# The health-adjusted dependency ratio as a new global measure of the burden of ageing: a population-based study

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## Summary

**Background** The old-age dependency ratio (OADR), which is the ratio of older people (aged ≥65 years) to working age people (aged 20–64 years), is the most common way to assess and compare the burden of population ageing in different countries. However, the relationship between chronological age and dependency varies widely across countries. We therefore present the health-adjusted dependency ratio (HADR), a new measure of ageing burden based on the ageing-related health of the adult population.

**Methods** In this population-based study we used health data for diseases and injuries for 2017 from the Global Burden of Disease project and population data for 2017 from the UN's Population Division to identify the number of adults (aged >20 years) in each country who have the same or higher ageing-related disease burden as the global average 65-year-old. We then calculated the HADR as the ratio of adults who were less healthy than the average 65-year-old (dependent population) to those in better health (supporting population) and compared the HADR with the OADR for 188 countries. We also used cross-sectional, bivariate regression analysis to investigate whether the HADR is a more powerful predictor of changes in per capita health-care expenditure than the OADR as a measure of predictive validity.

**Findings** Many demographically younger populations have an earlier onset of ageing-related disease, and many demographically older populations have a later onset. For instance, Pakistan has an OADR of 0·09 and an HADR of 0·19, and France has an OADR of 0·35 and an HADR of 0·13. Relative to the OADR, the HADR suggests that Asia, western Europe, and North America have a lower ageing burden, whereas central Asia, southern Asia, and Africa have a greater burden. While Japan and countries in western Europe have the highest OADR, Russia, Papua New Guinea, and countries in southeast Europe have the highest HADR. Relative to the OADR, the HADR suggests that there is much less variation in the burden of ageing across countries than has previously been assumed. HADR was also more closely associated with growth in health spending than the OADR. A 0·1 increase in the HADR was associated with a 2·9 percentage points larger growth rate in per capita spending (p=0·0001), and a 0·1-point increase in the OADR was associated with a 1·8 percentage point larger growth rate.

**Interpretation** The OADR probably overestimates the burden of population ageing in many demographically older countries and underestimates the ageing burden in many demographically younger countries, which implies that the challenges associated with ageing are more universal than previously thought, and that the world cannot easily be divided in a young and an old groups of nations.

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## Introduction

Population ageing can put a burden on society if older people must depend on others for financial support and care. Traditional indices of the burden of ageing such as the old age dependency ratio (OADR) tend to assume that individuals become dependent at a fixed age.[1] However, chronological age means very different things in different countries. For instance, age-patterns in health vary considerably across nations and also influence retirement age and productivity.[2,3]

In recent decades, populations around the world have grown chronologically older due to decreasing fertility and increasing life expectancy. Substantial differences between countries nevertheless remain due to differences in the speed of changes in age-specific mortality and in fertility rates.[1,4] Given widespread concern that having an older population strains societal resources, several indices have been developed to summarise the burden of ageing in different countries.

The OADR is among the most used metrics of ageing burden. The OADR is designed to capture the economic burden of ageing. Based on the assumption that older people do not work and hence must be financially supported by the working population, the OADR is calculated as the ratio between older adults (non-working) and working age people in a population. The cut-off used to define older age is assumed to be fixed and typically defined as being aged 65 years or older and

## Research in context

### Evidence before this study

We searched PubMed, Google Scholar, and Web of Science using the terms "ageing dependency", "demographic ageing", and "old age dependency" in English, German, and Norwegian until Aug 31, 2021. Evidence from the identified studies suggest that indices of the burden of population ageing such as the old age dependency ratio (OADR) are often based on the assumption that individuals become dependent at a fixed and universal age. These studies generally find that demographic ageing is associated with a greater ageing burden. However, chronological age means very different things in different countries.

### Added value of this study

We propose a new dependency metric: the health-adjusted dependency ratio (HADR). Unlike existing indices, the HADR accounts not only for a population's demographics but also for its ageing-related health. We calculated the HADR for 188 countries and compared it to the OADR. We find that many demographically older populations have a relatively low ageing burden when both demography and ageing-related health are considered. However, many demographically younger populations have a relatively high dependency due to poor ageing-related health. The HADR is a stronger predictor of changes in health-care spending than the OADR, reflecting that it better reflects the financial burden of ageing.

