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Twin Peaks: more twinning in humans than ever before

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STUDY QUESTION: How many twins are born in human populations and how has this changed over recent decades?

SUMMARY ANSWER: Since the 1980s, the global twinning rate has increased by a third, from 9.1 to 12.0 twin deliveries per 1000 deliveries, to about 1.6 million twin pairs each year.

WHAT IS KNOWN ALREADY: It was already known that in the 1980s natural twinning rates were low in (East) Asia and South America, at an intermediate level in Europe and North America, and high in many African countries. It was also known that in recent decades, twinning rates have been increasing in the wealthier parts of our world as a result of the rise in medically assisted reproduction (MAR) and delayed childbearing.

STUDY DESIGN, SIZE, DURATION: We have brought together all information on national twinning rates available from statistical offices, demographic research institutes, individual survey data and the medical literature for the 1980–1985 and the 2010–2015 periods.

PARTICIPANTS/MATERIALS, SETTING, METHODS: For 165 countries, covering over 99% of the global population, we were able to collect or estimate twinning rates for the 2010–2015 period. For 112 countries, we were also able to obtain twinning rates for 1980–1985.

MAIN RESULTS AND THE ROLE OF CHANCE: Substantial increases in twinning rates were observed in many countries in Europe, North America and Asia. For 74 out of 112 countries the increase was more than 10%. Africa is still the continent with highest twinning rates, but Europe, North America and Oceania are catching up rapidly. Asia and Africa are currently home to 80% of all twin deliveries in the world.

LIMITATIONS, REASONS FOR CAUTION: For some countries, data were derived from reports and papers based on hospital registrations which are less representative for the country as a whole than data based on public administrations and national surveys.

WIDER IMPLICATIONS OF THE FINDINGS: The absolute and relative number of twins for the world as a whole is peaking at an unprecedented level. An important reason for this is the tremendous increase in medically assisted reproduction in recent decades. This is highly relevant, as twin deliveries are associated with higher infant and child mortality rates and increased complications for mother and child during pregnancy and during and after delivery.

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Introduction

Twins have fascinated scientists (Mackenzie,1841; Duncan, 1865; Zeleny,1921) and the general public (Segal 2017) for centuries. Part of this interest is driven by the health implications of twin pregnancies. Twins have more complications at birth, are more often born premature, and have lower birth weights and higher still birth and infant mortality rates (Pison, 1992; Guo and Grummer-Strawn, 1993; Larroque *et al.*,2004; Delobel-Ayoub *et al.*, 2009; Monden and Smits, 2017). Also, the risk of complications for the mother, e.g. gestational diabetes, pre-eclampsia and post-partum depression and maternal mortality, are substantially increased in twin pregnancies (Bdolah *et al.*,2008; Choi *et al.*, 2009; Rauh-Hain *et al.*,2009; Jena *et al.*, 2011).

It has long been known that the frequency of twin births varies across populations (Bulmer,1970) as does the treatment and social status of twins (Eells,1892; Pison, 1992). A first overview of the global twinning distribution by the end of the 20th century was provided by Pison (2000) based on rough estimates for low and middle income countries (LMICs). Given that the situation has been highly dynamic in recent decades and better data for LMICs have become available (Smits and Monden, 2011), there is need for a new and truly global overview of twinning distribution in the world. In this article, such an overview is provided for the period 2010–2015. In addition, a similar overview is presented for the period 1980–1985, so that the shifts in the absolute and relative global twinning distribution over a period of 30 years can be observed.

We already know that, in the 1970s, twinning rates were low in (East) Asia, at an intermediate level in Europe and North America, and high in several African countries, where Nigeria was seen as the twinning champion of the world (Bulmer,1970; Hall, 2003; Hoekstra *et al.*,2008). More recently, it was shown that rates were also low in Central and South America (Gómez *et al.*,2019), particularly in countries with large indigenous populations, and that Nigeria is part of a broader Central African high twinning zone running from west to east across the continent (Smits and Monden, 2011). Although the extant literature suggests some general patterns, it provides a highly fragmented picture as most studies concern one or just a few countries, refer to different years, and ultimately do not cover the majority of countries.

