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Heat wave 2003 and mortality in Switzerland

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Summary

Questions under study: During June to August 2003, high temperatures were reported across Europe including Switzerland. In many European countries, particularly in France the heat wave was associated with an increase in mortality. This is the first analysis investigating whether the high temperatures during summer 2003 in Switzerland had a measurable impact on mortality.

Methods: Daily data on all-cause mortality for the period January 1990 to December 2003, and meteorological data from 20 different stations for the same period were analysed. Excess mortality for different age groups, gender and geographic regions was calculated. Daily mortality and temperature in 2003 was correlated with lags of temperature up to 7 days.

Results: An estimated 7% increase in all cause mortality occurred during June to August 2003. Excess mortality was limited to the region north of the Alps, to inhabitants of cities and suburban areas and was more pronounced among the elderly and the inhabitants of Basel, Geneva and Lausanne. North of the Alps, deviations in daily mortality were significantly correlated with deviations in maximum daily temperatures and night temperatures. The combination of day temperature above 35 °C and night temperatures above 20 °C predominantly occurred in Basel and Geneva and might in part explain the regional differences in excess mortality.

Conclusions: As the number of elderly people in Switzerland continues to rise and the occurrence of heat waves is predicted to increase as a consequence of global warming, preventive programmes targeting susceptible populations during heat waves are warranted.

Key words: mortality; heat wave; air pollution; prevention

Introduction

During June to August 2003, record-breaking high temperatures were reported across Europe including Switzerland. According to Meteo Schweiz, the summer of 2003 was the warmest for the last 250 years [1]. (In the European Alps, the average thickness loss of glaciers reached approximately 3 meters water equivalent, which was nearly twice as much as during the previous record year of 1998 (1.6 meters) [2]). France was the European country most affected by the heat wave with an estimated excess mortality of 54% [3]. Across 13 of the largest French cities, 14800 excess deaths were estimated for the period between August 1 and August 20 [4] triggering fierce political discussions. The combination of elevated temperatures during the day and during the night showed the strongest association with mortality, alluding to the importance of elevated night temperature for the heat effects on health. Other European countries such as Italy [5], Spain [6], the Netherlands [7], Germany [8] and England [9] also reported excess mortality during summer 2003. The Swiss Federal Statistical Office published a press release in November 2003 indicating that there was no striking increase in mortality during summer 2003 in Switzerland [10].

From previous research, it is known that persons with pre-existing cardiovascular and respiratory diseases have an increased risk of death from ambient heat exposure and that this risk is higher for several population groups including the elderly, infants and persons of low socio-economic status [11]. Other specific risk factors compromising adequate behavioural adaptation to heat include living alone, lack of access to transportation, living on higher floors of multi-storey buildings, using tranquillisers and having a mental illness [3].

As the number of elderly people in the Swiss population continues to rise and the occurrence of heat waves is predicted to increase as a consequence of global warming, the number of heat related deaths might increase. This raises the question of how to meet this public health threat best.

We present here the first results of an analysis

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investigating whether the high temperatures occurring during summer 2003 had a measurable impact on the mortality of the Swiss population, specifically focussing on demographic and regional patterns of excess mortality.

Methods

Mortality data

Daily data on all-cause mortality in Switzerland were obtained from the Swiss Federal Statistical Office for the period of January 1990 to December 2003. Deaths that occurred outside Switzerland were excluded from the analyses. Mortality variables included daily death counts by gender, age, and area of residence. Causes of deaths were only available up to the year 2001 and could therefore not be included in the analyses.

