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Using grip strength to compute physical health-adjusted old age dependency ratios

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ABSTRACT

The standard approach for comparing the potential challenges of population aging across countries based on conventional old-age dependency ratios (OADR) does not account for cross-population differences in health, functional capacity or disability, despite their importance for labor force participation and dependency more broadly. We investigate how OADRs observed across selected low-, middle-, and high-income countries change if population differences in physical health measured by hand-grip strength are accounted for. Specifically, we propose and calculate an adjusted measure of the OADR based on hand-grip strength, which serves as an objective indicator of muscle function and has been shown to predict future morbidity, disability and mortality. We show that adjusting the OADR for differences in hand-grip strength results in substantial changes in country rankings by OADR compared to a ranking based on the conventional OADR definition. Accounting for cross-population differences in hand-grip strength, the estimated OADRs for low- and middle-income countries tend to increase compared to the conventional OADR approach based on age only, whereas the estimated OADRs in high-income countries decline substantially relative to the standard approach. Since hand-grip strength is an important prerequisite for maintaining functional capacity and productivity and preventing disability—especially in economies in low-income settings—our grip-strength-adjusted OADRs clearly show that population aging is not just a challenge in high-income countries but also an important concern for economies in the developing world.

1. Introduction

Many populations across the world are rapidly aging. Although there are substantial cross-national differences in its pace and extent, population aging represents a largely universal phenomenon that occurs in populations across the entire spectrum of economic development ranging from high-income to low-income countries/regions (Bloom, Canning, & Lubet, 2015; Bloom et al., 2015; Chan, Saito, & Robine, 2016; Chan et al., 2016; Gavrilov & Heuveline, 2003; World Health Organization, 2015b). Global population aging is thereby not a stand-alone phenomenon, but has a wide range of consequences for labor markets (Bloom, Canning, & Fink, 2010; Börsch-Supan, 2003), pension systems (Bloom, Boersch-Supan, McGee, & Seike, 2011; Bongaarts, 2004; Kudrin & Gurvich, 2012), the health care sectors (Dall et al., 2013; de Meijer, Wouterse, Polder, & Koopmanschap, 2013) and

many other economic and social institutions, social aspects such as intergenerational relationships (Bowers, 1987; Lee & Mason, 2011; Payne, Pesando, & Kohler, 2019; Zhang & Xiang, 2014) or the ongoing evolution of economic and social roles and responsibilities of older generations (Johnson, 2015; Vidovicová, 2018).

Old-age dependency ratios (OADRs) represent important demographic indicators for potential old-age-related challenges and opportunities in a given population. In its conventional form, the OADR is computed as the share of the population aged 65 and older relative to the share of the working age population aged 15 to 64. While the so computed conventional OADR is most useful for assessing the implications of demographic aging on social programs, for which uptake is primarily based on age, it is less practical to evaluate the challenges and opportunities of population aging in general.

In particular, an increasing number of social programs worldwide are

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using alternatives to chronological age of 65 years as a threshold to define “old age” (Hudson, 2010; Wiatrowski, 2001), which tends to make the conventional OADR more arbitrary. Specifically, in view of other major demographic trends such as continuous improvements in population health and raising female labor force participation, it is rather unclear whether the conventional OADR that is solely based on chronological age is a particularly useful indicator for comparing the challenges and opportunities of population aging across countries or different points in time. This criticism of the OADR is not new, and the basic alternative approach of measuring age as remaining life years, rather than chronologically since birth, has its origin in Ryder (1975, pp. 3–28). More recent approaches have been proposed to expand this insight and also account for certain simultaneous health, economic and social trends. The goal of these newly proposed measures is to move to a more dynamic, and often health- and/or economic status-dependent definition of “old-age dependency” that explicitly accounts for population differences in longevity, remaining life expectancy and mortality (Sanderson, Scherbov, Weber, & Bordone, 2016; Sanderson & Scherbov, 2013; Scherbov & Sanderson, 2016), human capital (Skirbekk, Staudinger, & Cohen, 2019), intergenerational transfers and national transfer accounts (Lee & Mason, 2014; Mason & Lee, 2018, 2011) or economic status such as labor market participation (Bussolo, Koettl, & Sinnott, 2018; Koettl, 2015).

A set of recent studies have measured aging by introducing health-based aging metric that not only incorporates longevity but also health status and diseases severity on the population level (Chang, Skirbekk, Tyrovolas, Kassebaum, & Dieleman, 2019; de la Fuente et al., 2018; Lowsky, Olshansky, Bhattacharya, & Goldman, 2013) use the Global Burden of Diseases, Injuries, and Risk Factors Study 2017 to calculate the ages at which age-related diseases start to accumulate and assess country differences in the onsets of aging burden. They find substantial variations in the onsets and patterns of accumulating age-related disease burden even among countries with similar age-standardized death rates. They do however not study the implications of these country variations in health-based aging on the old-age dependency ratio as the present study does. These new approaches are specifically relevant in the case of low- and middle-income countries (LMICs), where more sophisticated measures of intergenerational dependency and population aging often cannot be computed due to serious data limitations, or lack of thereof, and as a result better and more innovative comparisons of population aging trends with data-rich High Income Countries (HICs) or regions are limited.

The purpose of this paper is twofold. First, we use a range of surveys on aging from the wider international family of “Health and Retirement Studies” to document variation in physical health as measured by hand-grip strength across countries with different levels of economic development. In particular, we highlight major differences in older adults’ physical health across low-income, middle-income and high-income countries that are likely to be relevant for assessing key challenges associated with population aging such as physical health and functioning at older ages. We then study the implications of these population-level differences in physical health for estimating OADRs. We argue that adjustments for differences in physical health across populations may be especially important when comparing the demographic challenges resulting from population aging in middle- and low-income countries/regions, where persistent differences in physical health and declines of physical health with age represent a key dimension and driving force of the burden of population aging and intergenerational dependency. As illustrated below, the burden of diseases and thereof prevalence of physical disabilities in LMICs are substantially higher compared to developed economies, resulting in lower economic productivity and higher dependence on social and familial transfers (Köhler, Köhler, Anglewicz, & Behrman, 2012; Payne, Pesando, & Köhler, 2019; World Health Organization, 2015b).