Since the first records began, twinning rates have been moving with the tide of marriage age and family size, as older mothers and higher birth orders are associated with more twins (Duncan,1865; Pison and D'Addato, 2006). However, the effects of changes in age at birth and fertility were small to modest compared to the regional differences in the global pattern of twinning rates (Bulmer,1970; Pison *et al.*, 2015). Over the last three decades, new medical technologies have become important determinants of twinning. Medically assisted reproduction (MAR) has been one of the main drivers of increasing twin rates in several countries (Imaizumi, 1997; Blondel and Kaminski,2002; Hoekstra *et al.*,2008; Martin *et al.*,2012; Pison *et al.*, 2015; Gómez *et al.*, 2019). It is unclear, however, how the rise of MAR on the one hand and changing demographic behaviour on the other have changed the absolute and relative number of twins and their distribution around the globe.

Medically assisted reproduction has increased substantially since the 1970s (Deng *et al.*,2019; European IVF monitoring Consortium, 2020). MAR refers to a broader set of treatments other than those known as assisted reproductive technology (ART), which refers to treatments in which both sperm and oocyte are handled outside (i.e. *in vitro*) of the woman's body and embryos are transferred to establish a pregnancy. ART includes, but is not limited to, *in vitro* fertilization (IVF) and its variant, intracytoplasmic sperm injection (ICSI). However MAR also includes simpler techniques, such as ovarian stimulation and artificial insemination. Techniques such as ovarian stimulation and IVF are associated with increased numbers of multiple births (Nyboer Andersen *et al.*, 2007; Hoekstra *et al.*,2008). Most of this increase is in dizygotic twinning, although there is also evidence for a smaller increase in monozygotic twinning associated with MAR (Astonet *al.*, 2008).

As the diffusion and large scale use of these techniques varies significantly among countries (Collins, 2002; Ferraretti *et al.*, 2017), the global twinning landscape has likely altered dramatically. Large scale use of MAR started in the 1970s in the most developed countries, spread in the 1980s and 1990s to emerging economies in Asia and Latin America, and reached South Asia and the most wealthy groups in Africa only after 2000 (Collins, 2002; Inhorn and Patrizio, 2015; Pison *et al.*, 2015; Botha *et al.*, 2018). Availability and accessibility are still very low in most low income countries.

We contrast twining rates in 2010–2015, when the influence of MAR reached a peak (European IVF monitoring Consortium, 2020), to rates in 1980-1985, when MAR was still at low levels, even in high income countries, and when genetic differences, overall fertility, age at childbearing and parity were the major driving factors (Meulemans *et al.*, 1996; Beemsterboer *et al.*, 2006; Derom *et al.*, 2011). Since the early 1980s, many countries have seen significant changes in age at birth and parity distributions. There is evidence, at least for some countries, that the natural twinning rate (i.e. excluding births after MAR) remained stable (Derom *et al.*, 2011) and that increases in the total twinning rate were driven by the combination of changing age at birth and MAR (Pison *et al.*, 2015). Imaizumi's (1997) analysis of 10 countries shows that until 1980 there is no clear effect of MAR on twin rates.

We have systematically brought together information on national twinning rates for 165 countries, covering over 99% of the global population, for the 2010–2015 period. For 112 countries, we were also able to measure or estimate a twinning rate for 1980–1985. This new database allows us to present a comprehensive global overview of twinning rates and assess how the global distribution of twinning has changed over three decades.

Materials and methods

Materials

Data on twin deliveries for 165 countries or territories were brought together into a new database called the Human Multiple Births Database (HMBD; https://www.twinbirths.org/), which aims to bring together all available information on twin deliveries at the national level across the globe. For countries which have reliable statistics on births by multiplicity that are based on complete or nearly complete civil registration (mostly developed countries and a few developing countries), data derived from vital statistics systems of national statistical offices were used. For the first period, we used the mean of the available

data for the years 1980–1985 and for the second period, we used the mean of the available data for 2010–2015.

