Cohort Profile

Cohort Profile: The Ageing Trajectories of Health – Longitudinal Opportunities and Synergies (ATHLOS) project

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Why was the cohort set up?

The number of people aged 60 years or older is projected to significantly increase in the coming decades worldwide. According to United Nations estimates, this figure is expected to more than double by 2050 and to more than triple by 2100. Population ageing poses major challenges for the traditional social welfare state due to the greater needs for health and social care of older people.1

This project, Ageing Trajectories of Health – Longitudinal Opportunities and Synergies (ATHLOS), funded by the European Union’s Horizon 2020 Research and Innovation Program, aims to achieve a better understanding of the impact of ageing on health by developing a new single measure of health status. With this measure, the project intends to identify patterns of healthy ageing trajectories and their determinants, the critical points in time when changes in trajectories are produced, and to propose timely clinical and public health interventions to optimize and promote healthy ageing. To achieve this, a new cohort has been composed from harmonized datasets of existing international longitudinal cohorts related to health and ageing.

The ATHLOS project follows the World Health Organization’s definition of healthy ageing by studying healthy ageing as an ongoing process of developing and maintaining the functional ability that enables wellbeing in older age.2 This ongoing process interacts with the environment in which people live and can either favour health or be harmful to it. Environments are highly influential on individual behaviour, exposure to health risks, access to quality health and social care and the opportunities that ageing brings.2 Healthy ageing is thus not a unitary phenomenon but must be deconstructed into its components: mental (e.g. cognitive decline), physical (e.g. activities of daily living) and social functioning (e.g. participation in community activities).3–5

National and international research funding agencies and governments have supported several follow-up studies of population cohorts since the early 1990s [e.g. the ‘Health and Retirement Study’ (HRS)6]. HRS has been used as a model for many other longitudinal studies in a number of countries, such as the ‘English Longitudinal Study of Ageing’ (ELSA),7,8 the ‘Japanese Study of Aging and Retirement’ (JSTAR),9 the ‘Mexican Health and Aging Study’ (MHAS),10 the ‘China Health and Retirement Longitudinal Study’ (CHARLS),11 the ‘Longitudinal Aging Study in India’ (LASI)12 or the ‘Korean Longitudinal Study of Ageing’ (KLOSA).13 More recently, multi-country projects have also been initiated, such as the Study on Global Ageing and adult health (SAGE) funded by the World Health Organization,15 the Survey of Health, Ageing and Retirement in Europe (SHARE) funded by the European Commission16 and the 10/66 dementia research study.17

Although these studies have been powered to provide relevant national estimates, sample sizes might be limited for assessing the joint effect of several predisposing and protective factors.18 Additionally, although cross-country comparisons provide evidence of how contextual and health care factors impact population health, the few existing multi-country studies are limited to a selected group of countries and require a significant amount of time, co-ordination and financial resources.

Recently, strategies to harmonize data a posteriori from different longitudinal studies have been proposed to overcome some of the challenges stated above. For example, the Gateway to Global Ageing (G2AGING) is a platform funded by the National Institute on Aging, National Institutes of Health that aims to achieve data harmonization of longitudinal studies on ageing and to facilitate cross-national comparisons in population survey data.14 To date, G2AGING has harmonized the HRS datasets with the datasets of the other nine ‘HRS-family’ studies. In a broader context, an international research programme, called Maelstrom Research, provides systematic harmonization methodology and tools with the aim of leveraging the creation of research collaborations.18 In the context of ageing, Maelstrom Research has facilitated research consortia including the Integrative Analysis of Longitudinal Studies of Aging and Dementia (IALSA), which harmonized 9 studies, and the Promoting Mental Well-being and Healthy Ageing in Cities (MINDMAP), which incorporates 10 studies.19 These consortia have a specific focus on ageing and health and cover populations mostly from North America and Europe.

