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MPIDR Working Paper

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Abstract

The Short-Term Mortality Fluctuations (STMF) data series provides an opportunity for analysis of intra-annual excess mortality, in particular, human losses due to the COVID-19 pandemic. Nevertheless, the STMF has a limitation caused by the nature of the collected original weekly death counts. In many countries, weekly death counts are available only by broad age groups or/and are too small and shaky. Moreover, the original age scales somewhat vary by country. Thus, the STMF data file presents weekly deaths and death rates by broad age intervals. This simplifies the usage of the STMF and helps to conduct analyses but limits the comparability of results across countries and time. The comparisons may be biased due to differences between the population age composition. This study addresses the problem by providing a method for the estimation of week-specific standardized death rates (SDRs) that combines the aggregated weekly mortality data with detailed annual data on mortality and population. This allows deriving annual transition coefficients for the transformation of crude death rates into SDRs. We show that the derived SDRs approximate well exact SDRs across time and countries.

Background

The Short-Term Mortality Fluctuations data series (STMF) is a newly established part of the Human Mortality Database (www.mortality.org) that provides data on deaths and crude death rates (CDRs) by week for all ages combined and five broad age groups 0-14, 15-64, 65-74, 75-84, and 85+. Although STMF data allows analysis of seasonal mortality differences, intra-annual mortality excess, and human losses due to death, direct comparisons between countries and across time may be biased by variations in the population age compositions. Age-independent mortality indicators like standardized death rate or life expectancy by weeks, months, or quarters can not be directly calculated because of the lack of detailed age-specific data. This is especially important when the age-structure differences between populations being compared are substantial. For example, comparisons of the intra-annual mortality excess between the early 2000s and the late 2010s or between countries with “older” and “younger” populations (e.g. Italy vs. Poland) are especially problematic.

This paper proposes calculation procedures for the estimation of week-specific standardized death rates (SDRs) using broad age groups available in the STMF.

STMF data and adjustment for consistency with the core HMD

The STMF provides information on deaths and death rates for all ages combined and the five aggregated age groups by country/region, sex, year, and week. Importantly, STMF provides also input data containing deaths as they were originally published by national statistical offices or other data providers. Table 1 summarizes the STMF data over the period 2000 to 2020 (as of December 15, 2020). In total, the data by 5-year age groups are available for 30 out of 38 populations. A set of eight countries without detailed data by age (Australia, Canada, England and Wales, Germany, Israel, New Zealand, South Korea, and the USA) includes three large national populations that importantly contribute to the worldwide burden of excess mortality.

Each year in the STMF refers to 52 or 53 weeks. These are standardized weeks with 7 days in each of them according to ISO 8601-2004 guidelines (Jdanov et al. 2020). Consequently, the first week of some calendar years includes several days (and, respectively, deaths) from the previous year and/or the last week of some years includes several days of the following year, with the implication that a statistical year in the STMF might slightly differ from the respective calendar year and cover a slightly different number of deaths compared to the core HMD or the national statistics. Besides, the weekly data is based on the current registration of vital events and may slightly differ from the final annual statistical reports on population mortality. Thus, the annual sums of weekly deaths may somewhat differ from the annual death counts.

For our further elaborations and also for a general consistency between STMF and HMD, we adjust the STMF weekly deaths in every age group (either 5-year or aggregated) using the core HMD as a "golden standard":

$$\widetilde{D}_{y,w,x}^{STMF} = D_{y,w,x}^{STMF} \cdot \sum_{w=1}^{N} \frac{D_{y,w,x}^{STMF}}{D_{y,x}}, \tag{1a}$$

$$\widetilde{D}_{y,w,i}^{STMF} = D_{y,w,i}^{STMF} \cdot \sum_{w=1}^{N} \frac{D_{y,w,i}^{STMF}}{D_{y,i}}, \tag{1b}$$

where indices y, w, x, and i denote year, week, five year age group, and aggregate age group, respectively, N denotes the number of weeks, and D^{STMF} and D stand for the numbers of deaths in the STMF and HMD core, respectively.