### Implications of all the available evidence

Population ageing itself does not necessarily lead to higher ageing-related burden. For instance, western Europe is the world's demographically oldest region but has a similar ageing burden as many demographically younger regions due the relatively late onset of ageing-related disease. Demographically younger nations need to focus on delaying, preventing, and treating ageing-related disease to avoid high dependency ratios due to population ageing.

working age is typically defined as being aged 20–64 years.[1] Higher OADR values indicate more older people relative to younger adults in the population. In 2019, the OADR was nearly 0·30 in Europe and North America, indicating that there are approximately three working age adults for every adult aged 65 years or older in the population. The OADR in Europe and North America is projected to increase to around 0·49 by 2050. In Japan, the OADR was already 0·51 in 2019 and is expected to reach 0·81 by 2050. By contrast, the 2019 OADR was relatively low in south Asia (0·11), Latin America (0·15), and sub-Saharan Africa (0·07), but is expected to increase in the years to come.[1]

Although the OADR is commonly used in reports on ageing, for example by the UN,[1] it does not account for variation in the actual dependency (financial or otherwise) of the older population in different countries. In many European countries, substantial proportions of the older population are still working (eg, >20% of 65 to 69-year-olds in Denmark, Estonia, Ireland, Latvia, the Netherlands, Norway, Portugal, Sweden, and Switzerland in 2020[5]). Some countries have retirement ages in the 50s and others in the 70s.[2] Other research has shown that the average 75-year-old in Japan has the same ageing-related disease burden as a 45-year-old in Papua New Guinea.[6] The OADR also ignores variation across different countries in the extent to which the population of individuals of younger chronological age fulfil a supporting role for the older population (eg, by working). The age at which young people begin producing more than they consume, for instance, ranges from approximately 22 years in Cambodia and Colombia to 35 years in Ghana.[7] Hence, by using a fixed and universal cut-off based on chronological age to proxy dependency, the OADR provides only a very rough indicator of the ageing burden.

Given that the burden of ageing in a particular country is determined not only by the age but also by the health of the older population[8] indicators of the burden of ageing based on chronological age alone might be misleading. Several authors have proposed alternative indicators of ageing burden based on cut-offs more closely related to dependency than chronological age, such as health status or economic productivity.[9–11] Unfortunately, the scarcity of global, standardised, and harmonised economic activity data, including an absence of reliable data on informal work in many countries,[12] precludes calculating the ageing burden based on the actual labour force participation rates of different age groups. Some authors have calculated the burden of ageing based on indicators of the adult population's biological age, assessed using biomarkers such as triglyceride, oxygen uptake, white blood cell count, or genome-wide DNA methylation,[13,14] as well as indicators of the population's functional age, factors such as physical strength, cognition, mobility, hearing, or eyesight.[15–17] So far, such studies have been primarily limited to data from just one, often high-income country. Finally, some studies have used the average number of remaining life years at a particular chronological age to assess ageing burden.[18,19] However, because the number of remaining life years spent in better or worse health depends on the country,[20] indicators of population ageing based on remaining life years still offer only a very rough proxy of the proportion of the population that is actually dependent due to ageing. In sum, existing measures of ageing burden are typically based on poor proxies of old age dependency or can only be calculated for some countries.

In this study, we propose a new dependency metric: the health-adjusted dependency ratio (HADR), which, unlike existing indices, accounts not only for a population's demographics but also its ageing-related health. Using

existing data from the Global Burden of Disease (GBD) project, we assess the ratio of people with the same or higher disease burden as an average global 65-year-old person (dependent population) to people with a lower disease burden as an average global 65-year-old (supporting population). Unlike the OADR, the HADR thus uses a health-based threshold as opposed to the chronological age-based threshold to proxy dependency, and also accounts for differences in both between age distributions and age-specific health across different countries. Moreover, unlike the OADR that presumes that everyone below a particular age fulfils a supporting role, the HADR also accounts for morbidity occurring earlier in life. We calculate the HADR for 188 countries, covering most of the world's countries, regions, and major world economies, and compare it with the OADR. To assess how well the HADR describes age-related dependency, compared to the OADR, we compare the extent to which the HADR and the OADR are each related to changes in health expenditures.