The ATHLOS consortium constitutes a new collaborative research project that, among other things, uses the Maelstrom Research resources. Unlike G2AGING, Maelstrom Research offers open-source software and guidelines to harmonize data according to concrete research aims. Thus, a harmonized dataset comprising at least 17 longitudinal population studies, from Europe and international countries, was created. These studies include information on common health conditions, as well as a detailed assessment of participants’ functioning. Integrating data from existing cohort studies leads to greater sample size and statistical power to more precisely estimate the determinants and risk factors of healthy ageing. Furthermore, ageing trajectories can be compared between different countries and populations to evaluate if different cultures have diverse risk factors impacting the population’s healthy ageing.
Who is in the ATHLOS cohort?

The cohort comprises more than 410 000 individuals who participated in 17 general population longitudinal studies in 38 countries. The studies are the 10/66 Dementia Research Group Population-Based Cohort Study,17 the Australian Longitudinal Study of Aging (ALSA),20 the ATTICA Study,21 CHARLS,11 Collaborative Research on Ageing in Europe (COURAGE),22 ELSA,7 Study on Cardiovascular Health, Nutrition and Frailty in Older Adults in Spain (ENRICA),23 the Health, Alcohol and Psychosocial factors in Eastern Europe Study (HAPIEE),24 the Health 2000/2011 Survey,25 HRS,6 JSTAR,7 KLOSA,13 MHAS,10 SAGE,15 SHARE,16 the Irish Longitudinal Study of Ageing (TILDA)26 and the Uppsala Birth Cohort Multigenerational Study (UBCoS).27,28

Each study includes one or more populations and provides data on health determinants and age-related events. An overview of the included studies and their target populations is provided in Table 1. Table 2 presents sample sizes and response rates at baseline for each study and population. The median percentage of response rate at each study’s baseline was 75%, and the range was from 53% (SAGE-Mexico) to 96% (10/66-Rural China). It should be noted that the sample sizes of the CHARLS, ELSA, Health 2000/2011, HRS, JSTAR, KLOSA, MHAS and SHARE were increased in posterior waves of data collection. Supplementary Table S1, available as Supplementary data at IJE online, presents sample sizes, number of new participants, deceased participants and drop-outs for each study, population and wave.

All studies are cohorts based on questionnaires except for the UBCoS study, which collects routine health and social data for all babies born in the Uppsala Academic Hospital between the years 1915 and 1929, and their descendants. The UBCoS data were converted into periods of data collection to resemble the design of the other studies.

Finally, the study on the Identification of health and disability determinants on ageing in Italy (IDAGIT) will be subsequently included in the cohort.

How often have participants been followed up?

Most of the longitudinal studies included in the ATHLOS harmonized dataset started between 2000 and 2010 and have at least 2 waves of data collection (see Table 2). ALSA and HRS started much earlier, in the 1990s, and have more than 10 waves of data collection. SAGE has only 1 wave of data harmonized to date. However, new waves of data are expected to be harmonized in the future.

Regarding UBCoS, as register data have been collected approximately every 10 years from 1960 to 2008, we distributed the data in 6 waves.

What has been harmonized?

The data harmonization requires an a priori definition of the variables of interest and their possible values. Thus, the ATHLOS consortium defined a wide range of variables, called DataSchema variables, which included all health conditions, sociodemographic variables, personal functioning and contextual factors. These are usually assessed in population studies. Variables that have international standards or have been created by well-known scales and measured tests were employed in the harmonization process. For example, the International Classification of Functioning, Disability and Health (ICF) biopsychosocial model29 and the conceptualization of health suggested by the World Health Organization30 were used for characterizing the functioning-related variables.

The DataSchema variables were classified as follows: (i) sociodemographic and economic characteristics; (ii) lifestyle and health behaviours; (iii) health status and functional limitations; (iv) diseases; (v) death; (vi) physical measures; (vii) psychological measures; (viii) laboratory measures; (ix) social environment and life events; and (x) other administrative information. In Table 3, a list of core variables within the aforementioned domains, together with the individual studies, is provided.