Equations (1a) and (1b) apply to the years in which HMD data is available. Table 1 indicates, however, that for 2020 and a few previous years this data is unavailable in all or many countries. In these years, we use the adjustment factors $\sum_{w=1}^{N}(D_{y,w,x}^{STMF}/D_{y,x})$ and $\sum_{w=1}^{N}(D_{y,w,i}^{STMF}/D_{y,i})$ from the last year for which the HMD data is available.

To compensate for the absence of detailed annual data in the most recent years, we had predicted 5-year-age-specific annual death rates using HMD data starting from 2005 to the last available year with the Lee-Carter projection model (Jdanov et al. 2020; Lee, Carter 1992).

Table 1. Summary of STMF data in 2000-2020 as of 15.12.2020

N	Country	First available year in the STMF	Last available year in the STMF	Years, total	Weeks, total	5-year ages available in STMF	Last available year in the HMD
1	*Australia*	*2015*	*2020*	*6*	*294*	*No*	*2018*
2	Austria	2000	2020	21	1085	Yes	2017
3	Belgium	2000	2020	21	1087	Yes	2018
4	Bulgaria	2010	2020	11	568	Yes	2017
5	*Canada*	*2010*	*2020*	*11*	*558*	*No*	*2018*
6	Chile	2016	2020	5	256	Yes	2017
7	Croatia	2000	2020	21	1032	Yes	2018
8	Czechia	2005	2020	16	824	Yes	2018
9	Denmark	2007	2020	14	724	Yes	2019
10	*England and Wales*	*2010*	*2020*	*11*	*568*	*No*	*2018*
11	Estonia	2000	2020	21	1088	Yes	2017
12	Finland	2000	2020	21	1087	Yes	2019
13	France	2000	2020	21	1087	Yes	2018
14	*Germany*	*2016*	*2020*	*5*	*253*	*No*	*2017*
15	Greece	2016	2020	5	251	Yes	2017
16	Hungary	2000	2020	21	1085	Yes	2017
17	*Israel*	*2000*	*2020*	*21*	*1085*	*No*	*2016*
18	Italy	2015	2020	6	299	Yes	2017
19	Latvia	2000	2020	21	1089	Yes	2017
20	Lithuania	2000	2020	21	1087	Yes	2019
21	Netherlands	2000	2020	21	1086	Yes	2018
22	*New Zealand*	*2010*	*2020*	*11*	*515*	*No*	*2019*
23	Northern Ireland	2015	2020	6	307	Yes	2018
24	Norway	2000	2020	21	1087	Yes	2018
25	Poland	2000	2020	21	1084	Yes	2018
26	Portugal	2000	2020	21	1087	Yes	2018
27	Russia	2000	2019	20	1040	Yes	2018
28	Scotland	2000	2020	21	1088	Yes	2018
29	Slovakia	2000	2020	21	1084	Yes	2017
30	Slovenia	2000	2020	21	1087	Yes	2017
31	*South Korea*	*2010*	*2020*	*11*	*560*	*No*	*2018*
32	Spain	2000	2020	21	1087	Yes	2018
33	Sweden	2000	2020	21	1087	Yes	2019
34	Switzerland	2000	2020	21	1087	Yes	2018
35	Taiwan	2000	2020	21	1079	Yes	2014
36	*USA*	*2015*	*2020*	*6*	*410*	*No*	*2018*
37	Iceland	2000	2020	21	1088	Yes	2018
38	Luxembourg	2000	2020	21	1089	Yes	2019
	TOTAL, all countries	2000	2020	627	32359	Y or N	2019
	TOTAL, w/o Iceland & Luxembourg	2000	2020	585	30182	Y or N	2019
	TOTAL, w/o Iceland & Luxembourg, with 5-yr ages	2000	2020	503	25939	Y	2019

