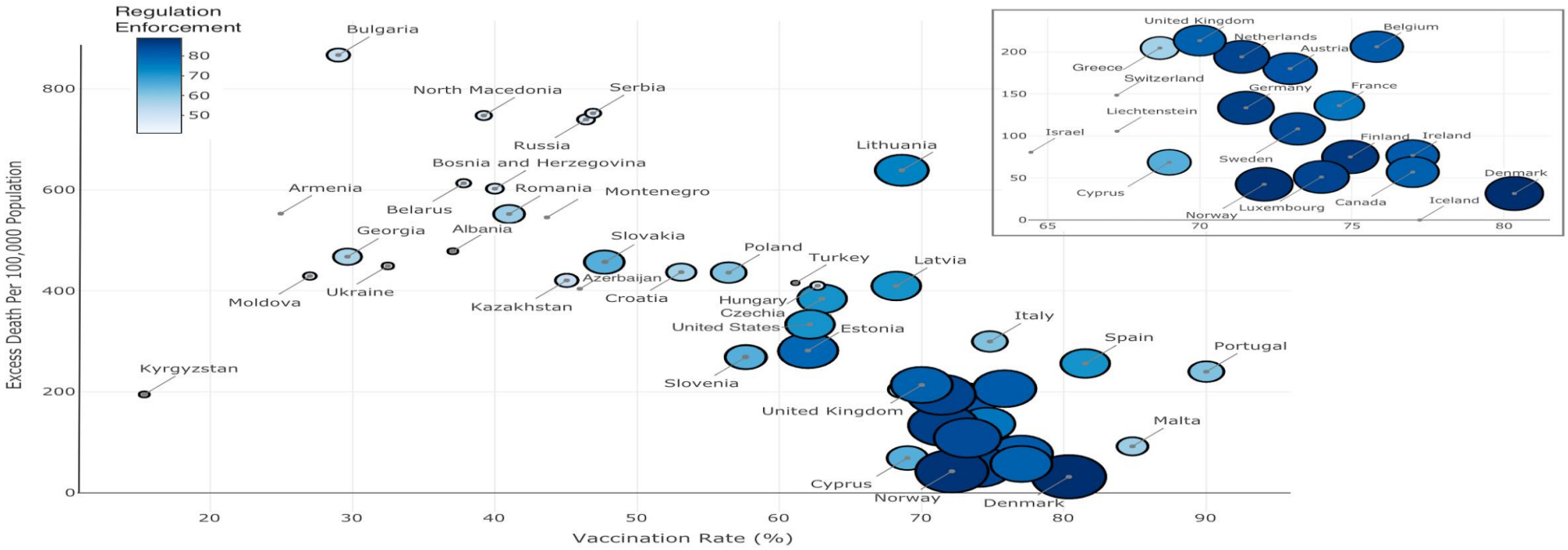
Sweden.[11] Hay and Murray replied for the authors of the Excess Mortality Collaborators and this reply illustrates the complexity of choosing agreed global methods, including how to allow for delays in death registration data processing completion) in the pre-pandemic baseline period, apart from the impact of under-registration or delayed registration.[12] The need for trusted sources of death data and statistics between and during pandemics is vital with independent public services that are separated from commercial interests.

From the start of a pandemic to its end, deeper country level understandings are also needed, including wider pandemic impacts and variations within a country's geography and vulnerable populations. Epidemiologists in Portugal advised of the need to study other causes of excess mortality, that may be distributed more evenly across the pandemic years, such as cancer related deaths and wider concerns, *"the persistence of excess non COVID-19 mortality raises questions about the long-term health consequences of COVID-19 on health and of other simultaneous social, economic, and healthcare services changes".*[13] The impact disruption of healthcare may be different for different disease groups however. For instance, cancer patients may have had some protection from infection by distancing given their immunosuppressed status. Patients with other chronic diseases such as cardiovascular, neurological and endocrine disorders may also have different impacts depending on their local systems. The early impacts in Italy were unevenly spread and all causes excess mortality was particular high on older age groups, and challenges such collating small area analysis and a "*need to recognise local drivers of excess mortality"*, while recognising *'increases in COVID-19 mortality may have outstripped diagnostic capacity early in the pandemic."* [14] In England an early analysis of regional pandemic excess mortality showed poorer Northern regions to be worst affected and raised the need to associate these higher rates with outcomes such as reduced productivity.[15] Early first and second wave observations showed higher age-standardised mortality rates in England for some ethnic minority population groups, particularly those in Pakistani and Bangladeshi men, show the value of good data on such characteristics.[16] However follow up studies of cumulative excess mortality variations across ethnic groups will be needed.

Initial broad comparisons, even of neighbouring high-income countries, like Norway and Sweden, need careful analysis and interpretation, with consideration of potential differing mortality displacement effects as contributors to overall mortality.[17] The global analyses may offer stark and realistic insights into disparities across continents, systems and people, but are reliant on broad

assumptions for dealing with uncertainties. There may be sensitivity to sweeping findings such as of inadequate data, such as found for countries in Africa, with arguments against making assumptions of population homogeneity or of local incompetence in those countries.[18] A strong argument could be made to support local and middle income countries to further develop their Civil Registration and Vital Statistics (CRVS) systems to be better prepared for future pandemics and to highlight countries or regions who develop earlier good practice models. Public Health skills are needed to analyse and interpret these well. BoD studies may later seek to highlight the associations between interventions and outcomes. A study of 50 countries within the WHO European Region showed inverse relationships between vaccine coverage and excess mortality. A similar pattern occurred with Non-Pharmaceutical Interventions; with both factors combined accounting for 62% of the variation in Excess Mortality between countries.[19] Such use of summary BoD metrics will probably assist policy evaluations in future comparative BoD studies of exploring variations in communicable diseases strategies and specific prevention programmes. Such studies need to be followed up in BoD strategies with detailed data linkage to reveal causal pathways and intra-country inequalities, such as for avoidability of exposure and access to preventive interventions. Socio-economic, income and ethnic gradients in vaccine coverage should be clarified, including robustness of data for call up registers and for vaccine records.

Figure 2. Graphic showing all cause excess mortality comparisons across Europe associated with COVID-19 vaccination rate[19]



The COVID-19 pandemic rolled out unevenly across Europe so the excess mortality studies below (Table 1) cover different time periods and a mix of single countries or groupings of countries. Also for different countries their data availability or study methodologies may vary, including whether they reported just COVID-19 deaths versus wider all causes mortality.

Table 1. Highlights of Excess Mortality reports that covered some European countries

Country	Method	Result	Comments and excerpts
29 high income countries, with 26 European.[2]	Compared 2020 Human Mortality database data with years 2016-2019.	The 5 highest Europe age- standardised rates in men were documented in Lithuania, Poland, Spain, Hungary, Italy. For women – Lithuania, Spain, Hungary, Slovenia and Belgium. No excess mortality in 2020 in Norway and Denmark.	All cause mortality (ACM) was examined to cover both direct and indirect COVID-19 effects. Most numbers of excess deaths exceeded numbers of reported COVID-19 deaths. On the contrary, Belgium, Denmark, Israel, France, Germany, Switzerland had higher numbers of COVID-19 deaths than all excess deaths.
Five European countries; England, Greece, Italy, Spain, and Switzerland.[4]	Used data for 2015–2019, and applied Bayesian spatiotemporal models to quantify the expected weekly deaths at the regional level had the pandemic not occurred in England, Greece, Italy, Spain, and Switzerland.	There were variations in excess mortality in 2020 between countries and within countries withSpain having the largest excess mortality.The Northern regions within Greece and Italy were more affected than other regions. Sub-national level trends during the first wave showed patterns of localised excess mortality in England, Italy, Spain and Switzerland whereas Greece'sexcess mortality was homogeneous. The second wave had lower excess deaths overall with a homogeneous distribution in England, Italy and Spain. In contrast, the second wave in Greece and Switzerlandwas more severe than the first.	ACM was examined across regions in each of the 5 countries. -Findings highlighted variations inexcess mortality across and within countries, and over time. They suggest that a timely lockdown led to reduced community transmissions and, subsequently, lower excess mortality. The main hotspots for transmission were established in the transit hubs and nearby large metropolitan areas during the first stages of the pandemic. The importance of rapid action to limit transmission around these hubs is emphasized to curb the spread to other regions and countries.
WHO Global Excess	WHO estimates for year the 2020, via its	There was an estimated 1.11-1.21 million ACM deaths in the European Region in	This study confirmed the need to use all causes mortality as the main measure when comparing

Mortality estimates (included 50 of the 53 WHO European region countries [6]	Technical Advisory Group on COVID-19 Mortality Assessment,	2020,representing about 50% more than reported COVID-19 certified deaths.	countries, in lieau of the varying SARS-CoV-2 testing capacities and other diagnostic differences.
EU/EEA countries.[5]	Looked at periods within 2020 and 2021. Used sources such as Eurostat and ECDC reports.	Western Europe – especially Spain, Italy, France, Belgium and the Netherlands had the most severe COVID-19 outbreak in the spring of 2020In addition, the second wave hit countries in Central and Eastern Europe. Several spikes of excess deaths were reported in Hungary, Slovenia, Romania, Slovakia, Bulgaria, Poland and Czechia lasting until June 2021. The latter four countries also reported the highest cumulative excess mortality rates in Europe. Overall, lower excess mortality was recorded in Northern European countries compared to the rest of Europe.	ACM was more reliable than COVID-19 death reports. "This was especially the case during the first two major waves of the pandemic in Europe – respectively, in the spring and autumn/winter of 2020, during which the number of excess deaths was almost double the official number of COVID-19 deaths." Nordic countries overall fared better than rest of European countries . "Among Nordic countries, Sweden – which introduced less stringent mitigation measures and at a later stage compared to the rest of Scandinavia – reported a higher excess mortality rate, which however remains below the EU average". There may however be concerns about under-reporting in BoD of undocumented and migrant groups there.
COVID-19 Excess Mortality Collaborators. Estimating excess	Developed a statistical model to predict excess mortality for all 191 national and 252 subnational locations	By Dec 31, 2021, there were 5.94 million global reported COVID-19 deaths. The estimated number of excess deaths was 18·2 million (17·1–19·6), representing 3·07-times (95% UI 2·88–3·30) greater. Excess mortality due to the COVID-19	The three times ratio of COVID-19 reported deaths to excess all causes mortality is relevant to some European countries. There is much debate about the study methodology and reliability of the data sources used.

mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21 2022.[7]	from Jan 1, 2020, to Dec 31, 2021"	pandemic globally was 120·3 deaths (113·1–129·3) per 100000 of the population. There were significant variations in western Europe; with some rates similar to previously reported rates, whilst others, including Iceland, Norway, Ireland, and Cyprus, recorded some of the lowest rates in the world, at less than 50 deaths per 100000.	Some European countries had a ratio nearer to one, however. "in some high-income countries like Belgium and Sweden, which have used audits to investigate potential COVID-19-related deaths and have taken an inclusive approach to statistical reporting (available on the European Statistical Recovery Dashboard), the ratio between excess deaths and reported COVID-19 deaths is close to 1".
WHO global figures 2023 for first two years.[6]	European (WHO) countries were best placed of the six WHO Regions for timely and relevant mortality data	Generally, there was reassurance for Europe that ACM levels were not several multiples of Covid certified deaths. Future work is needed in other regions to improve reporting capabilities. In comparison, ACM data were scarce in the African region, where studies have alsohighlighted the reported statistics may be an underestimation. This region's estimates of the ratio between excess mortality and reported COVID-19 deaths varies from 1 in Tunisia, 2.62 in South Africa, 12 in Egypt and more than20 in Algeria. The total regional ratio estimate of 8.03 may be within bounds of the lower. These excess estimates from sub-Saharan Africa are reported to be the robust due to data paucity.	As with other global cross-country comparisons this report highlights the need for greater consensus on methods and also for complete and timely electronic death recording and other registration systems. Inequalities in quality and completeness of surveillance data globally is raised as a major strategic concern. "Moreover, differential reporting coverage, the absence of electronic surveillance systems in some locations and limited investments in CRVS systems has resulted in many nations lacking the structures necessary to provide good-quality routine data, even before the onset of the pandemic. Correspondingly, they lack the capacity and data required to monitor ACM during this unprecedented pandemic".