## Methods

### Data sources

In this population-based study we combined health data for 2017 from the GBD Study[21] and population data from the 2017 Population Division of the Department of Economic and Social Affairs of the UN Secretariat.[1] The UN Populaiton Division database includes global age and sex distributions for every country or region by time period. The GBD Study provides information about the health of the adult population at different ages in 195 countries. The GBD collects data for diseases, injuries, and risk factors by age and sex. The combined dataset allows us to estimate the HADR for 188 countries, encompassing more than 96% of the global population.

### Measures

We used existing data on equivalent age from the GBD project.[6] Equivalent age is the age at which an average person in a particular country has the same ageing-related disease burden as an average global 65-year-old. The equivalent age was calculated for each of the 195 countries. The age of 65 years was chosen as a cut-off because this is a common retirement age and a commonly used cut-off in calculations of the OADR. Ageing-related disease burden was defined as the sum of all disability-adjusted life years of ageing-related diseases among adults. Ageing-related diseases were defined as conditions with incidence rates increasing quadratically with age after the age of 20 years. The ageing-related diseases included in the calculation are listed in the appendix (p 1). An equivalent age of less than 65 years means that adults in a particular country have an earlier onset of ageing-related disease burden.

See Online for appendix

We used the UN Population Division data to calculate HADR as the ratio of people who were the same age or

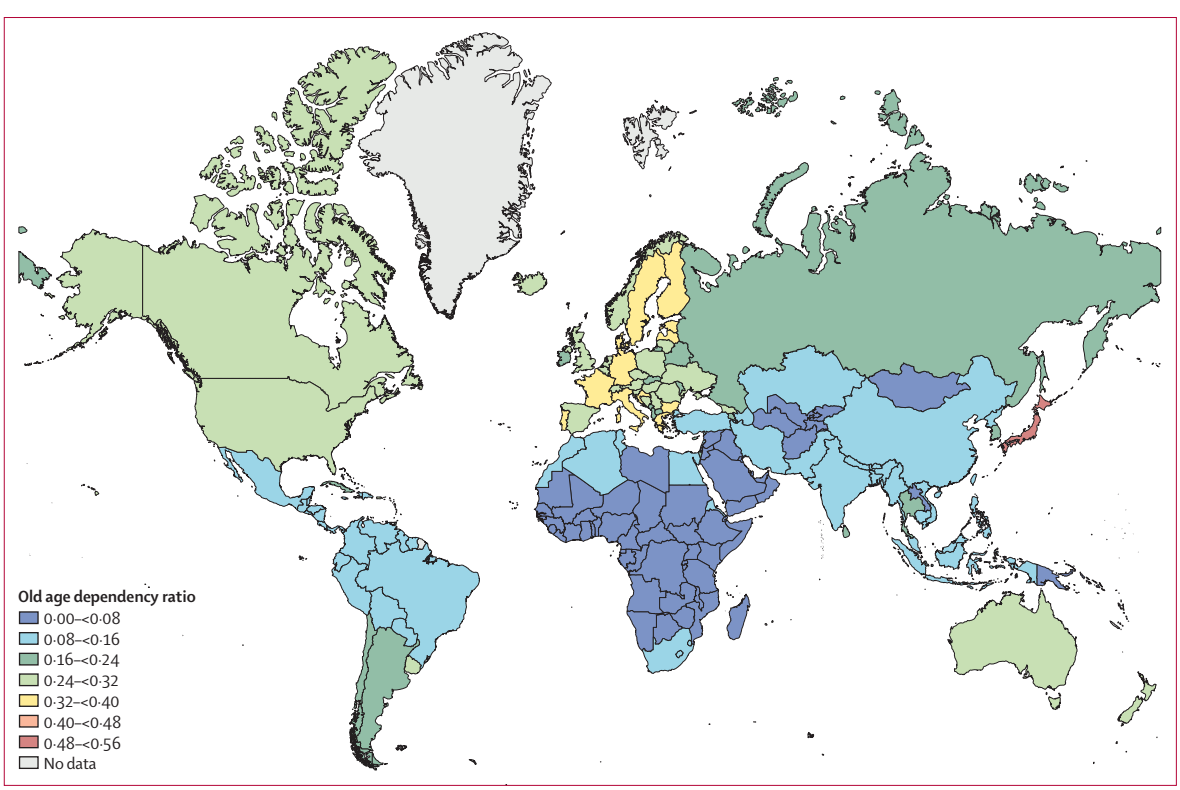


*Figure 1:* **Old age dependency ratio by country, 2017**
Higher values indicate higher ageing burden.

