	Maternal mortality ratio (per 100 000 livebirths)			Number of maternal deaths			Annualised rate of change in maternal mortality ratio (%)		
	1990	2003	2013	1990	2003	2013	1990–2003	2003–13	1990–2013
(Continued from previous page)									
Costa Rica	31·1 (26·9 to 36·0)	36·3 (31·7 to 41·5)	24·9 (20·1 to 30·3)	25 (22 to 29)	28 (24 to 31)	19 (15 to 23)	1·2% (−0·3 to 2·7)	−3·8% (−6·0 to −1·5)	−1·0% (−2·0 to 0·1)
El Salvador	105·5 (90·2 to 120·4)	57·5 (49·2 to 66·5)	65·8 (44·3 to 91·6)	181 (155 to 206)	77 (66 to 89)	86 (58 to 119)	−4·7% (−6·3 to −3·1)	1·2% (−2·6 to 4·9)	−2·1% (−3·8 to −0·4)
Guatemala	112·8 (101·0 to 126·2)	91·8 (81·2 to 104·2)	86·7 (65·8 to 110·8)	409 (367 to 458)	400 (353 to 454)	423 (321 to 541)	−1·6% (−2·8 to −0·4)	−0·6% (−3·5 to 2·0)	−1·2% (−2·4 to 0·0)
Honduras	153·1 (90·5 to 190·4)	119·5 (48·5 to 191·2)	72·0 (35·5 to 123·0)	295 (175 to 367)	238 (97 to 381)	153 (75 to 260)	−2·1% (−6·4 to 1·5)	−5·1% (−10·5 to 0·2)	−3·4% (−5·8 to −1·1)
Mexico	73·8 (70·4 to 77·1)	57·9 (55·0 to 60·5)	54·0 (50·3 to 58·2)	1774 (1691 to 1851)	1429 (1357 to 1493)	1224 (1139 to 1320)	−1·9% (−2·3 to −1·5)	−0·7% (−1·5 to 0·1)	−1·4% (−1·7 to −1·0)
Nicaragua	94·5 (81·2 to 109·4)	87·8 (76·7 to 101·0)	63·5 (49·0 to 80·0)	148 (127 to 171)	126 (110 to 145)	90 (69 to 113)	−0·6% (−2·1 to 1·0)	−3·3% (−6·2 to −0·7)	−1·8% (−3·0 to −0·5)
Panama	62·3 (53·0 to 72·7)	66·2 (57·2 to 76·3)	55·2 (40·6 to 73·2)	42 (35 to 49)	50 (44 to 58)	42 (31 to 56)	0·5% (−1·1 to 2·2)	−1·9% (−5·1 to 1·3)	−0·6% (−1·9 to 0·8)
Venezuela	66·6 (59·6 to 73·5)	62·0 (56·3 to 68·7)	54·7 (42·8 to 68·6)	377 (337 to 415)	373 (339 to 413)	336 (263 to 421)	−0·5% (−1·6 to 0·5)	−1·3% (−3·8 to 1·2)	−0·9% (−2·0 to 0·2)
Southern Latin America	55·5 (51·1 to 60·2)	51·2 (46·3 to 55·8)	44·2 (37·3 to 51·3)	603 (555 to 653)	513 (465 to 560)	445 (376 to 518)	−0·6% (−1·6 to 0·2)	−1·5% (−3·3 to 0·3)	−1·0% (−1·8 to −0·2)
Argentina	60·2 (54·9 to 66·0)	63·3 (57·0 to 69·7)	54·7 (45·3 to 64·6)	434 (396 to 476)	440 (396 to 484)	387 (320 to 456)	0·4% (−0·7 to 1·4)	−1·5% (−3·5 to 0·5)	−0·4% (−1·3 to 0·4)
Chile	47·8 (42·3 to 54·3)	22·0 (19·3 to 25·0)	18·7 (14·7 to 23·2)	146 (130 to 166)	56 (49 to 64)	47 (37 to 58)	−6·0% (−7·4 to −4·6)	−1·7% (−4·2 to 0·9)	−4·1% (−5·2 to −3·0)
Uruguay	38·7 (32·8 to 45·3)	32·5 (27·4 to 38·1)	22·9 (17·3 to 29·4)	23 (19 to 27)	17 (15 to 20)	12 (9 to 15)	−1·4% (−3·0 to 0·3)	−3·6% (−6·5 to −0·7)	−2·3% (−3·6 to −1·0)
Tropical Latin America	75·9 (68·0 to 84·6)	68·3 (60·9 to 75·6)	60·6 (47·5 to 75·6)	2818 (2522 to 3139)	2445 (2182 to 2708)	1969 (1542 to 2457)	−0·8% (−1·9 to 0·2)	−1·2% (−3·9 to 1·3)	−1·0% (−2·2 to 0·1)
Brazil	73·1 (65·0 to 82·0)	66·0 (58·4 to 73·7)	58·7 (45·8 to 73·5)	2609 (2320 to 2925)	2265 (2003 to 2530)	1813 (1414 to 2267)	−0·8% (−1·9 to 0·3)	−1·2% (−4·0 to 1·4)	−1·0% (−2·2 to 0·2)
Paraguay	145·6 (130·2 to 162·4)	119·8 (107·3 to 134·0)	95·2 (71·6 to 126·9)	209 (187 to 233)	181 (162 to 202)	156 (117 to 208)	−1·5% (−2·7 to −0·3)	−2·4% (−5·3 to 1·0)	−1·9% (−3·2 to −0·5)
North Africa and Middle East	131·0 (115·4 to 147·8)	101·8 (85·1 to 121·3)	78·1 (63·1 to 97·6)	13 106 (11 543 to 14 783)	10 370 (8672 to 12 351)	8907 (7204 to 11 135)	−2·0% (−3·2 to −0·9)	−2·7% (−4·3 to −1·0)	−2·3% (−3·2 to −1·3)
Algeria	126·1 (87·0 to 170·4)	81·0 (59·8 to 107·0)	51·5 (37·2 to 70·1)	949 (655 to 1283)	575 (424 to 759)	470 (340 to 641)	−3·4% (−6·5 to 0·1)	−4·5% (−8·6 to −0·5)	−3·9% (−5·8 to −2·0)
Bahrain	55·4 (40·7 to 73·4)	32·7 (24·9 to 41·9)	21·4 (15·5 to 29·0)	7 (5 to 10)	5 (4 to 6)	4 (3 to 6)	−4·0% (−6·9 to −1·1)	−4·3% (−8·0 to 0·1)	−4·2% (−6·1 to −2·2)
Egypt	83·7 (69·9 to 100·1)	44·8 (39·1 to 51·9)	32·6 (24·5 to 42·3)	1385 (1157 to 1656)	765 (668 to 888)	619 (465 to 803)	−4·8% (−6·5 to −3·0)	−3·2% (−6·2 to −0·3)	−4·1% (−5·5 to −2·8)
Iran	40·1 (27·0 to 57·2)	26·6 (21·9 to 31·6)	13·5 (9·4 to 18·3)	651 (439 to 929)	333 (275 to 396)	197 (137 to 266)	−3·1% (−6·2 to 0·2)	−6·9% (−10·9 to −3·1)	−4·7% (−7·0 to −2·6)
Iraq	110·6 (68·7 to 157·0)	88·0 (62·0 to 126·8)	65·8 (40·4 to 110·7)	736 (457 to 1045)	816 (574 to 1175)	695 (427 to 1170)	−1·7% (−5·6 to 2·5)	−3·1% (−8·1 to 2·3)	−2·3% (−4·8 to 0·7)
Jordan	102·2 (79·1 to 128·7)	60·2 (46·2 to 78·8)	29·8 (20·3 to 41·4)	112 (87 to 141)	92 (71 to 120)	57 (39 to 79)	−4·1% (−6·9 to −1·3)	−7·1% (−11·8 to −2·2)	−5·4% (−7·2 to −3·5)
Kuwait	17·8 (14·4 to 21·6)	11·4 (9·6 to 13·6)	9·5 (7·5 to 12·0)	6 (5 to 7)	5 (5 to 7)	7 (5 to 8)	−3·4% (−5·4 to −1·4)	−1·8% (−4·4 to 0·8)	−2·7% (−4·0 to −1·4)
Lebanon	101·4 (74·8 to 135·1)	42·4 (30·8 to 56·8)	18·1 (11·9 to 26·0)	65 (48 to 87)	23 (16 to 30)	12 (8 to 17)	−6·7% (−9·5 to −3·9)	−8·6% (−12·7 to −4·9)	−7·5% (−9·7 to −5·5)
Libya	41·8 (25·7 to 64·6)	30·7 (22·8 to 40·5)	27·0 (18·0 to 40·5)	46 (28 to 71)	37 (27 to 49)	33 (22 to 50)	−2·3% (−6·0 to 1·6)	−1·4% (−6·5 to 3·7)	−1·9% (−4·5 to 0·8)
Morocco	279·5 (236·0 to 338·9)	98·3 (75·2 to 120·8)	63·9 (45·1 to 85·8)	1971 (1664 to 2390)	603 (462 to 741)	472 (334 to 635)	−8·1% (−10·2 to −6·0)	−4·4% (−7·5 to −1·3)	−6·5% (−8·1 to −5·0)
Oman	47·0 (26·7 to 76·6)	20·4 (14·2 to 29·4)	12·8 (8·4 to 20·6)	30 (17 to 49)	11 (7 to 15)	9 (6 to 15)	−6·3% (−10·8 to −1·7)	−4·8% (−10·8 to 1·2)	−5·6% (−8·5 to −2·8)
Palestine	21·1 (12·3 to 34·3)	11·3 (8·7 to 14·4)	9·0 (5·5 to 13·2)	22 (13 to 35)	13 (10 to 17)	12 (7 to 17)	−4·6% (−9·0 to −0·4)	−2·5% (−7·5 to 2·3)	−3·7% (−6·8 to −0·7)

(Table 1 continues on next page)

	Maternal mortality ratio (per 100 000 livebirths)			Number of maternal deaths			Annualised rate of change in maternal mortality ratio (%)		
	1990	2003	2013	1990	2003	2013	1990–2003	2003–13	1990–2013
(Continued from previous page)									
Qatar	50·4 (36·2 to 69·8)	38·9 (29·6 to 50·1)	18·7 (12·4 to 27·2)	5 (4 to 7)	4 (3 to 6)	4 (3 to 6)	−2·0% (−5·1 to 1·0)	−7·4% (−12·2 to −2·8)	−4·3% (−6·6 to −2·2)
Saudi Arabia	15·7 (9·1 to 25·2)	9·3 (7·6 to 11·1)	7·0 (5·2 to 9·2)	88 (51 to 140)	49 (41 to 59)	38 (28 to 50)	−3·8% (−7·9 to 0·6)	−2·8% (−6·2 to 0·5)	−3·4% (−5·8 to −0·8)
Sudan	407·8 (304·2 to 502·9)	356·5 (237·6 to 478·8)	275·2 (181·1 to 377·5)	3558 (2654 to 4388)	4193 (2794 to 5631)	3528 (2322 to 4840)	−1·1% (−3·5 to 1·1)	−2·6% (−5·4 to 0·2)	−1·8% (−3·3 to −0·2)
Syria	120·5 (86·0 to 158·8)	64·8 (49·1 to 80·9)	44·1 (31·1 to 60·3)	513 (367 to 676)	309 (235 to 386)	229 (161 to 313)	−4·7% (−7·7 to −1·8)	−3·9% (−7·7 to 0·1)	−4·4% (−6·4 to −2·4)
Tunisia	62·2 (44·4 to 82·7)	28·5 (18·4 to 42·3)	19·0 (11·6 to 28·5)	124 (88 to 164)	48 (31 to 72)	35 (21 to 53)	−6·1% (−9·7 to −2·4)	−4·1% (−9·1 to 0·7)	−5·2% (−7·6 to −3·0)
Turkey	48·5 (34·7 to 65·2)	23·1 (17·1 to 30·9)	15·0 (10·7 to 19·9)	664 (475 to 893)	304 (226 to 408)	188 (134 to 250)	−5·7% (−8·9 to −2·6)	−4·3% (−8·4 to −0·1)	−5·1% (−6·9 to −3·2)
United Arab Emirates	55·8 (31·0 to 112·1)	21·6 (14·1 to 33·7)	12·8 (7·7 to 21·4)	23 (13 to 47)	12 (8 to 18)	17 (10 to 29)	−7·1% (−11·9 to −2·4)	−5·3% (−10·2 to 1·0)	−6·3% (−9·5 to −3·0)
Yemen	342·6 (182·1 to 519·2)	322·2 (182·7 to 524·9)	308·8 (168·6 to 555·4)	2151 (1143 to 3260)	2172 (1232 to 3538)	2279 (1244 to 4099)	−0·5% (−3·5 to 2·7)	−0·5% (−3·8 to 3·3)	−0·5% (−2·8 to 2·2)
High-income North America	11·9 (10·7 to 13·3)	17·0 (15·1 to 18·8)	17·6 (14·3 to 21·6)	555 (499 to 621)	784 (697 to 867)	829 (672 to 1016)	2·7% (1·5 to 3·8)	0·3% (−1·8 to 2·6)	1·7% (0·7 to 2·6)
Canada	7·1 (6·0 to 8·3)	9·2 (7·6 to 10·7)	8·2 (6·3 to 10·3)	28 (24 to 33)	32 (27 to 37)	33 (25 to 42)	2·0% (0·2 to 3·6)	−1·2% (−3·7 to 1·3)	0·6% (−0·7 to 1·9)
USA	12·4 (11·1 to 13·9)	17·6 (15·7 to 19·5)	18·5 (14·8 to 22·9)	527 (472 to 592)	752 (669 to 833)	796 (638 to 985)	2·7% (1·4 to 3·8)	0·5% (−1·8 to 2·8)	1·7% (0·8 to 2·7)
Oceania	599·9 (365·3 to 972·5)	577·8 (331·4 to 976·3)	494·1 (264·4 to 849·3)	1234 (752 to 2001)	1461 (838 to 2469)	1325 (709 to 2278)	−0·3% (−3·3 to 2·7)	−1·6% (−5·2 to 2·4)	−0·9% (−3·2 to 1·7)
Federated States of Micronesia	170·3 (82·9 to 310·8)	130·5 (66·6 to 235·5)	87·9 (44·7 to 154·5)	6 (3 to 10)	4 (2 to 7)	2 (1 to 4)	−2·0% (−6·0 to 2·0)	−3·9% (−8·5 to 0·7)	−2·9% (−5·6 to 0·0)
Fiji	109·6 (68·4 to 165·2)	100·8 (72·0 to 135·5)	68·2 (43·7 to 102·8)	24 (15 to 36)	19 (14 to 26)	12 (8 to 18)	−0·6% (−4·4 to 3·6)	−4·0% (−9·0 to 0·8)	−2·1% (−4·9 to 0·7)
Kiribati	213·3 (153·9 to 296·9)	142·4 (97·1 to 216·5)	100·9 (57·4 to 169·1)	6 (4 to 8)	3 (2 to 5)	2 (1 to 4)	−3·2% (−7·1 to 0·8)	−3·6% (−9·0 to 1·8)	−3·4% (−6·2 to −0·6)
Marshall Islands	74·7 (46·2 to 111·8)	109·4 (66·3 to 167·8)	95·6 (51·9 to 164·9)	2 (1 to 2)	2 (1 to 3)	2 (1 to 3)	2·9% (−1·6 to 7·4)	−1·5% (−7·8 to 5·1)	1·0% (−2·0 to 4·0)
Papua New Guinea	765·9 (456·7 to 1255·9)	702·6 (396·4 to 1197·8)	594·2 (312·7 to 1030·8)	1148 (684 to 1882)	1382 (779 to 2355)	1260 (663 to 2187)	−0·7% (−3·8 to 2·4)	−1·7% (−5·4 to 2·3)	−1·1% (−3·6 to 1·5)
Samoa	61·1 (36·2 to 99·7)	51·2 (32·5 to 76·3)	41·4 (26·9 to 62·8)	3 (2 to 5)	3 (2 to 4)	2 (1 to 3)	−1·3% (−6·0 to 3·3)	−2·1% (−7·0 to 3·3)	−1·6% (−4·6 to 1·1)
Solomon Islands	254·0 (127·4 to 454·4)	214·5 (112·5 to 379·3)	183·0 (95·9 to 338·5)	32 (16 to 56)	34 (18 to 60)	32 (17 to 59)	−1·3% (−5·2 to 2·7)	−1·6% (−6·0 to 3·2)	−1·4% (−4·5 to 1·6)
Tonga	188·1 (118·8 to 286·9)	143·3 (108·8 to 185·6)	111·2 (68·2 to 172·2)	6 (4 to 9)	4 (3 to 5)	3 (2 to 5)	−2·0% (−6·0 to 1·8)	−2·7% (−7·8 to 2·3)	−2·3% (−5·0 to 0·4)
Vanuatu	176·3 (83·5 to 329·7)	174·8 (88·2 to 333·0)	139·2 (72·3 to 257·6)	10 (5 to 18)	10 (5 to 20)	9 (5 to 17)	−0·1% (−4·2 to 4·1)	−2·2% (−6·6 to 2·4)	−1·0% (−4·0 to 2·2)
Central sub-Saharan Africa	456·3 (366·2 to 546·7)	419·1 (341·2 to 499·8)	353·1 (279·9 to 434·1)	12 178 (9773 to 14 591)	15 191 (12 369 to 18 118)	15 355 (12 174 to 18 880)	−0·7% (−2·2 to 0·8)	−1·7% (−3·8 to 0·3)	−1·1% (−2·3 to 0·1)
Angola	510·6 (324·9 to 747·3)	451·1 (308·9 to 657·8)	310·1 (198·3 to 472·2)	2976 (1894 to 4356)	3672 (2515 to 5355)	3032 (1939 to 4618)	−0·9% (−3·7 to 1·8)	−3·8% (−7·1 to −0·5)	−2·2% (−4·0 to 0·0)
Central African Republic	788·7 (576·4 to 1020·1)	999·4 (636·2 to 1415·6)	910·5 (578·3 to 1293·2)	973 (711 to 1258)	1473 (937 to 2086)	1459 (926 to 2072)	1·8% (−0·7 to 3·9)	−0·9% (−3·8 to 1·7)	0·6% (−1·0 to 2·0)
Congo	397·2 (275·6 to 545·1)	482·8 (322·1 to 673·7)	287·3 (189·6 to 427·1)	379 (263 to 519)	678 (452 to 946)	494 (326 to 735)	1·5% (−1·1 to 3·9)	−5·2% (−8·5 to −2·0)	−1·4% (−3·4 to 0·4)
DR Congo	420·1 (323·5 to 521·5)	369·5 (295·0 to 451·4)	342·3 (251·4 to 446·7)	7616 (5865 to 9455)	9069 (7241 to 11 081)	10 125 (7437 to 13 213)	−1·0% (−3·1 to 1·3)	−0·8% (−3·7 to 1·8)	−0·9% (−2·6 to 0·7)
Equatorial Guinea	599·9 (376·2 to 897·0)	487·3 (280·4 to 736·7)	369·6 (199·8 to 620·0)	109 (68 to 163)	110 (63 to 166)	100 (54 to 168)	−1·6% (−5·4 to 2·3)	−2·9% (−6·9 to 1·4)	−2·2% (−4·9 to 0·9)