Portugal.[1]	Estimated excess mortality registered in Portugal during the first month of the epidemic, from March 16 until April 14, 2020, using two different methods. Reported expected daily deaths (from historical over the past 10 years)	An excess of 1255 all-cause deaths was reported in this period amounting to14% more than expected. 49% of these estimated excess deaths reported at COVID-19 AND 51% as other natural causes. People aged 75+ had the most excess mortality.	This is an early country study looking at a short period in the first pandemic wave there. The need for ACM analysis is emphasized.
Sweden and Norway [17]	The paper looked at all-cause excess mortality deviations from the official COVID-19 mortality reported in Norway and Sweden, and examined the role of mortality displacement.	Excess all-cause mortality was reported as 517 (95%CI12, 1074) in Norway and 4329 [95% CI 3331, 5325] in Sweden between July 2019 – July 2020.	A higher number of excess deaths in a shorter acute epidemic period could be partly indicative of a displacement in time effect, with some likely deaths of vulnerable people occurring in the pandemic that were not affected in previous milder influenza years. "During the epidemic period of 11 March–11 November, there were 6247 reported COVID-19 deaths and 5517 (4701, 6330) excess deaths in Sweden". They also report that certified COVID-19 deaths were in the statistical confidence range of all-cause mortality for the period, indicating a limited gap there only. Characterisation of displacement is controversial. For instance should it only be used where people are already in the palliative care phase of an illness formally diagnosed or with the highest levels of frailty such that a) their physician would not be

			surprised if they died in the next 12 months and it is acknowledged that the next health challenge/illness faced is likely to be fatal?
50 European (WHO) Region countries where data available for the 2020 and 2021 periods[19]	Examined countries vaccination rates ("calculated as the percentage of the total population that had received at least two doses of vaccine as reported by national programmes"). and the relationship to implementation of regulation and excess mortality	There was a 4.1 per 100 000 increase in excess mortality per percentage decrease in vaccination rate, regardless of regulation enforcement and health care utilization (Table 1). Excess mortality increased by 6 per 100 000 for every unit less in the regulatory implementation index score. Overall, regulation enforcement, vaccination coverage, and outpatient visits accounted for about 62% of the variance of excess death (Table 1)	Inverse relationships between excess mortality and both vaccination coverage and intensity of regulation enforcement. "This provides key insights for Eastern Europe, which is understudied on this critical policy and public health topic."

ACM, All-cause mortality; ECDC, European Centre for Disease control; EM, Excess mortality; EEA, Eurasian Economic Union; EU, European Union

ii. Life Expectancy (LE):

For the EU overall, life expectancy decreased by more than eight months between 2019 and 2020, although this was varied across countries.[5] Several features emerged from an analysis of 2020 and 2021 data across 29 countries.[20] noting that 8 countries had a *'bounce-back'* in LE in 2021 from their reduced LE in 2020. **(**Belgium, England & Wales, France, Italy, Slovenia, Spain, Sweden, Switzerland).

In their review article Scholey and Kniffka queried **"***Mortality shocks' affect all countries but some countries bounce back in LE in 2021, but could this lead to overconfidence?",* given that life expectancy reduction occurred in all the European countries in their 2020 data

analysis but that they were more severe in sub-regions, particularly in former satellite states such as Bulgaria, Slovakia and Poland.[21] Even a small reduction in LE usually signifies an important health impact for that population. However, this LE reduction often continued into 2021, but not for instance notably, the Nordic countries who experienced the most *'bounce-back'* towards pre-2020 levels in LE when assessing 2021 deaths data. They highlighted variations in *'mortality shocks'* for different population groups across the countries assessed. Overall, under age 60 deaths contributed more in 2021 than 2020, and those with fewer vaccinations had greatest loss of life, along with excess levels in males. Major concerns were expressed about not seeing bounce back for LE former soviet countries. In terms of inequalities, they commented *"At least in the short term, the pandemic triggered a 'Matthew effect' of cumulative disadvantage leading to mortality divergence between European regions."* [21]

The (biblical) conceptual basis of a Matthew effect was used in evaluating scientific rewards and communication was developed by in 1968 by Merton,[22] and could be applied to pandemics. For instance, Hanine and Dinar [23] draw upon various sources to support their argument of the Matthew effect of the pandemic worsening the already precarious position of many people, such as the poorest half of the global population who own only 2% of wealth,[24] and Oxfam acknowledging the position of SARS-CoV2 as the *'inequality virus'*.[25] Early examples of evidence on excess mortality, and other indicators of inequalities, were growing in different vulnerable groups, and were captured in the 2021 OECD indicators, highlighting higher COVID-19 risks of living in deprived areas, having lower incomes, having lower educational attainment, being ethnic minorities and being immigrants.[26] This disproportionate effect in several minority ethnic groups was reported early in the UK, by May 2020.[27] Other factors such as roles of occupational exposures and varied social networks could also be covered more fully in future.

iii. Years of Life Lost:

Early cross-country reviews highlighted the ratio of all causes or total YLL versus COVID-19 specific YLL and how countries vary considerably. The total YLL is the most useful figure but care should be taken in interpretation between direct and indirect pandemic impacts and for country level contexts, such as their pandemic policies for countermeasures, vaccination rollout and data reliability.

Williams et al assessed remaining life years using two life table approaches for comparison in each of the 20 countries they studied, firstly using local country LE, and secondly using optimal highest global LE.[28] Generally, there was use of global reference life expectancy tables to enable international country comparisons. Over time there is greater accumulation of YLL understandings since the earlier reports based on pandemic waves in 2020. The spread of the pandemic across Europe was reflected in YLL league tables showing Italy high initially, while as the pandemic ran on in 2021 and 2022 the Mid European and Eastern European countries become more prominent - see table 3 below. Some studies focussed on variations between sub-regions in countries and associated these with deprivation. Others raised concerns such as inequalities between ethnic groups. Study authors acknowledged that a truer picture would emerge when future YLD measures would allow DALYs to be calculated. Initially YLD measures were probably not sufficiently able to collate real world data initially to combine with YLL data. The YLL studies use COVID-19 specific deaths or total all cause deaths. Total YLLs absolute numbers are less useful and needed to be calculated as crude rates per population, where age and sex standardised rates were not always possible. Data availability and data missingness should be noted for any BoD report.

Table 2. YLL* studies that include European countries *(* some YLL estimates with be found within the DALY studies in section v. below)*

Countries	Methods	Results	Comments and excerpts
20 countries (17European plus USA, Canada and South Korea (Published March 2022)[28]	Compared the burden of YLL using local (Relative) LE as well as global (optimal) RLE per age category from available data at 4th August 2021. Female and male life tables were extracted from the Global Burden of	Given per 1000 using optimal global RLE - Norway ranked the lowest, followed by Denmark 2nd lowest with England & Wales 18th, Romania 19th andMoldova 20th. Using the local LE tables can highly underestimate the YLL rates in some countries, versus using global LE (highest was Ukraine pre-conflict).	*"US, Ukraine, Moldova and Romania have a larger burden of YLL in younger age groups (<50 years) than the other included countries".* *"Of the countries in the study, with the exception of the United States, we found that the included High Income Countries had a higher portion of YLL due to COVID-19 in the older populations in overall terms, compared with the Lower-Middle Income Countries in the study who had a higher burden in younger age groups."*

	Disease Study 2019 Life Tables 1950-2019		*"Using the highest remaining life expectancy globally for calculating the YLL is in keeping with GBD methodology, as it allows for greater comparison between the included countries and is justified as an egalitarian approach by not valuing someone's contribution to the global burden of disease as higher in one country than another"* UK had highest over age 90 YLL, probably associated with very high mortality rates in care homes. Death certification procedures in care homes is an issue to compare between countries
81 countries including over 30 from the European region.[29]	Presented a snapshot of the impacts of COVID-19 on years of life lost (YLL) as of January 6, 2021	"*We find that in heavily impacted highly developed countries, COVID-19 is 2 – 9 times that of the common seasonal influenza (as compared to a median flu year for the same country), between 2- and 8-times traffic-related YLL rates, between a quarter and a half of the YLL rates attributable to heart conditions in countries (with rates as high as parity to twice that of heart conditions in Latin America). Variation across countries is large, as many countries have YLL rates due to COVID-19 still at very low levels. Results in our Supplementary Information show that these countries are often countries where relatively fewer days have passed since first confirmed case of COVID-19."*	*"The gender differential in years of life lost arises from two components: more men are dying from COVID-19, but men are also dying at younger ages with more potential life years lost than women. Holding the current age distribution of deaths constant, eliminating the gender differential in YLL would require on average a 34% reduction in male death counts; this suggests that gender-specific policies might be equally well justified as those based on age."* Three broad insights are generated. The authors acknowledge some potential biases and limitations. Appreciation of country context and nuanced interpretation is advised. *"Our results deliver three key insights. First, the total years life lost (YLL) as of January 06, 2021 is 20,507,518, which in heavily affected countries is between 2 and 9 times the median YLL of seasonal*

			influenza or between a quarter and a half of heart disease. This implies 273,947 "full lives lost" – or over two hundred thousand lives lived from birth to the average life expectancy at birth in our sample (74.85 years). Second, three quarters of the YLL are borne by people dying in ages below 75. Third, men have lost 45% more years of life than women."
Eight European countries including Portugal [30]	YLL due to COVID-19 were calculated from week 10 to week 52 in 2020 for eight European countries by methods defined by the WHO. Excess YLL was calculated from YLL in 2020 minus the average YLL from 2017 to 2019.	Portugal was documented with the highest rate of total YLL amounting to595 per 10,000 inhabitants in 2020, which was followed by Germany (58*2),* France (569), and the United Kingdom (567). However, the The three countries with the highest YLL per 10,000 inhabitants due to COVID-19 were the United Kingdom (62), Spain (55), and Italy (53)	Used mid-year of age bands due to data provided. Comparison against 2017-19 mortality data. Overall, total YLL was higher in 2020 than in 2017–2019 in all countries in this study, except for Germany Note the ratio of COVID-19 direct YLL versus overall YLL varied across these countries. *"However, Portugal reported the highest ratio (40%) between excess YLL to non-COVID-19 causes and YLL to COVID-19….This means that for every YLL to COVID-19, there was 0.4 YLL to non-COVID-19 causes."* A key finding is that total YLL was more accurate than COVID-19 ascribed YLL in that period. The authors acknowledge that the study needs to be repeated later as more countries make data available.
USA, Italy Germany.[31]	PYLLs were calculated for each age group and	In Italy, Only 1.1% of the deaths were below 50 years. There was a large	Data unavailability early in pandemic was a major challenge. *"Three countries (China, Spain, and*