Meteorological data

MeteoSwiss provided meteorological data from 20 different stations representing the climatic conditions of Switzerland for the time period of 1990–2003. The stations were: Altdorf, Basel-Binningen, Berne-Liebefeld, Chur-Ems, Davos, Geneva, Locarno-Magadino, Lugano, Luzern, Neuchâtel, Payerne, Pully-Lausanne, Reckenholz, Sion, St. Gallen, Taenikon, Vaduz, Wynau, Zürich-Swiss Meteorological Agency (SMA) and Zürich-Kloten. Meteorological variables were provided as hourly averages and included ambient temperature, relative humidity, and dew point. Daily means of these parameters, and daily 1-h minimum and maximum temperatures were calculated. A heat index, MAT (maximum apparent temperature) [12], was derived for each station as a function of maximum temperature and dew point temperature as follows: $-2.653 + 0.994 \cdot (T_{max}) + 0.0153 \cdot (Tdewpoint^2)$. This index is a measure of relative discomfort due to combined heat and high humidity. Daily mean and maximum concentrations of ozone (O_3), nitrogen dioxide (NO_2), and particulate matter (PM10) were obtained from the National Air Pollution Monitoring Network (NABEL) stations Berne, Binningen, Davos, Lausanne, Lugano, Magadino, Payerne, Taenikon, Sion, Zürich, and from the cantonal station of Geneva.

In addition, for the six larger cities, temperature data from inner city stations were included: Basel (St. Johann / Leonhard), Geneva (St. Clotilde), and from the NABEL stations in Berne, Lausanne, Lugano and Zürich (Kaserne).

Statistical analyses

To evaluate excess mortality in 2003, observed death counts were compared with the respective counts predicted from the data of the years 1990 to 2002. The predicted number of deaths for a given time interval in 2003 was computed by extrapolating a Poisson regression model for the death counts in the respective time intervals in 1990–2002. A trend variable (ie calendar year) was included in these regression models to account for the approximately linear negative trend in death counts over this 13-year period. Confidence intervals for relative deviations in mortality were derived from the covariance matrix of the regression coefficient[1]. Excess mortality was estimated for the period of June to August 2003 for the whole Swiss population and for age, gender, geographic region (North and South of the Alps), type of region (urban, suburban and rural) and for the larger cities (Basel, Berne, Geneva, Lausanne, Lugano, and Zürich).

Meta-analysis combining the risk ratios from each city was used and a test of heterogeneity was calculated to evaluate the percentage of total variation across cities that is due to heterogeneity rather than chance [14].

Switzerland covers all climates from Mediterranean to high alpine in a relatively small area. However, the majority of the population lives in areas between approximately 200 and 600 m above sea level. To characterise the temperature for the region "North of the Alps" and "South of the Alps", the average of the daily temperature values for the respective stations was computed. The subdivision into these two major regions could be justified by the high temporal correlations of temperature values at different sites within these regions. Predicted values of meteorological parameters for given time intervals in 2003 were calculated on the basis of the values from the respective time intervals in the years 1990–2002. "Very hot days" were defined as days with a maximum 1-h temperature >35 °C and a minimum 1-h night temperature >20 °C as suggested by the analyses of the heat wave in France 2003 [3].

To examine the association between daily mortality and temperature in 2003, the Spearman rank-order correlation between the relative deviation from predicted daily mortality and the relative deviation from predicted daily temperature was calculated. Lags of temperature up to day 7 were evaluated.

To evaluate the net effect of the excess heat on total mortality and to account for short-term mortality displacement (harvesting) monthly deviations from predicted mortality were successively added up from June 2003 until the end of December 2003. If all excess mortality had been due to harvesting, cumulative excess mortality would have dropped back to zero shortly after the end of the heat wave.

1 We first estimated the standard error of $\ln(Y / Y_{pred})$, where Y and Y_{pred} denote the observed and predicted death counts, respectively, for the time interval in question. This standard error was estimated by $\sqrt{1 / Y + SE(\ln(Y_{pred}))^2}$. The standard error of ln(Y) was approximated by $\sqrt{1 / Y}$ [13] and the standard error of ln(Ypred) was estimated using the covariance matrix of the parameter estimates of the underlying Poisson regression model. The 95%-confidence intervals for $E\,[(Y - Y_{pred}) / Y_{pred}]$ were then estimated according to $Y/Y_{pred} \cdot \exp\,[\pm 1.96\, SE(\ln(Y/Y_{pred}))] - 1$.

Results

In figure 1, daily mortality rates between May and October 2003 are plotted against the mean daily number of deaths 1990–2002. The highest peak in mortality was observed during August, but smaller peaks occurred also in June and July.