Crude death rates and two versions of standardized death rates

The precise $SDRs$ by year and week is to be computed from the data that contains detailed age-specific death rates $M_{y,w,x}^{STMF}$ by 5-year age-groups:

$$SDR_{y,w} = \sum_x (p_x^s M_{y,w,x}^{STMF}), \qquad (2)$$

where p_x^s is the standard population weight for the 5-year age group x. We use the European population standard 2013 (Revision of the European Standard Population 2013) with age groups 0-4, 5-9, … up to the last open-ended age 90+. The week-age-specific death rates $M_{y,w,x}^{STMF}$ are calculated as follows

$$M_{y,w,x}^{STMF} = \frac{\tilde{D}_{y,w,x}^{STMF}}{E_{y,x}/N},$$

if week-specific death counts are available at the required level of details. Following the STMF approach, we use yearly population exposures $E_{x,y}$ divided by the number of weeks N. Instead of original weekly death counts $D_{y,w,x}^{STMF}$ we use the adjusted weekly deaths $\tilde{D}_{y,w,x}^{STMF}$ (according to equations (1a) and (1b)).

Equation (2) determines exact weekly $SDRs$. Their calculation depends on the availability of weekly data by 5-year age groups. If the detailed weekly data is unavailable, one may straightforwardly calculate $SDR0$ for all ages combined as a weighted average of five CDRs (age groups 0-14, 15-64, 65-74, 75-84, and 85+):

$$SDR0_{y,w} = \sum_{i=1}^{5} (p_i^s CDR_{y,w,i}^{STMF}), \qquad (3)$$

where index i denotes the five aggregate age groups and the standard population weights p_i^s correspond to the five broad age intervals in the European population standard that are equal to 0.160, 0.645, 0.105, 0.065, and 0.025, respectively. Nevertheless, the $SDR0$ has a serious disadvantage. It is based on an assumption that the broad-group-specific values $CDR_{y,w,i}$ do not differ much from the respective weekly $SDR_{y,w,i}$. Only if this assumption holds, the weighting of the $CDRs$ with the standard population weights provides a good approximation of the precise $SDR_{y,w}$ values.

Another idea concerns using an annual ratio of standardized death rate SDR_y to crude death rate CDR_y for fitting the weekly $SDR_{y,w}$. Thus, instead of the detailed weekly rates $M_{y,w,x}^{STMF}$, we can use annual 5-year-age-specific rates $M_{y,x}$. Correspondingly, formula (2) has to be modified as follows

$$SDR1_{y,w} = CDR_{y,w}^{STMF} \cdot R_y; \quad R_y = \frac{\sum_x (p_x^S M_{y,x})}{CDR_y} \qquad (4a)$$

for all ages combined and

$$SDR1_{y,w,i} = CDR_{y,w,i}^{STMF} \cdot R_{y,i}; \quad R_{y,i} = \frac{\sum_{x \in X_i} (\rho_x^S M_{y,x})}{CDR_{y,i}} \qquad (4b)$$

In equation (4a), the crude death rate is calculated conventionally $CDR_y = \sum_x (p_{y,x} M_{y,x})$ with the population weights $p_{y,x}$ for year y and age x. In equation (4b), X_i denotes a set of 5-year age intervals belonging to an aggregate age group i. For example, the set X_1 = {0, 5, 10} corresponds to the first aggregate age group 0-14. Weight ρ_x^s is the standard population weight *within aggregated age group* i. It is being calculated as $\rho_x^s = p_x^s / (\sum_{x \in X_i} p_x^s)$. The crude death rate $CDR_{y,i}$ for an aggregated age group i is

$$CDR_{y,i} = \sum_{x \epsilon X_i} \rho_{y,x} M_{y,x} \text{ with weights } \rho_{y,x} = p_{y,x} / (\sum_{x \in X_i} p_{y,x}).$$

Equations (4a) and (4b) are based on the assumption that week-specific age patterns of mortality do not substantially differ from the annual age pattern.

If for a country in question, annual death rates by detailed ages are not available for one or more years (note HMD data availability in Table 1), one can use for these years predicted age-specific death rates $M_{y,x}^{predict}$. As we mentioned earlier, these rates were obtained by applying the Lee-Carter projection model (Lee, Carter 1992) to HMD data.