(published May 2020).	for the three upper age limits of 70, 75, and 80 years. The selection of ages 70 and 75 years was based on previous reports. In this study, age 80 was used as a new upper age limit based on the current life expectancy in most developed countries	number of years lost due to COVID-19—amounting to a total of 42,560, 66,070, and 132,260 person-years before the population reached age 70, 75, and 80 years, respectively. The age group of 60–69 years.. had the highest number of PYLL" Compared to Germany, standardized PYLL rates were in Italy were estimated 4 times higher, and rates in the US 23, 25, and 18 times higher at age 70, 75, and 80 years, respectively.	*France) were excluded because of the unavailability of the required data at the time of the study"* Used old style calculations of age 70 and 75 based on a nominated upper age, produces an underestimate given longer average LE in each of these three countries.
34 countries including 14 European.[32]	Estimated the YLL associated with COVID-19 in 34 different countries using data on COVID-19 cases and deaths up to March 27, 2021	YLL from COVID-19 in the European countries ranged from 7,000 to 32,000 for every 100,000 patients with Italy recording the highest (31,833) YLL per 100,000 patients while Norway had the lowest (7,389) in Europe.	Shows the initial COVID-19 impacts in 14 European countries. Slovenia had highest of the 34 countries in COVID-19 deaths per 100,000 people but was fourth, behind Peru, Mexico and USA as a rate of YLL per 100,000 people. Belgium and Italy were 5th and 7th in this measure. Further assessments of BoD similarities between neighbouring countries could be examined where there might be cross-border transmission dynamics.
COVID-19 in the 30 countries with the highest incidence of COVID-19 based on data provided by the WHO on April 13, 2020 -Included	Data as of 22April and 14th July 2020. YLLs estimated from the life expectancy of Japanese females at one-year age intervals (representing	Study found Belgium had the highest YLLs due to COVID-19 per 100,000 population, followed by the UK, Italy, Sweden, and France. Men had higher YLLs due to COVID-19 than women. 75% of the total YLL were attributed to 60 years and above.	International study of early 2020 data. Shows rates higher in older groups and males; illustrated the potential usefulness of the YLL measure for the pandemic. *"From the results, the burden of COVID-19 in context of YLLs were not only highly associated with the number of deaths, which contributes*

14 European countries [33]	thelongest life expectancy globally)	In this early period – findings revealed the total premature deaths due to COVID-19 was highest in USA, followed by Italy and France. Rates per 100,000 were highest in Belgium, Spain and Italy with COVID-19 YLL in Belgium and Spain at the time exceeding 3% of the total YLL.	*directly to YLLs as included in the calculation, but also with the number of confirmed cases, especially among the countries with a lower case fatality rate."*
Germany for year 2020 only.[34]	Analyzed all laboratory-confirmed cases of SARS-CoV-2 for the year 2020 reported to the Robert Koch Institute by 18 January 2021 were analyzed	Reported YLL due to COVID-19 in 2020 under 70 years which was 20.6% in women and 34.6% in men. Average years of life lost in this group was 25.2 years.	This was the first disease burden study in Germany published in 2021. This study confirmed the higher YLL in males and with advancing age up to 90. When combined with YLD into DALYs there was notable variations in 2020 for the Germany spatial planning regions, with several Eastern regions more heavily affected.
Scotland for 2020 and 2021 years.[35]	Used death registrations from National Records of Scotland for the years 2020 and 2021. Data included age, sex and postcode of residence individuals who died.	Reported YLL per death increased to from 15.4 in 2020 to 18.2 in 2021. The increases were disproportionate with highest rates in the most deprived areas.	Data was abstracted 8th March 2021 to allow for late death registrations. Authors acknowledge both vaccination coverage variations and structural factors in explaining these inequalities. They recognize the need to add YLD in later DALY studies. Overall an important study that begun to document inequalities related to COVID-19 burden.
France, UK and USA.[36]	An alternative approach is used to examine COVID-19	"*We also approved the varied length of the COVID-19 pandemic and its different number of waves occurring across three*	This unusual study is a major departure from YLL methodologies, arguing that five major limitations of YLL can be overcome in their novel approach.

	deaths as "early deaths that occurred sooner than predicted" and an index called early death weeks (eDW), is developed to measure COVID-19 mortality in units of weeks rather than of years.	*countries do not affect the total number of eDW, which does not present in the death counts, excess deaths and YLL methods. The average eDW of COVID-19 deaths in France, the UK and the USA after converting to early-death years are 1.2, 1.0 and 1.3 years, respectively. These numbers are much lower than the average result calculated by the YLL method in 81 countries, which reported 16 years per the COVID-19 death."*	*"In this study, we introduce an alternative approach that considers the COVID-19 deaths as early deaths that occurred sooner than predicted and develop a new index to measure the mortality of COVID-19 in units of weeks rather than of years".* *"We employ the natural mortality and social mortality laws to support the two essential assumptions: the sequential and translational early-mortality patterns of COVID-19".* Part of their argument appears to be around recognising impact of displacement effects.
England and Wales and their regions.[37]	National mortality registers in England and Wales, December 2014 until December 2020, YLLs used 2019 single year sex-specific life tables for England and Wales. Covered 3,265,937 deaths.	Reported 1,125 (95% CI: 997 to 1,252) excess YLL per 100,000 nationally, that ranged from 490 (95% CI: 319 to 661) per 100,000 in the South West to 1,550 (95% CI: 1,384 to 1,716) per 100,000 in the North West. Differences in Excess YLL per 100,000 population were noted, with unequal distribution across deprivation quintiles. Rates in quintiles 1 (916; 95% CI: 820 to 1,012) to 3 (977; 95% CI: 869 to 1,085) were similar, and thereafter steep increases were seen for quintiles 4 (1,218; 95% CI: 1,089 to 1,346) and 5 (1,645; 95% CI: 1,472 to 1,819).	The authors highlight the higher all cause mortality rates being several multiples in younger age groups in more deprived areas. *"Most measures of excess deaths do not fully account for differences in the ages at which people die in different social groups. If the pandemic killed disproportionally more young people in more deprived areas, then inequalities resulting from the pandemic will have been underestimated. Measuring years of life lost (YLL) rather than excess deaths would address this problem".*
Sweden.[38]	Used administrative linkage and an	Marked difference documented in the remaining life expectancy between	The authors argue for subgroup analysis of YLL. Some countries have different care strategies or

	incidence-based multistate model to to estimate remaining life expectancy stratified by age, sex, and care status and analyze the number of YLL during 2020 in Sweden	individuals with and without care. More than half of all COVID-19 deaths had a RLE less than 4 years. *"While the unadjusted YLL from COVID-19 amounted to an average of 7.5 years for women and 8.6 years for men, the corresponding YLL adjusted for care status were 5.4 and 6.6, respectively. The total number of YLL to Covid-19 in 2020 is comparable to YLL from ischemic heart disease in 2019 and 2020".*	may have protected care home residents more strongly than others. *"Our results urge the use of subgroup specific mortality when counting the burden of Covid-19. YLL are considerably reduced when the varying susceptibility for death is considered, but even if most lifespans were cut in the last years of life, the YLL are still substantial."*
Switzerland population as the main focus.[39] (With extrapolations to some other countries)	Looked at YLL due to the psychosocial consequences of COVID-19 mitigation strategies. Considered a number of risk factors including suicidality, depression, alcohol use disorder (AUD), changes in marital status, and social isolation.	Projected findings revealed the average person would suffer 0.205 YLL due to psychosocial consequence of COVID-19 mitigation measures that would be borne by only2.1% of the population, who will suffer an average of 9.79 YLL.	The authors recognise this is likely an underestimate. Given other adverse factors, particularly psychological, during population confinement such as grief, job losses, financial hardship, elder abuse, and sedentary lifestyle. This report offers an exploratory model looking into indirect pandemic impacts, using YLL estimates, (associations with factors linked with adverse socio-economic determinants).

DALY, Disability Adjusted Life Years; LE, Life expectancy; RLE, Relative life expectancy, YLD, Years Lived with Disability; YLL, Years of Life Lost

iv. Years Living with Disability: most YLD studies are integrated and reported within the DALY metric studies

For several Covid-19 related BOD studies, five health states – asymptomatic, moderate, severe, critical and PAC are included with Disability Weights attached. An early study of 16 countries (for period 27 January 2020 to 15 November 2020) offered further insights but acknowledged its reliance on a pre-Covid-19 disability weight of Lower Respiratory Infections (LRT 0.133).[40] which would need updating as further disability studies on COVID-19 emerged. YLD is a key component of the DALY calculation – a discussion on YLD reported thus far in European bod studies and discussion around assumptions is combined with DALY section below. Table 3 below outlines the summary studies reporting DALYs and YLD for the European region.

v. Disability Adjusted Life Years:

One of the early studies estimated DALYs for 16 EU/EEA countries from January 2020 and depicted the differential burden across countries documenting earlier on the highest burdens in Italy, Sweden and Czechia whilst Finland, Estonia and Slovakia had the lowest up to that point.[40] As Covid-19 disability weight data was not then available, they instead '*attributed to lower respiratory tract infection (LRTI), the health outcome comparable with the case definition of COVID-19'.* This study opened up the necessary study of DALYs across European countries, whatever its limitations in methodological assumptions. The variations and burdens suffered also highlighted the need to continue and improve the DALY investigations as the population burden of disease has accumulated. While initially they were unable to assess the relationships between health impact and different governments' interventions or public health countermeasures for each country, this opportunity for DALY analysis was flagged up.

Subsequently several studies have combined the YLD and YLL measures to document the health impacts of Covid-19 thus far in the European region. In most of the single country studies below (Table 3), between 93 - 99% of DALYs are accounted for by YLLs.[41-43] Covid-19 mortality has been the most rigorously followed and widely reported metric since the beginning of the pandemic. However, over time, recognition has expanded on Post Covid conditions, or 'Long-COVID', a constellation of persisting symptoms officially defined by WHO as *"a condition occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms that last for at least 2 months and cannot be explained by an alternative diagnosis".*[44] The European burden of disease network included this in the Covid health states as "post-acute consequences - *person infected with COVID-19 developed chronic sequalae (without necessarily having being diagnosed with PCR)*[45]*.*

A recent systematic review of COVID-19 studies identified that within DALYs, the YLL component dominates the overall losses. Issues of study methodology are raised, including exclusion of pre-mortality times and the long-term consequences, which were omitted completely.[46] Other factors at play are differences in assumptions around the duration of illness.[34] Large shifts in YLD could be demonstrated with sensitivity analyses in Scotland.[47] Other countries with DALY studies included Ireland and Netherlands and most likely had limitations around YLD underestimation.[48,49] Whether YLD will in future assume a higher proportion of cumulative DALY losses will probably need to depend on improved and widely agreed methodologies based on improved understanding and estimation of COVID-19 disease progression and disability. The wider issues of estimating indirect impacts of the pandemic remain limited and is a major strategic goal for BoD investigators to pursue. Metrics other than those discussed above will also be needed to supplement DALY estimates. Additional risk indicators, such as number of days bedridden, could be examined to point to post-COVID mental health sequelae like depression and sleep problems.[50]