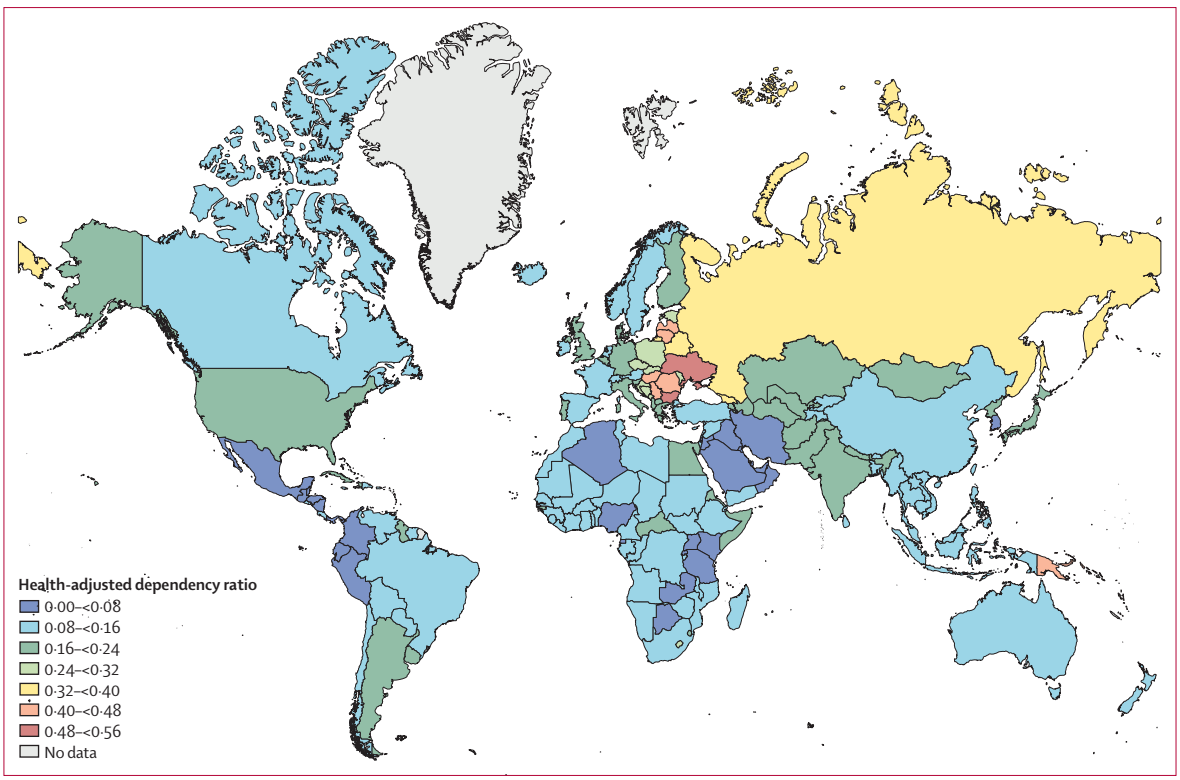


*Figure 2:* **Health-adjusted dependency ratio by country, 2017**
Higher values indicate higher ageing burden.