Table 1 gives the number of observed and predicted deaths and the number of estimated excess deaths for selected demographic and regional characteristics in Switzerland during summer 2003. A total of 975 (6.9%) extra deaths occurred during the three summer months. The biggest deviation from predicted mortality was observed for August 2003 (June: 5.0%, 95% CI: 1.7–8.5%, July: 4.7%, 95% CI: 1.4–8.2%, and August 10.9%, 95% CI: 7.4–14.4%). Significant excess mortality was mainly observed in the region North of the Alps, in urban and suburban areas and in the cities of Basel, Geneva and Lausanne. Significant heterogeneity existed between the cities (test of heterogeneity p = 0.008, excluding Lugano heterogeneity p = 0.015) (figure 2). Death rates were higher than predicted in males and in females, but people aged 80 years and older were most strongly affected.

During June–August 2003, the mean daily temperature North of the Alps was 3.7 °C above the mean for the reference period 1990–2002 and 3.5 °C South of the Alps. The number of nights with minimum night temperature above 17 °C (corresponding to the 99th percentile of the minimum temperature distribution) was clearly higher than predicted in all regions of Switzerland; the highest temperatures during the day were registered in Basel and Geneva (table 2). Averaging temperatures across the meteorological stations north or south of the Alps resulted in only few "very hot days". However, in Basel and Geneva the combination of hot temperatures at night and during the day occurred more often. When temperature data from local stations situated in the centres of the cities were considered, the number of nights

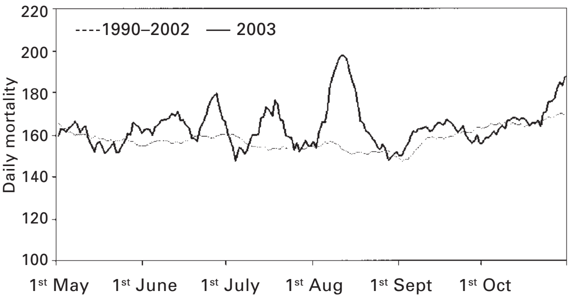


Figure 1

Daily total mortality (7 day moving average) in Switzerland from May to October 2003 plotted against the mean daily number of deaths of the reference period 1990–2002.

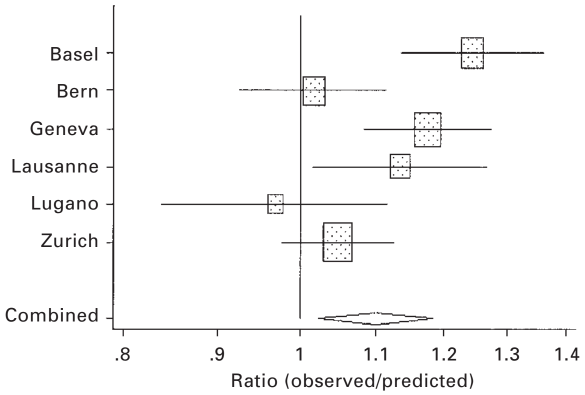


Figure 2

Random effects meta-analysis of the ratio observed/predicted number of deaths (June to August 2003) in each city. The combined ratio is 1.098 (95% confidence interval 1.029–1.17). Test of heterogeneity: p = 0.008.

Table 1

Number of observed and predicted deaths and number of estimated excess deaths, by selected demographic and regional characteristics in Switzerland during June-August 2003.

Characteristics	no. of observed deaths	no. of predicted deaths	estimated no. excess deaths	variation *		
				%	(95% CI)	p-value
All of Switzerland	15 169	14 194	975	6.9	4.9–8.8	<0.001
North of Alps	14 467	13 507	960	7.1	5.1–9.2	<0.001
South of Alps	702	688	14	2.1	–6.4–11.3	0.64
Urban	5287	4900	387	7.9	4.6–11.3	<0.001
Sub-urban	5885	5341	544	10.2	6.9–13.6	<0.001
Rural	3997	3957	40	1.0	–2.6–4.7	0.59
Age groups (yrs)						
20 to 39	358	345	13	3.8	–7.7–16.8	0.53
40 to 59	1462	1392	70	5.0	–1.1–11.5	0.10
60 to 79	4994	4833	161	3.3	0.1–6.7	0.05
80+	8186	7527	659	8.8	6.0–11.6	<0.001
Male	7304	6884	420	6.1	3.3–9.0	<0.001
Female	7865	7317	548	7.5	4.7–10.3	<0.001
Basel	654	526	128	24.4	13.6–36.3	<0.0001
Berne	585	575	10	1.7	–7.4–11.7	0.72
Geneva	823	700	123	17.5	8.4–27.4	0.0001
Lausanne	438	386	52	13.5	1.6–26.6	0.03
Lugano	252	260	–8	–3.1	–16.0–11.9	0.67
Zürich	1005	958	47	4.9	–2.4–12.7	0.19

* Number of excess deaths multiplied by 100, divided by number of predicted

Table 2

Meteorological and air pollution characterisation during summer 2003 (June to August).