Table 3. Early DALY studies from single countries and multi-country reports

Country	Method	Result	Comments and excerpts
Denmark[41] Data between February 2020 to February 2021	Used standard European Model**(SEM)	30,181 estimated DALY's due to COVID-19 (95% UI 30,126; 30,242), (Approximately 520 DALYs/100,000). Highest for Males more than females, and highest in > 70 years. Years of life lost (YLL) contributed with more than 99% of total DALYs.	Appears to underestimate YLD element?(earlier focus on short-term impact; milder cases less likely to be represented) *"A total of 232 years of life were lost due to disability (YLD) in the one year period (Table 3), overall equal to around 1% of total DALY. Mild cases contributed overall with 35% of YLD, severe with 5%, and critical cases with 60%"* This study showed more DALYs lost in men in the older age groups. Burden 100% from YLD in 10-19 and 20-29 years, both sexes

Malta[42] Data from March 2020 for 12 months	**SEM and assumptions around long COVID-19 remains largely uncertain and noted different entities provide different definitions and durations	Mortality contributed to 95% of DALYs, while post-acute consequences contributed to 60% of morbidity.	This study did not explore the issues of inequalities. Again, the question arises of how far YLD is underestimated given the focus on short term impacts post covid. *"Limited post-acute follow up data used. However, since the YLD contributed to only 5% of the DALYs, fluctuations in post-acute consequences had a greater impact on DALYs only when maximizing the YLD health status outcome (Sensitivity analyses). It is recommended that further research is performed on post-acute consequences to have a better understanding on the progress of this condition."*
Netherlands[48] *(McDonald et al)*	Estimated years of life lost (YLL), years lived with disability, DALY and DALY per 100,000 population due to COVID-19, excluding post-acute sequelae	"*The per-capita burden increased steeply with age, starting from 60 to 64 years, with relatively little burden estimated for persons under 50 years old."* *"Total disease burden due to acute COVID-19 in the Netherlands overwhelmingly determined by premature mortality (>99% of DALY is YLL), in particular from age 35 and up*"	No post-acute data. As with the Denmark study above this methodology is likely to be underestimating the burden.
Ireland [49] March 2020 – Feb 2021	Estimated, YLL, YLD and calculated DALYs for one full year in RoI	Estimated 51,532 DALYs as a result of COVID-19 with 98.7% contribution from YLL. 11.3 YLL per death estimated.	Life expectancy based on GBD study life tables 2019 – valuation tables Used the respective disability weight from the GBD 2019 study for infectious diseases of the lower respiratory tract

		Age group 65 – 79 had the largest YLL. Males 80+ had the highest number of deaths when considering by age and sex group. Slight male predominance in DALYs; largest contributing age-group for YLD was 25 – 44 years and PAC contributed 55%.	No data was publicly available for <24 years which may have underestimated the YLD component of DALY.
Scotland[47] Data from 2020	Used the EBDN methods	Findings reveals DALY's from COVID-19 ranged from 96,500 – 108, 200	*"Direct COVID-19 DALYs were substantial enough to be framed as the second leading cause of disease and injury, with only ischaemic heart disease having a larger impact on population health. Mortality contributed 98% of total DALYs."* *" Periodic estimation of DALYs during 2021, and beyond, will provide indications of the impact of DALYs averted due to the national roll-out of the vaccination programme and other continued mitigation efforts, although new variants may pose significant challenges."* NB: Large shifts in YLD arose with their PAC sensitivity analyses. COVID-19 was rated the second leading cause of death in Scotland.
Germany, 2020[34] For the year 2020 – January 2021 *(This study is being updated to include*	Estimated YLL, YLD and DALYs for 2020 in Germany	Estimated 305,641 DALYs due to Covid-19 in 2020 (368.2 per 100,000 persons DALY) 99.3% composed YLL (303 608 YLL)	*Late sequalae of Covid-19 not considered* *YLD affected by assumptions in the duration of illness, but overall minimal* *"The COVID-19 disease burden was higher in western and southern regions of Germany, and lower in the north and*

improved post-COVID data and the time period up to end of 2022)		Average 9.6 YLL per Covid-19 death. (M>W) Total 2033 YLD in 2020 in Germany. 99.3% composed YLL Average 9.6 YLL per Covid-19 death.	*northeast. These regional differences persisted after standardization for age (Figure 4, eFigure 7). The disease burden was especially high in areas ("spatial planning regions," Raumordnungsregionen, ROR) located in the states of Bavaria and Saxony. This was mainly due to the high case numbers experienced during the first and second waves of infection in Bavaria and Baden-Württemberg, and in the second wave in Saxony".* *Different duration of health states compared to Ireland*
Other Data from 16 EU/EEA countries[40] January to November 2020. (Austria, Croatia, Czechia, Denmark, Estonia, Finland, Germany, Ireland, Italy, Luxemberg, Malta, Netherlands. Poland, Portugal, Slovakia, Sweden)	Data taken from repositories – ECDC, World Bank, WHO	Variations in burden apparent -Italy, Czechia and Sweden highest when standardized to population size. Estonia, Finland, Slovakia – significantly different from other countries with lowest DALYs. Consistent with previous studies, 98% attributable to Years of life lost (YLL)	Contribution of post - acute sequalae not included and implications for underestimating YLD Database shortcomings and incompleteness of reports – probably underestimated resulting in differences with subsequent individual country reports. Used LRTI disability weights Did not take into account different tiers of disease severity (i.e., mild, moderate, severe and very severe) and asymptomatic individuals. *A total estimate 852,790 DALYs for the countries reported (Italy highest with 379,695 DALYs). Clusters noted with Eastern European countries having a low peak in the first wave and greater peak in the second wave*
Italy[43] Nurchis et al, 2020	Estimated DALYs age and gender stratified for acute disease.	121,449 DALYs Males 2x > females Highest DALYs 80 – 89 years 99.48% due to YLL	Looks at only acute phase of illness Different health states as reported in EEA study were not used – probable impact by underestimating YLD

	Data from ISTAT/INPS locally		

DALY, Disability Adjusted Life Years; EBDM, European Burden of Disease Methods; ECDC, European Centre for Disease Preventio and Control, EU, European Union, EEA, Eurasian Economic Union; RoI, Republic of Ireland; SEM, Standard European Methods; YLL, Years Life Lost

Discussion: Findings from the European BoD studies above can help us raise important detailed questions that could be considered in the coming months. There is limited reporting of health inequalities although it is clear that some countries, particularly in Mid and Eastern Europe have fared worse overall. Also some intra-country geographical health inequality examples were highlighted. Overall the emphasis has not been sufficient around inequalities in the above BoD studies (tables 1,2,3). This leaves us with questions of how to secure a fundamental emphasis on inequalities within BoD studies. Also it raises questions of what other BoD tools/methods do we need to fully estimate health inequality losses? How are inequalities measured? Do we have other useful data or suitable proxies?

Complexity - There is complexity in understanding or interpreting local data for instance regarding attribution of causes of death or illness - what are the 'rules' by which data are attributed to different causes? How is this validated? Methods to address potential biases are needed for exploring causal pathways, such as collider bias and immortal time bias.

Competition - what are the competing causes of death/poor health/quality of life/disability? Are some causes crowding out others and do we know why that is? Is the good health of the majority and/or systemic discrimination crowding out significant burdens in population subgroups and specific populations? The COVID-19 pandemic is an example of this in relation to e.g. addressing the variety of direct and indirect health impacts on children and young people. Also, is the burden of disease clearer for mainstream and more influential groups versus, for example, the population living on less than the minimum income needed for healthy living?

Remedies - is there the potential for an effective course of action or to create evidence that could be used to develop prevention, treatment and care or are we grouping this in 'other' because it is too difficult, a condition deemed undeserving of action or not a 'real' or priority health problem? The humane and effective health and social care of elderly people has long been a challenge in ageing

societies.[51] Studies could address difficult caring capacity issues, especially given a significant proportion of those over 50 are formal and informal carers and the losses of their caring capacities (other than healthcare workers) has not been fully considered.

Conflicts of interest - Are the data from appropriate sources? Are there any blind-spots and gaps in sources sought and used or in the methods (NB commercialisation of tools etc)? Have we followed the finances and power to confirm that conflicts of interest are set out in full? Do any conflicts of interest or funding from non-standard sources lead us to question the data?

Missingness - Who is missing from our data? How do we find them? Consider those who are undocumented, have limited access to healthcare, or are otherwise excluded or marginalised. BoD methodologies should seek to align with other deeper imputation methods such as oral autopsy, and broadly incorporate them and the associated expertise into future BoD strategies. Ensuring comprehensive access to primary health care is vital to data gathering. Multimorbidity needs to be considered not only in elderly people but also from earlier adult ages given the large absolute numbers affected in those major population groups.[52]

Comparisons - How do regions and countries compare to others? What learning can we share? Different deprivation and inequality indicators may be used in European countries,[53] and cross-validation and greater harmony of usage in differential BoD estimation could be pursued. The term 'burden' has been used in a Norway based study of immigrants, but this was used for comparing notified infection cases and hospitalisations rather than one of the five standard BoD metrics above.[54] The important insights from this study however offer a basis for using standard BoD measures there to show burdens such as via YLL and YLD for such more highly vulnerable groups.

Case studies. Can we learn from Case Studies in countries with existing expertise and more in-depth assessments have looked at BoD before and during the pandemic? Some countries have a historic leadership in developing BoD research linked to health inequalities and inequity. See Scotland Case study below

Case study: Scottish Burden of Disease Study

Authors: Grant Wyper, Public Health Researcher at Public Health Scotland and Hon Senior Research Fellow, School of Health and Wellbeing, University of Glasgow. Alison McCallum University of Edinburgh and ASPHER COVID-19 Task Force.

Currently, few studies can compare COVID-19 disease burden estimates with pre-pandemic estimates and consider the combined future impact of pre-pandemic BoD estimates and COVID-related disease burdens. Exceptions include independent Burden of Disease studies (European: Scotland, Germany, Belgium; Non-European: Korea, Australia). Some European countries also produce sub-national BoD estimates; however only Scotland examines inequalities in health and BoD associated with each affected person's socioeconomic circumstances.

Background

The Scottish Burden of Disease (SBOD) study was established in 2012 as a population health surveillance system to monitor the diseases, injuries and risk factors that prevent the Scottish population from living longer lives in better health. It is used as a tool to aid strategic decision-making and is formally hosted by Public Health Scotland.

Historical context

Scotland has a tradition of producing summary area profiles: examining health and care use by Scottish populations analysed by area, health condition and measures of inequality. Data from diverse sources were originally brought together by matching by census enumeration district, then partial postcode and, more recently, secure data linkage in safe and ethical settings. SBOD draws on this landscape of routine and study-specific data much of it recorded as a by-product of individual encounters across the universally available, and free at point-of-contact, healthcare services in Scotland and long-standing national studies. Together these dataflows detail vital events, life circumstances, health status and service use. SBOD brings together existing data sources, investigates gaps, attempts to resolve data quality issues, add sources as appropriate and minimise 'missingness' of population groups. Modelling is used on an exceptional basis to fill significant data gaps.

Pre-pandemic Burden of Disease Reporting and Projections

SBOD assesses the impact of over 100 established causes of disease and injury. The team has developed their understanding of the impact of different methodological choices on resulting DALY estimates, documenting inequalities, improving data/information methods and making reports publicly available. Since 2017 SBOD has reported inequalities in DALYs by socioeconomic deprivation. In the areas with the lowest levels of multiple deprivation, the burden of disease was less than half of that in the areas experiencing the highest levels of multiple deprivation. The gradient was shallowest, but still present, in those aged 1-15 years.