For countries for which vital statistics on births by multiplicity are missing or not reliable, the HMBD includes twin deliveries derived from published sources or computed on the basis of household surveys that include birth histories of women. Since the 1960s, many national representative household surveys have been held in LMICs that include information on twin deliveries. For the current article, twin rates were used from well-established large-scale survey programs: the Demographic and Health Surveys (https://www.dhsprogram.com/) and UNICEF's Multiple Indicator Cluster Surveys (mics.unicef.org). Data from these surveys programs are routinely employed by national and international institutions (World Bank, UNDP) to document the socio-demographic and health characteristics of LMICs.

The group of countries for which survey data are used can be subdivided into countries where the use of MAR in the period 1980–2010 was negligible and countries for which some influence of MAR can be expected. All sub-Saharan African countries belong to the first group (Botha *et al.*, 2018; Dyer *et al.*, 2020). For these countries, little change in twinning rates was expected as MAR was only available to a very small elite. These countries do not have reliably sources for direct measures for 1980–1985. We use births in the 2000–2009 period to estimate twin rates for the earlier period and assume that the twin rate has not changed significantly since 1980–1985. Supplementary Figure S2 shows that this is a reasonable assumption for births since 1990. There is no evidence for an increase in the twin rate across sub-Saharan Africa in the DHS starting in the 1990s.

The second group of countries for which no reliable vital statistics are available and hence survey data are used, includes countries in Latin America, parts of Asia and the MENA region (Middle East and North Africa). These countries were wealthy enough during the period under study to expect some influence of MAR. For these countries, we estimated figures for the 1980–1985 period with retrospective information from surveys held between 1987 and 1995 on births that occurred in the 10 years before these surveys. For the second period, we used information from surveys held after 2009 on births that occurred between 2010 and 2015.

For some countries, we derived twin rates from published sources, like journal articles or demographic reports. Data derived from these sources vary in quality depending on the kind of data on which they are based (e.g. national representative data or hospital based surveys). We only used reports where the data sources were clearly described and could be reasonable taken as nationally representative.

The twinning rate is defined as the proportion of twin deliveries out of the total number of deliveries, expressed per 1000 deliveries. Most, but not all, of the variation in twinning rates observed in this study reflects variation in dizygotic twinning, as monozygotic twinning rates are about 4 per 1000 deliveries everywhere in the world (Bulmer,1970; Bortolus *et al.*, 1999). All rates and their sources are available in Supplementary Tables SII and SIII and can be downloaded from https://www.twinbirths.org/.

Methods

In a first step, we determined the absolute number of twin deliveries and the total number of deliveries in a particular year for each country, including those for which reliable vital statistics on births are missing. We used the total number of deliveries in the country, as estimated by the United Nations (2017), and the twinning rate, as we estimated it, and apply the formula below.

We define
a = total number of births
b = twinning rate (expressed as a proportion)
c = number of twin deliveries
d = total number of deliveries

We obtain a from the UN World Population Prospects and b from our own calculations. We then calculate $c = a * b / (1+b)$ and $d = a - c$.

In a second step, we calculated the absolute and relative number of twin deliveries for groups of countries (regions, continents), and for the whole world, by summing the absolute number of twin deliveries and the total number of deliveries of each country. We are then able to calculate the twinning rate for groups of countries, or for the whole world, by dividing the number of twin deliveries by the total number of deliveries.

When we calculate the number of twin deliveries for a whole group of countries, but no estimate for the twinning rate for a particular country of this group is available, we suppose that the twinning rate in this country is equal to that one for their whole group computed on the basis of countries for which we do know the twinning rate.

Further details of the total number of deliveries, the number of twin deliveries, and the proportion of twin deliveries for each country are provided in Supplementary Tables SI, SII and SIII.

Results

Figure 1 depicts the distribution of twinning rates for 2010–2015, Supplementary Fig. S1 depicts the distribution of twinning rates for 1980–1985, and Fig. 2 depicts the change in twinning rates between 1980–1985 and 2010–2015. In both periods, Africa had the highest twinning rates and, for this continent, no significant increase between the two periods was observed. On the other hand, the high rates observed in the 2010–2015 period in, for example, Greece, Denmark and South Korea, are the result of rapid increases in the twinning rates between the two periods.