However, the resulting $M_{y,x}^{predict}$ values may not be precise enough. This is particularly important for the pandemic year 2020. Therefore, we further adjust the predicted death rates by using STMF death rates that are available until the most recent year. The adjustment coefficient for year y and aggregated age group i is

$$k_{y,i} = \frac{CDR_{y,i}^{STMF}}{CDR_{y,i}^{predict}}$$

with the crude death rates in the numerator and the denominator being

$$CDR_{y,i}^{STMF} = (\sum_w CDR_{y,w,i}) / N \text{ and } CDR_{y,i}^{predict} = \sum_{x \epsilon X_i} (\rho_{y,x} M_{y,x}^{predict}).$$

Finally, for countries and years not covered by the HMD, the age-specific death rate at age x such that $x \in X_i$, in equations (4a) and (4b) has to be replaced by the adjusted death rate

$$\widetilde{M}_{y,x} = k_{y,i} \cdot M_{y,x}^{predict}.$$

This way the weekly $SDR1$ values can be obtained for all countries and years available in the STMF.

Figures 1 and 2 show four types of weekly death rates from the first week of 2000 to the last week of 2020 as well as the ratios of CDR, $SDR0$, and $SDR1$ to the exact standardized death rate SDR for Spain and Hungary, respectively.

Both countries experienced sizeable intra-annual fluctuations with pronounced seasonal maximums combined with long-term mortality decline. The difference between CDR and SDR depends on temporal change in the age composition of country populations and in the age patterns of mortality. The CDR/SDR continuously rises due to the progressive population aging. For men, CDR/SDR values are below 1, for women they are slightly below 1 in the early 2000s and are substantially above 1 in the late 2010s.