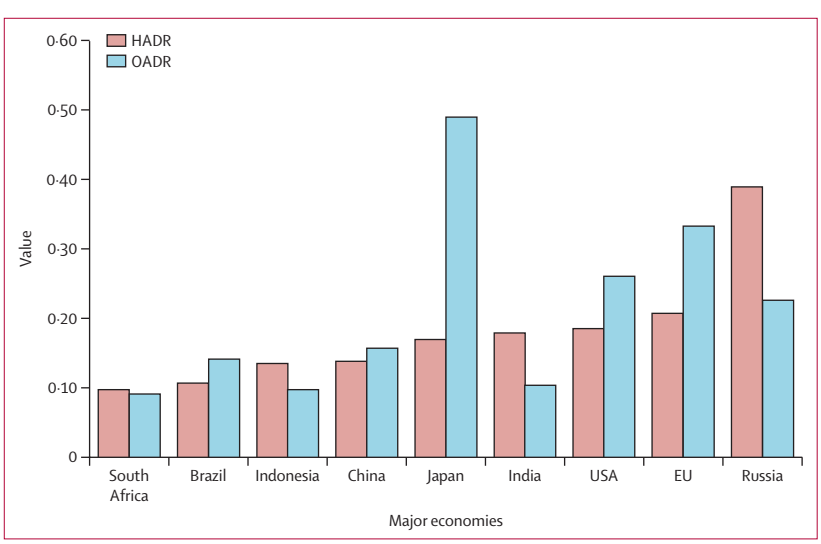


*Figure 3:* **HADR and OADR for selected major economies**
Higher values indicate higher ageing burden. HADR=health-adjusted dependency ratio. OADR=old-age dependency ratio.

older than the equivalent age (dependent population) to people who were younger than the equivalent age (supporting population):

$$\mathrm{HADR}(t) = \frac{\mathrm{DP}(t)}{\mathrm{SP}(t)} = \frac{\int_{E(t)}^{\omega} P(x,t)\mathrm{d}x}{\int_{S}^{E(t)} P(x,t)\mathrm{d}x}$$

where $t$ is time, $E(t)$ is the equivalent age at time $t$ (here set to 2017). $\mathrm{DP}(t)$ is the dependent population at time $t$ calculated by summing the population $P(x,t)$ over ages $E(t)$ to (maximum lifespan). $\mathrm{SP}(t)$ is the supporting population at time $t$, which is the population from age $S$ (the age at which a person is presumed to begin fulfilling a supporting role, here set to age 20 years) to $E(t)$. A higher HADR score implies that a country has more individuals in poor health relative to the disease burden of a global average 65-year-old, accounting for chronological age distributions. The calculation of the HADR for selected countries is shown in the appendix (p 7).

We used the UN Population Division data to calculate OADR as the ratio of the number of people aged 65 years or older to the number of people aged 20–64 years for each country.

Data on total, inflation adjusted per capita health expenditure (inclusive of government, donor, and private spending) measured in US$ in 2017 and 2019 were extracted from the Institute for Health Metrics and Evaluation Financing Global Health 2020 database.[22]

## Data analysis

We computed and descriptively compared the HADR and OADR indices by country, world region, and selected major economies (South Africa, Brazil, Indonesia, China, Japan, India, USA, EU, and Russia). To test the predictive validity of HADR, we separately used simple linear