1.1. Link between physical health and working status in LMICs and HICs

To illustrate this key difference in the relationship between physical health and working status observed between LMICs and HICs, we compare in Fig. 1 the rates of working and disabled individuals by age in Malawi, a LIC in sub-Saharan Africa, China, a middle-income country (MIC), the USA and North/Western Europe, with the latter representing high-income economies with different labor market and pension system characteristics. We use measured grip strength to define disability status in Fig. 1. Men with a maximum hand grip strength below 30 and women with a maximum hand grip strength below 20 are classified as disabled. These cutoffs correspond to diagnostic thresholds that best identify persons who are subject to sarcopenia and mobility limitations (for further discussion see Section 2.2). We also define country/region-specific work status to account for differences across the countries/regions. Specifically, work status in MLSFH-MAC is determined by whether respondents spent at least 10 h in salaried employment, paid agricultural wage labor, other work to earn income, such as handicraft production, transporting goods, etc., or in doing unpaid work for their own household farm during the last completed weeks. Work status in CHARLS is determined by whether respondents worked for at least 1 h over the past week (to earn a wage, run own business and unpaid family business work etc.) or engaged for more than 10 days in agricultural work in the past year. Work status in the HRS and SHARE is based on a question asking respondents about their current employment situation. We considered respondents as working if they were “working now/employed/self-employed” or “unemployed and looking for work”.

Fig. 1 illustrates that chronological age is a strong predictor of working status irrespective of physical health/disability status. This is particularly the case in HICs, especially in North/Western Europe, where pension systems are characterized by strong public sector involvement providing old-age security and also early retirement, and has a redistributive element where persons who have only accrued small pensions can receive a higher benefit (Mayrhuber et al., 2011). Specifically, the rate of the working population in North/Western Europe and the USA declines sharply after age 50, even though very modest disability rates are observed in the same age groups. In sharp contrast, individuals in Malawi maintain high rates of work until late in life, when the disability rate increases sharply with age. In addition, Fig. 1 clearly shows that the rate of disabled individuals is increasing with age in all regions/countries considered, however, this rate is more than twice higher in Malawi at age 50, and the increase in the rate of disabled population with age is substantially steeper compared to North/Western Europe and the USA. The patterns for China, a MIC, falls in-between the ones observed for North/Western Europe and USA and Malawi. The age gradient in work participation is steeper in China than in Malawi but not as steep as the one in North/Western Europe and the USA. Age per se in China therefore does not predict work participation as well as in HICs. What appears to be the driver of work status in China however is physical disability, as one can see that, unlike in HICs, work participation decreases as physical disability increases, as it is the case in Malawi. These broad patterns in the relationship between work status and physical disability are broadly similar for both men and women, as evidenced in Figure A1 in the Online Appendix A.1.

The main insight illustrated in Fig. 1 is that the relationship between physical health and work status above age 50 is different in LMICs vs HICs. Specifically, in a low-income context such as Malawi, physical health (e.g., disability status) predicts work status much better than chronological age, and individuals withdraw from active labor force participation because of physical health limitations rather than because of getting old per se. While in Malawi and China we have very detailed data, the general pattern about labor force participation, and possibly also health at older ages, are likely to be generalizable to other LMICs. The work-health relationship shows a much stronger gradient in the low- and middle-income context of Malawi and China than in the USA and North/Western Europe, where work status above age 50 is primarily

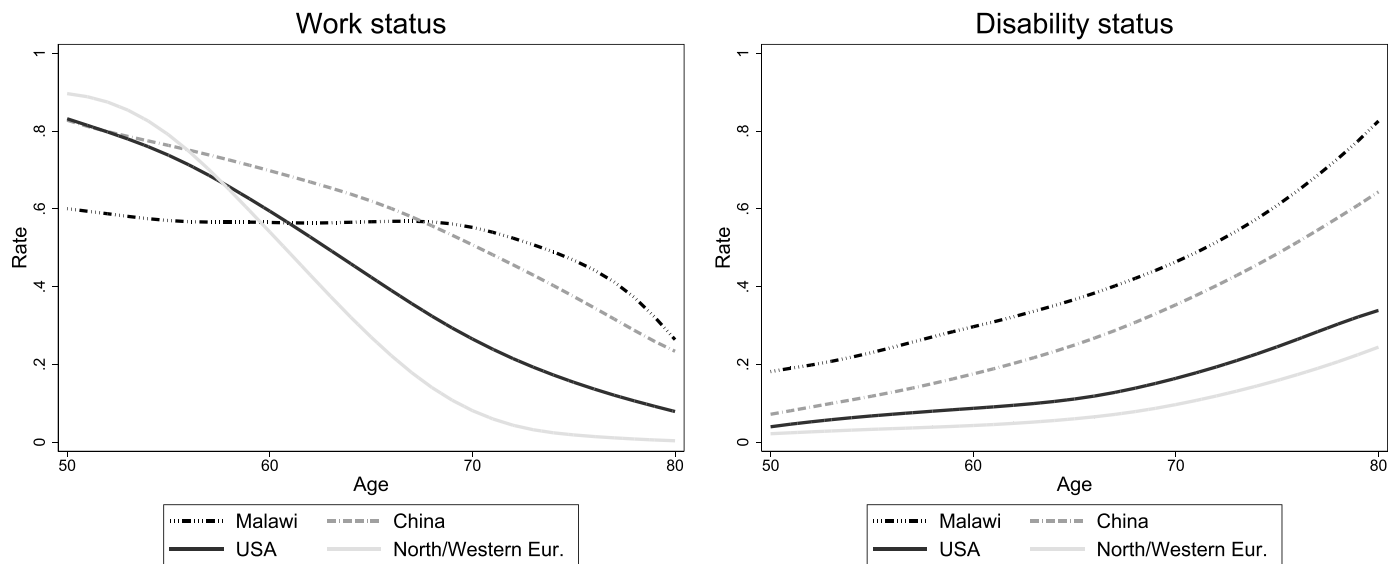


Fig. 1. Differences in the rate of individuals who are working (left) and who are disabled (right), by age.