(Table 1 continues on next page)

	Maternal mortality ratio (per 100 000 livebirths)			Number of maternal deaths			Annualised rate of change in maternal mortality ratio (%)		
	1990	2003	2013	1990	2003	2013	1990–2003	2003–13	1990–2013
(Continued from previous page)									
Gabon	345·7 (265·2 to 438·6)	413·0 (301·0 to 541·8)	267·3 (184·1 to 370·3)	126 (96 to 159)	189 (138 to 248)	144 (99 to 199)	1·3% (–1·3 to 4·0)	–4·4% (–7·9 to –1·3)	–1·2% (–2·9 to 0·6)
Eastern sub-Saharan Africa	511·7 (461·5 to 562·3)	564·7 (490·8 to 640·0)	387·2 (331·5 to 453·0)	45 250 (40 808 to 49 719)	65 050 (56 537 to 73 735)	52 269 (44 747 to 61 144)	0·7% (–0·3 to 1·9)	–3·8% (–5·1 to –2·4)	–1·2% (–1·8 to –0·6)
Burundi	757·1 (560·5 to 977·3)	712·3 (538·5 to 899·9)	370·8 (240·4 to 504·3)	2122 (1571 to 2739)	2240 (1693 to 2830)	1683 (1091 to 2289)	–0·5% (–3·0 to 1·9)	–6·6% (–10·2 to –3·7)	–3·1% (–5·1 to –1·4)
Comoros	527·4 (319·7 to 830·5)	383·0 (219·8 to 646·7)	329·2 (171·9 to 584·5)	82 (50 to 130)	88 (50 to 148)	85 (45 to 152)	–2·5% (–6·0 to 1·1)	–1·7% (–6·6 to 2·6)	–2·2% (–4·9 to 0·7)
Djibouti	526·3 (334·8 to 788·7)	629·3 (405·3 to 962·4)	523·5 (329·8 to 821·8)	124 (79 to 186)	138 (89 to 211)	123 (77 to 193)	1·4% (–1·9 to 4·6)	–1·9% (–5·2 to 1·5)	0·0% (–2·2 to 2·2)
Eritrea	614·2 (493·7 to 747·0)	679·9 (475·9 to 902·1)	566·0 (351·2 to 817·7)	949 (763 to 1154)	1241 (868 to 1646)	1313 (814 to 1896)	0·7% (–1·8 to 3·1)	–1·9% (–5·1 to 0·9)	–0·4% (–2·3 to 1·3)
Ethiopia	708·0 (600·4 to 815·0)	657·8 (486·3 to 839·6)	497·4 (371·5 to 648·8)	16 740 (14 197 to 19 271)	18 941 (14 001 to 24 173)	15 234 (11 378 to 19 871)	–0·6% (–3·1 to 1·4)	–2·8% (–5·2 to –0·2)	–1·6% (–2·8 to –0·3)
Kenya	315·5 (250·1 to 382·2)	559·2 (375·0 to 773·0)	277·2 (175·4 to 414·1)	3047 (2416 to 3692)	7628 (5115 to 10 543)	4361 (2759 to 6514)	4·3% (1·3 to 7·4)	–7·1% (–10·8 to –3·9)	–0·6% (–2·6 to 1·4)
Madagascar	314·0 (246·9 to 375·5)	378·0 (255·9 to 480·7)	297·7 (174·3 to 448·6)	1723 (1355 to 2061)	2610 (1766 to 3319)	2455 (1438 to 3699)	1·4% (–1·0 to 3·4)	–2·6% (–6·4 to 1·6)	–0·3% (–2·3 to 1·5)
Malawi	550·3 (440·5 to 669·6)	815·3 (567·4 to 1111·1)	334·7 (224·5 to 465·1)	2627 (2103 to 3197)	4542 (3161 to 6189)	2260 (1516 to 3140)	3·0% (0·7 to 5·3)	–8·9% (–12·5 to –6·1)	–2·2% (–3·8 to –0·6)
Mauritius	66·8 (56·8 to 79·1)	55·9 (47·8 to 65·8)	43·7 (34·4 to 54·7)	15 (13 to 18)	10 (8 to 12)	6 (5 to 8)	–1·4% (–3·0 to 0·4)	–2·5% (–5·1 to 0·0)	–1·9% (–3·0 to –0·6)
Mozambique	363·4 (262·6 to 463·2)	250·0 (184·3 to 322·0)	248·7 (151·4 to 365·4)	2190 (1583 to 2791)	2339 (1724 to 3012)	2574 (1567 to 3783)	–2·9% (–5·7 to 0·2)	–0·2% (–3·9 to 3·0)	–1·7% (–4·0 to 0·5)
Rwanda	656·1 (528·6 to 791·5)	612·6 (477·4 to 766·5)	291·0 (189·9 to 400·7)	2021 (1628 to 2438)	2142 (1669 to 2680)	1185 (773 to 1631)	–0·5% (–2·6 to 1·6)	–7·6% (–11·6 to –4·0)	–3·6% (–5·6 to –1·9)
Seychelles	21·2 (16·4 to 26·7)	14·9 (11·6 to 18·9)	15·7 (12·2 to 20·7)	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	–2·7% (–5·0 to –0·2)	0·5% (–2·8 to 4·0)	–1·3% (–2·8 to 0·3)
Somalia	486·9 (276·2 to 766·6)	422·4 (264·4 to 706·2)	407·7 (247·4 to 684·2)	1574 (893 to 2479)	1673 (1047 to 2797)	1903 (1155 to 3194)	–1·1% (–4·2 to 1·9)	–0·4% (–3·5 to 2·9)	–0·8% (–2·8 to 1·6)
South Sudan	763·8 (432·8 to 1129·7)	872·9 (602·8 to 1172·3)	956·8 (685·1 to 1262·8)	2138 (1211 to 3162)	2718 (1877 to 3650)	3912 (2801 to 5163)	1·2% (–2·3 to 4·9)	0·9% (–2·5 to 4·8)	1·1% (–1·2 to 3·8)
Tanzania	498·0 (399·2 to 593·4)	622·9 (449·6 to 812·0)	389·6 (266·5 to 548·7)	5814 (4661 to 6929)	10 148 (7324 to 13 228)	7745 (5298 to 10 908)	1·7% (–0·7 to 3·9)	–4·7% (–7·9 to –1·7)	–1·1% (–2·7 to 0·4)
Uganda	296·3 (215·6 to 392·4)	461·5 (319·6 to 615·9)	324·9 (213·8 to 450·2)	2800 (2037 to 3708)	6159 (4265 to 8219)	5385 (3544 to 7461)	3·4% (1·0 to 5·9)	–3·5% (–6·6 to –0·6)	0·4% (–1·4 to 2·2)
Zambia	354·6 (256·2 to 464·3)	475·1 (301·7 to 697·1)	315·1 (206·7 to 459·3)	1283 (927 to 1679)	2435 (1547 to 3574)	2044 (1341 to 2980)	2·2% (–0·5 to 4·5)	–4·1% (–7·3 to –0·7)	–0·6% (–2·1 to 1·0)
Southern sub-Saharan Africa	150·8 (115·9 to 182·6)	490·4 (367·8 to 626·1)	279·8 (202·6 to 381·5)	2455 (1886 to 2973)	8406 (6305 to 10 733)	4898 (3547 to 6679)	9·1% (6·5 to 11·8)	–5·6% (–8·1 to –3·0)	2·7% (1·2 to 4·4)
Botswana	205·8 (101·3 to 325·6)	1061·1 (523·3 to 1793·6)	480·8 (211·8 to 828·4)	95 (47 to 151)	504 (249 to 852)	228 (100 to 393)	12·6% (6·9 to 18·0)	–8·1% (–12·5 to –3·7)	3·6% (–0·1 to 6·7)
Lesotho	189·5 (130·9 to 255·2)	606·5 (419·2 to 849·2)	510·6 (303·5 to 772·7)	107 (74 to 144)	343 (237 to 480)	295 (175 to 446)	8·9% (5·5 to 12·7)	–1·8% (–5·1 to 1·5)	4·3% (1·9 to 6·6)
Namibia	165·2 (99·1 to 223·4)	307·5 (212·4 to 440·0)	149·6 (90·3 to 236·1)	89 (54 to 121)	184 (127 to 263)	89 (54 to 141)	4·8% (1·5 to 8·5)	–7·3% (–11·5 to –3·3)	–0·5% (–2·6 to 1·6)
South Africa	134·0 (93·3 to 175·2)	341·8 (227·8 to 481·0)	174·1 (96·3 to 274·9)	1403 (977 to 1835)	3739 (2492 to 5262)	1925 (1065 to 3041)	7·2% (3·3 to 11·1)	–6·9% (–11·1 to –2·7)	1·0% (–1·6 to 3·8)
Swaziland	111·2 (78·1 to 151·1)	272·9 (191·9 to 385·2)	148·5 (91·1 to 229·1)	41 (29 to 56)	97 (68 to 137)	55 (34 to 85)	6·9% (3·2 to 10·5)	–6·2% (–10·1 to –2·2)	1·2% (–1·3 to 3·6)
Zimbabwe	185·8 (143·8 to 232·9)	840·9 (490·4 to 1238·2)	520·7 (313·5 to 786·2)	719 (556 to 901)	3539 (2064 to 5212)	2306 (1388 to 3481)	11·5% (8·3 to 14·4)	–4·8% (–8·3 to –1·4)	4·4% (2·6 to 6·3)
Western sub-Saharan Africa	480·4 (419·0 to 544·8)	563·3 (489·7 to 639·1)	468·9 (385·4 to 564·0)	44 133 (38 493 to 50 052)	69 443 (60 370 to 78 794)	70 858 (58 231 to 85 221)	1·2% (–0·2 to 2·6)	–1·9% (–3·3 to –0·3)	–0·1% (–1·1 to 0·8)
Benin	523·5 (418·4 to 619·6)	415·8 (311·4 to 522·8)	328·6 (229·2 to 441·3)	1259 (1006 to 1490)	1347 (1009 to 1694)	1246 (869 to 1674)	–1·8% (–4·1 to 0·5)	–2·4% (–5·2 to 0·2)	–2·1% (–3·6 to –0·6)

(Table 1 continues on next page)

	Maternal mortality ratio (per 100 000 livebirths)			Number of maternal deaths			Annualised rate of change in maternal mortality ratio (%)		
	1990	2003	2013	1990	2003	2013	1990–2003	2003–13	1990–2013
(Continued from previous page)									
Burkina Faso	301·5 (224·9 to 383·1)	409·2 (307·2 to 517·5)	310·5 (223·1 to 406·2)	1325 (989 to 1684)	2443 (1834 to 3090)	2185 (1570 to 2858)	2·3% (0·1 to 4·6)	−2·8% (−6·1 to 0·3)	0·1% (−1·5 to 1·6)
Cameroon	436·4 (351·7 to 510·0)	614·4 (472·3 to 789·3)	564·6 (414·0 to 743·6)	2451 (1975 to 2865)	4476 (3441 to 5750)	4772 (3499 to 6285)	2·6% (0·5 to 5·0)	−0·9% (−3·4 to 1·4)	1·1% (−0·4 to 2·6)
Cape Verde	110·4 (83·5 to 138·3)	80·5 (47·8 to 128·1)	47·6 (27·9 to 76·2)	15 (11 to 19)	9 (5 to 15)	5 (3 to 8)	−2·6% (−6·6 to 1·2)	−5·3% (−11·2 to 0·4)	−3·8% (−6·2 to −1·4)
Chad	429·8 (352·9 to 510·2)	659·2 (506·9 to 808·4)	597·6 (408·4 to 809·5)	1424 (1170 to 1691)	3245 (2496 to 3980)	3593 (2456 to 4868)	3·3% (1·3 to 5·3)	−1·1% (−3·8 to 1·3)	1·4% (−0·3 to 2·9)
Côte d'Ivoire	496·9 (374·7 to 606·4)	729·8 (521·8 to 968·7)	501·5 (354·3 to 653·9)	2539 (1915 to 3099)	4771 (3411 to 6333)	3824 (2702 to 4987)	2·9% (0·5 to 5·2)	−3·7% (−6·8 to −0·9)	0·0% (−1·4 to 1·3)
Ghana	374·3 (247·7 to 528·1)	418·1 (309·6 to 532·9)	293·4 (193·5 to 410·4)	2143 (1418 to 3024)	2933 (2172 to 3739)	2343 (1545 to 3277)	0·9% (−2·6 to 4·7)	−3·6% (−7·3 to −0·3)	−1·1% (−3·6 to 1·4)
Guinea	660·4 (564·4 to 768·8)	676·3 (542·1 to 811·8)	615·4 (470·5 to 781·9)	1966 (1680 to 2289)	2642 (2118 to 3171)	2720 (2080 to 3457)	0·2% (−1·7 to 1·8)	−1·0% (−3·1 to 1·0)	−0·3% (−1·6 to 0·9)
Guinea-Bissau	708·1 (417·3 to 1052·9)	837·7 (573·6 to 1154·5)	885·3 (616·5 to 1230·2)	334 (197 to 497)	478 (327 to 659)	576 (401 to 800)	1·4% (−1·6 to 4·5)	0·6% (−2·3 to 3·5)	1·0% (−1·0 to 3·0)
Liberia	630·1 (487·9 to 782·0)	779·5 (605·3 to 962·1)	627·3 (467·5 to 793·2)	624 (483 to 775)	1038 (806 to 1281)	974 (726 to 1232)	1·6% (−0·8 to 4·1)	−2·2% (−4·6 to 0·1)	0·0% (−1·6 to 1·4)
Mali	573·0 (500·0 to 649·8)	506·7 (415·9 to 603·8)	388·3 (300·6 to 487·3)	2326 (2030 to 2638)	2936 (2410 to 3499)	2966 (2295 to 3722)	−1·0% (−2·5 to 0·7)	−2·7% (−5·0 to −0·5)	−1·7% (−2·9 to −0·5)
Mauritania	680·6 (585·6 to 789·8)	681·0 (501·2 to 856·1)	568·8 (363·6 to 793·6)	580 (499 to 673)	772 (568 to 971)	761 (487 to 1062)	0·0% (−2·4 to 1·8)	−1·9% (−4·6 to 0·6)	−0·8% (−2·7 to 0·7)
Niger	481·0 (394·4 to 567·6)	427·3 (348·3 to 523·0)	406·5 (308·2 to 505·0)	2217 (1818 to 2616)	2920 (2379 to 3573)	3873 (2936 to 4811)	−0·9% (−2·7 to 0·9)	−0·5% (−2·9 to 1·7)	−0·7% (−2·1 to 0·5)
Nigeria	483·2 (359·9 to 608·4)	585·7 (445·6 to 717·8)	496·4 (335·9 to 666·2)	21 233 (15 814 to 26 737)	34 810 (26 480 to 42 656)	36 698 (24 829 to 49 252)	1·5% (−1·2 to 4·0)	−1·7% (−4·4 to 0·9)	0·1% (−1·8 to 1·9)
São Tomé and Príncipe	297·5 (211·4 to 395·6)	195·7 (133·1 to 251·6)	134·9 (65·2 to 208·6)	13 (9 to 18)	11 (8 to 14)	9 (4 to 14)	−3·2% (−6·6 to −0·1)	−4·0% (−9·5 to 0·9)	−3·6% (−6·5 to −1·0)
Senegal	518·8 (441·9 to 601·7)	462·2 (366·1 to 557·3)	347·2 (249·2 to 455·2)	1727 (1471 to 2003)	2018 (1598 to 2433)	1881 (1350 to 2466)	−0·9% (−2·9 to 0·9)	−2·9% (−5·5 to −0·5)	−1·8% (−3·2 to −0·5)
Sierra Leone	521·4 (383·9 to 668·2)	665·1 (535·3 to 795·8)	622·6 (447·9 to 790·5)	943 (694 to 1209)	1360 (1095 to 1627)	1399 (1006 to 1776)	1·9% (−0·6 to 4·3)	−0·7% (−3·4 to 1·6)	0·8% (−1·0 to 2·3)
The Gambia	444·4 (230·1 to 685·5)	368·2 (191·4 to 580·8)	264·5 (135·5 to 434·7)	205 (106 to 316)	232 (121 to 366)	216 (111 to 356)	−1·4% (−5·0 to 2·4)	−3·3% (−6·9 to 0·6)	−2·2% (−5·0 to 0·6)
Togo	496·7 (407·1 to 603·8)	477·4 (332·4 to 644·0)	326·2 (210·7 to 473·0)	807 (662 to 981)	1001 (697 to 1350)	817 (528 to 1185)	−0·4% (−3·1 to 2·2)	−3·9% (−7·4 to −0·4)	−1·9% (−3·8 to −0·1)

Data in parentheses are 95% uncertainty intervals.