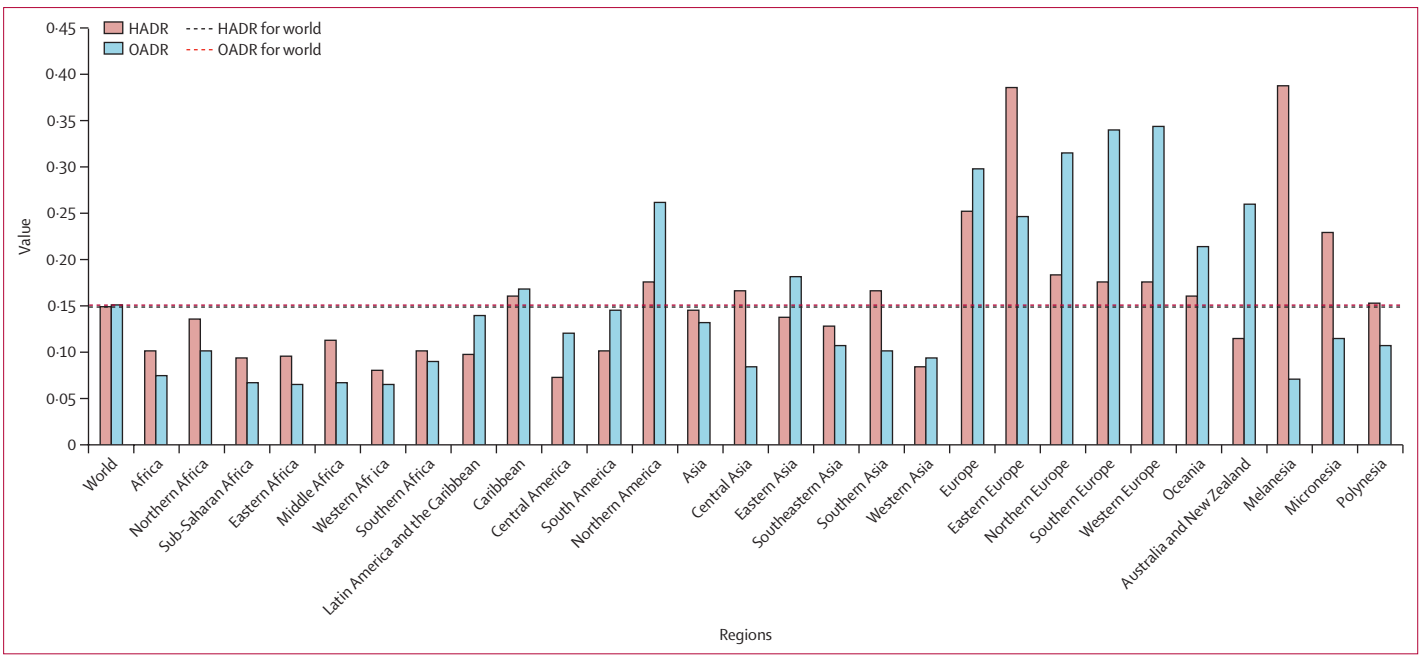


***Figure 4:*** **HADR and OADR by world region**
Higher values indicate higher ageing burden. HADR=health-adjusted dependency ratio. OADR=old-age dependency ratio.

regression and regressed the percentage change in health expenditure estimates between 2017 and 2019 on HADR and OADR. Data analysis was done using Stata/SE (version 15.1).

### Role of the funding source

There was no funding source for this study.

## Results

In 2017, Japan had the highest OADR (0·49), followed by the selected countries in western Europe (with OADR>0·32; figure 1). Oceania, USA, Canada, Uruguay, China, South Korea, Thailand, the countries in eastern Europe had somewhat lower, but still relatively high OADRs (OADR>0·24). According to the OADR, these countries therefore had the highest burden of ageing. The countries with the lowest OADR were in the Middle East and Africa (OADR≤0·08).

Figure 2 shows the HADR across countries in 2017. Relative to the OADR, the HADR implies that Asia, western Europe, and North America had a lower ageing burden, whereas central Asia, southern Asia, and Africa had a greater burden. While Japan and the countries in western Europe had the highest OADR, Russia, Papua New Guinea, and countries in southeast Europe had the highest HADR.

HADR and OADR for all countries and a basic comparison of the HADR and OADR level and rank order are shown in the appendix (pp 2–6). Some countries had a low OADR but relatively high HADR, such as Afghanistan (OADR 0·06; HADR 0·21), Central African Republic (0·07; 0·2), Egypt (0·10; 0·19), India (0·10; 0·18), Pakistan (0·09; 0·19), Madagascar (0·07; 0·16), Mongolia (0·07; 0·19), and Somalia (0·07; 0·17). Other countries had a relatively low HADR, but relatively high OADR, such as Australia (OADR 0·26; HADR 0·11), Canada (0·27; 0·12), China (0·16; 0·14), France (0·35; 0·13), Japan (0·49; 0·17), Norway (0·28; 0·13), Portugal (0·36; 0·17), Singapore (0·15; 0·04), Switzerland (0·3; 0·11), and the USA (0·26; 0·18).

The HADR and OADR in selected major economies are shown in figure 3 and the HADR and OADR in selected world regions are shown in figure 4. Among major world economies (EU, China, USA, India, and Japan), Japan had the highest ageing burden according to the OADR but a similar ageing burden, compared to other major economies, according to the HADR.