What has ATHLOS found? Key findings and publications

ATHLOS includes data from all populated continents, with Europe being the most represented. Sociodemographic information by continent and country is shown in Table 4. The median year of birth was around the 1940s, with people from America being older (born in the 1930s) and those in Australia much older (born in 1914). Overall, the median age at baseline was about 60 years. Sweden exhibits a younger average age at baseline, as UBCoS cohorts were based on register data starting in 1960. The percentage of female participants was slightly above 50%, other than in Australia and Ghana, which had lower percentages. The average percentage of primary education or less stood at about 37%, but in general there was heterogeneity even in countries from the same study as in SHARE. In Europe, for example, the lowest percentage was observed in Germany (2%) and the highest percentage in Spain (58%); in South America, the percentage was very high in Venezuela (81%) and Dominican Republic (90%).

Advanced analytical approaches have already been applied to some studies of the ATHLOS dataset to test the methodology for developing a single measure of health status and to identify different patterns of health trajectories over time. This measure will allow for the comparison of...
health status across populations and longitudinal studies included in ATHLOS. Specifically, these analyses have already been conducted on harmonized datasets comprising ELSA and HRS studies. Evidence suggests that the average health scores and trajectories are sensitive to age and that the health status measure is a good predictor of mortality.\textsuperscript{31,32} Additionally, a large systematic review (with more than 90 000 articles screened) was conducted to summarize and synthesize the current evidence on social, biological, behavioural, psychological and sociodemographic determinants of healthy ageing.\textsuperscript{33} This systematic review indicated limited research about healthy ageing in low- and middle-
Table 2. Coverage time of interview, sample sizes and response rates at baseline of each study and population included in the ATHLOS cohort

| Study / Population | Year of interview | Sample size at baseline | Response rate at baseline |
|--------------------|-------------------|-------------------------|---------------------------|
| 10/66 Cuba         | 1915-29 1930-90 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 | 2813 94 | 2004 72 |
| India              | W1 W2            | 1160 74                | 1002 96                   |
| Urban China        | W1 W2            | 1965 80                | 2011 95                   |
| Rural China        | W1 W2            | 1381 80                | 532  88                   |
| Dominican Rep.     | W1 W2            | 1000 86                | 1000 84                   |
| Venezuela          | W1 W2            | 12099 66               | 2009 93                   |
| Urban Peru         | W1 W2            | 2087 55                | 2087 55                   |
| Rural Peru         | W1 W2            | 18245 81               | 4753 70                   |
| Urban Mexico       | W1 W2            | 4071 67                | 4071 67                   |
| Rural Mexico       | W1 W2            | 2519 60                | 2519 60                   |
| Puerto Rico        | W1 W2            | 10728 61               | 10728 61                  |
| ALSA               | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 W13 | 3037 75 | 18245 81 |
| ATTICA             | W1 W2 W3         | 4753 70                | 4753 70                   |
| CHARLS             | W1 W2            | 4071 67                | 4071 67                   |
| COURAGE Spain      | W1 W2 W3         | 2519 60                | 2519 60                   |
| Poland             | W1 W2            | 10728 61               | 10728 61                  |
| ELSA               | W1 W2 W3 W4 W5 W6 W7 | 12099 66 | 2009 93 |
| ENRICA             | W1 W2 W3 W4 W5 W6 W7 | 2519 60 | 2519 60 |
| HAPIEE Poland      | W1 W2            | 10728 61               | 10728 61                  |
| Czech Republic     | W1 W2            | 8857 55                | 8857 55                   |
| Lithuania          | W1 W2            | 7111 65                | 7111 65                   |
| HEALTH 2000/2011   | W1 W2            | 8028 93                | 8028 93                   |
| HRS HRS sub-sample | W1 W2 W3 W4 W5 W6 W7 | 12877 82 | 12877 82 |
| AHEAD              | W2 W3            | 8297 80                | 8297 80                   |
| CODA               | W4 W5 W6 W7 W8 W9 W10 W11 W12 | 2364 73 | 2364 73 |
| WRB                | W4 W5 W6 W7 W8 W9 W10 W11 W12 | 2622 70 | 2622 70 |
| EBB                | W4 W5 W6 W7 W8 W9 W10 W11 W12 | 3400 75 | 3400 75 |
| MBB                | W4 W5 W6 W7 W8 W9 W10 W11 W12 | 5102 60 | 5102 60 |
| JSTAR 5 cities     | W1 W2 W3         | 3862 60                | 3862 60                   |
| 2 cities           | W1 W2            | 1440 60                | 1440 60                   |
| 3 cities           | W1 W2 W3         | 1966 64                | 1966 64                   |
| KLOSAL             | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 10254 64 | 10254 64 |
| MHAS               | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 15146 89 | 15146 89 |
| SAGE South Africa  | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 4227 75 | 4227 75 |
| Ghana              | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 5373 81 | 5373 81 |
| China              | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 15050 93 | 15050 93 |
| Russia             | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 12198 68 | 12198 68 |
| Mexico             | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 5448 53 | 5448 53 |
| SHARE              | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 30816 62 | 30816 62 |
| TILDA              | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 8504 62 | 8504 62 |
| UBCOS Birth generation | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 20732 62 | 20732 62 |
| Descendants        | W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 | 13052 62 | 13052 62 |