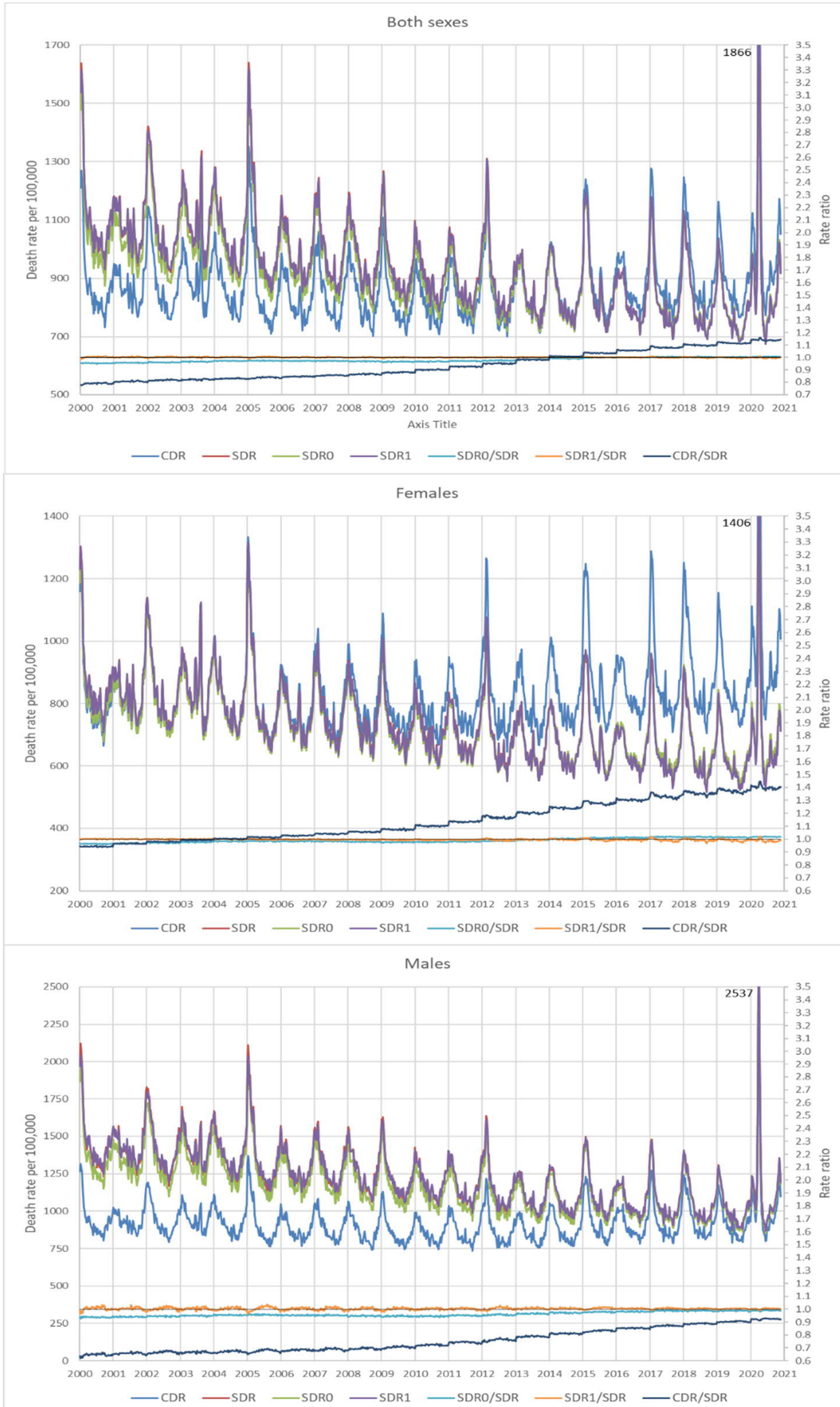

Figure 1. Crude death rate (*CDR*) and age-standardized death rates *SDR*, *SDR*0, and *SDR*1 per 100 000 person-years (left axis) and rate ratios *CDR*/*SDR*, *SDR*0/*SDR*, and *SDR*1/*SDR* (right axis) in Spain in 2000-2020, for both sexes, men, and women.