Note: The Malawi data come from the “Mature Adults Cohort of the Malawi Longitudinal Study of Families and Health (MLSFH–MAC)” (2017) (Kohler et al., 2020). The China data come from the “China Health and Retirement Study (CHARLS)” (2015) (Zhao, Hu, Smith, Strauss, & Yang, 2012). The USA data come from the “Health and Retirement Study” (2010) (Sonnega et al., 2014). The North/Western Europe data, which comprise Austria, Belgium, Switzerland, Germany, Denmark, France, Luxembourg and Sweden come from the “Survey of Health, Aging and Retirement in Europe (SHARE)” (2015) (Börsch-Supan et al., 2013). Disabled individuals are defined as those with a maximum hand-grip strength below 30 for men and 20 for women. Work status in MLSFH–MAC is determined by whether respondents spent at least 10 h in salaried employment, paid agricultural wage labor, other work to earn income, such as handicraft production, transporting goods, etc., or in doing unpaid work for their own household farm during the last completed weeks. Work status in CHARLS is determined by whether respondents worked for at least 1 h over the past week (to earn a wage, run own business and unpaid family business work etc.) or engaged for more than 10 days in agricultural work in the past year. Work status in the HRS and SHARE is based on a question asking respondents about their current employment situation. We considered respondents as working if they were “working now/employed/self-employed” or “unemployed and looking for work”.

determined by chronological age. This difference in the relationship between work and physical health status represents an important contrast between LMICs and HICs and motivates the present analysis. Specifically, we investigate how differences in physical health and functional limitations (i.e., disability status) observed at older ages across countries along the development spectrum impact estimates of OADRs. We present evidence that it is important to adjust the OADRs by incorporating physical health and functioning into the estimates to better reflect health differences across populations and the fact that in LMICs, where manual labor is widely prominent, participation in the labor force is largely dependent on health status and functioning rather than on chronological age and/or social welfare or retirement benefits entitlement rules (International Labor Organization, 2014).

2. Material and methods

2.1. Data

Our analysis focuses on a diverse set of countries along the social, economic and human development spectrum. We utilize data from well-established aging studies that have collected measurements of grip strength following comparable study protocols using the procedures developed by the “Health and Retirement Study (HRS)” in the U.S. as the standard for these studies (Kwon & Hu, 2018; Survey Research Center, 2004; World Health Organization, 2006). The following data sources have been used for this analysis: HRS for the United States, the “Mature Adults Cohort of the Malawi Longitudinal Study of Families and Health (MLSFH–MAC)” for Malawi, the CRNS Heidelberg Aging Study (CHAS) in Burkina Faso, the “Survey of Health, Aging and Retirement in Europe (SHARE)” for northern/western, southern and eastern European countries, the “China Health and Retirement Study (CHARLS)”, the “Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI)” for South Africa and the “Mexican Health and Aging Study (MHAS)” for Mexico. We use the

“WHO Study on global AGEing and adult health (SAGE)” data to estimate the patterns of grip strength for Ghana, India and Russia.¹

Table 1 summarizes the main characteristics of the data used in this study. To account for notable demographic, social and economic differences between countries, we define three European regions and we group the data for several countries: North/Western Europe, Southern Europe and Eastern Europe. Our study sample consists of 99,915 observations across all countries considered in this analysis. Once weighted, our study sample represents a total population of about 753.4 million individuals.²

Finally, we use data from the World Population Prospects (2017 Revision) (United Nations, 2017) to obtain the age-group and sex-specific population counts by region/country to compute and compare the conventional and adjusted OADRs (see Section 2.3).

2.2. Measurement of physical health

While physical health and functioning can be conceptualized and measured in different ways, their comparison across populations and context requires a common *measured* indicator that is objective and has followed similar measurement protocols.

In the present analysis, we use hand-grip strength as measured (rather than self-reported) indicator for physical health and functioning

¹ Details on these studies can be found on the following website: SAGE <https://www.who.int/healthinfo/sage/en/>, HRS <https://hrs.isr.umich.edu/about>, SHARE <http://www.share-project.org/home0.html>, MHAS <http://www.mhasweb.org/>, CHARLS <http://charls.pku.edu.cn/>, MLSFH-MAC <https://malawi.pop.upenn.edu/>, CHAS (Witham et al., 2019) and HAALSI <https://haalsi.org/>.

² Note that weights are not available for the MLSFH, HAALSI and CHAS data.

Table 1
Descriptive statistics of our study samples.

Region/Country	Dataset	Years	Number of obs.	Women (%)	Survey weights available
United States of America	HRS	2010	7913	56.8	yes
North/Western Europe	SHARE	2015	26,142	54.5	yes
Southern Europe	SHARE	2015	15,940	54.4	yes
Eastern Europe	SHARE	2015	16,260	59.1	yes
Russia	SAGE	2007–2010	3007	63.0	yes
Mexico	MHAS	2012	1867	58.4	yes
China	CHARLS	2015	12,377	51.7	yes
India	SAGE	2007	6029	48.6	yes
Ghana	SAGE	2007–2008	3898	45.7	yes
Malawi	MLSFH–MAC	2017	1114	58.8	no
Burkina Faso	CHAS	2018	1656	54.6	no
South Africa	HAALSI	2014–2015	3712	53.4	no

Note: North/Western Europe comprises Austria, Belgium, Switzerland, Germany, Denmark, France, Luxembourg and Sweden. Southern Europe comprises Spain, Italy, Israel, Greece and Portugal. Eastern Europe comprises Croatia, Poland, Czech Republic, Slovenia and Estonia. Our sample is restricted to individuals with valid measures of grip strength as explained in the text and to those who are 50 and above. Once weighted, our study sample represents a total population of about 753.4 million individuals (note that sample weights are not available for the MLSFH-MAC, HAALSI and CHAS data).

that is widely available and collected following standard procedures in aging studies across the globe.³ Hand-grip strength is a measured marker of physical health (more precisely it measures upper body strength) that has been shown to be related to physical performance in a wide range of day-to-day tasks. Moreover, hand-grip strength has been consistently shown to be predictive for future mobility decline, disability and mortality (Cooper et al., 2010; Giampaoli et al., 1999; Hicks et al., 2011; Rantanen et al., 2000, 1999; Sallinen et al., 2010; Sasaki, Kasagi, Yamada, & Fujita, 2007; Syddall, Cooper, Martin, Briggs, & Aihie Sayer, 2003; Taekema, Gussekloo, Maier, Westendorp, & de Craen, 2010). These associations of hand-grip strength with health outcomes have been shown for younger and older individuals and in many different contexts and settings (developed and developing countries, community-dwelling populations, etc.). As a result, hand-grip strength as a reliable measured indicator of physical health has been collected in many well-established aging studies across the globe, thus allowing comparative analyses of a widely accepted measured indicator of physical health and aging across a wide range of countries^{4,5}.