Substantial increases in twinning rates, even doubling or more, could be seen in many other countries in Europe, North America and (East) Asia. Except for the poorest countries in Africa and South Asia and a number of countries in Central and South America, the majority of countries showed a substantial increase in twinning rates. For 74 of 112 countries, we observed an increase of more than 10% whereas a decrease of more than 10% was found in only seven countries. For most countries, the current proportion of twin deliveries has never been higher since records began.

At the regional level, increases in twinning rates and a shift in the distribution of twins is also evident. Table 1 presents twinning rates for the world as a whole and for major regions in the two time periods. Apart from Africa and South America, where twinning rates have remained nearly unchanged, all regions show substantial increases, ranging from 32% in Asia to 71% in North America (Fig. 3). The absolute number of twin deliveries has increased everywhere except in South America. In North America and Africa, the absolute number of

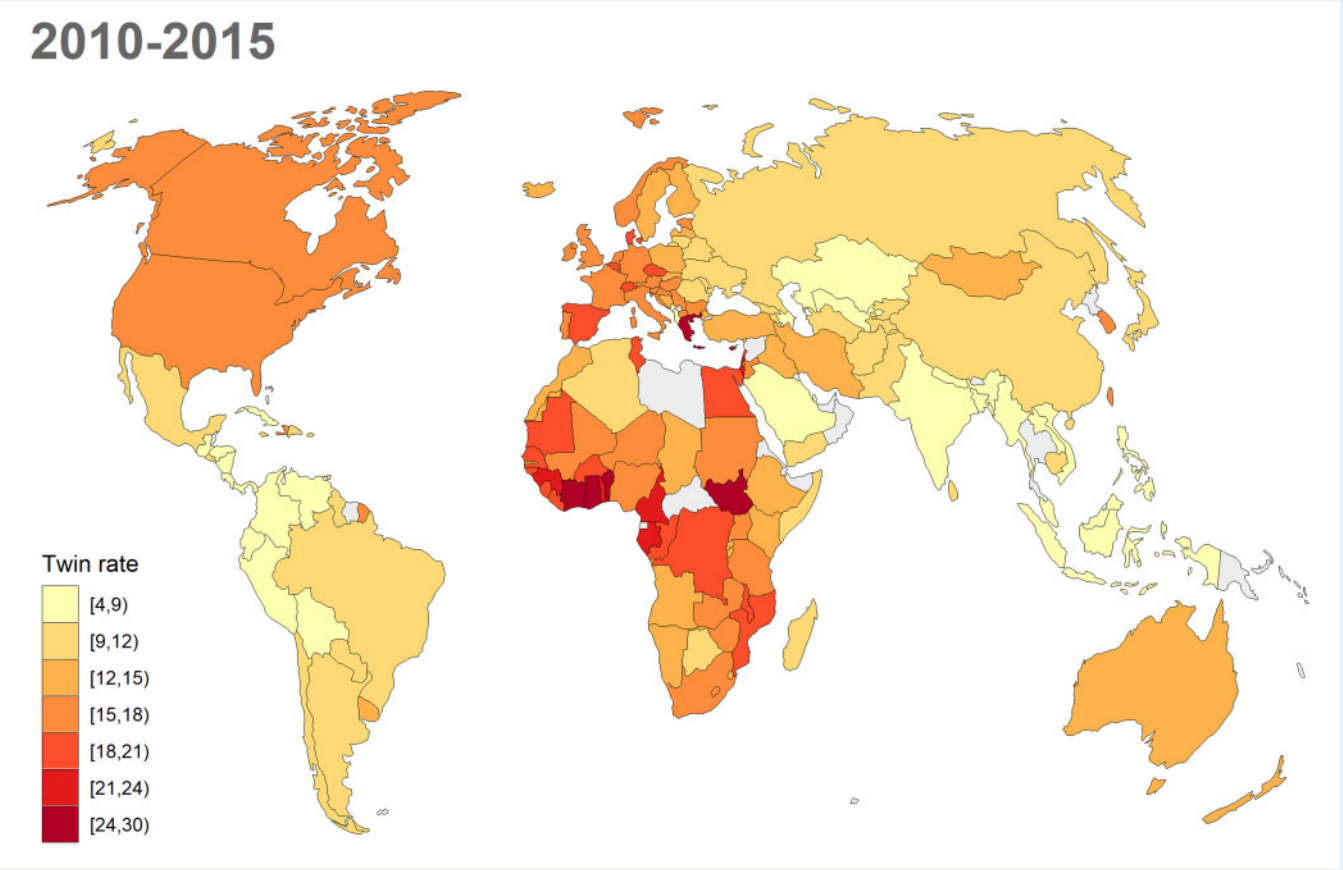

Figure 1. Twin deliveries per 1000 total deliveries in 2010–2015.

twin deliveries has increased by more than 80%. In Africa, this increase is almost entirely caused by population growth.

The figures make clear that changes over the last three decades have altered the global twinning landscape completely. These changes were largely driven by reproductive and fertility choices of households, and were initially concentrated in Europe and North America, followed by a number of emerging economies in (East) Asia. This remarkable change in the global pattern has remained hidden in the highly fragmented information on trends in twinning rates.

It is important to note that the number of children implied by the twinning rates for 2010–2015 are substantial. For example the North American twinning rate of 16.9 per 1000 deliveries implies that 3.4% of all children born in North America in that period were twins. For Africa the same percentage applies. The twinning rate of 12.0 for the world as a whole means that one of every 42 children born on earth is a twin.