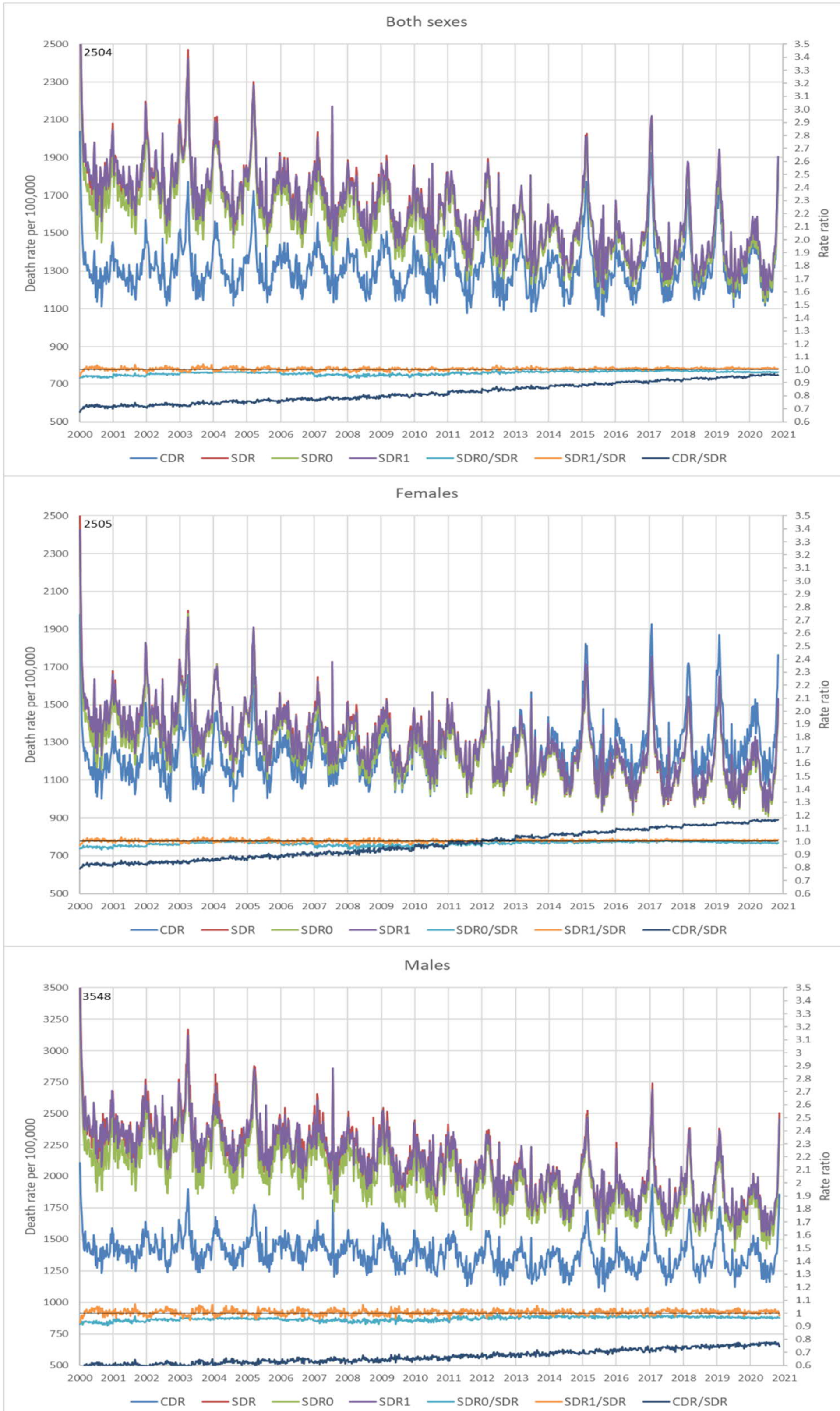

Figure 2. Crude death rate CDR and age-standardized death rates SDR, SDR0, and SDR1 per 100 000 person-years (left axis) and rate ratios CDR/SDR, SDR0/SDR, and SDR1/SDR (right axis) in Hungary in 2000-2020, for both sexes, men, and women.

Figures 1 and 2 suggest that the $SDR0/SDR$ ratio somewhat deviates (mostly downward) from 1. It tends to be more pronounced for men than for women and tends to be larger in the 2000s and the early 2010s than in the late 2010s.

The $SDR0/SDR$ ratio lies systematically below 1. The mean $SDR0/SDR$ ratio for males is 4% in Spain and 4.2% in Hungary. The maximal downward shifts for males are 7% in Spain and 10% in Hungary. The $SDR1/SDR$ ratio is not systematically higher or lower than 1. The mean SDR1/SDR ratio is 0.4% in Spain and 0.7% in Hungary. The maximal deviations are ±3% in Spain and ±7% in Hungary.

Deviations of *SDR*1 from *SDR*. Advantage of *SDR*1 compared to *SDR*0

In this section, we are finding out how well the exact weekly SDR values are approximated by $SDR0$ and $SDR1$, which are calculated without the usage of detailed weekly death rates by 5-year age groups. The examples of Spain and Hungary suggest that deviations of $SDR1$ from SDR may be quite small and that deviations of $SDR0$ from SDR are somewhat larger. Table 1 shows that in 30 regions/countries detailed HMD data is available, which allows calculation of SDR. Iceland and Luxembourg have very small populations leading to high instability of week-age-specific death rates. After the exclusion of these two countries, the remaining data set consists of 28 countries, 503 years, and 25939 weeks (Table 1). Below, we systematically examine deviations of $SDR0$ and $SDR1$ from SDR across countries and weeks in this data.

Table 2 provides country-specific medians, as well as 5th and 95th percentiles of the $SDR1/SDR$ ratios for all ages combined. The ratios are generally low. The average of country-specific medians (across year-week combinations) exceeds 1 by +0.1% for both sexes, by -0.03% for women, and by +0.5% for men. 90% of country-specific median values lie between -2.7% and +2.3% for both sexes, -2% and +2.4% for women, and -3.5% and +4.7% for men. Chile is the only country that lies out of the range with deviations up to 7%-10%. Information similar to Table 2 for the age ranges 0-14, 15-64, 65-74, 75-84, and 85+ is given in Supplementary Annex 1.