Table 1: **Maternal mortality ratio, numbers of maternal deaths, and annualised rates of change for 21 Global Burden of Disease regions and 188 countries**

Bethesda, MD, USA (X Che PhD); **Cyprus University of Technology, Limassol, Cyprus** (C A Christophi PhD); **Cedars-Sinai Medical Centre, Los Angeles, CA, USA** (Prof S S Chugh MD); **University of Salerno, Baronissi, Italy** (Prof M Cirillo MD); **Mayo Clinic, Rochester, MN, USA** (L T Cooper MD); **Medical Research Council Lifecourse Epidemiology Unit, University of Southampton, Southampton, UK** (Prof C Cooper FMedSci); **National School of Public Health (ENSP/Fiocruz), Rio de Janeiro, Brazil** (I da Costa Leite PhD); **Public Health Foundation of India, New Delhi, India** (Prof L Dandona, R Dandona PhD,

annualised rate of change from 2003 to 2013 to predict the MMR for 2030. For countries with an increasing MMR in that period, we assumed that the MMR would remain constant. We used UN Population Division forecasts of the population aged 15–49 years and births to forecast the number of maternal deaths for each country. We calculated annualised rate of change for 1990–2013 using the continuous rate-of-change formula. Achievement of the MDG 5 target would be equivalent to a sustained 5·5% decrease per year from 1990 to 2015.

Uncertainty

We report 95% uncertainty intervals (UIs) for maternal deaths, the MMR, causes of maternal death, timing of maternal deaths, and annualised rates of change. The ensemble models for maternal mortality generate 1000 draws from the posterior distribution; the validity of the UIs was confirmed through 50 iterations of cross-validation with data held out during CODEm estimation. Additionally, DisMod-MR produced 1000 draws from the posterior distribution for the cause analysis and time-of-death analysis. We assumed uncertainty in the estimated fraction of maternal deaths due to each cause or the estimated fraction of maternal deaths in different timings to be independent of the uncertainty in the occurrence of maternal mortality. We calculated uncertainty with 1000 draws from the posterior distribution of every step of the estimation process, which allows for quantification and propagation of uncertainty associated with each of the epidemiological variables in the GBD framework. These UIs are different from confidence intervals, which would only quantify

sampling uncertainty in the underlying data for a specific model.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The authors had access to the data in the study and had final responsibility for the decision to submit for publication.

Results

The total annual number of maternal deaths decreased from 376 034 (95% UI 343 483–407 574) in 1990, to 292 982 (261 017–327 792) in 2013 (figure 3A, table 1). The reduction accelerated steadily from 1990 to 2013 (figure 3B), with corresponding decreases in MMR (table 1). Between 2003 and 2013, the annual rate of change in MMR was greater than –1%, reaching –3·3% for 2012–13 (figure 3B).

MMR was highest in the oldest age groups and lowest in women aged 20–29 years in both 1990 and 2013 (figure 4). However, it decreased significantly between 1990 and 2013 for almost all age groups (figure 4). We used data for the proportions of births in different maternal age groups and calculated that 9·5% of maternal deaths are in the group aged 15–19 years, 43·1% in women aged 20–29 years, and 47·0% in those aged 30 years and older, with the remainder occurring in the group aged 10–14 years. Despite much higher rates of mortality in older age groups, the total number of deaths is roughly equal before and after the age of 30 years. The MMR in mothers aged 15–19 years in 2013 was 1·5 times higher than that in women aged 20–24 years, and 1·4 times higher than in those aged 25–29 years. In 2013, the MMR was 9·5 times higher for a woman aged 45–49 years (1374·4, 95% UI 1117·1–1694·9) than for a woman aged 20–24 years (144·1, 120·6–169·9).

We recorded substantial differences across the GBD regions in the trends in maternal deaths and the MMR (figure 5). Of the regions where the MMR was more than 300 in 1990, south Asia made the greatest progress by 2013 (figure 5A, table 1). In eastern and western sub-Saharan Africa, MMRs increased until 2005, but have since reduced substantially (figure 5A). The MMR in eastern sub-Saharan Africa has been changing at a rate of –4·5% per year (95% UI –6·0 to –2·8) since 2005.

Of regions that had MMRs of 100–300 in 1990, southeast Asia has had the most notable decreases (figure 5B). The MMR in the Caribbean has followed a similar trend to eastern and western sub-Saharan Africa—ie, increasing to 2005, before falling—and it has improved only slightly in north Africa and the Middle East (figure 5B). The MMR in southern sub-Saharan Africa increased greatly between 1990 and 2006, rising from 150·8 (95% UI 115·9–182·6) to 565·7 (420·1–737·2), but then fell to 279·8 (202·6–381·5) in 2013 (figure 5B).

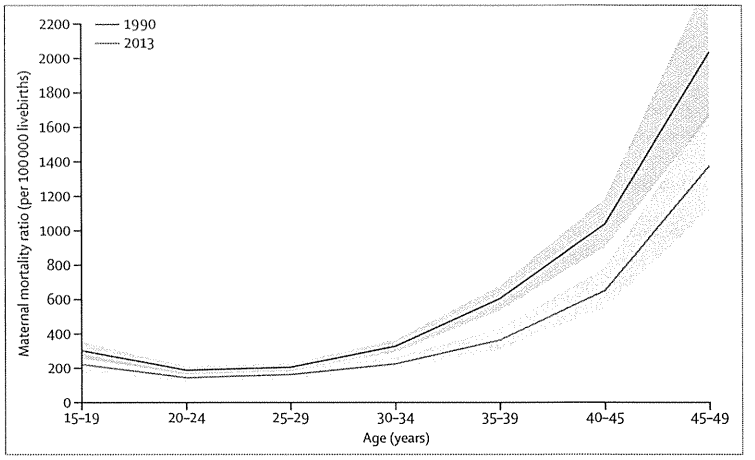

Figure 4: **Global maternal mortality ratio in 1990 and 2013, by age**
Shaded areas show 95% uncertainty intervals.

We recorded decreases in MMRs in all regions that had an MMR of 30–100 in 1990 (figure 5C, table 1). This reduction is particularly evident in east Asia (figure 5C, table 1). The rates of change in southern Latin America and central Latin America since 2000 seem to have been slower than those before 2000 (figure 5C). In regions with low MMR in 1990 (<30), the MMR has continued to reduce slowly, except for in the high-income region of North America (figure 5D, table 1).

Except for late maternal deaths and HIV-related deaths, the absolute numbers of deaths due to every cause decreased significantly (p<0·001) from 1990 to 2013 (table 2, appendix). However, in sub-Saharan Africa, the number of deaths due to all causes increased from 1990 to 2013 (table 1). Globally, the biggest absolute reduction was in deaths due to maternal haemorrhage: from 71 295 (95% UI 64 562–78 329) in 1990, to 44 190 (38 273–50 819) in 2013. The biggest percentage decrease was in maternal sepsis, which caused 11·6% (11·4–11·8) of all maternal deaths in 1990, but 9·7% (9·5–9·9) in 2013 (figure 6A). The proportion of maternal deaths due to indirect causes increased slightly from 9·1% (95% UI 8·9–9·4) in 1990, to 10·2% (10·0–10·5) in 2013 (figure 6A). Additionally, the proportion of maternal deaths due to other direct causes rose from 16·5% (95% UI 16·3–16·8) in 1990, to 17·0% (16·7–17·3) in 2013 (figure 6A). The number of late maternal deaths decreased globally by 3·0%, from 44 814 (95% UI 36 414–53 106) in 1990, to 43 507 (35 667–52 395) deaths in 2013. In 2013, HIV accounted for 1·5% (0·9–2·0) of all maternal deaths in sub-Saharan Africa, but only 0·4% (0·2–0·6) worldwide. The number of abortion-related deaths decreased significantly at the global level (p=0·002; figure 6A) and in all regions other than Oceania, where no significant change occurred (p=0·35), and sub-Saharan Africa, where the number of deaths increased significantly after abortion (p<0·001).

G A Kumar PhD, R B Kumar MD); **Public Health England, London, UK** (Prof A Davis PhD); **School of Medicine** (A Dayama MD), **Emory University, Atlanta, GA, USA** (Prof Y Liu PhD, S B Omer PhD); **The Kirby Institute** (A J Vallely PhD), **University of New South Wales, Sydney, NSW, Australia** (Prof L Degenhardt PhD); **Griffith University, Brisbane, QLD, Australia** (Prof D De Leo DSc); **University of Auckland, Auckland, New Zealand** (B del Pozo-Cruz PhD); **Africa Medical and Research Foundation in Ethiopia, Addis Ababa, Ethiopia** (M Dessalegn MPH); **Hospital for Sick Children, University of Toronto, Toronto, ON, Canada** (G A deVeber MD); **University of Peradeniya, Peradeniya, Sri Lanka** (S D Dharmaratne MD); **Harvard School of Public Health** (E L Ding ScD), **Harvard University, Boston, MA, USA** (Prof J A Salomon PhD); **Hatter Institute for Cardiovascular Research in Africa, Faculty of Health Sciences** (Prof K Sliwa PhD), **University of Cape Town, Cape Town, South Africa** (Prof R E Dorrington MPhil); **Sydney School of Public Health** (T R Driscoll PhD), **University of Sydney, NSW, Australia** (J Leigh PhD); **The Institute of Social and Economic Studies of Population at the Russian Academy of Sciences, Moscow, Russia** (Prof S P Ermakov DSc); **Non-Communicable Diseases Research Centre** (F Farzadfar MD);

Endocrinology and Metabolism Research Centre (Prof A Esteghamati MD, N Hafezi-Nejad MD, S Sheikhbahaei MD), Digestive Diseases Research Institute (S G Sepanlou MD), MS Research Centre (M A Sahraian MD), Sina Trauma and Surgery Research Centre (Prof V Rahimi-Movaghar MD), Tehran University of Medical Sciences, Tehran, Iran; Departamento de Saúde Pública, ARS Norte IP, Porto, Portugal (M M Felicio MD, C M Teixeira MD); Department of Medical Epidemiology and Biostatistics (E Weiderpass PhD), Karolinska Institutet, Stockholm, Sweden (S-M Fereshtehnejad MD, R Havmoeller MD); Northern Region Health Administration (V M P Machado MSc), Public Health Department, Unidade Local de Saúde de Matosinhos, Porto, Portugal (G M Ferreira de Lima BSC); Federal University of Minas Gerais, Belo Horizonte, Brazil (E B Franca PhD); National Centre for Disease Control and Public Health of Georgia, Tbilisi, Georgia (K Gambashidze MS, K Kazanjan MS, M Kereselidze MD, M Shakh-Nazarova MS, L Sturua PhD); Clinique Coopérative de Parakou, Parakou, Borgou, Benin (F G Gankpé MD); Public Health Unit of Primary Health Care Group of Almada-Seixal, Almada, Setúbal, Portugal (A C Garcia MPH); Division of Human Nutrition, Wageningen University, Wageningen, Netherlands (J M Geleijnse PhD); Monash University, Melbourne, VIC, Australia (K B Gibney MBBS, B K Lloyd PhD); University Hospital of Dijon, Dijon, France (Prof M Giroud MD); Heller School for Social Policy and Management (E L Glaser MA), Brandeis University, Waltham, MA, USA (B T Idrisov MD, E A Undurraga PhD); Ministry of Labour, Health and Social Affairs, Tbilisi, Georgia (K Goginashvili MPH); University of Massachusetts Medical School, Worcester, MA, USA (Prof P Gona PhD); National Institute of Public Health, Cuernavaca, Mexico (D González-Castell MSc, I B Heredia Pi PhD, F Mejía-Rodríguez MSc, J C Montañez Hernandez MSc, T G Sánchez Pimienta MSc, E E Servan-Mori MSc,

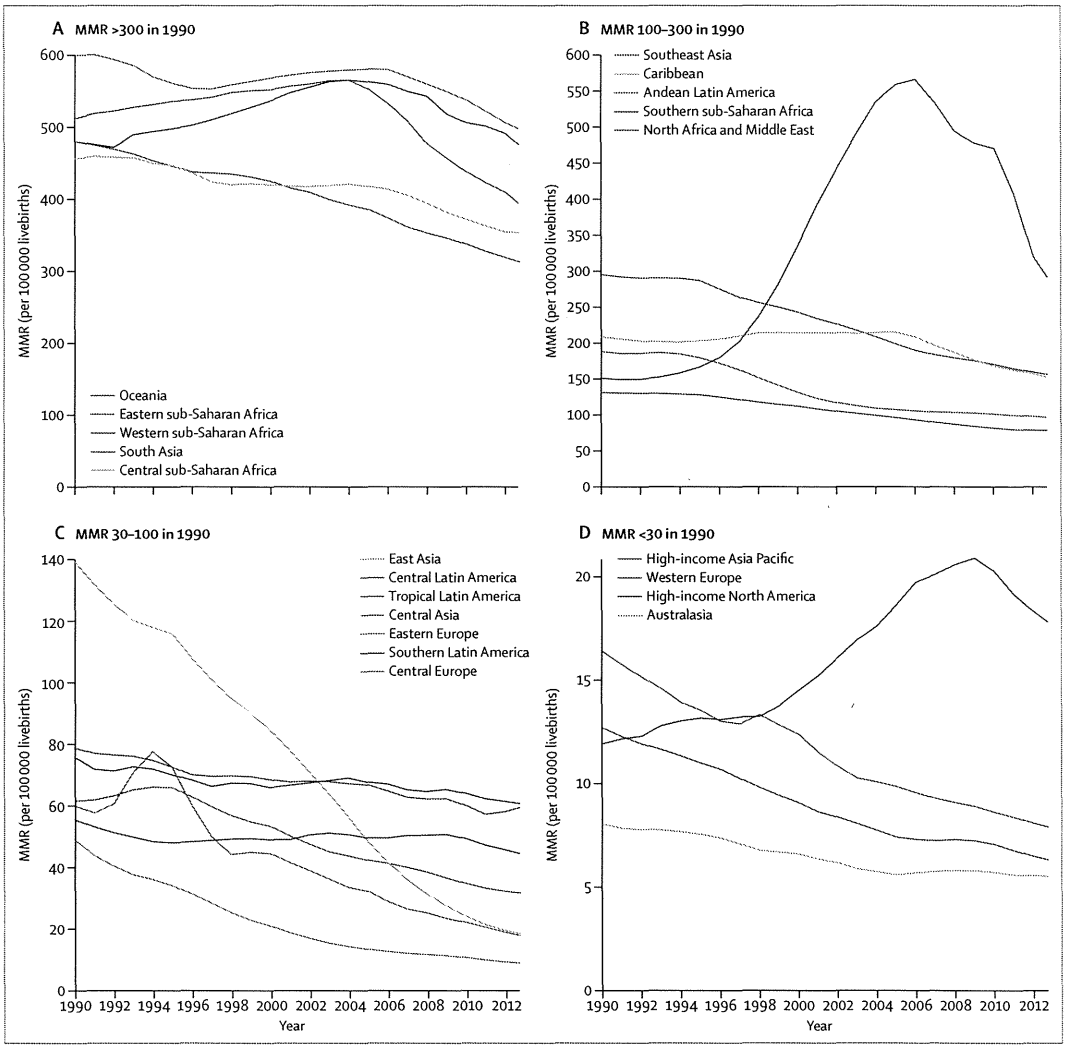

Figure 5: **Change in MMR between 1990 and 2013, by region**
MMR=maternal mortality ratio.

Cause patterns vary by regions. The two most important causes of maternal death in high-income regions in 2013 were indirect and other direct causes (figure 6B), owing largely to a decrease in abortion-related deaths, which was the most important cause of maternal mortality in high-income regions in 1990. The number of deaths due to haemorrhage, hypertension, and maternal sepsis have also decreased significantly, whereas the numbers of deaths due to indirect and late maternal causes have increased since 1990 (figure 6B, appendix). By contrast, the most important causes in low-income countries—other direct, abortion, and haemorrhage—have not changed between 1990 and 2013, although different trends are apparent in different regions. For example, east Asia had significant decreases in all causes except HIV (which was estimated to be the cause of 0·003% of all maternal deaths in 2013; appendix). The total global number of HIV-related maternal deaths in 2013 was 2070 (95% UI 1290–2866), reduced from a peak of 3280 (2041–4403) in 2004. The increase in proportion of deaths due to indirect maternal causes was most notable in Latin America and the Caribbean, where the proportion increased from 9·2% (95% UI 8·8–9·8) in 1990, to 11·5% (10·9–12·2) in 2013.

In 2013, on average, nearly a quarter of deaths occurred antepartum (24·6%, 24·1–25·2), a quarter intrapartum and immediately postpartum (27·7%, 27·1–28·2), a third

subacute and delayed postpartum (35·6%, 34·9–36·2), and 12·1% (11·9–12·5) late. The biggest absolute change was in intrapartum deaths (table 2, appendix), which decreased by more than 35%, but equally notable was that despite a decrease in the mean fraction of postpartum deaths, the proportion of total deaths occurring postpartum and late actually increased at the global level (p<0·001).