*aSample sizes derived from datasets provided by the study owners. Spouses of participants can be included.

*bThe HAPIEE study has a continuous mortality and cardiovascular follow-up from 2005 to 2015.

*cDataset will eventually be included.

*d5 cities: Adachi-Kanazawa-Shirakawa-Sendai-Takikawa.

*e2 cities: Tosu-Naha.

*f3 cities: Chofu-Tondabayashi-Hiroshima.
| Domain                              | Sub-domains | 10/66 | ALSA | ATTICA | CHARLS | COURAGE | ELSA | ENRICA | HAPIEE | H2000/11 | HRS | JSTAR | KLOSA | MHAS | SAGE | SHARE | TILDA | UBCoS |
|------------------------------------|-------------|-------|------|--------|--------|---------|------|--------|--------|----------|-----|-------|-------|------|------|-------|-------|-------|
| Sociodemographic and economic characteristics | Birth       | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Sex         | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Marital status | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Education    | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Living alone | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Employment/retirement | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Wealth       | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Lifestyle and health behaviours    | Tobacco      | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Alcohol      | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Physical activity | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Health status and functional limitations | Memory         | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Dizziness     | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Orientation   | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Walking speed | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Energy        | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Sleep         | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Pain          | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Incontinence  | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Hearing/sight | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Mobility      | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Activities of Daily Living (ADL) | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Instrumental ADL | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Cognitive impairment | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Self-reported health | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Falls         | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Diseases                           | Diabetes      | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Respiratory   | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Hypertension  | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Joint disorders | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Cardiovascular disease | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Cancer        | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Death                              | Living status | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Physical measures                  | Body measures | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Grip strength | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Blood pressure | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Psychological measures             | Screening measure of cognition | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Depression    | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Anxiety       | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Laboratory measures                | Glucose, cholesterol, ... | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Social environment and life events | Social network | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Social support | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Social participation | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Social trust/cohesion | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Life events   | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
|                                    | Loneliness    | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
| Administrative variables           | ID participant/household, date of interview, etc. | ✓     | ✓    | ✓      | ✓      | ✓       | ✓    | ✓      | ✓      | ✓        | ✓   | ✓     | ✓     | ✓    | ✓    | ✓     | ✓     | ✓     |
income countries and confirmed the heterogeneity in the conceptualization and definition of healthy ageing.

What are the main strengths and weaknesses of ATHLOS?