Table 2. The median, 5th, and 95th percentiles of weekly $SDR1/SDR0$ ratios by sex for 28 countries and all ages combined in 2000-2020

Country	Both sexes			Females			Males		
	Median	p 5%	p 95%	Median	p 5%	p 95%	Median	p 5%	p 95%
Austria	1.0021	0.9894	1.0147	1.0009	0.9848	1.0153	1.0049	0.9737	1.0382
Belgium	1.0013	0.9887	1.0116	0.9981	0.9831	1.0119	1.0065	0.9750	1.0379
Bulgaria	1.0070	0.9905	1.0238	1.0087	0.9878	1.0283	1.0055	0.9767	1.0325
Chile	1.0547	1.0351	1.0758	1.0894	1.0759	1.1049	1.0236	0.9852	1.0632
Croatia	1.0056	0.9762	1.0336	1.0059	0.9730	1.0353	1.0069	0.9478	1.0651
Czechia	1.0058	0.9828	1.0239	1.0053	0.9830	1.0230	1.0089	0.9708	1.0438
Denmark	0.9977	0.9900	1.0057	0.9936	0.9869	1.0022	1.0045	0.9752	1.0336
Estonia	1.0029	0.9729	1.0319	1.0025	0.9698	1.0339	1.0096	0.9204	1.0916
Finland	1.0023	0.9906	1.0162	1.0010	0.9884	1.0139	1.0063	0.9669	1.0496
France	0.9966	0.9831	1.0070	0.9919	0.9720	1.0085	1.0049	0.9833	1.0208
Greece	1.0027	0.9944	1.0104	1.0011	0.9878	1.0123	1.0050	0.9984	1.0130
Hungary	1.0065	0.9881	1.0207	1.0072	0.9886	1.0201	1.0082	0.9758	1.0372
Italy	0.9986	0.9919	1.0059	0.9948	0.9833	1.0093	1.0051	0.9985	1.0133
Latvia	1.0039	0.9758	1.0279	1.0034	0.9751	1.0307	1.0058	0.9409	1.0749
Lithuania	1.0050	0.9773	1.0261	1.0054	0.9777	1.0295	1.0028	0.9503	1.0558
Netherlands	1.0028	0.9881	1.0138	0.9992	0.9930	1.0060	1.0112	0.9684	1.0400
Northern Ireland	0.9981	0.9866	1.0127	0.9941	0.9831	1.0056	1.0057	0.9611	1.0519
Norway	0.9997	0.9905	1.0115	0.9969	0.9808	1.0158	1.0059	0.9779	1.0339
Poland	1.0037	0.9849	1.0186	1.0033	0.9886	1.0157	1.0058	0.9714	1.0323
Portugal	1.0008	0.9901	1.0157	0.9989	0.9877	1.0109	1.0064	0.9749	1.0375
Russia	1.0015	0.9781	1.0192	1.0011	0.9838	1.0131	1.0011	0.9628	1.0320
Scotland	1.0001	0.9897	1.0096	0.9975	0.9898	1.0046	1.0060	0.9725	1.0371
Slovakia	1.0054	0.9781	1.0320	1.0060	0.9743	1.0335	1.0059	0.9578	1.0609
Slovenia	1.0043	0.9667	1.0374	1.0035	0.9693	1.0345	1.0086	0.9219	1.0971
Spain	0.9992	0.9929	1.0063	0.9968	0.9852	1.0041	1.0043	0.9884	1.0190
Sweden	0.9996	0.9942	1.0067	0.9964	0.9842	1.0093	1.0063	0.9885	1.0235
Switzerland	0.9998	0.9915	1.0078	0.9965	0.9849	1.0080	1.0071	0.9759	1.0329
Taiwan	0.9976	0.9780	1.0247	0.9961	0.9740	1.0273	0.9989	0.9730	1.0311
Total	1.0013	0.9840	1.0230	0.9997	0.9809	1.0240	1.0058	0.9653	1.0473