We use hand-grip strength as an indicator of physical health across

³ Unlike walking speed tests for which measurement protocols and measurement units vary across some aging studies, hand-grip strength has the attractive feature that the method used for its measurement is standardized and directly comparable across studies.

⁴ A related question of broad interest pertains to whether long-term changes in the association between grip strength and subsequent health and mortality can be anticipated when countries move across the development spectrum and experience mortality decline. Because of the lack of longitudinal data in grip strength across populations, historical trends in this association cannot be established, and there are no reliable estimates of how the association between grip strength and subsequent health and mortality changes as countries experience mortality decline. Estimates based on the longitudinal MLSFH-MAC show that hand-grip strength predicts mortality in a very poor context that has experienced significant increases in life expectancy within a 10 year period. Hence, the association between grip strength and subsequent health and mortality that has been documented in high-income countries holds in at least one low-income country. While it is difficult to generalize based on a single low-income country dataset, these results suggest that hand-grip strength is predictive of health and mortality across the development spectrum.

⁵ Note that we use absolute measure of grip strength in our analysis because the cutoffs we use to determine the disability status of the individuals are based on absolute measures of grip strength. An alternative approach proposed by Choquette et al. (2010); Lawman et al. (2016) is to use relative grip strength with respect to BMI (i.e., grip strength divided by BMI), which is considered a measure of cardiovascular health. Figure A2 in the Online Appendix A.2 shows that using relative grip strength with respect to BMI yields very similar age patterns across countries/regions.

populations by computing the maximum measurement of hand-grip strength obtained by the respondents in the respective studies using their dominant hand, assuming that at least two measurements were recorded for the dominant hand and the difference between these two measurements was no larger than 20 kg (Andersen-Ranberg, Petersen, Frederiksen, Mackenbach, & Christensen, 2009; Frederiksen et al., 2006).⁶ For those who were ambidextrous, we consider the maximum of the four measurements assuming that four measurements were recorded for these individuals and we excluded those for which the difference was greater than 20 kg in the two measurements of the hand for which the highest score was recorded. Following prior research (Bertoni, Maggi, & Weber, 2018), we define observations corresponding to the top and bottom 1% of the hand-grip strength measurement in each country/r-region as outliers and remove them from the analysis.⁷

Using respondent's hand-grip strength values, we then compute the percentages of individuals aged 50 years and older in a given country/region who have their measured hand-grip strength below the grip strength threshold used for the diagnosis of sarcopenia, a syndrome characterized by a degenerative loss of skeletal muscle and strength associated with aging and risk of adverse outcomes such as physical disability (Delmonico et al., 2007; Goodpaster et al., 2006). Following the definition of "The European Working Group on Sarcopenia in Older People (EWGSOP)", we define the value of these thresholds as 20 kg for women and 30 kg for men (see Cruz-Jentoft et al. (2010) for more details). These thresholds were identified by Lauretani et al. (2003) as the diagnostic thresholds in hand-grip strength that best identify individuals subject to sarcopenia and mobility limitation, irrespective of whether mobility limitation was defined in terms of low walking speed (<0.8 m/s) or in self-reported inability to walk for 1 km.⁸ We show in the Online Appendix A.4 and A.5 that our results are robust to using 28 or 32 and 18 or 22 as thresholds for men and women, respectively.

2.3. Method and calculation of the hand-grip strength-adjusted OADR (HGSA-OADR)

We first document the variation in physical health as measured by hand-grip strength across countries with different levels of economic

⁶ In their meta-analysis on the link between physical capability and mortality, Cooper et al. (2010) found that most studies tend to use maximum value of hand-grip strength measurement in their analysis.

⁷ Sensitivity analysis presented in the Online Appendix shows that including those outliers in our analysis does not affect the results (see Online Appendix A.3).

⁸ These results were derived using Receiver Operating Characteristics (ROC) analysis and data from Italy.

development. More specifically, we compute age-, sex- and country/regions-specific weighted means of maximum hand-grip strength and perform sex- and country/region-specific locally weighted regressions of these weighted means on age.⁹

We then compute and compare conventional OADR and hand-grip strength-adjusted OADR (HGSA-OADR) by adapting the methodology of Skirbekk, Loichinger, and Weber (2012) for computing cognition-adjusted OADRs.

The conventional OADR is usually computed as follows:

$$OADR_i = \frac{|men_{65+,i}| + |women_{65+,i}|}{|men_{15-64,i}| + |women_{15-64,i}|} \quad (1)$$

where *OADR* stands for the conventional old age-dependency ratio, *i* the name of the region/country under consideration, and *|·|* represents population size of the corresponding group.

We adjust the measurement of the old age-dependency ratio by considering the region/country- and sex-specific rates of individuals who are limited in their physical health and functioning as indicated by low levels of hand-grip strength, following a similar approach as Skirbekk et al. (2012). Specifically, our proposed adjusted OADR takes into account the sex- and region/country-specific rates of individuals above 50 years old with physical health limitations above a certain threshold. Mathematically, our adjusted age dependency ratio HGSA-OADR takes the following form:

where *HGSA – OADR* stands for hand-grip strength-adjusted old age-dependency ratio, *i* the name of the region/country under consideration, *|·|* represents population size of the corresponding group and *r_{s,i}* the sex-specific rate of individuals aged 50+ who have physical health

$$HGSA - OADR_i = \frac{|men_{50+,i}| * r_{m,i} + |women_{50+,i}| * r_{f,i}}{|men_{15-49,i}| + |men_{50+,i}| * (1 - r_{m,i}) + |women_{15-49,i}| + |women_{50+,i}| * (1 - r_{f,i})} \quad (2)$$

limitations at a level that is lower than a specific threshold (as explained above), in region/country *i* with *m* and *f* representing men and women, respectively.