The harmonized dataset in the ATHLOS project constitutes a new cohort that has been created by collecting data from 17 longitudinal studies from five continents. The harmonization approach and tools used in this project were adapted from the methodology developed by Maelstrom Research.18 This approach is systematic and rigorous to ensure that harmonized variables are comparable.

It should be noted that the harmonization is a retrospective process, as studies were not initially designed to be harmonized. The heterogeneity in study design, instruments and data collection limits the amount and quality of

| Continent | Country | n   | Year of birth (median) | Age at participant’s baseline (median) | Female (%) | Primary education or less (%) | Studies involved |
|-----------|---------|-----|------------------------|----------------------------------------|------------|------------------------------|-----------------|
| Europe    | Austria | 6411| 1945                   | 63                                     | 58         | 14                           | SHARE           |
|           | Belgium | 8720| 1948                   | 60                                     | 55         | 21                           | SHARE           |
|           | Czech Republic | 18092 | 1946 | 60                      | 56         | 14                           | HAPIEE, SHARE   |
|           | Denmark | 5553| 1948                   | 60                                     | 54         | 13                           | SHARE           |
|           | Estonia | 7075| 1945                   | 65                                     | 59         | 6                            | SHARE           |
|           | Finland | 9673| 1948                   | 47                                     | 54         | 47                           | Health2000      |
|           | France  | 8105| 1946                   | 61                                     | 57         | 40                           | SHARE           |
|           | Germany | 8690| 1946                   | 62                                     | 54         | 2                            | SHARE           |
|           | Greece  | 6969| 1949                   | 55                                     | 54         | 38                           | ATTICA, SHARE   |
|           | Hungary | 3076| 1948                   | 63                                     | 57         | 2                            | SHARE           |
|           | Ireland | 9638| 1948                   | 62                                     | 46         | 29                           | SHARE, TILDA    |
|           | Italy   | 7158| 1945                   | 63                                     | 55         | 48                           | SHARE           |
|           | Lithuania | 7111 | 1945 | 61                      | 55         | 12                           | HAPIEE, SHARE   |
|           | Luxembourg | 1610 | 1950 | 62                      | 53         | 37                           | SHARE           |
|           | Netherlands | 6547 | 1946 | 61                      | 54         | 14                           | SHARE           |
|           | Poland  | 17532| 1947                  | 58                                     | 54         | 20                           | COURAGE, HAPIEE, SHARE |
|           | Portugal | 2080 | 1947                  | 64                                     | 57         | 56                           | SHARE           |
|           | Slovenia | 3755| 1948                   | 63                                     | 56         | 10                           | SHARE           |
|           | Spain   | 15952| 1944                  | 65                                     | 54         | 58                           | COURAGE, ENRICA, SHARE |
|           | Sweden  | 66243| 1945                  | 16                                     | 50         | 35                           | SHARE, UBCoS    |
|           | Switzerland | 4571 | 1946                  | 62                                     | 55         | 11                           | SHARE           |
|           | United Kingdom | 18489 | 1944     | 59                     | 54         | 38                           | ELSA            |
| Eurasia   | Russia  | 4947| 1946                   | 62                                     | 64         | 9                            | SAGE            |
| Asia      | China   | 38990| 1951                  | 59                                     | 53         | 60                           | 10/66, CHARLS, SAGE |
|           | India   | 14202| 1947                  | 55                                     | 61         | 58                           | 10/66, SAGE     |
|           | Israel  | 3857 | 1946                  | 61                                     | 55         | 21                           | SHARE           |
|           | Japan   | 7268 | 1945                  | 63                                     | 52         | 25                           | JSTAR           |
|           | South Korea | 10254 | 1945                | 61                                     | 56         | 45                           | KLOSA           |
| North America | United States of America | 37317 | 1938 | 56                     | 56         | 27                           | HRS             |
|           | Cuba    | 2813 | 1930                  | 74                                     | 65         | 58                           | 10/66           |
|           | Dominican Republic | 2011 | 1931 | 74                      | 66         | 90                           | 10/66           |
|           | Mexico  | 28817| 1944                  | 59                                     | 58         | 72                           | 10/66, MHAS, SAGE |
|           | Puerto Rico | 2009 | 1932                | 76                                     | 67         | 44                           | 10/66           |
| South America | Peru     | 1933 | 1932                  | 74                                     | 61         | 56                           | 10/66           |
|           | Venezuela | 1965 | 1935                 | 71                                     | 64         | 81                           | 10/66           |
|           | Ghana   | 5573 | 1950                  | 60                                     | 49         | 47                           | SAGE            |
|           | South Africa | 4227 | 1947                | 60                                     | 57         | 62                           | SAGE            |
| Oceania   | Australia | 2087 | 1914                  | 78                                     | 49         | 36                           | ALSA            |
| Total     |         | 411320| 1945                | 58                                     | 54         | 37                           | The 17 studies  |
information that can be pooled. Thus, we are conducting thorough documentation of the whole process, not only for the sake of reproducibility and transparency, but also to estimate the quality of harmonization for every variable.