Table 1 also shows that Asia and Africa are now home to more than 80% of the world twin deliveries and share them nearly equally (42% and 41% respectively). Africa's share has increased between the two periods whereas that of Asia's share has decreased. Africa's share of all twin deliveries (42% in 2010–2015) is much higher than its share of the overall world population (15%; United Nations, 2017) because of a high birth rate and a high twinning rate. Unfortunately these African twins still face a very high absolute mortality rate (Monden and Smits, 2017).

In 2010–2015, the absolute number of twin deliveries was higher than ever before, at the world level, as well as for all global regions except South America, where the absolute number of twin deliveries has declined slightly. While the global total number of births has increased by only 8%, the number of twin deliveries has increased by 42% (Fig. 3). By 2010–2015, more than 1.6 million sets of twins were born every year. This increase will become even more visible among (young) adults as lower mortality means that more twin pairs than ever before will survive until adulthood. In 2010–2015, about 2.4% of all newborns was a twin child.

The sharp increase in twinning rates in Europe and Asia has resulted in a seemingly counterintuitive finding: while there were fewer deliveries in these two regions in 2010–2015 than in 1980–1985, there were more twin deliveries in the later period, as Fig. 3 illustrates.

Supplementary Table SI provides similar information as Table 1, but is based on the more detailed Geographic Regions of the United Nations Statistic Division (https://unstats.un.org/unsd/methodology/m49/). This table shows that in Europe, the changes in twinning rates were smaller in the East European countries than in the other parts of the continent. In Asia, the largest changes have taken place in the West Asian and East Asian countries, while South Asia and South-East Asia