3. Results

Fig. 2 shows cross-country comparisons of hand-grip strength using age- and sex-specific weighted means by country/region¹⁰. For all regions and countries considered in our analysis, hand-grip strength is declining with age with a rate of decline that is roughly similar across countries. What is perhaps more surprising is the variation in the level of hand-grip strength across regions/countries as depicted in Fig. 2. For instance, at age 50, a man from Eastern Europe has on average a hand-

grip strength that is about 20 kg higher than a man of the same age in Malawi or India. The gap remains important as men and women age, although the difference is less pronounced at older ages¹¹

The horizontal solid black lines in the two panels of Fig. 2 represent the hand-grip strength level that predicts mobility limitations as defined in Bertoni et al. (2018) and Lauretani et al. (2003), and that corresponds to 30 kg for men and 20 kg for women. Fig. 2 shows that age-specific average hand-grip strength among men in high income regions/countries are well above the 30 cutoff at all ages below 80 years. Men from African countries and India however appear to have age-specific average hand-grip strength levels that are substantially closer to the critical cutoff at all ages and cross the cutoff well below age 80.

For women (lower panel of Fig. 2), we observe similar patterns as for men. The lines depicting hand-grip strength level in HICs and middle-income regions/countries on average cross the cutoff predicting physical limitations above ages 70+ years whereas women from Malawi and South Africa on average cross that threshold at around 70 and even earlier in India.

Fig. 2 may hide substantial heterogeneity within the same region/country and age group as the plots only represented age- and country/region-specific averages. In Fig. 3, we therefore plotted the weighted share of individuals in our study samples who have hand-grip strength level that is above the sex-specific thresholds derived by Lauretani et al. (2003) by region/country and age. Again, variations in these rates across regions/countries are quite remarkable across our three sets of regions/countries. While more than 95% of the men from Europe and the USA have hand-grip strength levels above the threshold, that is the case for about 60–80% of men in Ghana, Malawi, South Africa and India at the age of 50. These differences persist over time and men from HICs consistently measure on average higher hand-grip strength than men

from the other regions/countries considered in our analysis, at least up to 80 years old. Rates of women exhibit similar patterns to the ones of men: women from HICs also performed better in terms of hand-grip strength as compared to their counterparts from LMICs. It is interesting to note however that although these rates decline over time for both women and men and in all the regions/countries considered, the relative rate of decline of women with respect to men appears to be somewhat more pronounced in HICs than in LMICs.

Table 2 reports the values of the conventional OADR (computed using equation (1)) and the HGSA-OADR that adjusts for physical limitations (computed using equation (2)). We also report the corresponding ranks in these ratios of the regions/countries we consider in our analysis. The ranking of regions/countries by the conventional OADR reveals a close relationship between OADR and income level in a particular region/country: LICs have low dependency ratios whereas HICs have high

⁹ Weights were used when available.

¹⁰ Note that taking median values of hand-grip strength instead of mean values for each different category reveals very similar patterns.

¹¹ Several factors have been proposed to explain differences in grip strength across countries and individuals. Perhaps the most prominent one is related to the prenatal and natal environment. Birth weight, prepubertal and pubertal growth, earlier infant motor development strength for instance are associated with adult grip strength, even after controlling for later body size (Kuh et al., 2006; Sayer et al., 2008). Additional evidence shows that parental anthropometric characteristics also explain birth weight (Sayer et al., 2008), which suggests the presence of intergenerational transmission of physical health and hence possibly grip strength. Grip strength is almost certainly also shaped by patterns of physical activity/work during the life-course (e.g., agricultural vs non-agricultural work), and gender-differences in physical activity/work.