Before the pandemic SBOD provided comprehensive estimates for the Health Boards responsible for protecting and improving the health of their local populations and local government regions responsible for services related to the broader determinants of health and quality of life, including education, social care, environmental health and housing.

COVID-19 related Burden of Disease

The expertise established before the pandemic facilitated timely development of Scotland's COVID-19 BoD methods and assessments. These rapidly highlighted pandemic-related inequalities in the impact of population shocks and crises on the overall burden of disease and DALYs.

The SBOD study model for non-COVID causes remains as it was pre-pandemic. Methodological consistency means that COVID-19 related estimates can be framed alongside pre-pandemic causes of disease burden, highlighting the comparative scale of population health loss. Consistency in the estimation of socioeconomic inequalities also enables comparable framing of estimates of inequality in disease burdens and DALYs.

Looking forward

Before the pandemic SBOD developed burden of disease and DALY forecasts. The SBOD study is currently forecasting the extent of population health challenges that Scotland looks set to face in the next 20 years. While there are significant uncertainties regarding the ongoing and long-term direct and indirect impacts of COVID-19 on levels of health, disability and life expectancy, the established

approach to addressing gaps in data and improving data quality and methods taken by SBOD should continue to provide a rich source of evidence for action at local, national and international level. At a broader level, the work undertaken by SBOD enables COVID-19 to be considered as a sentinel, with methods that can be adapted to examine the impact of novel conditions on the estimates of the overall burden of disease and inequalities in its distribution.

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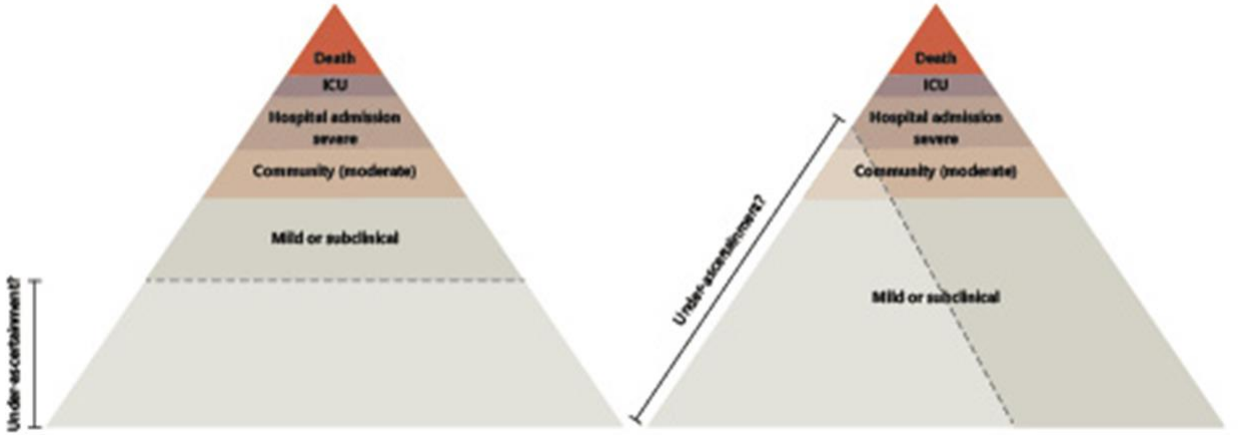
PART 3: BOD CONCEPTS AND COMPETENCIES FOR TEACHING AND TRAINING IN PH – with greater emphasis on examining health inequalities (*Burden of Disease – Examining European Health Inequalities - BoD-EEHI*)

5. What Conceptual models are used? Consideration of Burden of Disease pyramids and the 'Iceberg of Disease' concept in the COVID-19 pandemic

The accelerated growing scientific literature on the pandemic BoD employs many assumptions and assumes some theoretical metaphors but there is relatively little explanation of their conceptual underpinning. Some explanatory notes are covered below to help us generate a more shared understanding and to help for our academic teaching and BoD investigations.

Surveillance pyramids are useful epidemiological tools for explaining the need for multiple data systems and methods and to allow for under-ascertainment, as pointed out by Peixoto and colleagues early in the COVID-19 pandemic.



'Surveillance Pyramids': These ways of understanding, are surveillance paradigms used in teaching on epidemiological concepts and methods. Two interesting illustrations representing COVID-19 under ascertainment, linked to a typical surveillance pyramid, as shown in Peixoto and colleagues graphic - below. (Epidemic Surveillance of Covid-19: Considering Uncertainty and Under-Ascertainment, *Port J Public Health*. 2020;38(1):23-29. doi:10.1159/000507587)

Historically, the eminent epidemiologist John Last originally in 1963, developed his thinking in on his 'Iceberg of Disease' model/metaphor *"the metaphor of the iceberg is a valuable communications aid, immediately grasped by everyone. It is relevant to surveillance, measurement of population health, measuring the burden of illness, screening, needs assessment, health services planning and much else, for instance understanding selection bias. It clarifies the relationship between clinical epidemiology (which deals only with the visible part) and population-based epidemiology."* [1,2]

We can develop these concepts and models into BoD pyramid/iceberg models for use in public health teaching to emphasise to students the need for multiple surveillance methods to better capture the wider population experience and not just the obvious more severe cases who die or get specialist care (Figure 1). This is not a hierarchical pyramid but rather a schematic illustration that a proportion of cases typically fit into each category, especially where an infection has a relatively low case fatality and a broad spectrum of illness severity. Where surveillance systems are weak or only partially cover the different reporting sources of COVID-19 illness then BoD will be underestimated, and apply the iceberg metaphor of hidden morbidity. This is particularly for community-based cases that do not reach more formal and usually more complete reporting systems for deaths and hospitalisations (at least in high income countries). BoD 'pyramids' or 'icebergs' could be used in at least three ways – see Figures 1,2,3 below. There is some overlap in using these three approaches.

Figure 1. Typical reporting systems for COVID-19 illness. These show the different sources of reports that are needed to capture where data for COVID-19 cases arise generated

Figure 2. Disease Severity pyramid. A pyramid can be used to represent five differing levels of disease severity.

Figure 3. BoD metrics layers. A pyramid could show the additive BoD metric layers; moving from cruder mortality statistics through to metrics including DALYs and beyond to supplementary or more focussed studies, that can help us better understand health inequalities and losses in vulnerable populations groups

Whichever of these three models is used there is a need to teach about sensitivity of reporting systems. At each level of the reporting stage, from unreported cases to death registration, there is a probability of reporting and validation processes may be different. We also need to teach also about death ascertainment and classification of causes of death, e.g., Dying from and with Covid-19 but from another primary cause. Teaching about uncertainty and under-ascertainment may also wish to use 'surveillance pyramid' examples see box and graphic in example below. A COVID-19 surveillance pyramid example in Figure 1. below.

Figure 1. Typical Pyramid for Reporting systems such as for COVID-19. Under ascertainment can occur in each layer.

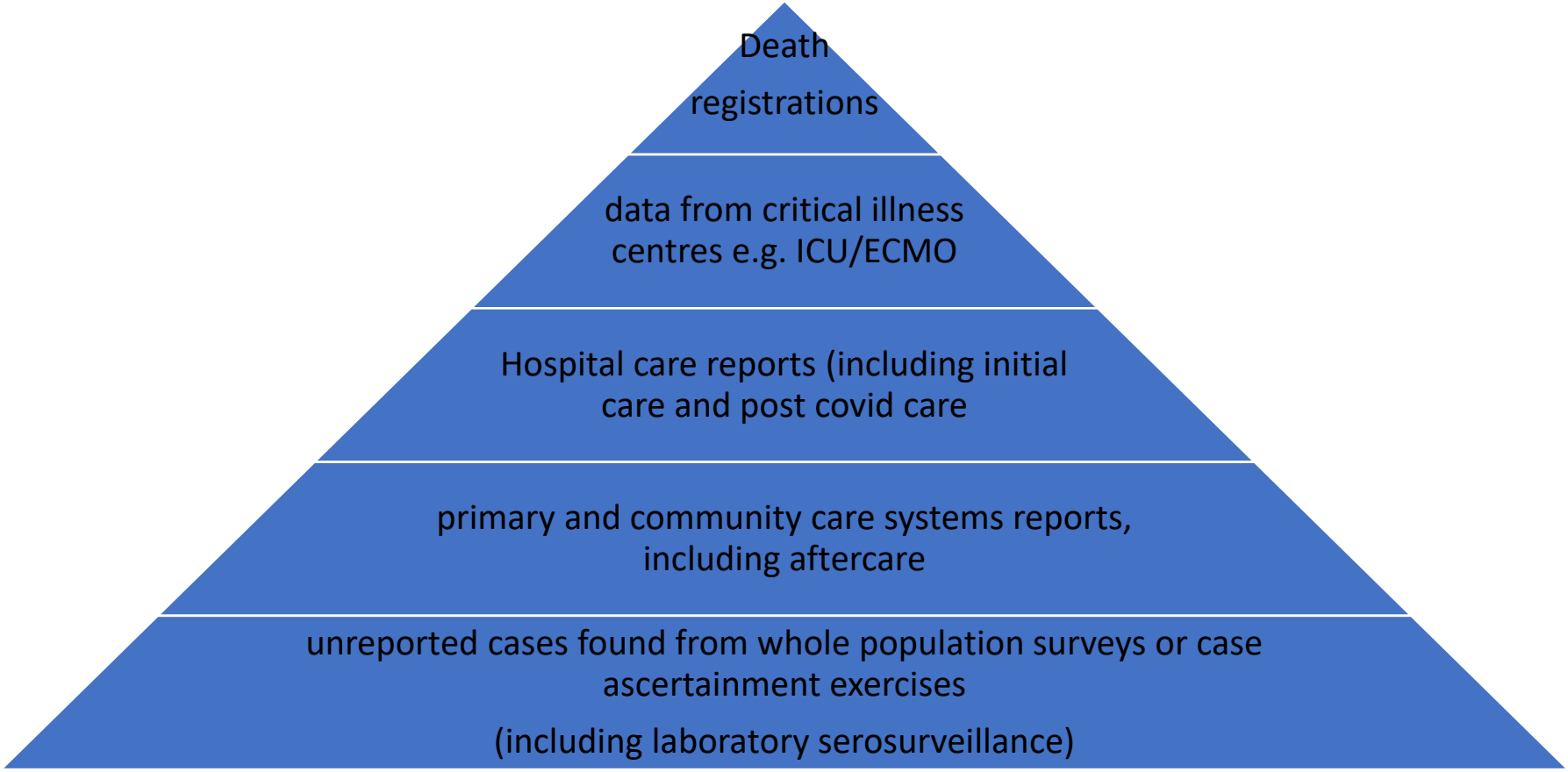
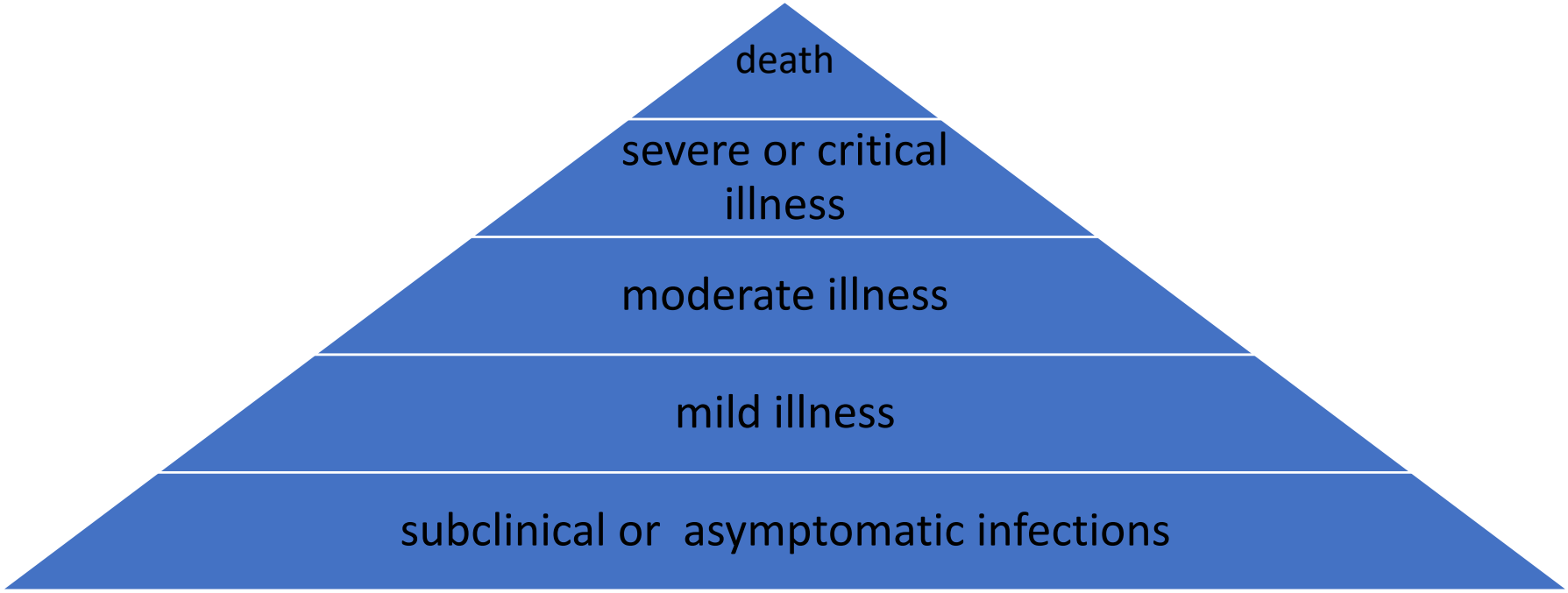