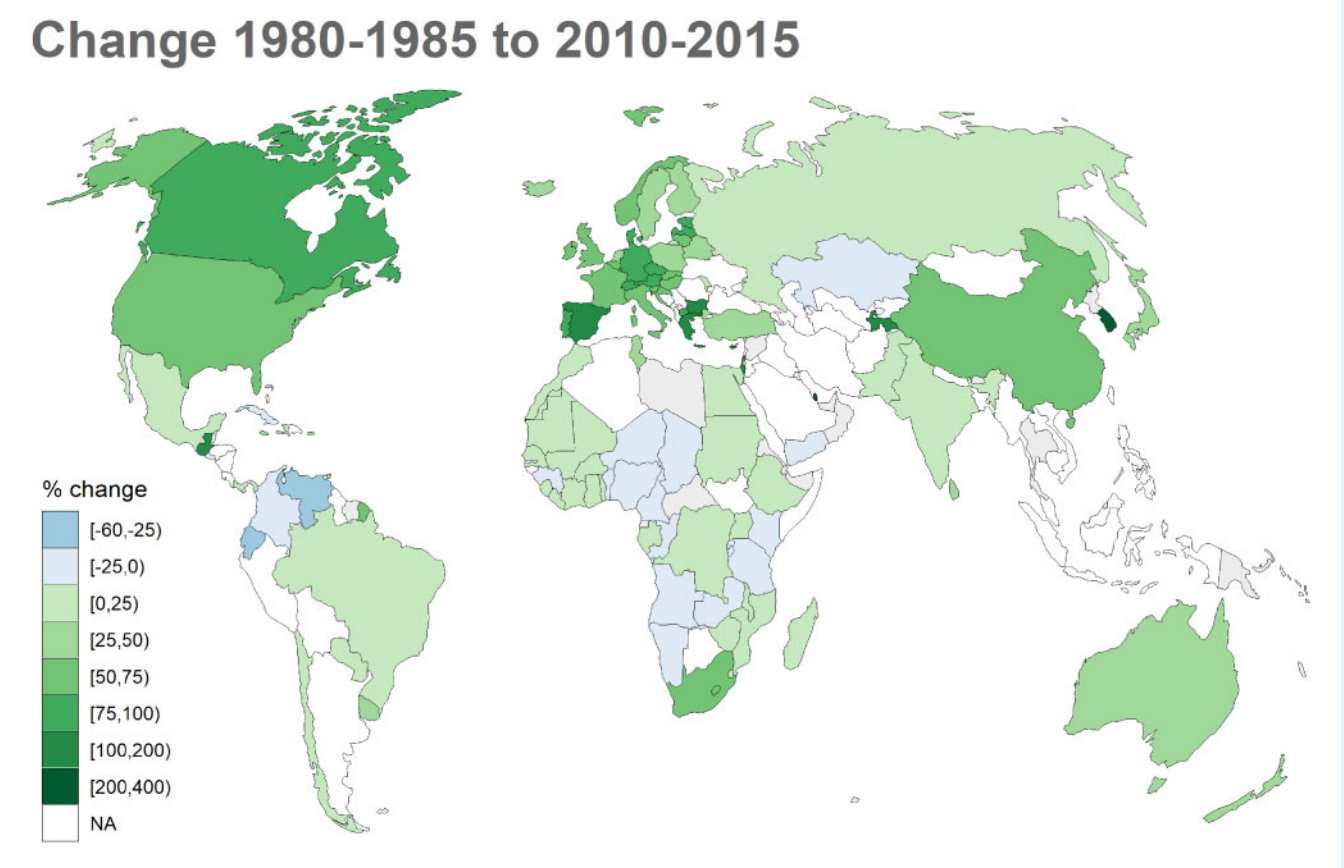

Figure 2. **Percentage change in twin deliveries per 1000 deliveries between 1980–1985 and 2010–2015.**

Table 1 **Absolute and relative number of twin and all deliveries, in the world and by region, in 1980–1985 and 2010–2015.**

	Number of twin deliveries (thousands)		Share of all twin deliveries in the world		Total number of deliveries (thousands)		Share of all deliveries in the world		Twinning rate (twin deliveries per 1000)	
	1980–1985	2010–2015	1980–1985	2010–2015	1980–1985	2010–2015	1980–1985	2010–2015	1980–1985	2010–2015
Africa	373	674	32%	41%	22,684	39,559	18%	29%	16.5	17.1
Asia	556	693	48%	42%	80,006	75,435	62%	54%	7.0	9.2
Europe	90	113	8%	7%	9,944	7,878	8%	6%	9.1	14.4
North America	38	71	3%	4%	3,937	4,251	3%	3%	9.9	16.9
Oceania	4	9	0%	1%	481	640	0%	0%	10.1	14.8
South America	102	100	9%	6%	11,772	10,823	9%	8%	8.7	9.3
World	1,165	1,663	100%	100%	128,827	138,590	100%	100%	9.1	12.0

Notes: Own calculations.

still lag behind. In Africa, the North African and particularly South African countries have been catching up with the West African and Central African countries, which in 1980–1985 still had the highest twinning rates in the world. In the Central and South American region, the more dynamic changes can be observed in the Caribbean and Central American countries, whereas South America showed hardly any change.