S Villalpando PhD, Prof R Lozano); **Department of Diabetes Research, National Centre for Global Health and Medicine, Tokyo, Japan** (A Goto PhD);

	Cause of death									Timing of death			
	Abortion	Haem-orrhage	Hyper-tension	Obstructed labour	Sepsis	Late	Other direct	Indirect	HIV	Ante-partum	Intra-partum*	Postpartum†	Late
Worldwide	43 684 (38 336–49 843)	44 190 (38 275–50 819)	29 275 (25 664–33 376)	18 789 (16 281–21 747)	23 717 (20 045–27 993)	43 507 (35 667–52 395)	56 114 (48 671–64 245)	31 058 (26 818–35 679)	2070 (1290–2866)	61 176 (52 959–70 010)	64 823 (55 562–74 856)	123 476 (109 051–139 584)	43 507 (35 667–52 395)
Andean Latin America	160 (115–215)	165 (126–211)	174 (131–217)	64 (46–84)	128 (98–163)	260 (194–331)	125 (95–158)	85 (65–109)	0 (0–0)	154 (114–204)	285 (210–370)	465 (348–590)	260 (194–331)
Australasia	2 (2–3)	2 (2–3)	3 (2–4)	2 (2–3)	2 (1–2)	2 (1–2)	5 (4–6)	3 (2–4)	0 (0–0)	6 (4–8)	6 (5–8)	7 (5–9)	2 (1–2)
Caribbean	132 (83–195)	146 (90–228)	284 (198–415)	73 (43–111)	119 (80–175)	92 (50–146)	129 (81–194)	90 (53–140)	7 (4–11)	272 (168–419)	300 (163–480)	410 (276–612)	92 (50–146)
Central Asia	58 (47–72)	84 (69–100)	55 (45–67)	52 (41–67)	64 (50–80)	81 (66–100)	107 (86–133)	67 (55–83)	0 (0–0)	174 (139–215)	114 (92–141)	199 (164–242)	81 (66–100)
Central Europe	24 (20–28)	15 (12–18)	12 (10–14)	11 (9–14)	9 (7–11)	11 (8–13)	17 (14–20)	13 (10–16)	0 (0–0)	24 (19–27)	40 (33–48)	38 (31–45)	11 (8–13)
Central Latin America	331 (294–376)	478 (426–537)	563 (495–635)	196 (173–223)	227 (198–261)	215 (177–251)	446 (394–505)	486 (428–546)	1 (1–2)	513 (392–672)	1112 (917–1347)	1110 (858–1354)	215 (177–251)
Central sub-Saharan Africa	2679 (2031–3491)	2233 (1663–3018)	1645 (1215–2197)	863 (652–1106)	1386 (1010–1870)	2350 (1664–3154)	2831 (2078–3712)	1222 (823–1629)	114 (62–167)	4805 (3654–6210)	1298 (815–1876)	6902 (5184–8723)	2350 (1664–3154)
East Asia	395 (324–467)	709 (578–854)	322 (260–385)	365 (292–443)	298 (246–356)	376 (305–458)	545 (446–643)	518 (414–614)	0 (0–0)	725 (503–976)	1780 (1369–2213)	654 (439–899)	376 (305–458)
Eastern Europe	66 (54–80)	50 (39–60)	34 (26–42)	46 (34–60)	26 (20–33)	39 (27–53)	93 (75–112)	78 (62–95)	0 (0–0)	192 (150–235)	44 (28–63)	159 (127–195)	39 (27–53)
Eastern sub-Saharan Africa	10 142 (8413–12 152)	6276 (5228–7707)	5286 (4327–6467)	2718 (2248–3261)	4908 (3967–5996)	4702 (3732–5807)	13 312 (11 350–15 591)	3976 (3237–5126)	844 (524–1144)	13 429 (11 038–16 452)	9176 (7334–11 319)	24 962 (20 629–30 208)	4702 (3732–5807)
High-income Asia Pacific	17 (13–22)	22 (17–29)	12 (9–17)	10 (7–13)	13 (9–18)	7 (5–10)	26 (20–35)	21 (16–27)	0 (0–0)	51 (37–68)	33 (24–48)	37 (24–50)	7 (5–10)
High-income North America	97 (76–122)	44 (33–57)	64 (48–83)	51 (31–78)	63 (49–78)	143 (112–178)	224 (176–280)	143 (112–178)	0 (0–0)	120 (72–176)	254 (180–341)	313 (224–411)	143 (112–178)
North Africa and Middle East	1130 (843–1500)	1831 (1421–2415)	1294 (1008–1713)	838 (632–1095)	809 (610–1084)	836 (556–1206)	1300 (996–1741)	847 (616–1171)	3 (2–5)	2129 (1620–2907)	2692 (1950–3638)	3249 (2384–4402)	836 (556–1206)
Oceania	212 (108–363)	244 (123–437)	136 (68–249)	117 (59–203)	102 (53–185)	180 (92–335)	212 (111–379)	116 (58–205)	2 (1–3)	297 (151–543)	583 (308–1035)	264 (129–484)	180 (92–335)
South Asia	12 074 (9081–15 883)	16 453 (11 957–22 330)	10 656 (7805–14 072)	7099 (5425–9206)	9382 (6734–12 841)	19 900 (14 138–27 257)	19 433 (14 257–26 136)	12 601 (9303–16 472)	26 (13–43)	21 202 (15 555–27 811)	23 518 (17 274–30 621)	43 207 (32 787–55 636)	19 900 (14 138–27 257)
Southeast Asia	2638 (1964–3459)	2656 (1968–3460)	2388 (1718–3144)	1346 (941–1855)	1460 (1044–1935)	2274 (1672–3009)	3217 (2348–4232)	2001 (1498–2654)	9 (5–14)	4007 (2980–5262)	8039 (6154–10 319)	3708 (2836–4927)	2274 (1672–3009)
Southern Latin America	94 (77–115)	44 (35–54)	45 (36–56)	28 (20–37)	73 (59–88)	29 (22–36)	51 (41–61)	80 (66–98)	0 (0–1)	196 (151–246)	107 (73–150)	114 (69–158)	29 (22–36)
Southern sub-Saharan Africa	718 (488–1026)	517 (360–714)	624 (428–868)	298 (197–437)	627 (430–914)	604 (376–914)	463 (313–662)	657 (435–942)	381 (217–563)	1059 (660–1542)	1014 (571–1662)	2221 (1471–3256)	604 (376–914)
Tropical Latin America	225 (171–287)	196 (147–253)	341 (259–435)	69 (51–92)	249 (192–317)	272 (178–378)	279 (214–356)	332 (253–426)	1 (1–2)	295 (191–418)	544 (349–776)	858 (623–1158)	272 (178–378)
Western Europe	55 (45–62)	35 (29–41)	34 (28–39)	23 (19–27)	24 (20–29)	23 (18–28)	60 (50–68)	34 (28–40)	0 (0–0)	65 (52–78)	89 (74–104)	112 (92–132)	23 (18–28)
Western sub-Saharan Africa	12 436 (10 015–15 401)	11 990 (9449–15 320)	5301 (4139–6773)	4521 (3382–5992)	3749 (2745–4945)	11 114 (8229–14 535)	13 239 (10 539–16 609)	7687 (5894–9976)	680 (372–1039)	11 460 (8923–14 807)	13 795 (10 460–18 323)	34 489 (27 764–42 248)	11 114 (8229–14 535)

*Intrapartum and immediate postpartum. †Subacute and delayed postpartum.

Table 2: **Global and regional maternal deaths in 2013, by cause and timing**

School of Population Health (D G Hoy PhD), University of Queensland, Brisbane, QLD, Australia (H N Gouda PhD, L Knibbs PhD); Saint James School of Medicine, Kralendijk, Bonaire, Netherlands (Prof H C Gugnani PhD); Kanawha Charleston Health Department, Charleston, WV, USA (Rahul Gupta MD); Fortis Escorts Hospital, Jaipur, India (Rajeev Gupta PhD); Arabian Gulf University, Manama, Bahrain (Prof R R Hamadeh DPhil); Wayne County Department of Health and Human Services, Detroit, MI, USA (M Hammami MD); School of Medicine and Pharmacology, University of Western Australia, Perth, WA, Australia (Prof G J Hankey MD); Parnassia Psychiatric Institute, The Hague, Netherlands (H W Hoek MD); Albert Einstein College of Medicine, Bronx, NY, USA (Prof H D Hosgood PhD); Public Health Division, Secretariat of the Pacific Community, Noumea, New Caledonia (D G Hoy); Birzeit University, Birzeit, Ramallah, Palestine (A Husseini PhD); National Institute for Health Development, Tallinn, Estonia (K Innos PhD, M Leinsalu PhD); School of Public Health (Prof N Kawakami MD), Graduate School of Medicine (M Inoue PhD), University of Tokyo, Tokyo, Japan (Prof K Shibuya MD); George Mason University, Fairfax, VA, USA (K H Jacobsen PhD); Ochsner Medical Centre, New Orleans, LA, USA (E Jahangir MD); Graduate School of Public Health, Yonsei University, Seoul, South Korea (Prof S H Jee PhD); Postgraduate Institute of Medical Education and Research, Chandigarh, India (Prof V Jha DM); Tianjin Centres for Diseases Control and Prevention, Tianjin, China (G Jiang MD); Department of Ophthalmology, Medical Faculty Mannheim, University of Heidelberg, Heidelberg, Germany (Prof J B Jonas MD); National Institute of Public Health, Copenhagen, Denmark (Prof K Juel PhD); Vanderbilt University, Nashville, TN, USA (E K Kabagambe PhD, U Sampson MD); Fudan University, Shanghai, China (H Kan MD); University of Balamand, Beirut, Lebanon (N E Karam MD); Helmholtz Centre for Infection Research, Braunschweig, Germany (A Karch MD); Malaria and Other

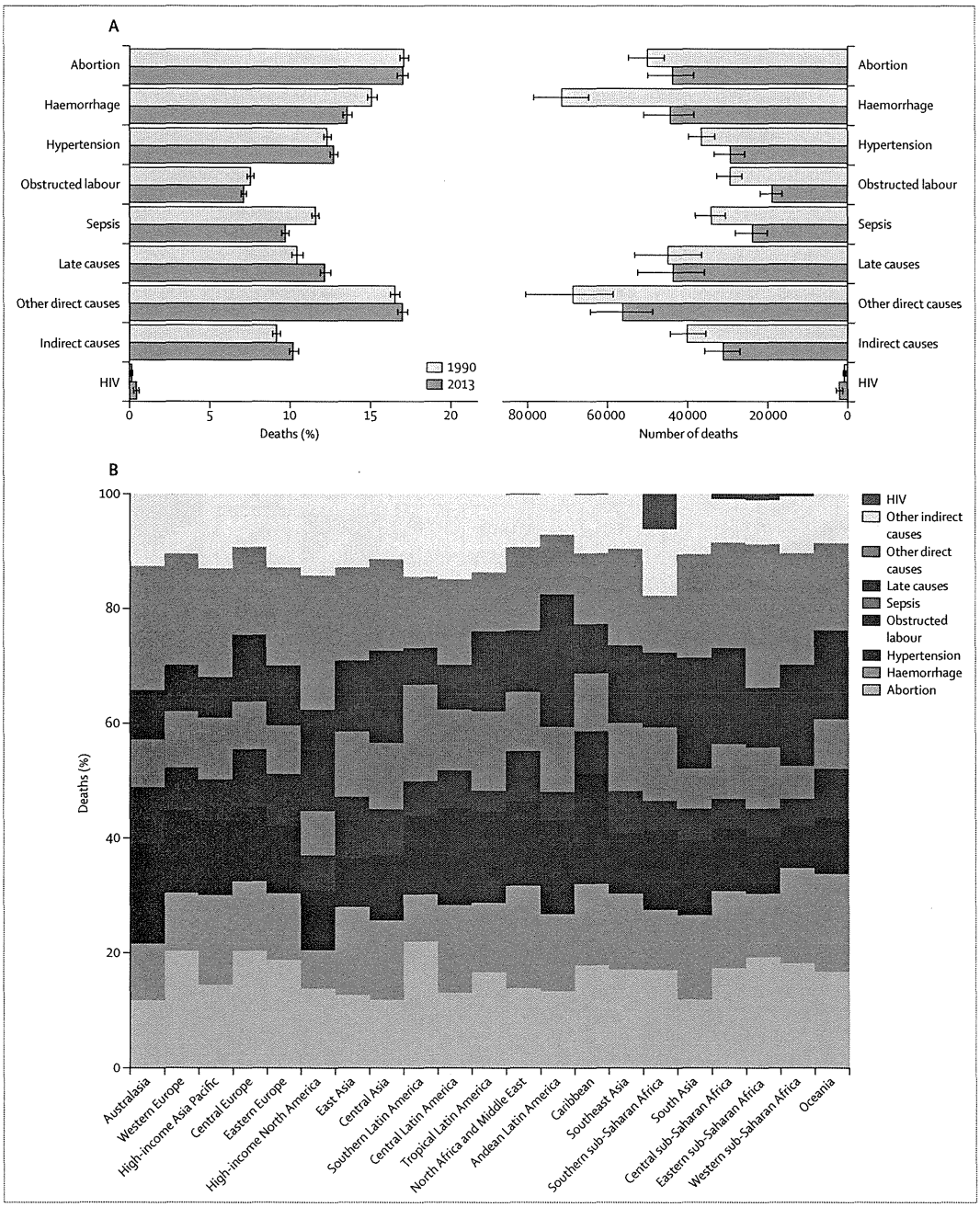

Figure 6: Causes of maternal death
(A) Mean proportion (left) and total number (right) of maternal deaths due to different causes in 1990 and 2013. Error bars show 95% uncertainty intervals. (B) Proportion of maternal deaths due to different causes in 2013, by region.

In 2013, 16 countries had MMRs of between 500 and 1000: Afghanistan, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Djibouti, Eritrea, Guinea, Guinea-Bissau, Liberia, Lesotho, Mauritania, Papua New Guinea, Sierra Leone, South Sudan, and Zimbabwe (figure 7, table 1). 15 countries had MMRs of less than 5: Andorra,

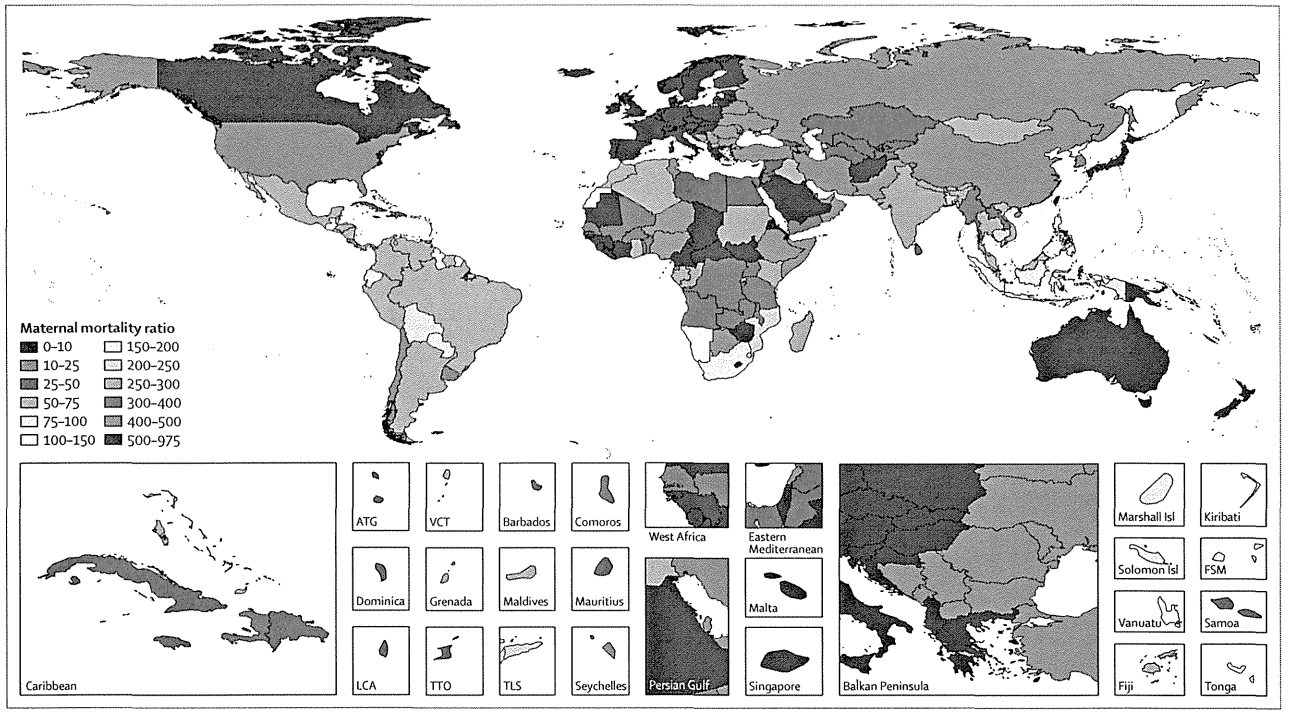

Figure 7: **Maternal mortality ratio in 2013**
ATG=Antigua and Barbuda. VCT=Saint Vincent and the Grenadines. Isl=Islands. FSM=Federated States of Micronesia. LCA=Saint Lucia. TTO=Trinidad and Tobago. TLS=Timor-Leste.