What are the main problems inherent to the harmonization?

In the course of the harmonization process, we encountered several challenges. First, the harmonization potential is a trade-off between the number of studies (quantity) that can be included and the content equivalence (precision) within the study-specific variables. For example, education can be harmonized using standard criteria, such as the ISCED2011, creating a categorical variable based on the highest qualification or generating a continuous variable for years of education. Greater precision in the definition of education would entail a lower number of studies that could be included. Second, some variables were at times conceptually different across studies, even though they described the same underlying construct. For example, employment may be addressed directly (e.g. are you employed?) or indirectly (e.g. are you retired?). The same applies to energy level, which can be addressed in terms of presence of energy (e.g. do you have energy for daily life?) or inversely (e.g. did you feel tired out or low in energy?). In this case, our intention was to address the variable in aggregate and not the way in which the question was asked. Further, ethical and legal issues may restrict the sharing and pooling of individual data. For example, studies may not publicly provide biomarker or mortality information of participants who have been lost to follow-up. Therefore, managing and pooling large datasets from different studies poses significant challenges, but the advantages seem worthwhile if we consider the global coverage and the gain in statistical power.

Can I get hold of the data? Where can I find out more?

A platform of free software applications, developed by Maelstrom Research, is used to store the original datasets, guide the harmonization process and create a web portal for the studies from the ATHLOS Consortium, as well as the final harmonized databases. These software applications have General Public Licences and can therefore be used and freely modified according to the ATHLOS project needs. The web catalogue can be found at: https://athlos.pssjd.org. External users interested in using the harmonized datasets should contact the ATHLOS Scientific Committee: (athlos@pssjd.org).

Profile in a nutshell

- The Ageing Trajectories of Health – Longitudinal Opportunities and Synergies (ATHLOS) cohort harmonizes existing longitudinal data from 17 international cohort studies.
- It aims to achieve a better understanding of the impact of ageing on health and to propose timely clinical and public health interventions to optimize and promote healthy ageing.
- The cohort comprises more than 411 000 individuals from 38 countries. Most of the studies started between 2000 and 2010 and have between 2 and 13 waves of data collection. New waves of data collected during the ATHLOS project and other studies will be incorporated in updated versions of the harmonized dataset.
- Harmonized datasets include variables classified in the following areas: (i) sociodemographic and economic characteristics; (ii) lifestyle and health behaviours; (iii) health status and functional limitations; (iv) diseases; (v) death; (vi) physical measures; (vii) psychological measures; (viii) laboratory measures; (ix) social environment and life events; and (x) other administrative information.
- The catalogues of the studies and final harmonized databases, together with documentation of the whole harmonization process, can be found in the web portal: (https://athlos.pssjd.org). External users interested in using the harmonized datasets should contact the ATHLOS Scientific Committee: (athlos@pssjd.org).

Supplementary data

Supplementary data are available at IJE online.

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