Meteorological parameters measured at SMA stations	North of Alps	South of Alps	Basel-Binningen	Berne-Liebefeld	Geneva-Cointrin	Lausanne-Pully	Lugano-SMA	Zürich-SMA
Minimum night temperature °C:								
mean (SD)	16.3 (2.0)	19.7 (2.1)	17.5 (1.3)	15.3 (1.9)	17.8 (2.4)	19.3 (2.4)	21.0 (2.1)	17.2 (2.3)
Range	11.7–21.2	14.7–24.4	11.9–22.1	10.3–21.0	11.7–23.9	13.6–25.0	15.8–25.1	12.1–22.2
Number of nights with mean temp >17 °C / expected	58 / 17.2	90 / 64.5	71 / 33.2	39 / 17.2	77 / 35.9	85 / 52.3	91 / 69.6	66 / 27.1
Daily maximum temperature °C:								
mean (SD)	27.5 (4.0)	29.6 (2.6)	28.9 (4.3)	27.7 (4.1)	30.0 (4.0)	28.0 (3.9)	29.4 (2.5)	27.1 (4.4)
Range	16.5–35.3	24.0–35.3	18.6–38.0	17.0–35.8	19.6–37.1	17.3–36.7	23.5–35.3	14.4–35.5
Number of days with max temperature >30 °C / expected	22 / 3.4	42 / 5.4	31 / 7.8	24 / 3.9	46 / 10.3	22 / 2.2	39 / 3.8	23 / 4.8
Total number of 'very hot days' (>30 °C day and >20 °C night)	1	1	10	0	14	0	1	1

Figure 3

Plot of the daily percentage difference between observed and predicted mortality (bars) and of the deviation of daily apparent temperature from the respective 1990–2002–average (line) for the region of Switzerland north of the Alps.

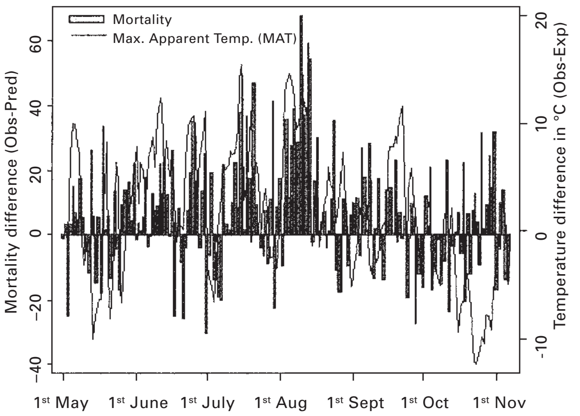
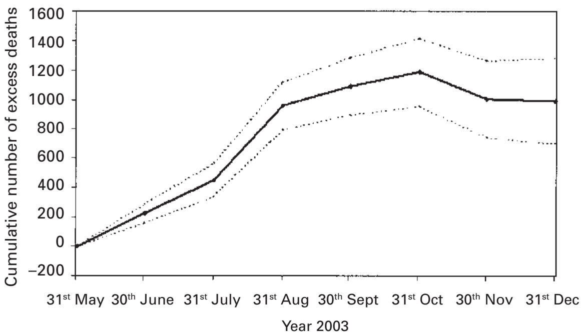


Figure 4

Cumulative number of excess deaths from June to December 2003 and its 95% confidence intervals.



with minimum temperature above 17 °C increased in Berne (Bollwerk: 70 compared to the suburban station Liebefeld: 39) and Zürich (Kaserne: 85 compared to the SMA-station at Zürichberg: 66). However, there were hardly any differences between suburban and central stations in Basel, Geneva and Lausanne. For all inner city stations, the mean of the maximum daily temperature during June to August 2003 was on average 1–2 °C higher than at the corresponding SMA stations located on the outskirts. The number of "very hot days" at the inner city meteorological station in Geneva was 22 and in Basel 13. In the other cities the numbers of "very hot days" did not differ between inner city stations and the corresponding outskirts SMA-stations.