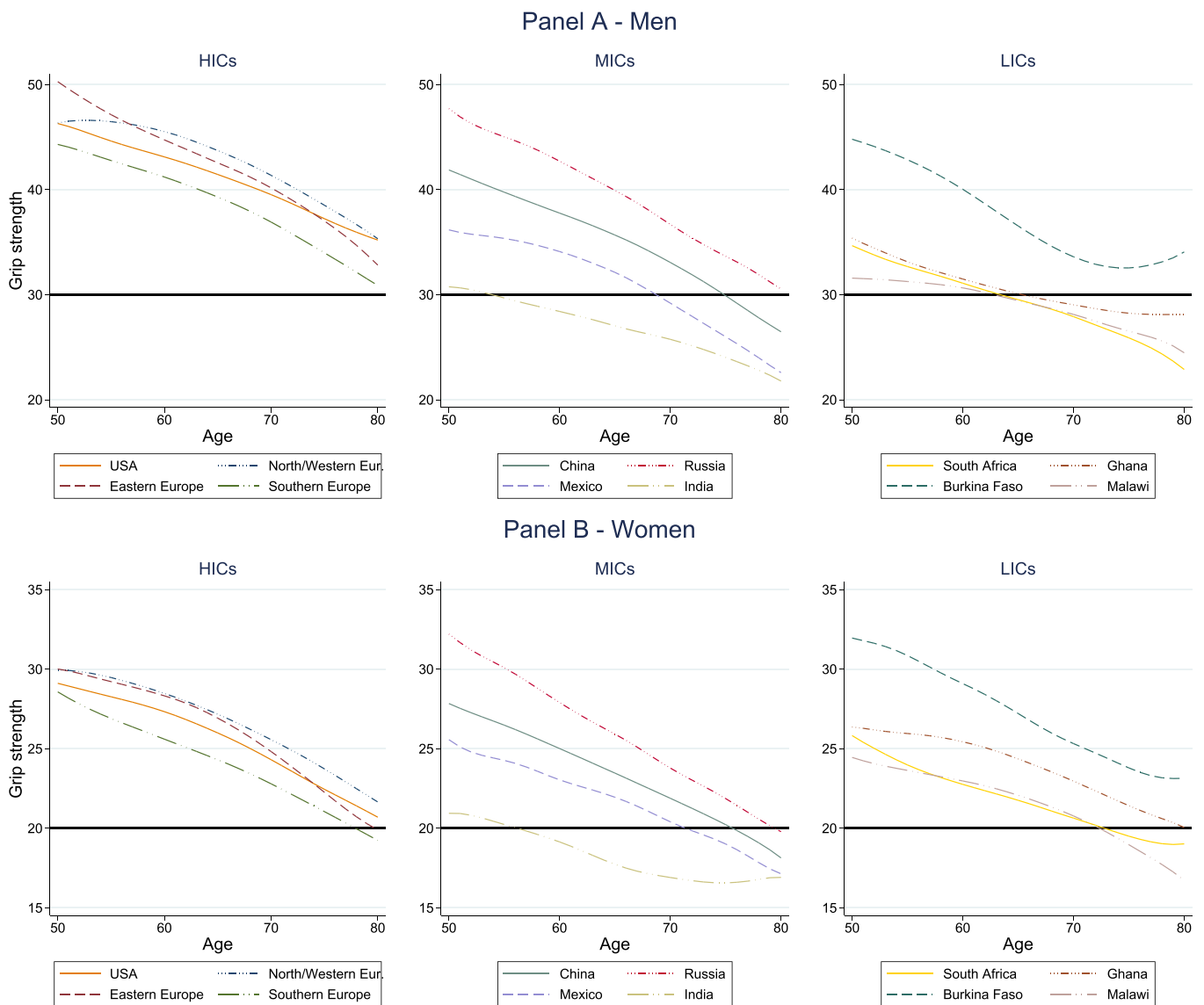


Fig. 2. Average maximum hand-grip strength measurements for men (first panel) and women (second panel) across regions/countries by age. *Note:* North/Western Europe comprises Austria, Belgium, Switzerland, Germany, Denmark, France, Luxembourg and Sweden. Southern Europe comprises Spain, Italy, Israel, Greece and Portugal. Eastern Europe comprises Croatia, Poland, Czech Republic, Slovenia and Estonia. [Table 1](#) describes in detail the dataset we use in our analysis. The horizontal solid black lines represent the hand-grip strength level that predicts mobility limitations as in [Lauretani et al. \(2003\)](#), which is equal to 30 for men (first panel) and 20 for women (second panel). Top and bottom 1% of hand-grip strength measurements in each country/region have been discarded.

dependency ratios. Middle Income countries like India, China and Russia stand in the middle.

The picture is somewhat different based on the HGSA-OADR that adjusts for regional and country-specific differences in physical health. Even though most of the LICs still have the lowest dependency ratio, one can see that the ranking between middle and high income countries changes quite substantially when considering differences in population health as estimated with the HGSA-OADR. More specifically, the European regions and the USA appear to have significantly lower age-dependency ratios when adjusting for physical health differences. On the other hand, India, South Africa and Ghana have their dependency ratios that increase, which is also reflected in their jump in the ranking by dependency. Comparing to other developed countries/regions, the USA and Southern Europe also experience a decrease in the adjusted dependency ratio, although that decrease is less pronounced, which explains a smaller jump towards the top rank.

[Fig. 4](#) illustrates the changes in the dependency ratios and

corresponding ranking after we adjust for physical health as measured by hand-grip strength. As clearly visible in [Fig. 4](#), developed countries (solid lines) do relatively well in terms of physical health as their dependency ratio significantly drops once we account for physical health differences. While some LMICs experience a small decrease in their ratios as compared to HICs (dashed lines), many of them see their dependency ratios increase. Our adjustment results in a convergence in the dependency ratios in which HICs are not in the top ranks anymore.¹²

4. Discussion

The wide use of the conventional OADR in the public discourse and

¹² Corresponding analyses when including outliers, defining cutoffs to be at 28 for men and 18 for women or 32 for men and 22 for women can be found in the Online Appendix Sections A.3, A.4 and A.5, respectively. Conclusions when departing from our benchmark analysis remain similar.