The relationship between OADR and HADR across all countries and seven world regions is shown in figure 5. Comparison of central eastern Europe with western Europe provides a particularly pertinent example of how accounting for the ageing-related health of the adult population produces a very different picture of the ageing burden between different regions compared with a burden based on chronological age. Despite having a similar OADR (central eastern Europe was 0·27; rest of Europe was 0·32), the mean HADR for central eastern Europe (0·33) was more than double that of the rest of Europe (0·15).

Results of the regression analyses showed that the HADR was more closely associated with growth in health spending between 2017 and 2019 than the OADR. A 0·1 increase in the HADR was associated with a 2·9 percentage points larger growth rate in per capita spending ($p<0·0001$), and a 0·1-point increase in the OADR was

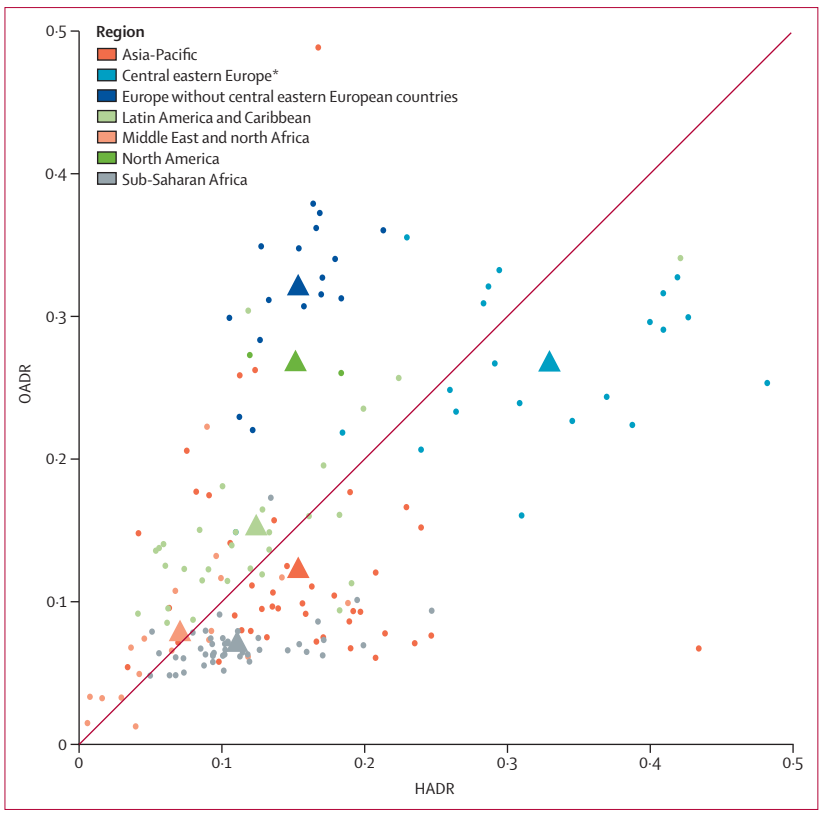


***Figure 5:*** **Relationship between OADR and HADR in seven world regions**
Higher values indicate higher ageing burden. Circles represent countries and triangles represent word regions. *The central eastern European countries are Albania, Bosnia and Herzegovina, Bulgaria, Belarus, Croatia, Czech Republic, Slovenia, Estonia, Georgia, Hungary, Latvia, Lithuania, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Ukraine, and North Macedonia. HADR=health-adjusted dependency ratio. OADR=old-age dependency ratio.

associated with a 1·8 percentage point larger growth rate and also included more uncertainty (p=0·009).

## Discussion

Population ageing has resulted in widespread concerns about the potential effect of rising ageing-related dependency.[3,23,24] Our study provides a potentially more relevant measure of the burden of ageing than the metrics usually employed by accounting for ageing-related health of a population. Our study reveals that many countries with chronologically older populations, such as Japan and the Netherlands, in fact have a lower ageing burden because the onset of ageing-related disease occurs later. At the same time, many countries with a younger age structure, such as Indonesia and Lesotho, have a greater ageing burden because the onset of ageing-related disease occurs earlier. Overall, the differences between countries, regions, and the world's major economies tend to be smaller when using the HADR than the OADR. Our results point to the ambiguity of defining the point at which old age begins and the need to address perceptions (and misperceptions) of old age and ageing.[25,26]