The photochemical air pollutant "ozone", which is readily formed under warm and sunny conditions, also peaked during summer 2003. The correlation coefficient between daily maximum temperature and maximum 1-h ozone concentration for the region North of the Alps was r = 0.80 (95% CI: 0.78–0.82). At all stations of the NABEL network, the medians of maximum 1-h ozone concentrations were significantly higher in 2003 than during the reference period 1990–2002. On the other hand, the medians of daily mean concentrations of particulate matter and nitrogen dioxide during summer 2003 were comparable to the corresponding levels of the reference period (data not shown).

Deviations from predicted daily mortality were significantly correlated with deviations from predicted daily temperatures (maximum and apparent) as illustrated in figure 3 for the region North of the Alps. For the whole summer period (June to August) the correlation was similar whether deviations of maximum, minimum or apparent temperature were considered (r = 0.50, 95% CI: 0.32–0.63). For the region South of the Alps, no significant correlations between daily mortality and daily temperature were observed. Mortality was significantly correlated with maximum temperature up to a lag of six days, and with minimum temperature up to lag of 3 days. The strongest correlations were noted for maximum temperature of the previous day (r = 0.52, 95% CI: 0.35–0.65) and minimum temperature of the previous night (r = 0.48, 95% CI: 0.30–0.62).

Some of the heat-related deaths may be short-term displacements of the deaths of critically ill people who would have died soon even in the absence of hot weather. If all excess mortality were due to harvesting, cumulative excess mortality would drop back to zero shortly after the end of the heat wave. However, as can be seen in figure 4, the cumulative number of excess deaths in the region North of the Alps remained elevated after the end of the heat wave in August.

Discussion

The present analyses give evidence of an estimated 7% increase in all cause mortality associated with the heat episodes occurring in Switzerland during summer 2003. Excess mortality was limited to the region north of the Alps and more pronounced among inhabitants of the cities of Basel, Geneva and Lausanne, and among the elderly. For the region North of the Alps, about 960 excess deaths were estimated. Deviations in daily mortality followed deviations in temperature, with deaths occurring on the same day as or ≤3 days from elevated temperature. Cumulated deaths remained elevated after the end of the heat wave in August, suggesting that the observed increase in mortality is only in part explained by short-term displacement of deaths among terminally ill persons. A sudden drop in temperature at the end of October further contributed to excess mortality possibly masking a further decrease of the summer excess mortality.

The observed increase in total mortality in Switzerland is much lower than the 54% excess of mortality in France [3]. In Spain, excess mortality was reported to be 15% [6]. In the metropolitan area of Rome, excess mortality during June to August 2003 was 24% [5]. In all countries, older people were more strongly affected. France experienced a much more ferocious heat wave than Switzerland with more than one third of the counties experiencing five and more consecutive days with maximum temperatures above 35 °C and night temperatures above 20 °C, whereas this combination of extreme temperatures was much less frequent in Switzerland.

Striking regional differences in excess mortality within Switzerland were observed. In Ticino, there was no temperature related increase in mortality. It is conceivable that the population of the Ticino with its more Mediterranean climate is better adapted to warm summers than the population living North of the Alps. Similarly in France, the highest death toll was caused by the heat wave in Paris (142%) and the central parts of the country, whereas in the South of France excess mortality was less pronounced (Marseille 25%, Toulouse 36%) [3]. The absence of large urban centres might be an additional explanation for the lack of heat related deaths in Ticino.

Regional differences in excess mortality also occurred in the region North of the Alps. Urban centres and suburban areas showed a similar increase in mortality, whereas in rural areas only the August heat wave was associated with a significant increase in mortality. Similar patterns of heat-related mortality have been observed in France [3]. Increased mortality in urban centres has been attributed to the urban heat island effect [11, 15]. Urban areas typically experience higher night temperatures than surrounding suburban or rural areas, because heat is retained more efficiently in densely built urban areas.