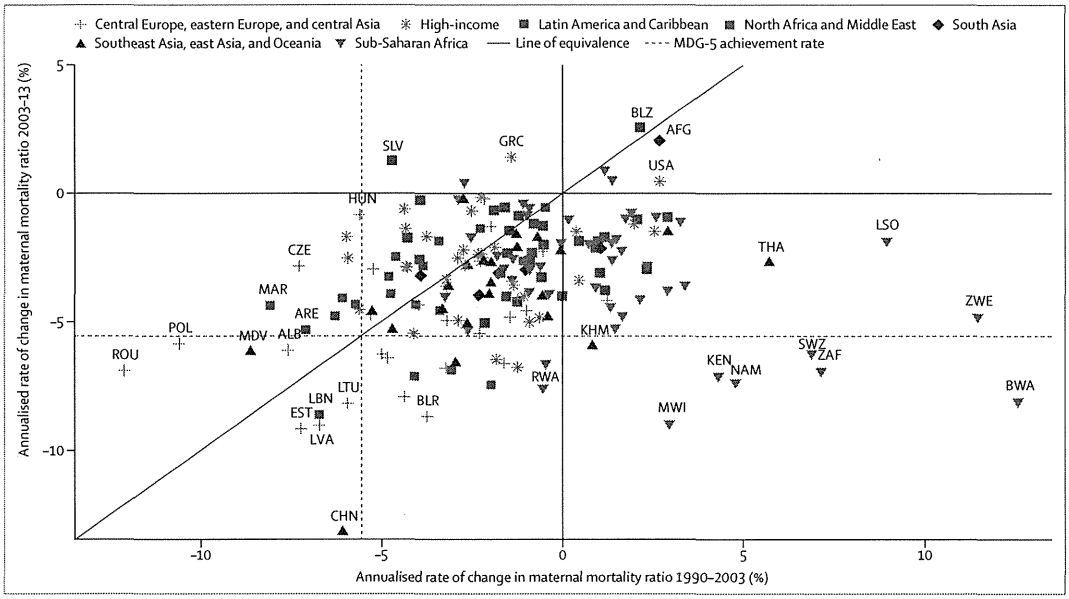

Figure 8: **Annualised rate of change in maternal mortality ratio in 1990–2003 and 2003–13**
Countries are grouped by Global Burden of Disease super-region. Countries are labelled when at or near the MDG5 achievement rate, or if they had large increases in either period. MDG=Millennium Development Goal. ROU=Romania. POL=Poland. MDV=Maldives. MAR=Morocco. ALB=Albania. CZE=Czech Republic. ARE=United Arab Emirates. EST=Estonia. LBN=Lebanon. LVA=Latvia. CHN=China. LTU=Lithuania. HUN=Hungary. SLV=El Salvador. BLR=Belarus. GRC=Greece. RWA=Rwanda. KHM=Cambodia. BLZ=Belize. AFG=Afghanistan. MWI=Malawi. KEN=Kenya. NAM=Namibia. THA=Thailand. SWZ=Swaziland. ZAF=South Africa. LSO=Lesotho. ZWE=Zimbabwe. BWA=Botswana.

Parasitic Diseases Division (C K Karema MSc), **Ministry of Health, Kigali, Rwanda** (F Sayinzoga MD); **Oklahoma State University, Tulsa, OK, USA** (A Kaul MD); **University of California San Francisco, San Francisco, CA, USA** (D S Kazi MD); **University of São Paulo, São Paulo, Brazil** (Prof A H Kemp PhD, Prof P A Lotufo DrPH, Prof G V Polanczyk PhD, Prof I S Santos PhD); **South African Medical Research Council, Cape Town, South Africa** (A P Kengne PhD); **Jordan University of Science and Technology, Al-Ramtha, Jordan** (Prof Y S Khader ScD); **Supreme Council of Health, Doha, Qatar** (S E A H Khalifa MSc); **Health Services Academy, Islamabad, Pakistan** (E A Khan MPH); **Institute of Health Policy and Management, Seoul National University College of Medicine, Seoul, South Korea** (Prof Y-H Khang PhD); **Department of Preventive Cardiology, Department of Preventive Medicine and Epidemiologic Informatics, National Cerebral and**

Cardiovascular Centre, Suita, Japan (Y Kokubo PhD); Centre for Community Empowerment, Health Policy and Humanities, National Institute of Health Research and Development, Jakarta, Indonesia (S Kosen MD); University of Montreal, Montreal, QC, Canada (Prof B Kuate Defo PhD); Rajrajeshwari Medical College and Hospital, Bangalore, India (Prof C Kulkarni PhD); Arkansas State University, Jonesboro, AR, USA (V S Kulkarni PhD); International Institute for Population Sciences, Mumbai, India (K Kumar MPS); Indian Institute of Public Health, Public Health Foundation of India, Gurgaon, India (R B Kumar); Boston Medical Centre, Boston, MA, USA (G Kwan MD); Fourth View Consulting, Tallinn, Estonia (T Lai PhD); Australian Research Centre for Population Oral Health (ARCPOH), School of Dentistry, University of Adelaide, Adelaide, SA, Australia (Prof R Lalloo PhD); Institute of Health Policy and Development Studies, National Institutes of Health, Manila, Philippines (Prof H Lam PhD); International

Australia, Austria, Denmark, Finland, Iceland, Ireland, Israel, Italy, Malta, Norway, Poland, Singapore, Sweden, and Switzerland (table 1). Some countries had noticeably higher MMRs than neighbouring countries did (figure 7). In the Caribbean, only Guyana and Haiti had MMRs of more than 100 in 2013 (figure 7, table 1). Similarly, in South America, only Bolivia had an MMR of more than 100 (figure 7, table 1). Afghanistan had the highest MMR in south Asia, Yemen had the highest MMR in north Africa and the Middle East, and Papua New Guinea had the largest value in southeast Asia and Oceania in 2013 (figure 7, table 1). The MMR in China was 17·2 (95% UI 14·0–20·3) compared with 18·5 (14·8–22·9) in the USA. In sub-Saharan Africa, Mauritius, Seychelles, Namibia, Swaziland, Cape Verde, and São Tomé and Príncipe have MMRs of less than 150 (figure 7, table 1).

137 countries had higher annualised rates of change in MMR between 2003 and 2013 than between 1990 and 2003 (figure 8). Nevertheless, only 40 countries have achieved the MDG 5 decrease of 5·5% per year in either time interval (figure 8). From 1990 to 2013, Albania, United Arab Emirates, Bosnia and Herzegovina, Belarus, China, Estonia, Lebanon, Lithuania, Latvia, Morocco, Maldives, Mongolia, Oman, Poland, Romania, and Russia had reductions of greater than 5·5% (table 1). These countries—which represent 5·1% of all developing nations—are likely to achieve the MDG 5 target of a reduction in the MMR of three-quarters. 30 countries had annual reductions in the MMR of MDG 5 pace or better from 2003 to 2013, eight of which were in sub-Saharan Africa (Botswana, Burundi, Kenya, Malawi, Namibia, Rwanda, South Africa, and Swaziland) and ten in central and eastern Europe (Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Estonia, Latvia, Lithuania, Poland, Romania, and Russia; table 1). Between 2003 and 2013, eight countries had annualised rates of change of more than 8%: Belarus, Botswana, China, Estonia, Latvia, Lebanon, Lithuania, and Malawi (figure 8, table 1). From 1990 to 2003, MMR increased in 50 countries, 27 of which were in sub-Saharan Africa (table 1). Between 2003 and 2013, only eight countries had increases: Afghanistan, Belize, El Salvador, Guinea-Bissau, Greece, Seychelles, South Sudan, and the USA (figure 8, table 1).

In our fairly optimistic forecast scenario for 2030, we would expect 184 100 (95% UI 133 600–244 700) maternal deaths worldwide in 2030. 53 countries—all of which are in sub-Saharan Africa, except for Afghanistan, Bangladesh, Bhutan, Bolivia, Haiti, India, Indonesia, Laos, Myanmar, Nepal, Pakistan, Papua New Guinea, Solomon Islands, and Yemen—will still have MMRs of more than 100 (figure 9). Despite accelerated reductions in many countries, our simple forecasts suggest that in 2030, 74 countries are likely to still have a MMR of more

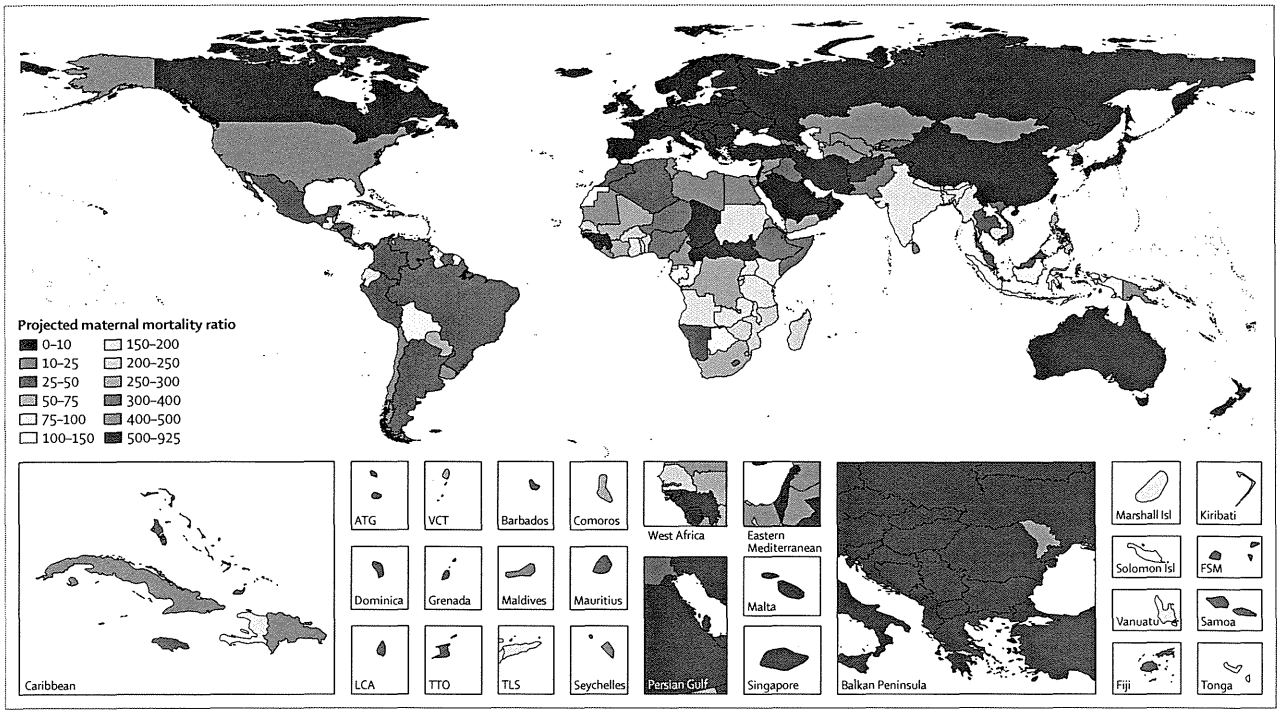

Figure 9: Projected maternal mortality ratio in 2030
ATG=Antigua and Barbuda. VCT=Saint Vincent and the Grenadines. Isl=Islands. FSM=Federated States of Micronesia. LCA=Saint Lucia. TTO=Trinidad and Tobago. TLS=Timor-Leste.

than 50, and 89 countries will have MMRs of less than 30, compared with 72 countries in 2013.

Discussion

On the basis of recent data and a refined understanding of the association between HIV and maternal mortality, we have shown that worldwide maternal mortality has decreased by 1·3% per year since 1990. Despite reductions in the number of maternal deaths—from about 376 000 in 1990 to about 293 000 in 2013—only 16 countries, seven of which are developing countries, are expected to achieve the MDG 5 target of a 75% reduction in the MMR by 2015. We noted two different patterns in developing countries: sustained substantial decreases in most of Asia and Latin America, and stagnation or increases from 1990 to 2003 in sub-Saharan Africa and Oceania. Increases in some high-income countries such as the USA are a deviation from the general trend downwards in developed countries. However, the substantial acceleration in the decreases since 2003—especially in sub-Saharan Africa—provides hope that more countries can achieve rapid and sustained reductions.

Ambitious calls for progress in maternal mortality in the next 15–20 years and reductions in MMRs to less than 30 in all countries have been deemed financially and technically feasible.[48] Our finding that rates of change in maternal mortality in some developing countries have exceeded 8% in the past decade (eg, in China) lends support to ambitious aspirational goals. However, on the accelerated trajectory from 2003 to 2013, MMRs will still be high in several countries in west and central Africa, and in the Horn of Africa. Unsurprisingly, projections for child mortality in 2030 are also high in these areas of the world. A focus on levels of maternal mortality equivalent to those in high-income nations in all countries will need special policy attention, national action, and global investment in the countries that are predicted to be left far behind a grand convergence. Many of the countries in central and west Africa that will present the greatest challenge to achievement of low MMRs have historically received less development assistance for health than have other low-income countries.[49] Although development assistance for maternal, newborn, and child health has been increasing at a pace faster than that for most thematic areas, excluding HIV, especially since 2009, increases in central and west Africa have not been as large as in other regions. A new focus on these countries will probably need action by multilateral, bilateral, and private global health funders, and shifts in the historical allocation of funds across low-income countries.

The drivers of improvement (or lack thereof) in underlying causes of maternal deaths have important clinical, public health, and policy implications. Maternal mortality has been successfully reduced in many countries. Although the absolute numbers of deaths due to abortion, maternal haemorrhage, and hypertensive disorders of pregnancy have decreased in real terms, these causes remain important, collectively accounting for nearly 50% of all deaths. Continued promotion of policies to reduce anaemia and malnutrition, prevent malaria in pregnancy, provide calcium and micronutrient supplementation, encourage skilled birth attendance and in-facility delivery, discourage early motherhood, and reduce unsafe abortion should lead to sustained dividends.[50–52] Such focus should be expected to reduce the risk of life-threatening complications of pregnancy, but the complications will not be eliminated altogether. Increased coverage of skilled birth attendance and delivery in facilities properly resourced for emergency obstetric care is essential for prevention of these deaths.

Health-system re-engineering is necessary to begin preparations for the new challenges that lie ahead. The increasing relative importance of other direct, indirect, and late maternal causes of death is consistent with global epidemiological transition, and suggests that many health systems are inadequate to meet the needs of an increasing number of pregnant women with pre-existing conditions and high-risk pregnancies. The risks of sepsis-related deaths are known to be increased by the prevalence of obesity and diabetes in women of reproductive age.[53] Moreover, because of the inherent difficulty in diagnosis of maternal sepsis, the problem could be larger than we have estimated in countries with high overall maternal mortality. Therefore, prevention of sepsis will need not only a focus on medical management of comorbidities, but also improved sanitation and access to routine prophylactic antibiotics during caesarean section for facilities that intend to provide such a service, both of which have been shown to be effective and cost-effective strategies to reduce maternal death.[54,55]

Many diseases—eg, sickle-cell anaemia, obesity, diabetes, hypertension, and chronic kidney conditions—confer increased mortality risk during pregnancy. These indirect causes of maternal death are likely to continue increasing in importance where they are commonly encountered.[56–60] A focus on health-system strengthening will be needed to reduce the effect of other direct causes of maternal death, because the most likely underlying aetiologies are complications of anaesthesia, embolism (air, amniotic fluid, and blood clot), and the less common but often fatal condition of peripartum cardiomyopathy.[61–64] Health systems must begin to plan for these changes through increasing the size and training of the perioperative workforce and investment in family planning services, adequate infrastructural resources for facilities, and systems to identify and follow women who are at risk of life-threatening puerperial and postpartum complications.