The HADR measure accounts for variation in both ageing-related health and demographic age structures across countries. The HADR metric thus captures ageing-related dependency in a more relevant manner than the OADR and other indicators that use a fixed and universal chronological age threshold as a proxy for dependency. Our study suggests that high fertility rates and young age structures are no guarantee that a population is healthy and productive since the health of the adult population tends to be worse and ageing-related disease burden tends to occur earlier in life in many populations with younger ages structures. For instance, Japan has the oldest age structure in the world, but also one of the healthiest older populations. The Japanese HADR was therefore only slightly higher than the world mean OADR (0·17 *vs* 0·15), and was quite similar to that of countries with much younger age structures (eg, India with an HADR of 0·18). The HADR for Latin America was the same as that for Africa (0·10), even though Latin America had a much older demographic age structure. The demographically oldest world region, western Europe, had an OADR of 0·34, and the youngest, sub-Saharan Africa, had an OADR of 0·07; a discrepancy of 0·28. However, the HADR of western Europe was 0·18 and sub-Saharan Africa was 0·10 (a difference of just 0·08), just a quarter of what the OADR would suggest. Thus, according to the HADR, most of Africa (and also Asia) has an ageing burden similar to that of western Europe, despite having chronologically much younger populations. The observation that western Europe, Singapore, Japan, Israel, and South Korea have a relatively low HADR, despite having a relatively high OADR, can be explained by better ageing-related health in those countries.[21]

Population ageing is inevitable. The HADR can help countries to plan, develop, and implement ageing-related policies that effectively address the challenges of population ageing. There is a strong need to delay, prevent, and treat ageing-related diseases to lower the burden of ageing, particularly in world regions such as southern Asia and eastern Europe, where demographic ageing and poor age-specific health occurs at the same time, implying high HADR levels. Also, Papua New Guinea had a very high HADR (0·43), despite having a young age structure. Some countries are affected by both demographic ageing as well as high ageing-related disease burden, such as Russia and several countries in eastern Europe. For these countries, the high HADR reflects the combined effect of older age structures and relatively early onset of ageing-related disease.

Policies should incentivise lifestyles that reduce the risks and delay the onset of common non-communicable diseases that play an increasing role in ageing-related disease burden.[20] In particular, strengthening health care, promoting healthy lifestyles, and raising education levels can promote better health in old age.[27,28] Delaying the onset of more severe ageing-related disease burden would have

a critical effect on the health-care system and economy, and would decrease the challenges of population ageing for health care and social security systems. In countries with a relatively high HADR but relatively low OADR (eg, India) there might be potential of reducing future ageing burden by investing in adult health.

We found that the HADR was more predictive of changes in health-care spending than the OADR. Health spending is projected to increase in most countries globally and is expected to exceed 10% of the economy in many countries by 2050. Improving ageing-related health could not only prevent increases in health-care costs, but also enable more people to productively contribute to the economy for longer.

The HADR does not consider youth dependency (ie, the population younger than 20 years) and considers only ageing-related disease burden as a proxy of dependency. The HADR does not consider other indicators of dependency such as economic activity, income, functional health, or need for care. We were unable to calculate the HADR for 3·7% of the world's population due to missing health, demographic, or both kinds of data. Moreover, we did not address the reasons for differences in the HADRs across countries.

Our study has revealed that demographic ageing itself does not necessarily lead to higher ageing-related dependency ratios. Moreover, differences in the burden of ageing across world regions are much lower, according to the HADR, than have been assumed thus far. Our results clearly demonstrate that even chronologically younger populations can have a high ageing-related burden. All nations are ageing, and demographic ageing will occur more rapidly in world regions with demographically younger populations. Rapidly ageing regions urgently need to improve ageing-related health.

#### Contributors

VS had the idea for this study and AYC, JLD, VS, MS, and ST wrote the paper and carried out revisions. VS, AYC, JLD, KF, and MS accessed and verified the data. All authors had full access to all of the data. The corresponding author had the final responsibility to submit for publication.

#### Declaration of interests

We declare no competing interests.

#### Data sharing

All study data are publicly available from the UN Population Division (https://population.un.org/wpp/) and from the Global Burden of Disease project (https://www.healthdata.org/gbd/2019) from the Institute for Health Metrics Evaluation.

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