Figure 2. Five levels of severity of initial COVID-19 illness pyramid.

This does not include disabling sequelae for any level from mild to critical survivors. This is a major challenge and a key iceberg feature so far for COVID-19 BOD studies, particularly as the BOD is expected to be unevenly distributed in populations specially for those already more vulnerable and disadvantaged. Another aspect is “sensitivity” of persons to present themselves to health care system, to seek help. Access to health care, geographical and socioeconomical also influence probability of reporting. Residual disability after infections is also possible for each level of severity – as with Post Covid Conditions.



One of the challenges in assessing BoD will be to link long term 'post-COVID conditions' (so called 'long covid') with the initial severity of infection. We should also allow for specific deeper impacts on vulnerable groups such as children or for women's and foetal outcomes associated with pregnancy. While all deaths or severe disease episodes are tragic there could be long life periods with disability or reduced quality of life for those surviving into subsequent decades. Follow-up care with clear clinical pathways is needed, and longitudinal data from them should inform relevant disease or disability registers on the ensuing health burdens.

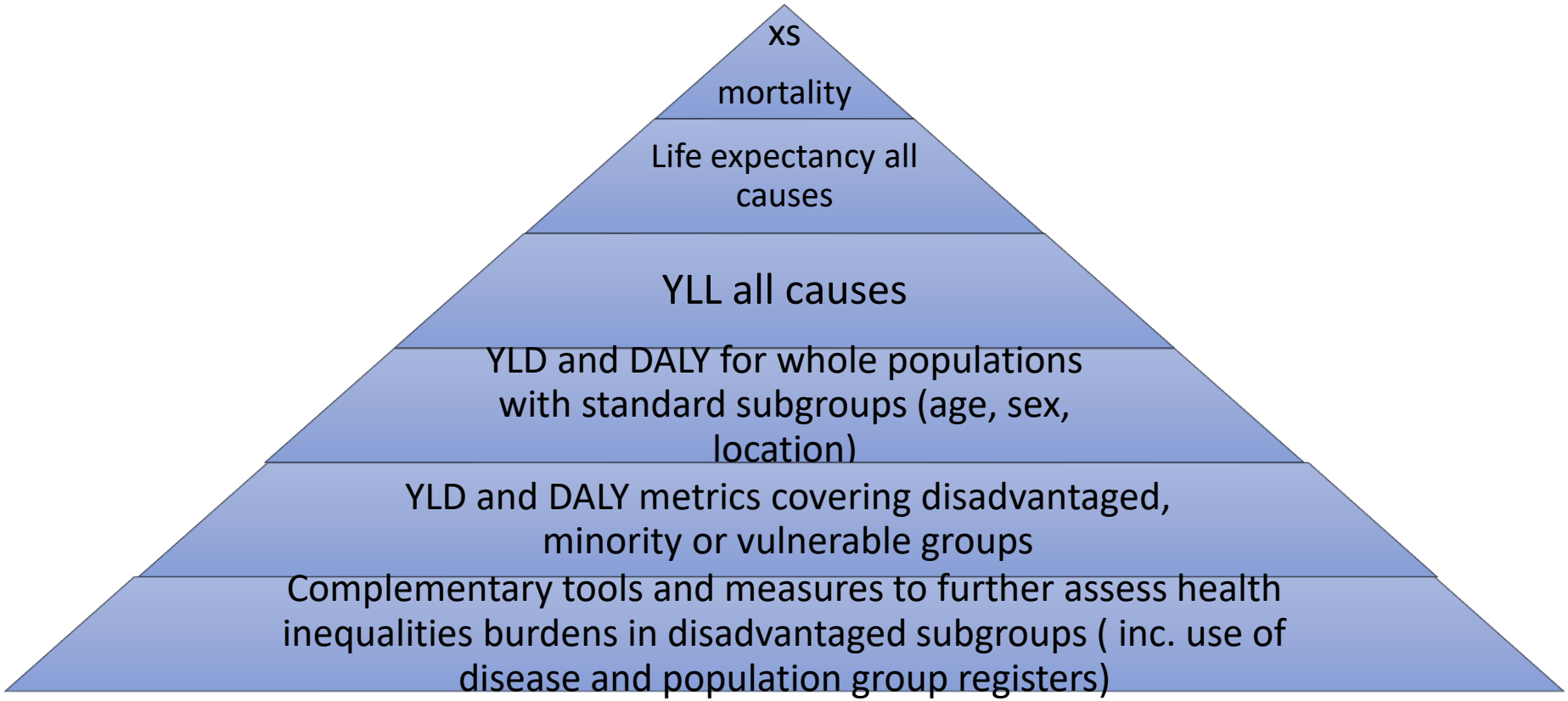
Integrating Iceberg of Disease concepts:

One of the roles of complete BoD studies are to reveal the extent of health outcomes that are hidden below the surface, i.e. the submerged and more substantial portion. This implies that disease reporting may initially focus more on the easily accessible data such as the deaths registered or the admissions to hospital facilities such as ICU. However, with most diseases there are many people who have mild to moderate severity conditions that may not be present to healthcare services, or not be diagnosed by attending clinicians, or not be reported through healthcare surveillance systems or disease registers. Also, this under-ascertainment phenomenon also depends on the adequacy of testing and diagnostic facilities, that can vary substantially across countries.

Public health teaching embraces a population-wide approach that should acknowledge that all surveillance and reporting systems are imperfect, even those in most advanced societies. Public health professionals need to be aware of these imperfections in their work on health needs assessment, burden of disease and advising on prevention and control policies. The COVID-19 pandemic has revealed many flaws in surveillance and reporting systems that can be discussed in MPH courses. Newer systems such as genomic surveillance and wastewater surveillance were accelerated during the pandemic and should be incorporated in teaching. Their contribution to future BoD programmes should be explored. Inequity in comprehensive provision of such more expensive surveillance systems is also worth consideration.

Another potential useful aspect of the Iceberg of Disease concept is that minority and disadvantaged groups, and others most vulnerable or excluded, may be overlooked in standard health care provision and in their typical disease reporting systems. This could include those experiencing barriers to healthcare or lack of recording of minority or vulnerable group membership. Differential exposure to the virus is also relevant given, for instance, higher incidence rates in ethnic minorities reported in several countries. Pandemic associated mental health burdens are also likely to be undercounted, especially for already vulnerable groups. A six-layer BoD Pyramid model is proposed below that incorporates additional special studies and an inequalities emphasis. Such an emphasis on completeness, fairness, transparency is needed to fully assess the health inequalities experienced during the COVID-19 pandemic. Moreover, such a wide-ranging approach needs to be developed for capturing BoD in future pandemics.

Figure 3. Iceberg of Disease as a BoD conceptual six-layer metrics model – for identifying fuller BoD measures including the inequalities dimensions and vulnerable groups.



Other Conceptual models and theories of relevance to BoD teaching

Case studies are vital to help us show the art of the possible, and to absorb them in our teaching and epidemiological developments. The country example of Scotland's BoD leading edge studies were highlighted in Part 3. Specific vulnerable groups need also to be studied. For instance, in the UK there has been recognition of severe pandemic impacts in people with learning disabilities.[3] Avoidable excess deaths in those with learning disabilities were already higher than expected in the pre-pandemic period. Systems for health monitoring and routine review enquiries of all such deaths were improving but not always satisfactory. Such systems could be integral to tools complimentary to standard BoD metrics, in highlighting either direct or indirect pandemic impacts on such highly vulnerable people.

All three Pyramids or Iceberg of Disease models above are concerned with reporting and assessing direct impacts of infection. However, the pandemic has wider indirect, largely negative, health impacts and wider conceptual models are also needed.

We encourage that conceptual models should be updated to reflect wider theories and principles that were illustrated and employed in the pandemic. Principles of upstream factors or wider determinants should be identified clearly, alongside downstream and proximal determinants, into how they shaped the pandemic's burdens, and they should be incorporated in revised public health teaching models. Pathways for differential exposure and impact should also be estimated, [4-8] Intersectionality concepts and 'intersectional practice' should be explored further in public health teaching and training, and how to recognise how intersectionality is operationalised, such as with Christofferson's five types for 'intersectionality's conceptualisation and use among equality organisations and policymakers'.[9]

COVID-19 has been described as a syndemic where multiple factors and social relationships are influencing the additional burdens of disadvantaged groups. Schools of Public Health should incorporate explanations relating to integrated multi-factorial causation models within syndemic theory.[10-16]

The disproportionate impacts and burdens during the COVID-19 pandemic could also be partly explained through theoretical perspectives such as the Matthew effect, [17,18]

Tudor Hart's Inverse care law is widely used in public health teaching,[19] This example that could be considered when BoD discussions are taking account of disrupted health and social care systems in the pandemic.