In 2013, HIV accounted for 1·5% of maternal deaths in sub-Saharan Africa, rising to 6·2% in southern sub-Saharan Africa. However, HIV infection is associated with the smallest number of deaths worldwide of any of the causes we examined. Increased ART coverage has led to reduced HIV-related mortality in sub-Saharan Africa and

Agency for the Prevention of Blindness and Vision 2020, Weston, FL, USA (V C Lansingh PhD); Korea University, Seoul, South Korea (Prof J-T Lee PhD, S-J Yoon PhD); University at Albany, Rensselaer, NY, USA (R Leung PhD); National Centre for Birth Defects Monitoring of China, Chengdu, China (X Li MD); National Centre for Chronic and Non-Communicable Disease Control and Prevention (Yichong Li MPH, S Liu PhD, J Ma PhD, Prof L Wang MD, Prof M Zhou PhD), National Institute of Occupational Health and Poison Control (Prof F Tan MD), Chinese Centre for Disease Control and Prevention, Beijing, China (X Liang PhD); Genentech, South San Francisco, CA, USA (Yongmei Li PhD); National Office for Maternal and Child Health Surveillance, West China Second University Hospital, Sichuan University, Chengdu, China (Prof J Liang MD, Prof Y Wang MS, Prof J Zhu MD); Wayne State University, Miami, FL, USA (S E Lipshultz MD); National Institute of Environmental Health Sciences, Research Triangle Park, NC, USA (S J London MD); Ministry of Health Singapore, Singapore, Singapore (S Ma PhD); Xpharmconsult, Kumasi, Ghana (N K Mainoo MMRCB); Department of Public Health, Faculty of Health Sciences and Social Work, Trnava University, Trnava, Slovakia (M Majdan PhD); University of Zambia, Lusaka, Zambia (C C Mapoma PhD); Queen Mary University of London, London, UK (Prof W Marcenes PhD); University of the East Ramon Magsaysay Memorial Medical Centre, Quezon City, Philippines (M B Marzan MSPH); University of York, York, UK (A J Mason-Jones PhD); Janakpuri Super Specialty Hospital, New Delhi, India (Prof M M Mehndiratta MD); UN Population Fund, Lima, Peru (W Mendoza MD); Pacific Institute for Research and Evaluation, Calverton, MD, USA (T R Miller PhD); University of Ottawa, Ottawa, ON, Canada (E J Mills PhD); University of Papua New Guinea, Port Moresby, Papua New Guinea (Prof G L Mola MD); Institute for Maternal and Child Health Istituto di Ricovero e Cura a

Carattere Scientifico Burlo Garofolo, Trieste, Italy (L Monasta DSc, L Ronfani PhD); Bureau of International Health Cooperation, Manila City, Philippines (J de la Cruz Monis MSc); University of North Texas, Denton, TX, USA (Prof A R Moore PhD); Iran University of Medical Sciences, Department of Community Medicine, Tehran, Iran (M Moradi-Lakeh); National Centre for Child Health and Development, Setagaya, Tokyo, Japan (R Mori PhD); Philipps-University Marburg, Marburg, Germany (Prof U O Mueller PhD, R Westerman PhD); Tokyo Medical and Dental University, Tokyo, Japan (M Mukaigawara MD); International Centre for Diarrhoeal Diseases Research, Dhaka, Bangladesh (A Naheed PhD); University of KwaZulu-Natal, Durban, South Africa (Prof K S Naidoo PhD); Ministry of Health Fiji, Suva, Fiji (D Nand MPH); Suraj Eye Institute, Nagpur, India (Prof V Nangia MD); School of Public Health, City University of New York, New York, NY, USA (D Nash PhD); Faculty of Medicine, Fez, Morocco (Prof C Nejjari PhD); National Institute of Diabetes and Digestive and Kidney Diseases, Phoenix, AZ, USA (R G Nelson PhD); Norwegian Centre for Addiction Research (SERAF), University of Oslo, Oslo, Norway (S P Neupane MBBS); Kenya Medical Research Institute Wellcome Trust Programme, Kilifi, Kenya (Prof C R Newton MD); Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain (M J Nieuwenhuijsen PhD); University of Bergen, Bergen, Norway (Prof O F Norheim PhD); Kyung Hee University, Seoul, South Korea (I-H Oh PhD); Teikyo University School of Medicine, Tokyo, Japan (Prof T Ohkubo MD); Centre for Healthy Start Initiative, Lagos, Nigeria (B O Olusanya PhD); Lira District Local Government, Lira Municipal Council, Lira, Uganda (J N Opio MPH); Toxicology Unit, Faculty of Pharmacy, University of Port Harcourt, Port Harcourt, Nigeria (Prof O E Orisakwe PhD); Christian Medical College Ludhiana, Ludhiana, India

has been associated with decreased mortality in HIV-positive women during pregnancy.[45,65] Nevertheless, the increase in maternal mortality during the mid-2000s in southern Africa is well in excess of the number of HIV-associated maternal deaths. There are at least four possible explanations for this finding. First, we could have underestimated the RR of death for a pregnant woman with HIV infection compared with a pregnant woman without HIV infection. Our meta-analysis results are consistent with previous studies, but the RR could be biased downwards if included studies are from areas with better care or access to ART.[22,34] Second, we could have overestimated maternal mortality if the UNAIDS Spectrum estimates of HIV prevalence in pregnancy are underestimates. These values suggest that age-specific fertility rates decrease by 24% in HIV-positive women compared with HIV-negative women when aged 20–24 years, but fertility decreases by 56% by age 45–49 years.[66] Third, we assume the RR is generalisable across different levels of HIV prevalence in pregnant women, which might not be true. Fourth, the HIV epidemic could be diverting resources from maternal care because of a huge demand for care. Although this situation is theoretically possible, several studies and reports have not shown this relation; indeed, there could be synergies between ART scale-up and clinic and hospital productivity.[67] Perhaps the most important finding is that with the scale-up of ART, MMR seems to decrease rapidly (eg, in Malawi).[68]

In our study, we have not tested the association between development assistance for maternal health programmes and MMR. However, accelerated decreases occurred in 106 of 138 developing countries in 2003—3 years after the Millennium Declaration—coinciding with the scale-up of development assistance for maternal and child health programmes.[49] Rigorous testing of the hypothesis that global priority setting and investments in maternal health programmes have had an important role in the acceleration of progress is needed. This research is important because it could strengthen the basis on which post-2015 requests for funding of continued expansion of maternal health services are made. Because we have reported much slower rates of change than the UN has,[6] the importance of establishing the case for continued investment in maternal health programmes is even greater; ambitious goals for regions such as sub-Saharan Africa will probably need major investments.

We compared our estimates of maternal mortality with those from the GBD 2010 and the 2012 UN estimates.[6] The correlation between our MMR estimates and those of GBD 2010 for 1990 was 0·96, and for 2010 was 0·89. The correlation figures with the UN analysis for the same two periods were 0·88 and 0·85. Perhaps the most notable difference between the UN 2012 analysis and ours is the number of maternal deaths in 1990: 543 000 compared with 376 000. The difference in numbers for 2010 is smaller: 287 000 deaths compared with 317 300. The much higher number from the UN for 1990 raises the estimated annualised rate of change in the MMR from 1990 to 2010 substantially, to –3·1% per year compared with –1·1% per year in our study. One of the most important differences between our assessment and the UN's seems to be related to the WHO estimates of reproductive-age mortality in some

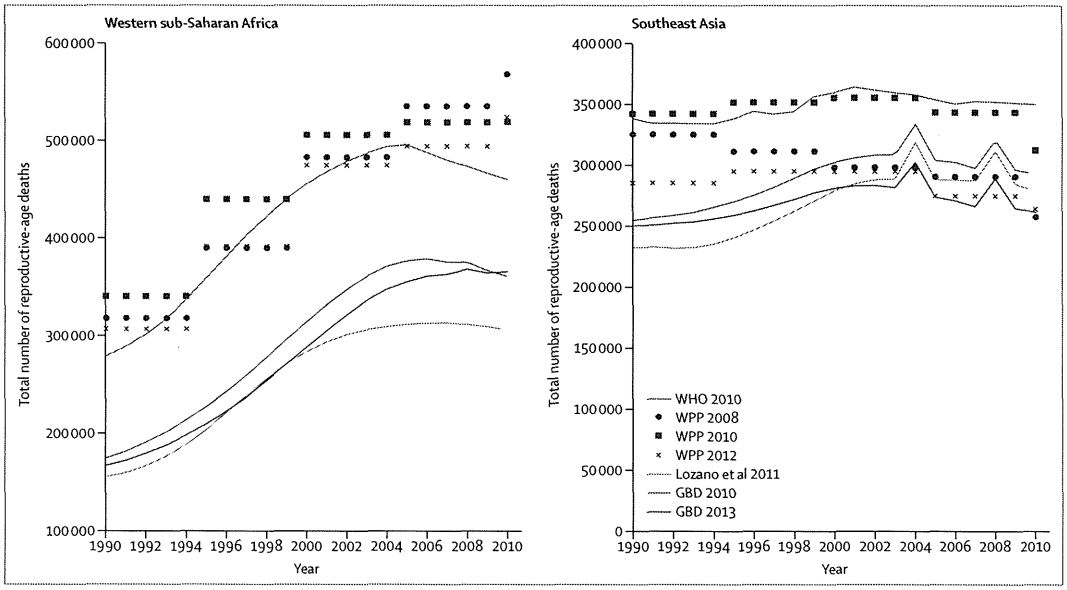

Figure 10: Comparison of all-cause reproductive-age mortality envelopes between 1990 and 2010
WPP=World Population Prospects. GBD=Global Burden of Disease Study.

regions with high fractions of reproductive-age mortality due to maternal causes. These estimates are substantially higher than the GBD 2013 estimates for west Africa, north Africa and the Middle East, and southeast Asia in 1990, ranging from 7% higher in Ghana to 58% higher in Nigeria. The differences between estimates of reproductive-age mortality in western sub-Saharan Africa and southeast Asia are large (figure 10). In some cases, the most recent UN Population Division estimates (World Population Prospects 2012) converge towards the GBD estimates, although WHO estimates are substantially higher (figure 10). The UN Population Division and WHO almost exclusively predict levels of adult mortality in west Africa on the basis of child mortality, whereas we make substantial use of survey and census data from the region in our GBD analysis.[69] The reasons for the changes between successive revisions of maternal mortality estimates depend on the country, but are driven both by new data for levels of reproductive-age mortality and maternal causes or the fraction of deaths that are related to pregnancy.

Our study, which brings together a wide array of data sources for the levels, causes, and timing of maternal deaths for many countries, has important limitations. First, although ICD-coded vital registration systems have clear rules for assignment of causes of death, we used census and survey data for the fraction of deaths to distinguish explicitly between deaths caused by pregnancy (maternal deaths) and those that were incidental (pregnancy-related deaths). We made adjustments for incidental deaths related to HIV, but have not made similar adjustments for other types of incidental deaths due to causes such as injuries. Studies[70,71] suggest that deaths due to injury are less common in non-pregnant women than in pregnant women of the same age, but they do occur in both groups, which leads to a bias upwards in our assessment. That bias must be tempered with the potential bias that sibling and household reports of pregnancy-related deaths could lead to selective under-reporting of abortion-related deaths.[72] Second, uncertainty in the estimates of maternal death in many countries is substantial.[73] Within the same country, sources can differ widely. For example, we used many different types of sources in India: in rural regions, data are largely from the Survey of Causes of Death-Rural, the Sample Registration System, and verbal autopsy studies, whereas Medical Certification of Causes of Death covers largely urban populations.[4]

Third, there is still no definitive way to estimate the interaction of HIV and pregnancy in death. Only 21 studies were available for estimation of the excess risk of death during pregnancy in women with HIV. Only two studies[44,45] inform the excess risk of death during pregnancy in women with HIV. These two studies provide widely divergent findings and could reflect the complex interaction between ART (and the associated greater care received by women taking it) and pregnancy as much as the effect of pregnancy on the progression of HIV. As such data continue to be developed and because of the important implications for policy making, we will continue to work to find new data sources, improve data quality, and incorporate updated methods as necessary to continue providing updates for global, regional, and national maternal mortality.

Fourth, because of sparse data, we could not quantify the contributions of other infections, such as influenza (eg, H1N1), malaria, tuberculosis, and hepatitis, to maternal mortality at the population level.[74] Fifth, our method of estimating the detailed causes of maternal death used all available data, but such specific data are not available for many countries, or, if they are available, are coarse with respect to age. Therefore, we might have underestimated the true extent of the interplay between cause and age in maternal mortality and differences between countries in the same region.

Sixth, we have estimated UIs for each component of the analysis. CODEm provides confirmation that the UIs for the maternal mortality model have a data coverage of 97·9%, so they could be slightly overestimated. Finally, our estimates of maternal mortality are affected by estimates in each age group of other causes of death developed for the GBD 2013 because of the requirement that cause-specific mortality must sum to all-cause

(J D Pandian MD); **Sungkyunkwan University School of Medicine, Suwon, South Korea** (Prof J-H Park MPH); **Universidad de Cartagena, Cartagena, Colombia** (A J Paternina Caicedo MSc); **University of Calgary, Calgary, AB, Canada** (Prof S B Patten PhD); **All India Institute of Medical Sciences (AIIMS), New Delhi, India** (Prof V K Paul MD); **WHO, Waigani, Papua New Guinea** (B I Pavlin MD); **London School of Hygiene & Tropical Medicine, London, UK** (Prof N Pearce PhD); **3B's Research Group in Biomaterials, Biodegradables and Biomimetics, University of Minho, Headquarters of the European Institute of Excellence on Tissue Engineering and Regenerative Medicine, and ICVS/3B's PT Government Associate Laboratory, Braga Portugal** (Prof D M Pereira PhD); **Flinders University, Adelaide, SA, Australia** (Prof K Pesudovs PhD); **Centre for Applied Biostatistics, Sahlgrenska Academy, University of Gothenburg, Sweden** (Prof M Petzold PhD); **McMaster University, Hamilton, ON, Canada** (D Poenaru MD); **Erasmus Medical Center,**

Panel: Research in context

Our analysis continues a body of analytical work into levels and trends in maternal mortality that began with Hogan and colleagues' report[4] and was followed by that by Lozano and colleagues[5] and the Global Burden of Disease Study 2010 (GBD 2010).[16] With each subsequent study, there have been important advances in the data available for analysis and the methods of analysis. Lozano and colleagues[5] moved from one preferred regression model, as used by Hogan and colleagues and the UN measurement efforts,[6,20] to an ensemble of multiple models developed through rigorous out-of-sample predictive validity testing. The maternal mortality analysis included in GBD 2010 extended the analysis in two important ways: maternal mortality was assessed with all other causes of death subject to the constraint that sum of individual causes of death equalled the demographic assessment of all-cause mortality in each age group of reproductive-age women, and it included estimates of the major causes of maternal mortality. In our study, in addition to 2421 site-years of new data, several important methodological innovations improve the estimation of maternal mortality. First, we have analysed sibling history data for the fraction of reproductive-age deaths that are related to pregnancy by calendar year for each 5-year age group of mothers, pooling data from several surveys when events for the same calendar year were recorded. Second, we have substantially revised the approach to understand the effect of HIV on maternal mortality. We did a systematic review and used relative risks from cohort studies to accurately assign a fairly small fraction of HIV-related deaths during pregnancy or the puerperium to be maternal deaths. Third, we have quantified other direct maternal causes, indirect maternal causes, and late maternal death for the first time. Fourth, we have analysed previous reports and other sources about the timing of maternal deaths to provide guidance on when most deaths occur. Our data and improved methods have led to a different understanding of the evolution of global maternal deaths with important implications for target setting in the post-MDG era.

Department of Public Health, Rotterdam, Netherlands (S Polinder PhD); University of Liverpool, Liverpool, UK (D Pope PhD); University of British Columbia, Vancouver, BC, Canada (F Pourmalek PhD); College of Pharmacy (D Qato PhD), University of Illinois, Chicago, IL, USA (K M Tabb PhD); Contech International, Lahore, Pakistan (A Rafay MS); Hamad Medical Corporation, Doha, Qatar (S ur Rahman FRCPCH); University of Missouri, Columbia, MO, USA (M Raju PhD); Department of Public Health, University of the Punjab, Lahore, Pakistan (S M Rana PhD); Walden University, Minneapolis, MN, USA (Prof A Refaat PhD); Bhaba Atomic Research Center Hospital, Mumbai, India (N Roy MD); Marshall University, Huntington, WV, USA (M Sawhney PhD); Federal University of Santa Catarina, Florianópolis, Brazil (I J C Schneider PhD); University of Alabama at Birmingham, Birmingham, AL, USA (D C Schwebel PhD, J A Singh MD); Stellenbosch University, Cape Town, South Africa (Prof S Seedat PhD); Health Canada, Ottawa, ON, Canada (H H Shin PhD, S Weichenthal PhD); Heriot-Watt University, Edinburgh, UK (I Shiue PhD); Reykjavik University, Reykjavik, Iceland (I D Sigfusdottir PhD); University of Pennsylvania, Philadelphia, PA, USA (Prof D H Silberberg MD); Instituto Nacional de Epidemiología Dr Juan H Jara, Mar del Plata, Buenos Aires, Argentina (A P Silva MgSc); Norwegian Institute of Public Health, Oslo, Norway (Prof V Skirbekk PhD); Federal Research Institute for Health Organisation and Informatics of Ministry of Health of the Russian Federation, Moscow, Russia (S S Soshnikov PhD); Department of Clinical Neurological Sciences, Western University, London, ON, Canada (L A Sposato MD); University Tunku Abdul Rahman, Kajang, Malaysia (C T Sreeramareddy MD); Hellenic Centre for Disease Control and Prevention (KEELPNO) Greece, Athens, Greece (K Stroumpoulis PhD); Department of Criminology, Law and Society (and Sociology), University of California Irvine, Irvine, CA, USA (B L Sykes PhD);

mortality. Errors in the estimates for other causes of death could bias upwards or downwards our assessments of maternal mortality.

An important part of improved measurement in the future is a recommendation that surveillance of late maternal mortality (>42 days but <1 year) be included in surveys and censuses. With the assumption that maternal mortality will continue to decrease, severe maternal morbidity or so-called near miss cases are likely to increase, some of which might be expected to lead to increased late maternal death.[54] Perhaps more importantly for some regions, HIV has been described by some as being a risk factor for late maternal death. If this description is true, these deaths might not be captured appropriately, because neither reproductive health surveys nor demographic and health surveys quantify late maternal death. In view of the major dependency on sibling histories and the recall of pregnancy-related deaths in household surveys, major changes would be necessary to track late maternal deaths through these instruments.

Measurement of maternal mortality remains challenging (panel). It depends both on robust demographic assessment of reproductive-age mortality rates and data for the fraction of deaths in each age group that are maternal or related to pregnancy. Changes between systematic analyses in the levels and trends in maternal mortality are larger than for child mortality. As a result, users of any assessment of maternal mortality need to recognise that assessments could change as new data are identified or obtained. Despite continuing measurement challenges, there are strong reasons to continue a global focus on reductions in maternal death in the next 15–20 years. An important adjunct to both the framing of new goals and mobilisation of action for them will be regular updates about the evidence in the trends for maternal mortality by age, cause, and timing. We believe that it is this evidence that should fuel and inspire debates and policies to reduce maternal deaths. We believe the evidence is convincing that decreases in the MMR have accelerated in several countries since 2003. These accelerations should be carefully studied to provide qualitative insights into what has worked in different settings. As new global targets for maternal mortality are developed, it will be important to take lessons from these insights, but also begin planning for the evolving health and health-care needs of women of reproductive age. Achievement (or not) of arbitrary goals established without proper regard to the distribution of rates of change prevailing at the time is a political construct that obscures knowledge and praise for the substantial progress that has been made to reduce maternal mortality in the past decade. Furthermore, accelerated decreases in maternal mortality will be more likely if the evidence from policy responses in these countries is widely and effectively disseminated and implemented.