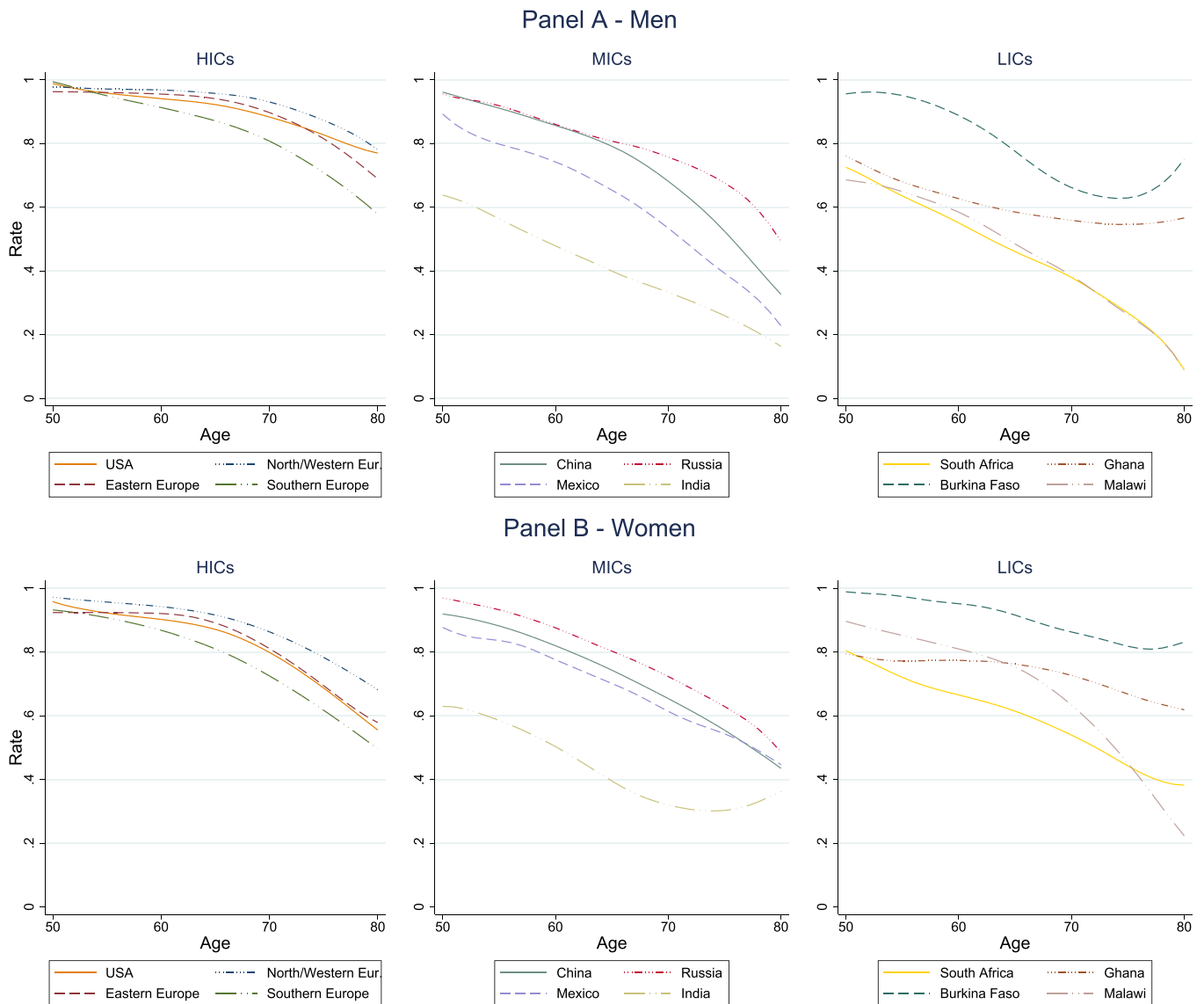


Fig. 3. Rate of men (first panel) and women (second panel) who have hand-grip strength level higher than the threshold by region/country and age category. *Note:* North/Western Europe comprises Austria, Belgium, Switzerland, Germany, Denmark, France, Luxembourg and Sweden. Southern Europe comprises Spain, Italy, Israel, Greece and Portugal. Eastern Europe comprises Croatia, Poland, Czech Republic, Slovenia and Estonia. [Table 1](#) describes in detail the dataset we use in our analysis. The rates correspond to the share of men and women who have a hand-grip strength level higher than 30 and 20, respectively. Top and bottom 1% of our measure of hand-grip strength in each country/region have been discarded.

by policy makers as an indicator of economic dependency and assessment of the pressure that labor markets and pension systems may face for supporting increasing numbers of older individuals across regions/countries has been legitimately questioned because of its methodological shortcomings. Specifically, the OADR only takes into account the age structure of populations and neglects the fact that populations around the globe differ by many other characteristics such as average physical health status, prevalence of disabling conditions, access to social and welfare systems, employment sectors and life expectancies.

The limitations of the conventional OADR measure based on chronological age are well known and recently several alternative characteristic-based measures capturing different dimensions of population aging have been proposed. For instance, the “prospective old-age dependency ratio (POADR)” is consistent with the idea that the onset of dependency may be delayed as life expectancy increases around the world ([Sanderson & Scherbov, 2005, 2010, 2015](#)). The “cognition-adjusted dependency ratio” takes into account differences in the age

profile of cognitive functioning and cognitive abilities across populations ([Skirbekk et al., 2012](#)). While undeniably important, this latter adjustment is less appropriate especially in the context of LICs, where manual labor is widely prominent and participation in the labor force depends to a large extent on the ability to perform high-intensity labor tasks that are strongly associated with and depend on physical health and functioning. Agriculture employment, for instance, was lower than 4% in HICs whereas it was as high as 26 and 65% in Middle- and Low-Income countries in 2018, respectively ([International Labor Organization, 2018](#)). And because formal retirement and pension systems do not exist in many LMICs ([Willmore, 2007](#)), older adults’ labor force participation in agriculture remains very high in these regions ([Martin & Kinsella, 1994](#)): male labor force participation for population aged 65 and over was about 54% in Africa whereas it was only about 8% in Europe in 2010 ([He, Goodkind, & Kowal, 2016](#)). Moreover, existing disparities in physical health status are among the most striking contrasts observed between populations in high-income economies versus

Table 2
Adjusted and conventional old age-dependency ratios.

Region	OADR	OADR rank	HGSA-OADR	HGSA-OADR rank	Δ ratio	Δ rank
Burkina Faso ^a	.046	1	.016	1	-.030	0
Malawi ^a	.057	2	.054	2	-.003	0
Ghana	.059	3	.064	5	+.005	+ 2
South Africa ^a	.077	4	.119	11	+.042	+ 7
India	.086	5	.152	12	+.066	+ 7
Mexico	.098	6	.088	9	-.010	+ 3
China	.133	7	.085	7	-.048	0
Russia	.194	8	.086	8	-.108	0
USA	.221	9	.068	6	-.153	-3
Eastern Europe	.240	10	.061	4	-.179	-6
North/Western Europe	.306	11	.059	3	-.247	-8
Southern Europe	.312	12	.114	10	-.198	-2

Note: Data from the World Population Prospects: The 2017 Revision. OADR stands for the conventional old age-dependency ratio and HGSA-OADR stands for hand-grip strength-adjusted old age-dependency ratio. ^a: no weight available. Top and bottom 1% of our measure of hand-grip strength in each country/region have been discarded.

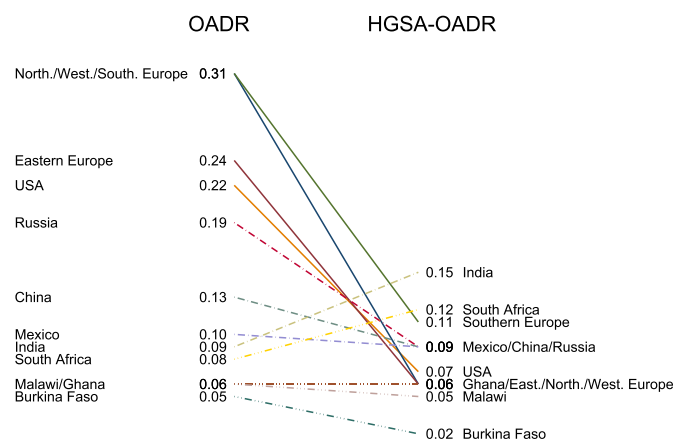


Fig. 4. Changes in the dependency ratios among the countries/regions in our sample after we adjust for physical health.

Note: North/Western Europe comprises Austria, Belgium, Switzerland, Germany, Denmark, France, Luxembourg and Sweden. Southern Europe comprises Spain, Italy, Israel, Greece and Portugal. Eastern Europe comprises Croatia, Poland, Czech Republic, Slovenia and Estonia. Table 1 describes in details about the datasets we use in our analysis. OADR stands for “old age-dependency ratio” as defined in equation (1) and AADR stands for “adjusted age-dependency ratio” as defined in equation (2). We used data from the World Population Prospects: The 2017 Revision to obtain the age-group and sex-specific population counts by country/regions.