The relative absolute-value deviations of $SDR0$ and $SDR1$ from SDR are be defined as

$$DEV0_{y,w} = \frac{|SDR_{y,w} - SDR0_{y,w}|}{SDR_{y,w}} \cdot 100\%,$$

$$DEV1_{y,w} = \frac{|SDR_{y,w} - SDR1_{y,w}|}{SDR_{y,w}} \cdot 100\%.$$

Comparison of $DEV1$ and $DEV0$ reveals the advantage of $SDR1$ compared to $SDR2$. Across all year-week-country combinations, the average $DEV1$ values are about twice lower than the average $DEV0$ values: 1.03% vs. 2.51% for both sexes, 1.23% vs. 1.93% for women, and 1.57% vs. 4.04% for men. Table 3 compares the medians and 90th percentiles of the *DEV*1 and the *DEV*0 distributions and also suggests the advantage of *SDR1*.

Table 3. Medians and 90th percentiles for the relative deviations *DEV*1 and *DEV*0 by sex for 28 countries in 2000-2020, all ages combined. (in %)

	*DEV*0		*DEV*1	
	Median	p 90%	Median	p 90%
Both sexes				
	1.04	2.51	0.47	1.44
Females				
	0.89	2.55	0.71	1.90
Males				
	2.66	4.66	1.08	3.27

Finally, Table 4 presents OLS regression that links *DEV*1 to sex and aggregate age group. The deviation values for men and women exceed the both-sexes reference by 0.2% and 0.6%, respectively. The deviations for age groups 0-14 and 85+ are higher than the all-ages reference by 1.9% and 0.6%, respectively. On the contrary, the deviations for age groups 15-64, 65-74, and 75-84 tend to be smaller than the all-ages reference by about -0.7 to -0.9%.

Table 4. OLS relationship between the absolute-value deviation *DEV1* with sex and aggregate age group for 28 countries over the period 2000-2020 (in %)

Independent variable	Regr. coef.	95%CI Low	95%CI High
Sex			
- both	0 (Ref)		
- female	0.220	0.208	0.232
- male	0.560	0.548	0.572
Age group			
- all ages	0 (Ref)		
- 0-14	1.861	1.844	1.878
- 15-64	-0.657	-0.674	-0.641
- 65-74	-0.882	-0.899	-0.866
- 75-84	-0.853	-0.87	-0.836
- 85+	0.647	0.63	0.664
Constant	1.013	0.999	1.027

Note. All regression coefficients significantly differ from 0 ($p<0.0001$).

Transition coefficients for computation of weekly *SDRs* from *CDRs*

The transition coefficients R (according to equations (4a) and (4b)) for 36 countries/regions (all countries but Iceland and Luxembourg available in STMF as of 15.12.2020) for all ages combined and for the five aggregated age groups in 2010-2020 are given in Supplementary Annex 2.xlsx.

One should note that the transition coefficients for the most recent years may change in response to updating of STMF and HMD.

Summary

This paper provides a simple method for the estimation of week-specific standardized death rates when detailed data is not available. The calculation does not require detailed age-specific weekly data but uses data on annual mortality by five-year age group.

Analyses of STMF data from 28 countries/regions for which weekly mortality by 5-year age groups showed that weekly SDRs may be derived from weekly CDRs. The resulting $SDR1$ values may be considered as a good approximation of the exact standardized death rates SDR. The inaccuracy of the estimation tends to be somewhat higher for ages below 15 and above 85 compared to all ages combined and ages 15 to 84 and for males compared to both sexes and females

The method can be applied for estimating SDRs:
- in populations and years for which weekly mortality by 5-year age groups is not available.
- in small populations with unstable weekly mortality by 5-year-age groups. In such populations, detailed mortality has to be grouped into broader age categories before analysis.

Supplementary files

Annex 1. The median, 5th, and 95th percentiles of weekly SDR1/SDR0 ratios by sex for 28 countries and age groups 0-14, 15-64, 65-74, 75-84, and 85+ in 2000-2020.

Annex 2. Transition coefficients for the calculation of standardized death rates from crude death rates for 36 countries/regions, all ages combined and age groups 0-14, 15-64, 65-74, 75-84, and 85+ in 2010-2020.

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