Contributors

NJK and CJLM prepared the first draft. NJK, CS, ADL, CJLM, and RL finalised the draft on the basis of comments from other authors and reviewer feedback. NJK, ADL, CJLM, and RL conceived the study and provided overall guidance. NJK completed all modelling. NJK, AB-V, and MSC did the statistical analysis of model results. All other authors provided data, developed models, reviewed results, initiated modelling infrastructure, and reviewed the report.

Declaration of interests

Cyrus Cooper has received consultancy fees, lecture fees, and honoraria from Amgen, GlaxoSmithKline, Alliance for Better Bone Health, Merck Sharp and Dohme, Eli Lilly, Pfizer, Novartis, Servier, Medtronic, and Roche. Katherine B Gibney received the National Health and Medical Research Council Gustav Nossal scholarship sponsored by CSL in 2012; this award is peer-reviewed through the standard National Health and Medical Research Countil peer-review process, and CSL does not play any part in selection of the awardee. Norito Kawakami has received fees from Meiji, Otsuka, EAP Consulting, Fujitsu Software Technologies, Japan Productivity Center, Occupational Health Foundation, Japan Housing Finance Agency, Aishin-Seiki, and the Japan Dental Association; consultancy fees from Sekisui Chemicals, Junpukai Health Care Center, and Osaka Chamber of Commerce and Industry; and royalties from Igaku-Shoin, Taisha-kan, Nanko-do, Nanzan-do, PHP Publication, and Fujitsu Software Technologies. Norito Kawakami has also received research grants from the Japanese Ministry of Education, Science, and Technology; the Japanese Ministry of Health, Labor and Welfare; Fujitsu Software Technologies; Softbank; and Japan Management Association. Guilherme V Polanczyk has received grants or research support from the National Council for Scientific and Technological Development, the São Paulo Research Foundation, and the University of São Paulo; has served as a paid consultant to Shire; has served on the speakers' bureau of Shire; and has received royalties from Editora Manole. Jasvinder A Singh has received research grants from Takeda and Savient; has received consultant fees from Savient, Takeda, Regeneron, and Allergan; is a member of the executive of OMERACT, an organisation that develops outcome measures in rheumatology and receives arms-length funding from 36 companies; is a member of the American College of Rheumatology's Guidelines Subcommittee of the Quality of Care Committee; and is a member of the Veterans Affairs Rheumatology Field Advisory Committee. The other authors declare no competing interests.

Acknowledgments

We thank the countless individuals who have contributed to the Global Burden of Disease Study 2013 in various capacities. We would like to acknowledge the extensive support from all staff members at the Institute for Health Metrics and Evaluation and specifically thank: Michael F MacIntyre, Peter Speyer, and Summer Lockett Ohno for their management of the Global Burden of Disease Study 2013; Kelsey Pierce for her valuable guidance; Peter Speyer, James Bullard, Serkan Yalcin, Edgar Sioson, Evan Laurie, Charles Atkinson, and Andrew Ernst for their tireless support of the computational infrastructure necessary to produce the results; Linda A Ettinger for her expert administrative support; Peter Speyer, Abigail McLain, Marissa Iannarone, and Eden Stork for their persistent and invaluable work to gain access to and catalogue as much data as possible to inform the estimates; Emily A Dansereau, D Allen Roberts, Katrina Ortblad, Herbert C Duber, Elizabeth K Johnson, and Jonathan C Brown for their efforts in developing and improving the HIV modeling process; Nicholas Graetz for computational support; Madeline L Moyer, Bryan K Phillips, Lee Richardson, Logan Sandar, and Stan Biryukov for data extraction and processing; Christopher Margono for assistance with referencing and submission; Thomas D Fleming for covariates and literature references support; and Meghan D Mooney for coordination of all-cause mortality estimates. No individuals acknowledged received additional compensation for their efforts.

References

1 Shiffman J, Smith S. Generation of political priority for global health initiatives: a framework and case study of maternal mortality. *Lancet* 2007; **370**: 1370–79.

2 Bustreo F, Requejo JH, Merialdi M, Presern C, Songane F. From safe motherhood, newborn, and child survival partnerships to the continuum of care and accountability: moving fast forward to 2015. *Int J Gynaecol Obstet* 2012; **119** (suppl 1): S6–8.

3 Commission on Information and Accountability for Women's and Children's Health. Keeping promises, measuring results. 2011. http://www.everywomaneverychild.org/images/content/files/accountability_commission/final_report/Final_EN_Web.pdf (accessed January 29, 2014).

4 Hogan MC, Foreman KJ, Naghavi M, et al. Maternal mortality for 181 countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. *Lancet* 2010; **375**: 1609–23.

5 Lozano R, Wang H, Foreman KJ, et al. Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. *Lancet* 2011; **378**: 1139–65.

6 WHO, UNICEF, UN Population Fund, World Bank. Trends in maternal mortality: 1990 to 2010. 2012. http://www.unfpa.org/webdav/site/global/shared/documents/publications/2012/Trends_in_maternal_mortality_A4-1.pdf (accessed Jan 31, 2014).

7 Bhutta ZA, Chopra M, Axelson H, et al. Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival. *Lancet* 2010; **375**: 2032–44.

8 Hounton S, De Bernis L, Hussein J, et al. Towards elimination of maternal deaths: maternal deaths surveillance and response. *Reprod Health* 2013; **10**: 1.

9 Leone T. Measuring differential maternal mortality using census data in developing countries. *Popul Space Place* 2013; published online July 8. DOI:10.1002/psp.1802.

10 Helleringer S, Duthé G, Kanté AM, et al. Misclassification of pregnancy-related deaths in adult mortality surveys: case study in Senegal. *Trop Med Int Health* 2013; **18**: 27–34.

11 Cross S, Bell JS, Graham WJ. What you count is what you target: the implications of maternal death classification for tracking progress towards reducing maternal mortality in developing countries. *Bull World Health Organ* 2010; **88**: 147–53.

12 Lawson GW, Keirse MJNC. Reflections on the maternal mortality Millennium Goal. *Birth* 2013; **40**: 96–102.

13 Mangham LJ, Hanson K. Scaling up in international health: what are the key issues? *Health Policy Plan* 2010; **25**: 85–96.

14 Naghavi M, Makela S, Foreman K, O'Brien J, Pourmalek F, Lozano R. Algorithms for enhancing public health utility of national causes-of-death data. *Popul Health Metr* 2010; **8**: 9.

15 Naghavi M, Wang H, Vos T, et al. Global, regional, and national levels of age-specific mortality and 239 causes of death during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* (submitted).

16 Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**: 2095–128.

17 WHO. International statistical classification of diseases and related health problems: tenth revision, volume 2. 2004. http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf (accessed Feb 3, 2014).

18 Confidential Enquiry into Maternal and Child Health. Why mothers die: 2000–2002. London: Royal College of Obstetricians and Gynaecologists Press, 2004.

19 Ronsmans C, Graham WJ, on behalf of *The Lancet* Maternal Survival Series steering group. Maternal mortality: who, when, where, and why. *Lancet* 2006; **368**: 1189–200.

20 UN Development Group. Indicators for monitoring the Millennium Development Goals: definitions, rationale, concepts, and sources. 2003. http://www.undp.org/content/dam/aplaws/publication/en/publications/poverty-reduction/poverty-website/indicators-for-monitoring-the-mdgs/Indicators_for_Monitoring_the_MDGs.pdf (accessed Feb 1, 2014).

21 Gakidou E, King G. Death by survey: estimating adult mortality without selection bias from sibling survival data. *Demography* 2006; **43**: 569–85.

22 Calvert C, Ronsmans C. The contribution of HIV to pregnancy-related mortality: a systematic review and meta-analysis. *AIDS* 2013; **27**: 1631–39.

23 Le Coeur S, Khlat M, Halembokaka G, et al. HIV and the magnitude of pregnancy-related mortality in Pointe Noire, Congo. *AIDS* 2005; **19**: 69–75.

24 Lionel J, Aleyamma TK, Varghese L, et al. HIV and obstetric complications and fetal outcomes in Vellore, India. *Trop Doct* 2008; **38**: 144–46.

25 Louis J, Landon MB, Gersnoviez RJ, et al. Perioperative morbidity and mortality among human immunodeficiency virus infected women undergoing cesarean delivery. *Obstet Gynecol* 2007; **110**: 385–90.

26 Kourtis AP, Bansil P, McPheeters M, Meikle SF, Posner SF, Jamieson DJ. Hospitalizations of pregnant HIV-infected women in the USA prior to and during the era of HAART, 1994–2003. *AIDS* 2006; **20**: 1823–31.

27 Khan M, Pillay T, Moodley JM, Connolly CA, for the Durban Perinatal TB HIV-1 Study Group. Maternal mortality associated with tuberculosis-HIV-1 co-infection in Durban, South Africa. *AIDS* 2001; **15**: 1857–63.

28 De Groot MR, Corporaal LJ, Cronjé HS, Joubert G. HIV infection in critically ill obstetrical patients. *Int J Gynaecol Obstet* 2003; **81**: 9–16.

29 Coley JL, Msamanga GI, Fawzi MC, et al. The association between maternal HIV-1 infection and pregnancy outcomes in Dar es Salaam, Tanzania. *BJOG* 2001; **108**: 1125–33.

30 Zvandasara P, Hargrove JW, Ntozini R, et al. Mortality and morbidity among postpartum HIV-positive and HIV-negative women in Zimbabwe: risk factors, causes, and impact of single-dose postpartum vitamin A supplementation. *J Acquir Immune Defic Syndr* 2006; **43**: 107–16.

31 Sewankambo NK, Gray RH, Ahmad S, et al. Mortality associated with HIV infection in rural Rakai District, Uganda. *AIDS* 2000; **14**: 2391–400.

32 McDermott JM, Slutsker L, Steketee RW, Wirima JJ, Breman JG, Heymann DL. Prospective assessment of mortality among a cohort of pregnant women in rural Malawi. *Am J Trop Med Hyg* 1996; **55**: 66–70.

33 Black V, Brooke S, Chersich MF. Effect of human immunodeficiency virus treatment on maternal mortality at a tertiary center in South Africa: a 5-year audit. *Obstet Gynecol* 2009; **114**: 292–99.

34 Zaba B, Calvert C, Marston M, et al. Effect of HIV infection on pregnancy-related mortality in sub-Saharan Africa: secondary analyses of pooled community-based data from the network for Analysing Longitudinal Population-based HIV/AIDS data on Africa (ALPHA). *Lancet* 2013; **381**: 1763–71.

35 Mmiro F, Ndugwa C, Guay L, et al. Effect of human immunodeficiency virus-1 infection on the outcome of pregnancy in Ugandan women. *Pediatr AIDS HIV Infect* 1993; **4**: 67–73.

36 Temmerman M, Chomba EN, Ndinya-Achola J, Plummer FA, Coppens M, Piot P. Maternal human immunodeficiency virus-1 infection and pregnancy outcome. *Obstet Gynecol* 1994; **83**: 495–501.

37 Nathoo K, Rusakaniko S, Zijenah LS, et al. Survival pattern among infants born to human immunodeficiency virus type-1 infected mothers and uninfected mothers in Harare, Zimbabwe. *Cent Afr J Med* 2004; **50**: 1–6.

38 Kumar RM, Uduman SA, Khurranna AK. Impact of maternal HIV-1 infection on perinatal outcome. *Int J Gynaecol Obstet* 1995; **49**: 137–43.

39 Nuwagaba-Biribonwoha H, Mayon-White RT, Okong P, Carpenter LM, Jenkinson C. The impact of HIV on maternal quality of life in Uganda. *AIDS Care* 2006; **18**: 614–20.

40 Maiques-Montesinos V, Cervera-Sanchez J, Bellver-Pradas J, Abad-Carrascosa A, Serra-Serra V. Post-cesarean section morbidity in HIV-positive women. *Acta Obstet Gynecol Scand* 1999; **78**: 789–92.

41 Ryder RW, Nsuami M, Nsa W, et al. Mortality in HIV-1-seropositive women, their spouses and their newly born children during 36 months of follow-up in Kinshasa, Zaïre. *AIDS* 1994; **8**: 667–72.

42 Lepage P, Dabis F, Hitimana DG, et al. Perinatal transmission of HIV-1: lack of impact of maternal HIV infection on characteristics of livebirths and on neonatal mortality in Kigali, Rwanda. *AIDS* 1991; **5**: 295–300.

43 Chilongozi D, Wang L, Brown L, et al. Morbidity and mortality among a cohort of human immunodeficiency virus type 1-infected and uninfected pregnant women and their infants from Malawi, Zambia, and Tanzania. *Pediatr Infect Dis J* 2008; **27**: 808–14.

Ministry of Public Health, Yaounde, Cameroon (R T Talongwa MD); **Memorial University, St John's, NL, Canada** (E Y Tenkorang PhD); **Department of Anesthesiology, University of Virginia, Charlottesville, VA, USA** (A S Terkawi MD); **Department of Anesthesiology, King Fahad Medical City, Riyadh, Saudi Arabia** (A S Terkawi); **The Earth Institute, Columbia University, New York, NY, USA** (A L Thorne-Lyman ScD); **Cincinnati Children's Hospital Medical Centre, Cincinnati, OH, USA** (Prof J A Towbin MD); **Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA** (B X Tran PhD); **Department of Medicine, University of Crete, Heraklion, Greece** (Prof M Tsilimbaris PhD); **Department of Veterans Affairs, Washington, DC, USA** (U S Uchendu MD); **Department of Internal Medicine, Federal Teaching Hospital Abakaliki, Abakaliki, Nigeria** (K N Ukwaja MD); **National Institute for Public Health and the Environment, Bilthoven, Netherlands** (C H van Gool PhD); **UKK Institute for Health Promotion Research, Tampere, Finland** (Prof T J Vasankari PhD); **Neuroscience Centre, Raffles Hospital, Singapore** (N Venketasubramanian MD); **University of Bologna, Bologna, Italy** (Prof F S Violante MD); **Higher School of Economics, Moscow, Russia** (Prof V V Vlassov MD); **Uniformed Services University of Health Sciences, Bethesda, MD, USA** (S Waller MD); **Shandong University Affiliated Jinan Central Hospital, Jinan, China** (X R Wang PhD); **Murdoch Children's Research Institute, Royal Children's Hospital, Melbourne, VIC, Australia** (R G Weintraub); **University of Miami, Miami, FL, USA** (J D Wilkinson MD); **Institute of Public Health, University of Gondar, Gondar, Ethiopia** (S M Woldeyohannes MPH); **Ateneo School of Medicine and Public Health, City of Pasig, Manila, Philippines** (J Q Wong MD); **Jimma University, Jimma, Ethiopia** (M A Wordofa MPH); **Nanjing University School of Medicine, Jinling Hospital, Nanjing, China** (Prof G Xu PhD); **University of North Carolina at Chapel Hill, Chapel Hill, NC, USA**

(Y C Yang PhD); Division of Cardiovascular Medicine, Jichi Medical University School of Medicine, Shimotsuke, Japan (Y Yano MD); University of Hong Kong, Hong Kong Special Administrative Region, China (Prof P Yip PhD); National Centre of Neurology and Psychiatry, Kodaira, Japan (N Yonemoto MPH); Jackson State University, Jackson, MS, USA (Prof M Z Younis PhD); Department of Epidemiology and Biostatistics, Global Health Institute, School of Public Health, Wuhan University, Wuhan, China (Prof C Yu PhD); TCM Medical Tk, Nusajaya, Johor Bahru, Malaysia (K Yun Jin PhD); Mansoura Faculty of Medicine, Mansoura, Egypt (Prof M E S Zaki MD); Chongqing Medical University, Chongqing, China (Prof Y Zhao MD); Zhongshan Ophthalmic Centre, Sun Yat-sen University, Guangzhou, China (Y Zheng PhD); and Cancer Institute and Hospital, Chinese Academy of Medical Sciences, Beijing, China (Prof X N Zou MD)

Correspondence to:
Dr Nicholas J Kassebaum, Institute for Health Metrics and Evaluation, University of Washington, 2301 Fifth Avenue, Suite 600, Seattle, WA 98121, USA
nickjk@uw.edu

See Online for appendix

44 Matthews LT, Kaida A, Kanters S, et al. HIV-infected women on antiretroviral treatment have increased mortality during pregnant and postpartum periods. *AIDS* 2013; **27** (suppl 1): S105–112.

45 Westreich D, Maskew M, Evans D, Firnhaber C, Majuba P, Sanne I. Incident pregnancy and time to death or AIDS among HIV-positive women receiving antiretroviral therapy. *PloS One* 2013; **8**: e58117.

46 Foreman KJ, Lozano R, Lopez AD, Murray CJ. Modeling causes of death: an integrated approach using CODEm. *Popul Health Metr* 2012; **10**: 1.

47 Romano M, Cacciatore A, Giordano R, La Rosa B. Postpartum period: three distinct but continuous phases. *J Prenat Med* 2010; **4**: 22–25.

48 Jamison DT, Summers LH, Alleyne G, et al. Global health 2035: a world converging within a generation. *Lancet* 2013; **382**: 1898–955.

49 Institute for Health Metrics and Evaluation. Financing global health 2013: transition in an age of austerity. Seattle, WA: Institute for Health Metrics and Evaluation, 2014.

50 Konje JC, Ladipo OA. Nutrition and obstructed labor. *Am J Clin Nutr* 2000; **72** (suppl 1): 291–97S.

51 Bhutta ZA, Das JK, Rizvi A, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet* 2013; **382**: 452–77.

52 Bhutta ZA, Ahmed T, Black RE, et al. What works? Interventions for maternal and child undernutrition and survival. *Lancet* 2008; **371**: 417–40.

53 Acosta C, Bhattacharya S, Tuffnell D, Kurinczuk J, Knight M. Maternal sepsis: a Scottish population-based case-control study. *BJOG* 2012; **119**: 474–83.