Our study also shows that differences in the proportion of twin deliveries between countries and regions have diminished between

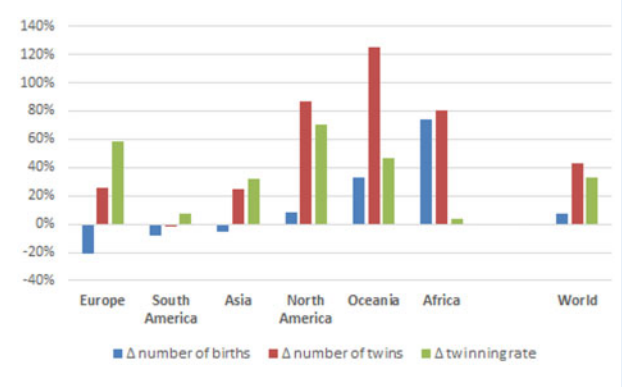

Figure 3. Change in number of total births, twin births and twinning rate from 1980–1985 to 2010–2015 by region.

1980–1985 and 2010–2015. We observed a convergence towards high twinning rates in almost all regions.

Discussion

We have brought together all available statistical information on the frequency of twin births across the globe, to document the variation in twinning rates among countries and how this variation has changed since the 1980s. Our results show that twinning rates were recently peaking at a historical high, with rates of over 15 twin deliveries per 1000 deliveries in many countries, including the USA, Canada, the European Union, Israel, South Korea, Taiwan, and almost all African countries. Only the poorer regions of Latin America and in South and South-East Asia had lower twinning rates, often (well) below 10 twin deliveries per 1000 deliveries.

We compared our recent twinning map with an earlier map, which we constructed on the basis of data for the first part of the 1980s, when twinning rates were still almost completely 'natural' in terms of the effects of MAR. This comparison revealed a huge rise in the global twinning rate, which increased by a third, from 9.1 to 12.0 twin deliveries per 1000 deliveries, in only three decades.

Also the distribution of twinning rates across the globe has changed considerably during this period. In the 1980s, global twinning rates were still largely dominated by high twinning rates in sub-Saharan Africa and moderate rates in North America and Europe. In the other areas of the globe, the rates were low at that time, often only slightly above the bottom line represented by the monozygotic twinning rate, which is about 4 twin pairs per 1000 deliveries everywhere in the world.

There is broad evidence that the enormous change in the global twinning rate is to a large extent caused by the increased use of MAR, which started in the wealthier regions of our world in the 1970s, spread to emerging economies in Asia and Latin America in the 1980s and 1990s, and reached the more prosperous subpopulations of South Asia and Africa only after 2000 (Imaizumi, 1997; Mills *et al.*, 2014; Inhorn and Patrizio, 2015; Botha *et al.*, 2018). While the important role of MAR is undisputed, also the increasing age at birth has contributed to increased twinning rates in high income countries.

According to Pison *et al.* (2015), the effect of MAR is on average about three times larger than the effect of delayed childbearing. However, there are substantial differences between countries. In Spain, Greece and Singapore, the effect of MAR is five to six times greater than that of delayed childbearing; in the United States, Canada and Switzerland it is three to four times greater, In France, Germany and Sweden it is about two times greater, and in Finland, Hungary and New Zealand the effects of both factors are about similar (Pison *et al.*, 2015). Besides MAR and delayed childbearing, also other factors may have contributed to the change, although no convincing evidence has been documented yet.

The strong increase in number of twin births due to MAR started to raise concerns in the 1990s among medical authorities and policy makers, because of the public health problems related to twin births. Twins are a high-risk group associated with complications during pregnancy, at birth and thereafter, including preterm deliveries, lower birth weight, increased still births and infant and maternal mortality (Bdolah *et al.*,2008; Choi *et al.*, 2009; Delobel-Ayoub *et al.*,2009; Jena *et al.*, 2011; Monden and Smits,2017).