Examples of conceptual models could be included, covering natural history of health and disease, linked with clinical thresholds and varied recovery or disease progression and types of eventual outcomes.[20]

6. Competencies: What should MPH and public health practitioners and specialists know or know-how in relation to BoD?

We can look at Burden of Disease competencies in public health based on four main components (as in the FPH UK 2022 new curriculum).[21] The typical levels of competency are: 'Know' (knowledge), 'Know-How' (basic familiarity with when and how tools and techniques such as statistical data analysis), 'Show-How' (ability to demonstrate competency in applying a competency in supervised practice) are all first developed during postgraduate and training programmes and 'Does' (competencies shown from their applied use in professional practice). The 'Does' level includes specialist level interpretation, prioritisation and decision making. This is largely derived from the widely used original clinical practice model based on Miller's pyramid.[22]

BoD is a developing but small part of the existing curricula for public health training.[23,24] It is likely however that only a small percentage of those in most public health roles will be involved in BoD estimation/calculation using analysis of large datasets and statistical models (show-how or show/does). It is likely that competencies will be more helpful that are based around underlying concepts and how to use BoD to influence policy formulation and public health programming.

Competencies should seek to address how best to address data gathering and analytical dilemmas such as for people with comorbidities it may be difficult to define whether the death was due to or with covid-19. There is a need to appreciate the additional pandemic burdens over and above the pre-existing health burdens, that for some poorer European countries were already some distance behind high income countries. There is a need to understand use of comparative pandemic BoD indicators between countries around Europe

and beyond, and whether it is reasonable to adjust BoD results to allow for the different social and economic indicators in those countries. This has ethical and political relevance as well as any technical and scientific debates.

The 'know' and 'know how' could be based on appreciation of several key features of BoD, largely gained during MPH studies. 'Show-how' and 'Show'/'Does' levels of competence would need deeper appreciation and hands-on usage, usually via linkage within a public health practice setting or in specialist team or centre of excellence. Death registration and review are important public health issues with knowledge and competence in registration and review processes, recognising that dealing with vital statistics an essential public health skill.

Table 1. Exploratory look at BoD Competency areas and example descriptions – for wider discussions

Competency sub-areas	Example descriptions
Know of surveillance systems that underpin BoD measures.	About the need for robust surveillance systems, and associated resources and expertise that can demonstrate high quality and timely data to allow ready generation of all of the current 5 main BOD metrics, (excess/less mortality, life expectancy, YLL, YLD, DALY). Role of BoD metrics in initial alerting or early warning mechanisms
Know the typical BoD morbidity and disability metrics, scales and tools:	This includes awareness of ways to grade severity and disability weights recommended applied in YLD and DALY.
Know-how to interpret published (peer-reviewed) high quality BoD studies	Including know how to interpret examples from COVID-19 and other case-studies covering NCDs (Non-communicable diseases). Also, this could link to knowing where to locate and search for BoD evidence and repositories.
Know of the strengths and weaknesses of BoD approaches:	Including the data, models and data from their localities/ and country where they work. Also be aware of the debate about BoD metrics links to other summary measures such as healthy life-expectancy and health economics tools such as use of valuing or costing measures for DALYs. This might include BoD relevance to children's health, mental health and pregnancy.
Know of relevant conceptual models or paradigms:	This could include appreciating the links with the 'iceberg of disease' concept, along with other examples, such as with the 'inverse care law' or rhetorical debates around simplistic measurability of aggregated outcomes versus qualitative measures and lived experience.

Know-how BoD measures are/can be used to influence public health policy and to help evaluate public health programmes.	This could also link to how BoD metrics fit into prioritisation across competing programmes. A BoD desk-top exercise could be used in prioritising for public health programmes locally although there may be small numbers of cases to evaluate.
Know of the financial resources needed to support BoD systems.	This might include knowledge of country infrastructure and of specialist funds allocated to expert centres or programmes.
Know-how to highlight health inequalities within BoD reports.	This could include being able assess how far BoD reports are able to cover the complex challenges to highlight health inequalities and disadvantaged groups in those populations and what supplementary or alternative tools are needed in addition. This could include knowing how to engage necessary different expertise and disciplines in research strategies, along with their roles in BoD calculations, visualisation and knowledge translation.
Know-how to commission BoD studies.	How to link draft tenders and link with external providers who may be engaged to conduct research, and know about good practice in commissioning and types of research service specifications.
Know demographic background and inequalities	Know of relevant demographic tools such as life expectancy tables and vital statistics that feature in BoD metrics

Table 2. MPH Cross modular BoD themes and topics – illustrative examples

MPH Module themes (examples)	BoD Topics (examples)
Epidemiology and statistics	Surveillance systems, completeness, timeliness and under-reporting; maximising ascertainment
Theories and concepts of public health	'Iceberg of Disease' concepts and links to heath inequalities
Economics of health	Prioritisation in programs. Links to valuation of life measures - including how DALYs are costed.
Communicable diseases	Local and international studies of BoD -COVID-19, NTDs, Vaccine studies

Non-communicable diseases	YLD and DALY use in highlighting (chronic) mental health and musculoskeletal problems
Policy, strategy and leadership	Communicating about BoD in policy and strategy setting
Research methods	Consider technical issues in study design
Dissertation	Potential of BoD as a dissertation topic for some students. Other students may need to consider the above BoD components to some degree, such as can BoD concepts add to the case of need for the proposal, or use in other ways such as in discussion section?

The above illustrations will need further development and consultation with Schools of Public Health with respect to good practice and overlaps with other competency guidance. This BoD focus represents a thematic focus that can dovetail with wider competency frameworks and associated academic and training curricula and materials.

Recent feedback (June 2023) shown below from Young Professionals working with ASPHER can also be used to guide how BoD curricula and competencies are developed, along with any future surveys or feedback from ASPHER's academic membership.

Table 3. Feedback from 5 Young Professionals – ASPHER discussion meeting June 2023

Discussion guide:
- What should MPH teach on BoD?
- What should MPH and public health practitioners and specialists know in relation to BoD?
- What has the pandemic has added to the MPH needs and opportunities.

Taught Experiences?
Overall was limited; short lecture and associated workshop focused on how to find data and introduction to methodology metrics definitions - YLD, YYL, DALYs, disability weights
In statistics and epidemiology- data source types for GBD (Global Burden of Disease)
Taught time range taken from 4 hours to 2 days – some aspects brushed on lightly.
The group saw it as an introduction to something, which needs more structure but also felt BoD may be too broad a topic to fully incorporate into MPH programs – planning should focus on important aspects that would set a foundation for understanding and interpreting BoD literature.
What you wish you knew further?
A general understanding of how to interpret the visualization tools, BoD metrics, and assumptions and biases in methodologies.
All MPH graduates to understand it is not raw data – its estimates – and how generated.
Understand the data used in BoD models – clinical informatics, surveillance data and their limitations.
Linking to valuation – costings of DALYs
Database/ maps for creating short reports or cases – use for science and prevention and patient health management
Other points
BoD – expanded with its strengths and weaknesses can be highlighted by Covid – case study opportunity for MPH teaching
BoD influencing public policy – ways of communicating about BoD in policy and strategy
e.g. the use of BoD studies to highlight inequalities between and within regions.
Importance of understanding both metrics – qualitative aspect also and what it can contribute to future BoD studies?

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PART 4. CONCLUSIONS AND RECOMMENDATIONS

i. ASPHER's Roles

ASPHER is an independent Europe wide public health body, and throughout the pandemic has acted as an advocate for equity and full recognition of vulnerable groups and health inequalities, as a critical friend of evolving surveillance and epidemiological investigations, and as a guide to improved public health education, training and competencies. This report builds upon previous reviews and statements that highlighted our concerns around the COVID-19 pandemic's health inequalities and the many different more vulnerable groups.[1,2]

History advises that we should recognise that pandemics can leave large numbers disabled.[3] The scientific basis for Burden of Disease investigations has evolved or more likely shifted forward during the pandemic, necessitated by this pandemic's large scale and its varied forms of morbidity and mortality. The pandemic's enduring health impacts, such as post-COVID health conditions, are still leaving many millions of people unable to resume full activities of their normal living. This can affect people across the life course, including younger people and children who can suffer long term impairment and restricted quality of life.[4] For example, in the UK in March 2023, there were estimated to be 1.9 million people self-reporting 'long covid' symptoms, of whom 1.3 million (69%) had symptom onset over 12 months previously.[5] Without a full exposition of such populations in each European country there may be large numbers left without recommended care and support. ASPHER would aspire that each country develops services to aid their recovery and rehabilitation, in pursuit of WHO care guidelines.[6]. Assembling a full BoD picture of in each country will be a formidable but essential process. ASPHER recognises the important work that the European Burden of Disease Network is pursuing across the European Region to standardise, harmonise and develop improved reporting systems.[7]

Recommendations:

1. ASPHER should adopt a proactive approach to promote the high-quality country level BoD assessments and advising on BoD research strategies in all 53 countries in the European Region.

2. ASPHER should place examining and tackling health inequalities as a central mission in advocating for vulnerable groups in pandemic (and other) Burden of Disease strategies.
3. ASPHER should seek active partnership with other bodies interesting in Burden of Disease, such as the EU Burden of Disease Network, WHO(E), ECDC, EPHA, and EOHSP.
4. An initial joint statement with the EU Burden of Disease Network would be a useful starting point for ASPHER's partnerships, highlighting key areas of common interest, mutual support and strategic direction.

ii. Evolving surveillance systems and BoD investigation methodologies (see Part 1 above)

Historically epidemiologists have used BoD studies to capture the under-reporting of illness. For example, the second UK GII (Gastrointestinal-Illness) study in 2012 noted that significant under-reporting of milder viral illnesses such as Norovirus, but also that only a minority of more severe infections such salmonella and E.coli 0157 cases reached formal surveillance reports.[8] Estimating true population burdens for most diseases needs to incorporate estimates of under-reporting or under-counting. Recognising levels of under-reporting can stimulate action to enhance surveillance systems.

There is considerable scope for COVID-19 pandemic-driven learning insights to help develop better applied surveillance and wider epidemiological methods in a move towards more comprehensive BoD surveillance and to assist associated scientific research. The under-reporting of COVID-19 mortality in several European countries was revealed from early in 2020 by using all causes (total) excess mortality figures. These discrepancies need to be addressed and allowed for in interpreting any governmental statistical releases covering excess mortality. These BoD methodologies need to be more standardised and harmonised - as advocated by colleagues in the European Burden of Disease Network, and also should embrace issues of disadvantaged groups and equity.[9,10,11,12]

BoD reports should have their own online reporting platforms that are an accessible resource for their populations and should feature health inequalities themes and minority populations, as for example in Australia.[13] There should be a focus on recognising pre-existing vulnerabilities and health conditions and how they intersect with a pandemic's extra burdens. Exploration of data linkage in a country

should be a key future theme for pandemic investigations, as recognised in Australia, including recognising that there will be ethical and legal considerations to overcome.[14]

Some European countries may however struggle to show a strong pandemic BoD profile. We appreciate that the European Burden of Disease network continues its work to advise and support such less able countries to gather relevant data systematically and to estimate their own population's BoD. Rapid data gathering and sharing may have some opposition from ethical, cultural and legal angles, and political, institutional and public trust may need to be built. The momentum from the pandemic should be sustained however, so that the European Region is better prepared for future pandemics and major public health emergencies.

<u>Recommendations:</u>

1. Work to develop high standards for Civil Registration and Vital Statistics (CRVS) should be promoted in each country.
2. A Burden of Disease online platform could be promoted in each country, probably linked to an overall Health Information platform, as for example found in Australia.
3. Country-level standards for BoD systems should be agreed that can be audited and reported regularly, such as for timely electronic data gathering and reporting.
4. Such standards should go much further than the five standard metrics referred to in this review, and highlight a wider range of examples of BoD work on impacts on those with particular clinical and other disadvantages or characteristics.
5. All causes excess mortality should be reported routinely in pandemics alongside those ascribed to the particular pandemic infection.
6. Collaborative preparatory work with journalists and media should be promoted.
7. Pandemic materials for journalists and media outlets should be developed, including examples for each BoD measure.