54 Say L, Pattinson RC, Gülmezoglu AM. WHO systematic review of maternal morbidity and mortality: the prevalence of severe acute maternal morbidity (near miss). *Reprod Health* 2004; **1**: 3.

55 Morgan J, Roberts S. Maternal sepsis. *Obstet Gynecol Clin North Am* 2013; **40**: 69–87.

56 Asnani MR, McCaw-Binns AM, Reid ME. Excess risk of maternal death from sickle cell disease in Jamaica: 1998–2007. *PloS One* 2011; **6**: e26281.

57 Wilkinson H, on behalf of the Trustees and Medical Advisers. Saving mothers' lives. Reviewing maternal deaths to make motherhood safer: 2006–2008. *BJOG* 2011; **118**: 1402–03.

58 Rahimy MC, Gangbo A, Adjou R, Deguenon C, Goussanou S, Alihonou E. Effect of active prenatal management on pregnancy outcome in sickle cell disease in an African setting. *Blood* 2000; **96**: 1685–89.

59 Nevis IF, Reitsma A, Dominic A, et al. Pregnancy outcomes in women with chronic kidney disease: a systematic review. *Clin J Am Soc Nephrol* 2011; **6**: 2587–98.

60 Gilbert WM, Young AL, Danielsen B. Pregnancy outcomes in women with chronic hypertension: a population-based study. *J Reprod Med* 2007; **52**: 1046–51.

61 Brar SS, Khan SS, Sandhu GK, et al. Incidence, mortality, and racial differences in peripartum cardiomyopathy. *Am J Cardiol* 2007; **100**: 302–04.

62 Goland S, Modi K, Bitar F, et al. Clinical profile and predictors of complications in peripartum cardiomyopathy. *J Card Fail* 2009; **15**: 645–50.

63 Sliwa K, Fett J, Elkayam U. Peripartum cardiomyopathy. *Lancet* 2006; **368**: 687–93.

64 Maman AFO-B, Tomta K, Ahouangbévi S, Chobli M. Deaths associated with anaesthesia in Togo, West Africa. *Trop Doct* 2005; **35**: 220–22.

65 The Antiretroviral Therapy in Lower Income Countries (ART-LINC) Collaboration and ART Cohort Collaboration (ART-CC) groups. Mortality of HIV-1-infected patients in the first year of antiretroviral therapy: comparison between low-income and high-income countries. *Lancet* 2006; **367**: 817–24.

66 Murray CJL, Ortblad KF, Guinovart C, et al. Global, regional, and national incidence and death for HIV, tuberculosis, and malaria during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* (submitted).

67 World Health Organization Maximizing Positive Synergies Collaborative Group. An assessment of interactions between global health initiatives and country health systems. *Lancet* 2009; **373**: 2137–69.

68 Colbourn T, Lewycka S, Nambiar B, Anwar I, Phoya A, Mhango C. Maternal mortality in Malawi, 1977–2012. *BMJ Open* 2013; **3**: e004150.

69 Wang H, Dwyer-Lindgren L, Lofgren KT, et al. Age-specific and sex-specific mortality in 187 countries, 1970–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**: 2071–94.

70 Yusuf HR, Akhter HH, Rahman MH, Chowdhury ME, Rochat RW. Injury-related deaths among women aged 10–50 years in Bangladesh, 1996–97. *Lancet* 2000; **355**: 1220–24.

71 Gissler M, Berg C, Bouvier-Colle M-H, Buekens P. Injury deaths, suicides and homicides associated with pregnancy, Finland 1987–2000. *Eur J Public Health* 2005; **15**: 459–63.

72 Shahidullah M. The sisterhood method of estimating maternal mortality: the Matlab experience. *Stud Fam Plann* 1995; **26**: 101–06.

73 Hill K, Thomas K, AbouZahr C, et al. Estimates of maternal mortality worldwide between 1990 and 2005: an assessment of available data. *Lancet* 2007; **370**: 1311–19.

74 Conroy AL, McDonald CR, Kain KC. Malaria in pregnancy: diagnosing infection and identifying fetal risk. *Expert Rev Anti Infect Ther* 2012; **10**: 1331–42.

Ochi et al. BMC Public Health 2014, 14:359
http://www.biomedcentral.com/1471-2458/14/359

BMC Public Health

RESEARCH ARTICLE Open Access

Association of socioeconomic status in childhood with major depression and generalized anxiety disorder: results from the World Mental Health Japan survey 2002–2006

Manami Ochi[1,2], Takeo Fujiwara[1,2*], Rie Mizuki[1], Norito Kawakami[3] and World Mental Health Japan Survey Group

Abstract

Background: Low socioeconomic status (SES) in childhood is known to be a significant risk factor for mental disorders in Western societies. The purpose of this study was to investigate whether a similar association exists in Japan.

Methods: We used data from the World Mental Health Japan Survey conducted from 2002–2006 (weighted N = 1,682). Respondents completed diagnostic interviews that assessed lifetime prevalence of major depression (MD) and generalized anxiety disorder (GAD), as defined by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition. Associations between parental education (a proxy of SES in childhood) and lifetime onset of both disorders were estimated and stratified by gender using discrete-time survival analysis.

Results: Among women, high parental education was positively associated with MD (odds ratio [OR]: 1.81, 95% confidence interval [CI]: 1.03-3.18) in comparison with low parental education, even after adjustment for age, childhood characteristics, and SES in adulthood. This same effect was not found for men. In contrast, higher parental education was associated with GAD (OR: 6.84, 95% CI: 1.62-28.94) in comparison with low parental education among men, but this association was not found among the women, in the fully adjusted model.

Conclusions: In Japan, childhood SES is likely to be positively associated with the lifetime onset of mental disorders, regardless of family history of mental disorders, childhood physical illness, or SES in adulthood. Further study is required to replicate the current findings and elucidate the mechanism of the positive association between mental disorders and childhood SES.

Keywords: Childhood environment, Socioeconomic status, Mental health, Depression, Anxiety, Gender

Background

It is widely known that low socioeconomic status (SES) is associated with psychological problems such as depression and anxiety disorders [1-5]. This association can be explained in two ways: (1) low SES actually induces a mental disorder (social causation); or (2) mental disorders limit employment opportunities, causing individuals to fall into the low SES category (health selection) [6,7].

Previous studies have shown that SES in childhood has a direct effect on the development of mental disorders later in life [8-15]. For example, Gilman et al. reported that participants whose parent was engaged in manual labor either at the time of their birth or when they were seven years old were significantly more likely to develop major depression (MD) in their lifetime, even after adjusting for SES in adulthood [11]. However, since most of these studies were performed in Western countries, it is uncertain whether a similar association exists in Japan, where SES likely affects mental disorders differently

* Correspondence: fujiwara-tk@ncchd.go.jp
[1]Department of Social Medicine, National Research Institute for Child Health and Development, 2-10-1 Okura, Setagaya-ku, Tokyo 157-8535, Japan
[2]Department of Developmental Social Medicine, Mie University Graduate School of Medicine, Mie, Japan
Full list of author information is available at the end of the article

[16,17]. For instance, while education has been found to be inversely associated with depression in the USA, no such association has been found in Japan [16].

MD and generalized anxiety disorder (GAD) must be addressed in particular, in view of their high prevalence [18,19]. The lifetime prevalence of MD and GAD in the US is 16.6% and 5.7%, respectively in 2001–2003 [18], and in Japan, 4.4% for MD in 2005 [20]. Because MD and GAD are associated with several major causes of death, such as suicide [21] or cardiovascular disease [22,23], and greater disability-adjusted life years [24], further prevention efforts are needed. An investigation into the associations between childhood SES and MD or GAD may provide crucial information concerning the possible etiologies of these disorders. Further, by stratifying the data according to gender, the higher prevalence of these disorders among women may be explained [11].

Against these backgrounds, we hypothesized that childhood SES is associated with the lifetime onset of mental disorders, regardless of family history of mental disorders, childhood physical illness, or SES in adulthood, based on life-course epidemiology [25]. By focusing on SES in childhood, we can include the early onset cases, which are usually excluded in studies of the association between SES in adulthood and mental disorders in order to avoid reverse causation [26]. Thus, the purpose of this study was to investigate whether SES in childhood was associated with MD and GAD in both adult men and women.

Methods

Sample

Data from the World Mental Health Japan (WMHJ) Survey conducted between 2002 and 2006 were used. The WMHJ conducted an epidemiological survey of Japanese people aged 20 years and older as part of the World Health Organization's World Mental Health Survey Initiative [27]. Details of the WMHJ survey design, sampling, and field procedures have been described in previous research [28].

Three urban cities and eight rural municipalities in Japan were selected as study sites. These sites were selected because of their geographic variation, the availability of site investigators, and the cooperation of local government officials. Participants were randomly selected from a pool of eligible voters (i.e., registered residents) aged 20 years or older.

An internal sampling strategy was used to reduce respondent burden by dividing the interview into two parts. Part I included a core diagnostic assessment (details given below) and obtained the demographic variables of all the respondents. Part II included questions about risk factors, including childhood SES. Part II was administered to 1,682 of the 4,134 individuals who responded to the questionnaire in Part I (including all respondents with one or more lifetime disorders, as well as a probability subsample of approximately 25% of the other respondents). The total response rate was 55.1%. This sampling method was not significantly different from those used in the World Mental Health Surveys conducted in other countries [29].

The data were weighted to adjust for differential probabilities of selection and non-response (Weighted N = 1,682; N [men] = 734; N [women] = 948). Details of sample weights have been reported previously [19]. Sample size was calculated by assuming the lifetime prevalence of mental disorders to be between 5 and 10% [29] in low and high childhood SES groups with equal distribution ratios (with a Type I error = 0.05 and Type II error = 0.2), respectively. This yielded a figure of 948 participants who were able to successfully complete this study.

Written consent was obtained from every respondent at all study sites. The survey recruitment, consent, and field procedures were approved by The Human Subjects Committees of Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, the Japan National Center of Neurology and Psychiatry, Nagasaki University's Graduate School of Biomedical Sciences, Yamagata University's Graduate School of Medical Science, and Juntendo University's Graduate School of Medicine.

Diagnostic assessment

The WMHJ used a Japanese-translated, computer-assisted version of the World Health Organization Composite International Diagnostic Interview, Version 3.0 (WHO-CIDI 3.0) to assess mental disorders in individuals according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition [27]. Details concerning the translation process from English to Japanese have been reported previously [19]. Lifetime diagnoses of MD and GAD were approximated by the presence or absence of diagnoses of these disorders that respondents admitted to having, up to the time of the interviews. Diagnostic hierarchy and organic exclusion rules were used for making diagnoses.

The CIDI retrospectively assessed the age of onset for the disorders; however, in view of the existing evidence that retrospective age-of-onset reports are often biased [30], a special question sequence (previously used in the National Comorbidity Survey Replication) was introduced to improve the accuracy of reporting. In brief, the age of onset reported by the respondents was confirmed by other sequential questions, such as "Was it before you went to school?". Onset age was set at the upper end of the bound of uncertainty (e.g., age: 12 years for respondents who reported that onset was before their teenage years). Previous research has shown that this

question sequence yields more credible responses than do standard age-of-onset questions [31].

Socioeconomic status in childhood

SES in childhood was measured using the proxy variable of parents' education, because parental education is usually determined before the birth of the respondent; thus, we can use this measure to assess the impact of childhood SES on the lifetime incidence of MD or GAD. The number of years of education for both parents was surveyed, and the responses were categorized into three groups: less than a high school (0–11 years), high school (12 years), and some college or more (≥13 years). If the number of years of education was unknown, this became a dummy variable. If a respondent's parents' years of education were in discord, we used the higher number of years as parental education for our study.

Covariates

Under the assumption that they could be possible confounders or mediators in the relationship between childhood SES and lifetime onset of MD and GAD, we assessed data on certain childhood characteristics and SES in adulthood. The childhood characteristics of interest included parental mental illness and the presence of personal physical illness in the respondent's childhood (based on responses to yes/no questions). SES in the respondents' adulthood was measured by the individual's number of years of education, categorized into less than high school (0–11 years), high school (12 years), some college (13–15 years), and college or more (≥16 years). Further, the respondent's current annual household income was categorized with reference to the poverty line in Japan [32,33], as either low (<3 million yen), middle (3–9.9 million yen), or high (≥10 million yen).

Analysis methods

The models were estimated in a discrete-time survival framework with person-years as the unit of analysis. The obtained person-oriented data set (containing information on the age of onset for each mental disorder) from the cross-sectional survey was converted into a person-period dataset (containing information on each discrete time period for the individual, censoring the onset of each mental disorder) [34]. Each model was controlled for person-years, age category, and covariates. The survival coefficients and their standard errors (SEs) in the best-fitting model were exponentiated and are reported in the form of odds ratios (OR) and 95% confidence intervals (CI).

Model 1 was adjusted for age, Model 2 included information in Model 1 plus childhood characteristics (parental mental illness and childhood physical illness), while Model 3 included the information in Model 2 plus SES in adulthood (educational attainment and annual household income). All analyses were stratified by gender. STATA MP 12 was used for the analysis.

Results

Characteristics of the sample population

Table 1 shows the mean ages of the men and women subjects were 50.1 (SE = 0.91) and 52.2 years (SE = 0.92) respectively, distributed normally. Regarding high SES in childhood, parental education was ≥13 years for 15.4% of the men and 11.7% of the women, although a significant portion of the participants did not know their parental educations (26.4% of the men and 28.3% of the women).

In terms of childhood characteristics, less than 5% of respondents across both genders reported having parents with psychiatric illnesses or having their own physical illnesses in childhood. As for SES in adulthood, 27.9% of the men and 11.4% of the women graduated from college or achieved some other level of higher education. Further, 18.3% of the men and 11.5% of the women earned more than 10 million yen per year. Finally, 4.7% of the men and 8.7% of the women developed MD, while 2.8% of the men and 3.0% of the women developed GAD during their lifetimes.

Association of SES with MD

Table 2 shows the ORs of childhood SES for MD among men. SES in childhood (i.e., parental education) was not associated with MD in Model 1 (adjusting for age), Model 2 (plus adjustment for childhood characteristics), or Model 3 (plus adjustment for SES in adulthood). Among the covariates, having a physical illness in childhood and a higher educational attainment (i.e., ≥16 years) were significantly independently associated with the onset of MD. That is, those who had physical illness in childhood were 2.89 (95% CI: 1.00-8.32) times more likely to develop MD than those who did not, and those who attained ≥16 years of education were 3.14 (95% CI: 1.08-9.14) times more likely to develop MD than those who attained 0–11 years of education.

In contrast, among women, high SES in childhood (i.e., parental education that went beyond high school), was positively associated with the onset of MD (Table 3), and this relationship was quite robust. Participants with high parental education were 1.85 (95% CI: 1.00-3.42) times more likely to develop MD than those whose parental education was lower than high school in Model 2, which was slightly attenuated in Models 3. Among other covariates, those who attained high school education were more likely to develop MD than those who attained education level lower than high school (OR: 2.39, 95% CI: 1.19–4.81).

Table 1 Weighted distribution of characteristics by gender

			Men (n = 734)	Women (n = 948)	p-value
			%	%	
Demographics	Age	<30 years	13.9	15.1	0.26
		30-39 years	18.0	14.3	
		40-49 years	16.7	14.9	
		50-59 years	20.2	18.3	
		60-69 years	15.4	15.8	
		70-79 years	11.8	14.2	
		80+ years	4.0	7.4	
Socioeconomic status in childhood	Parental education	0-11 years	35.6	39.5	0.35
		12 years	22.6	20.5	
		13+ years	15.4	11.7	
		Unknown	26.4	28.3	
Childhood characteristics	Parental mental illness	Yes	2.3	2.7	0.62
	Physical illness	Yes	2.9	3.4	0.69
Socioeconomic status in adult	Education	0-11 years	25.5	31.1	<0.001
		12 years	31.2	33.2	
		13-15 years	15.4	24.3	
		16+ years	27.9	11.4	
	Annual household income	<3 million yen	26.8	36.6	<0.001
		3- < 10 million yen	54.9	52.0	
		10+ million yen	18.3	11.5	
Mental disorders	Major depression		4.7	8.6	<0.001
	Generalized anxiety disorder		2.8	3.0	0.83

Table 2 Odds ratio of socioeconomic status in childhood and covariates for major depression by discrete-time survival analysis, men

			Model 1 (univariate, adjusted for age)		Model 2 (+childhood characteristics)		Model 3 (+SES in adult)	
			OR	95% CI	OR	95% CI	OR	95% CI
SES in childhood	Parental education	0-11 years	ref		ref		ref	
		12 years	1.18	(0.51-2.76)	1.24	(0.54-2.86)	1.04	(0.48-2.25)
		13+ years	0.83	(0.32-2.18)	0.77	(0.29-2.06)	0.51	(0.19-1.34)
		Unknown	1.12	(0.50-2.53)	1.17	(0.51-2.64)	1.21	(0.52-2.78)
Childhood characteristics	Parental mental illness	Yes			2.23	(0.64-7.74)	2.00	(0.56-7.11)
		No			ref		ref	
	Physical illness	Yes			**2.90**	**(1.02-8.28)**	**2.89**	**(1.00-8.32)**
		No			ref		ref	
SES in adulthood	Education	0-11 years					ref	
		12 years					1.05	(0.35-3.18)
		13-15 years					1.59	(0.45-5.65)
		16+ years					**3.14**	**(1.08-9.14)**
	Annual household income	<3 million yen					ref	
		3- < 10 million yen					0.91	(0.39-2.09)
		10+ million yen					0.79	(0.31-2.02)

Age was adjusted for all analysis. Values in bold are significant at the p = 0.05 level.