Because of these concerns, many developed countries started to change their MAR regulations and clinical practices around 2000 (Mills *et al.*, 2014; Pison *et al.*,2015), whereby reductions in the number of transferred embryos were implemented and the focus was directed towards the successful live birth delivery of singletons. It therefore is possible that, in these countries, the twinning rates observed for the 2010–2015 period are at an all-time high and the rates might start to decrease in the coming decade. In Europe, the number of transfers of a unique embryo in IVF/ICSI (during fresh cycles) was barely higher than 10% in the late 1990s, but has since increased continuously to just above 40% in 2017. The number of transfers involving two embryos has been fluctuating around 55%, while transfers of three or more have declined steadily (European IVF monitoring Consortium, 2020).

In line with these developments, in some of the most developed countries, twinning rates were found to plateau in the early 2000s (Pison *et al.*, 2015). However, in many other countries, no such pattern was observed, so it remains to be seen whether a reversal of the trend will actually take place. From a global perspective, the changes in these developed countries might easily be counterbalanced by developments in the highly populated South and South-East Asian countries, where the diffusion and growth of MAR in combination with still very low twinning rates might lead to a substantial increase in both twinning rates and absolute numbers of twins. These regions are likely to see further increases in age at birth too. This is another important factor that contributes to higher twinning rates.

For sub-Saharan Africa, which so far has not seen a strong increase in twinning rates, it remains an open question what the net effect will be of the combination of lower overall fertility, higher age at birth, and higher uptake of MAR. While the first development would reduce twinning rates, the latter two would lead to higher levels of twinning.

Some limitations need to be considered when interpreting our findings. One limitation concerns the quality of the data. For most developed countries, twin rates were obtained from statistical offices or national medical registrations, which are generally of high quality. For LMICs, in many cases representative household surveys with complete

birth histories were available, which are of reasonable quality (reflected in relatively low within-country variation between surveys held in different years (Monden and Smits, 2017)). For the 2010–2015 twin rates of China and Saudi-Arabia, we had to rely on published reports. While the Chinese data are of high quality and are nationally representative, the Saudi data come from one single hospital and therefore need to be treated as an estimate with considerable uncertainty. The twin rate may be overestimated if women pregnant with twins are more likely to deliver in this hospital rather than elsewhere compared to women pregnant with a singleton.

Unfortunately, we have not been able to produce a comprehensive overview of the situation before 1980. Nationally representative information on twinning rates is increasingly scarce for earlier periods, especially for LMICs. However, some of the main geographical differences in the 1980–1885 overview are in line, certainly in rank order, with evidence based on smaller studies from the mid or early 20th century, such as those collected by Bulmer (1970) in his seminal book. The main pattern of high twinning in Africa, low twinning in Asia and intermediate levels in Europe are generally thought to stem from genetic differences, while changes within the regions are driven by maternal age, fecundity and voluntary birth control (Bulmer, 1970; Imaizumi, 1997; Pison and Couvert, 2004).

In many countries, reliable statistics on MAR are still lacking. We should also bear in mind that substantial numbers of women travel to other countries for fertility treatments (Shenfield *et al.*, 2010; Mills *et al.*, 2014). It is unclear at the moment, how this may affect the twin rate in their country of residence. This might be particularly relevant for richer urban elites in emerging economies, for whom we still rely on survey data rather than vital register or census data. Accurate and detailed data on twin rates are also important for forecasting the demand for health services given the health implications for twins and their mothers. This is particularly important in low-income countries, where mortality among twins is highest and care for women expecting twins is often inadequate by modern standards (Monden and Smits, 2017). Improved registration and monitoring of twin births would help target these health issues. More generally, it would allow us to better understand the cultural, political and economic factors that contribute to differences in twin rates not only between but also within countries.

Supplementary data

Supplementary data are available at *Human Reproduction* Online.

Data availability

All data are available in the article and supplementary materials.

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Authors' roles

All authors contributed substantially and equally to the conception, design, data acquisition and drafting of the article.

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Conflict of interest

The authors declare no conflict of interest.

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