8. Further work is needed to cover morbidity and disability coverage, in particular for the range of post-COVID conditions, that will continue to be recognised during 2023 and beyond.
9. The current range of disability weights used in YLD and DALY studies should be updated to incorporate greater understanding of those with post-covid conditions as well as those who have suffered significant disability from early complications of COVID infection such as from strokes and other neurological impairments, and cardiac damage.
10. Developing better BoD systems will require sustained work to develop appreciation of ethical, cultural and legal constraints in each country and to gain trust and .

iii. Findings from European BoD studies including health inequalities (see Part 2 above)

BoD Methodologies demonstrating health inequalities are limited so far but some examples are shown in Part 3 above.

Various Eastern and Mid European countries have borne the most severe mortality burdens but their total BoD profiles are still not clear yet, as their DALY and morbidity/disability profiles continue accumulating. In terms of indirect impacts on health systems the pandemic put large scale pressures on the health systems of the four Visegrad countries (Poland, Hungary, Czechia, Slovakia) where, although hospital bed capacity was historically relatively high, the shortages of doctors and nurses, historically low, became a 'bottleneck' in response to rising numbers of cases later in 2020.[15] BoD assessment of such indirect impacts should be a key part of each country's inquiries into their pandemic losses and policy responses.

Socio-economic and demographic variations became evident quickly through morality analyses in 2020. For example, a review in Germany highlighted clustering in disadvantaged population subgroups and expectation of intersectional factors, for instance with migrant labour and immigration facilities, raising the need for strong future analyses, "intersectional marginalisation and discrimination these groups suffer with regard to working and living conditions as well as healthcare access presumably play key roles". [16]

Excess mortality surveillance systems from other countries, such as the UK and Sweden.[17],[18] Evidence gathered quickly on mortality disparities, such as geographical variations, more vulnerable demographic groups such as males higher than females, older ages and those in care facilities, pre-existing long term health problems, varying occupational risks and also those ethnic minorities more seriously affected.

Losses on other vulnerable groups in long term care facilities were reported such as in Portugal.[19] Losses in some population groups with special needs were highlighted in countries such as Netherlands, for those with intellectual disabilities.[20]

It is unlikely that standard BoD population-wide metrics will be able to fully capture deeper losses ad experiences of vulnerable population subgroups, including impact of loss of function and social potential from illness and disruption of care, needs to be recognised and addressed. Special studies, using a variety of quantitative and qualitative methodologies, will continue to be needed so that a more complete picture is gathered before we can say we fully understand, summarise and have reported widely the pandemic's burden of disease.

There is a global concern for direct COVID-19 impacts of for women in/after pregnancy, and for the foetus/new-born. deserving for special attention in a wider BoD framework. Inequalities are evident particularly for those in LMIC and MIC areas.[21] The pandemic's indirect impacts probably also have a role looking at inequalities in outcomes such as postnatal depression.[22] The indirect pandemic burdens are relatively underexplored so far, particularly for the BoD morbidity and disability metrics, including mental health and various impacts on children.

ASPHER has been concerned that some European countries reported increases in intimate partner violence, that can affect children as well as the direct victims.[23,24,25] There appears to be a rise in Adverse Childhood Experiences (ACES) during the pandemic.[26,27,28] Exploring such burdens and their health inequalities should be a priority for country BoD programmes. Adverse pandemic impacts on children such as changes in wellbeing, sleep time, screen time and physical activity need to be clarified and estimated.[29]

Apart from the broader indirect societal impact on mental health,[30] there is a need to highlight extra burdens from disrupted mental health care.[31,32] The additional pandemic Burdens associated with disrupted cancer care also need examination and exposition of their contribution to BoD estimates.[33,34]

New evidence is still accumulating on long term burdens. For instance, diabetes prevalence, which already has health inequalities features, could potentially be linked to COVID-19 infection and lead to increased burden of diabetes overall.[35,36]

Global and other international BoD collaborations have become established to assist in harmonisation and standardisation. Health inequalities Links on health inequalities should be fostered, for instance with the Health Equity Assessment Toolkit (HEAT and HEAT Plus).[37]

There is a danger however that remote or mechanistic handling of global BoD databases or megadata can lead to disputed finding and insensitive reporting or less accurate insights unless local experts and country-specific institutions are party to such wider and longer-term collaborations.

Journalists and non-public health commentators played an important part in helping explain the full picture. It will be important to include their role in preparing for future coverage of BoD and other scientific techniques, including their strengths and limitations.

<u>Recommendations:</u>

1. ASPHER should highlight the needs to do special pieces of BoD work, such as around cancer care and cancer screening disruption or disruption to mental health services.
2. There is a need for a special focus on health inequalities and how BoD studies can demonstrate specific burdens for the most vulnerable groups from COVID-19 infection or from indirect pandemic impacts.
3. Each country should develop standard BoD health inequalities reporting using a range of demographic and vulnerability population group categories.

4. The total burdens associated with individual diseases/injuries should be estimated such as for child and adult mental health, violence related harms, and pregnancy related losses.
5. A library should be assembled of useful case studies looking at burdens on such vulnerable groups and setting in Europe.
6. BoD links to online collaborations in equity, sharing data, should be encouraged such as the Health Equity Assessment Toolkit (HEAT and HEAT Plus).
7. Special attention to supporting Eastern European countries in the COVID-19 Pandemic BoD reviews and developing future reporting systems.
8. The losses and burdens from disruption to health and social care systems is becoming clearer but needs to continue and be comprehensive.
9. Given the scale of the pandemic and widespread health consequences and the major learning opportunities across the wider European region, it could be argued that a specific focus on inequalities and equity could be developed within BoD processes and systems
10. ASPHER could consider advocating for a comprehensive equitable programme for Burden of Disease – Examining European Health Inequalities (BoD-EEHI) to be a key foundation for prioritising future pandemic policies and strategies, as part of our aims for evidence based/led/informed policies and research led public health practice.
11. Moving from earlier reliance on rapid mortality measures, such as excess mortality and Years of Life Lost, is important. We welcome the YLD/DALY country/local levels and international comparative studies that are already done and are still being rolled out in Europe.
12. ASPHER would encourage however, that BoD studies should go beyond covering standard geographical levels and focus on specific vulnerable and disadvantaged groups in each country and across countries.

13. Where such vulnerable group numbers are small in any country, we recommend that extra efforts be made to capture their experiences using complimentary methods along with the standard BoD summative estimates.
14. We recommend re-looking at causative pathways and inequity mechanisms and relating them to BoD, as part of such an expanded focus.
15. ASPHER should advocate for collaborative BOD studies, albeit the number of countries initially participating is not wide enough. However leading-edge researchers could act as demonstration projects of several possible data sources and analyses.

iv. Supporting Public Health workforce capacity and competencies (see Part 3 above)

Pandemic related learning can be incorporated into future ASPHER public health competency frameworks, and into public health academic and service-based curricula development and into our teaching/training delivery practices. The accelerated growth of BoD studies into COVID-19, and the pandemic overall, places BoD as a central public health learning opportunity and requirement for future public health professionals. Lack of investment and erosion of public health capacity remains an underlying issue.

Foundational MPH level competencies could be gathered during academic studies, with more applied skills learned later in public health training or in specialist practice. Illustrations of 'know' and 'know-how' topics and themes were provided in Part 3 above to assist this debate. This would recognise also that public health capacity and expertise to cover BoD evidence is important, including for assessing and supporting vulnerable population groups to show how they suffer additional and multiple health insults during and later arising from a severe pandemic as with COVID-19. These vulnerable groups need to be specifically recognised in BoD studies, as they are more commonly infected, suffer greater direct and indirect pandemic consequences, while their personal circumstances and wider health determinants, such as their precarious income, have usually deteriorated.

Efforts to accommodate recent and historical learning on pandemic BoD should be incorporated in our future Public Health Schools curricula. Mapping the full extent of the losses associated with complex risk factors and wider determinants will be difficult but should build upon updated conceptual approaches.

BoD covers measurement of absolute losses and although difficult to attain this goal should not be secondary to measuring relative risks and outcomes.

"It is important to monitor both relative and absolute changes in social inequities in health, because they give different information about the magnitude and direction of change".[40] (Whitehead and Dahlgren 2006)

Models such as the 'iceberg of disease' should also be updated,[38,39] but with newer knowledge and clearer equity principles. Also, principles of upstream factors or wider determinants, should be identified clearly, alongside downstream and proximal determinants, into how they shaped the pandemic's burdens, and they should be incorporated in revised public health teaching models.[40,41] Pathways for differential exposure and impact should also be estimated, [43,44] and also incorporate explanations relating to integrated multi-factorial models such as syndemic theory.[45]

Concepts of intersectionality should be explored in BoD and other studies, given its increasingly central role in our understanding of population groups with multiple disadvantages.[46,47] Disability exclusion will be an issue to be faced when assessing losses.[48] Ethnic minorities in some countries have had worse experiences including exacerbations of existing health conditions. These inequalities and underlying mechanisms should be followed up with learning from Europe and global studies [49-55]

BoD studies can add to our understanding of wider economic costs to society. Metrics such as sickness absence can be used,[56] while economic losses can be estimated by associating each DALY with a given financial amount.[57]

ASPHER has links to academic expertise and special interests of its member schools of public health that were mobilised during COVID-19, including those within the ASPHER COVID-19 Task Force (now the ASPHER Public Health Emergencies Task Force).

ASPHER has had various roles in developing competency frameworks and tools to assist in curriculum development and delivery. This included developments during the pandemic such as the joint competency framework with WHO(E) in 2021 and with ECDC in the Core Competencies in Applied Infections Disease Epidemiology in 2022. Given the growing of importance of BoD concepts and evidence, and volume of pandemic BoD studies, there is a need to commence a review to elaborate MPH typical BoD content and also BoD

representation and levels with our current competency frameworks. The pandemic raises various questions for our competency frameworks but BoD could be one of the vital pandemic learning areas for the future, through "*formulating additionally and more specific and granular competences in the identified areas*".[60]

Recommendations:

1. Schools of Public health should be encouraged to help ASPHER in maintaining an overview of the expertise and interests and resources of member schools for seeking support in addressing pandemics and other disasters.
2. ASPHER should review with schools of public health to develop their teaching concepts, epidemiological approaches and other tools relating to BoD.
3. Exploration of Ontologies, Epistemologies and research paradigms underlying BoD investigations should be pursued.
4. ASPHER should supplement their competency frameworks with additional BoD guidance linking those frameworks with helpful support such as examples of training exercises or scenarios, highlighting ASPHER member expertise, and also signposting external tools and weblinks.
5. ASPHER should collaborate with EU-BoD network (or successor collaborations) on resources such as glossaries, toolkits and methods booklets.
6. MPH Dissertations looking into BoD should be encouraged.
7. Post MPH studies and ASPHER YPs should be encouraged to take an interest in BoD linking with EU-BoD network and other partners.
8. Schools of Public Health should seek PhD opportunities with wider linkages to EU-BoD and other international networks.
9. Concepts such as syndemics and intersectionality should be built into BoD teaching, to help allow for multiple losses during pandemics.

10. Methods for assessing wider economic costs of a pandemic should be reviewed and linked to BoD teaching.
11. Further feedback from MPH students and graduates could be sought within ASPHER surveys or separately.

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