LMICs (World Health Organization, 2015a, 2018). These differences in physical health status and prevalence of disability rates are in our opinion among the most prominent factors determining withdrawal from the labor markets, which, as our findings show, in LICs is driven by physical health rather than incentive structures (i.e., retirement benefits) such as in HICs.

To our best knowledge, no attempts have been made to adjust the OADR for important variations across regions/countries in the shares of populations with poor physical health and functioning, and high prevalence of mobility limitations, and are thus unable to work and actively participate in the labor force. We therefore propose a refined version of the age-dependency ratio that takes into consideration and adjusts for these differences in physical health and disability rates that are observed across populations around the globe.

Our results show that when adjusting for measured differences in physical health and functioning as measured by hand-grip strength, the ranking of countries based on their old-age dependency ratio shifts substantially: the adjusted HGSA-OADRs for LMICs increase, while they

greatly decline for high-income countries. These findings are of important policy relevance and illustrate clearly the contrast in the population aging patterns between LMICs and HICs. Our findings suggest that in LICs, and to some extent in MICs, work activity at older ages is related to health status, and the increase in the aging population in these countries translates into an increased dependency burden for which there is no easy public policy fix: the potential for “work at older ages” is limited by declines in physical health and increased prevalence of disability. This relationship between work and physical health status is much weaker in HICs and the results suggest that HICs at least in principal have options to deal with population aging and increasing dependency burden since withdrawal from the labor market seems to be driven by incentive structures rather than health per se. However, since physical health as measured by hand-grip strength is an important prerequisite for maintaining functional capacity and productivity and preventing disability—especially in economies in low-income settings—our grip-strength-adjusted OADRs clearly show that population aging is an important concern for rural economies in the developing world.

One of the potential limitations of our analysis is related to the measurement and comparability of physical health and disabilities. Cross-country analysis in health and functioning disability requires measured health indicator (rather than self-reported) that are comparable across countries and studies (Kämpfen, Wijemunige, & Evangelista, 2018). To assess differences in physical function impairment across countries, we use hand-grip strength, which is a well-known predictor of disability in older people (Giampaoli et al., 1999; Sallinen et al., 2010). While the rates of decline in hand-grip strength over age are relatively similar across countries in our analysis, we show that there are large variations in the level of hand-grip strength across countries and regions. These differences in hand-grip strength suggest that average disability rates among older populations could substantially vary across countries as well. However, there is no consensus or agreement about which hand-grip strength levels constitute a physical limitation. Our results are based on the assumption that the thresholds of the hand-grip strength measure we use are the ones that best predict physical limitations, irrespective of the specific countries/regions we are considering. These thresholds were derived using data from Italy and it is therefore possible that they do not reflect physical limitations in other countries/regions. While not completely arbitrary, these thresholds may therefore not be appropriate in some contexts. Related is the question if our country/region ranking will change if one were to consider a different age range, e.g. starting at age 45 instead of 50, as the earliest age to compute the rate of region/country- and sex-specific rate of disabled individuals as measured by grip strength. Our intuition is that a change in the age range will not have implications for our main findings. Indeed, as shown in Fig. 3, these rates appear to converge to 1 as age decreases and

reaches 50, at least in HMICs. The rates are therefore likely to plateau at younger ages. HMICs will therefore continue to perform relatively well as compared to LICs in terms of adjusted OADR whereas it will increase in LICs, as it is the case in our benchmark results. Hence, our country ranking is unlikely to be affected by grip strength differences before 50.

In addition, the cutoffs for grip strength we use to define physical limitations are only gender-specific. Ideally, the analysis would use cutoff points derived by age and gender, but at this time age- and gender-specific cutoffs in grip strength are not available. Assuming such age- and gender-specific cutoffs in grip strength would exist and be decreasing with age under the assumption that aging is accompanied by a decline in required physical strength, the use of age- and gender-specific cutoffs in grip strength will result in somewhat flatter curves in Fig. 3. The rates of individuals who have grip strength levels higher than their corresponding (age- and gender-specific) thresholds would however still follow the ranking of the countries/regions where LICs have the lowest levels of grip strength, followed by MICs and HICs. Therefore, we conclude that although a limitation, the use of gender-specific, but not age- and gender-specific, cutoff points of grip strength does not have implications on the general patterns and ranking of the countries/regions described in this analysis. An additional limitation is that individual weights are not available in all the countries and studies we consider. Results we derive using the MLSFH-MAC, CHAS and HAALSI datasets are therefore not representative of Malawi, Burkina Faso and South Africa, respectively. Differences in hand-grip strength measurement devices across studies (Kwon & Hu, 2018) can also potentially explain some of the variations we observe in our analysis. Data quality and harmonized approaches in data collections are therefore important issues that need to be kept in mind when interpreting our results.

5. Conclusion

A key message of our analysis is that there is a substantial difference in the work-age and work-health relationship between HICs and LMICs: in a first (and rough) approximation, in the former (HICs) age matters for work/labor force participation (70 years old individuals rarely work, irrespective of health status), while in the latter (LMICs), where informal labor market is still very high, health matters for work (70 years old work if they are healthy, but many 50 years old may not be productive due to poor physical health). The shifts in the ranking of countries based on the adjusted old-age dependency ratio suggest that the old-age dependence is driven by the interaction of “population-age and physical health” and this is particularly relevant for the LMICs, where fairly minor population aging translates into important dependency burden.

The results we derived based on our adjusted measure of the OADR that takes into account physical health and functional limitations as measured by hand-grip strength provide some nuanced insights on the comparison of the “real” dependency ratio across regions. Countries at different stage of economic development do not only differ in terms of age structure and population sizes, which are both indicators that are used to derive the original age-dependency ratio, but they also differ in terms of health and labor market characteristics. Because manual labor is widely prominent and participation in the labor force depends to a large extent on the ability to perform high-intensity labor tasks in LICs, our refined measure of dependency ratio that incorporates these elements therefore better reflects the real dependency ratio in these regions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2020.100579>.

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