When the six larger Swiss cities were compared, significant excess mortality in each individual summer month was only observed in Basel and Geneva. In Lausanne excess mortality occurred only during August. North of the Alps, daily maximum temperatures were highest in Basel and Geneva and a noticeably higher number of days with a combination of high temperatures at night and during the day was recorded in Basel and Geneva compared to other cities.

In France, county specific excess mortality differed according to the number of "very hot days" (defined as daily max. temperature >35 °C and night min. temperature >20 °C): excess mortality in counties experiencing only one "very hot day" was +34%, 2–5 "very hot days" were associated with 52% excess mortality and more than five consecutive "very hot days" with an excess mortality of +83%. Part of the heterogeneity of the excess mortality in Swiss cities might therefore be explained by this combination of extreme temperatures, reflecting a spread of the heat wave from France to the western part of Switzerland.

Alternatively, it may be argued that the age distribution in these cities and thus the proportion of vulnerable population might be different. However, according to a report on the age distribution of the population of various Swiss cities the proportion of people aged 80 years and older is 7.3% in Berne, 6.4% in Basel, 6.1% in Zürich, 5.6% in Lausanne and 4.9% in Geneva [16].

Some of the excess mortality occurring during the summer months of 2003 might be attributable to ozone and other air pollutants. Ozone levels exceeded the standards on all stations of the NABEL network about twice as often as during a typical summer. In an extensive review of the available scientific literature, WHO has concluded that daily total mortality is expected to increase by 0.3% when 8-h average ozone levels increase by 10 $\mu g/m^3$ during summer months [17]. The review also included data from Switzerland [18]. The Swiss Expert Commission for Air Hygiene recently published the results of an analysis of ozone attributable deaths during summer 2003 [19]. The number of ozone attributable deaths was estimated based on the population distribution of ozone during the summer months 2003, the daily mortality counts of Switzerland during this period and the WHO relative risk estimate. It was estimated that 130–300 deaths occurring during summer 2003 could be attributed to elevated ozone concentrations, resulting in 13% to 30% of the observed excess mortality. Similarly a recent British study attributed 21–38% of the total excess mortality to elevated ozone and PM10 concentrations [9]. A Dutch report attributed even 50% of total excess mortality to the effect of air pollution [7]. However, this research group applied a different risk estimate for the effect of air pollution on mortality than suggested by WHO. Further analyses to separate the effect of temperature from the effect of air pollutants on daily mortality are certainly warranted.

The present analysis has some noteworthy limitations. First, as the Federal Office of Statistics can only provide information on the causes of death for the year 2003 two years later, the present analyses had to be based on total mortality counts. In many previous reports on heat related mortality the strongest associations were seen for cardiovascular and respiratory causes of death. Yet, during summer 2003 in France the most frequent cause of deaths were reported to be dehydration and hyperthermia, followed by diseases of the cardio-vascular system. Secondly, long-term and standardized meteorological data for urban centres in Switzerland are not available; the stations of MeteoSwiss are typically located at the outskirts of urban centres. This limits our ability to assess micro-climatic conditions, which might further explain regional differences in excess mortality between urban centres.

Previous North American studies have shown that preventive measures are efficient in reducing heat-related mortality [20, 21]. Health watch warning systems predict and alert city's residents of dangerous weather conditions during summer. Intervention activities such as increasing emergency medical services, alerting groups of volunteers, providing guidelines for policy makers, and avoiding heat related illness for specific subgroups of the population, have shown to be effective in reducing heath related mortality. In several European countries health watch warning systems have been established as a consequence of the heat wave in 2003. In Switzerland, no such warning system exists on a federal level, but MeteoSchweiz is working on a heat wave warning system. Actually, only two cantonal authorities, Geneva and Ticino are known to have preventive programmes targeting susceptible populations during heat waves. Given the public health impact of heat waves and the potential to limit heath related mortality with timely and effective warning systems, which can be organised at relative low cost all cantonal authorities should develop heat action plans in the future. A similar recommendation has recently been published by WHO [22]. Primary prevention would propagate activities to reduce greenhouse gas emissions leading to an improvement of the global climate.

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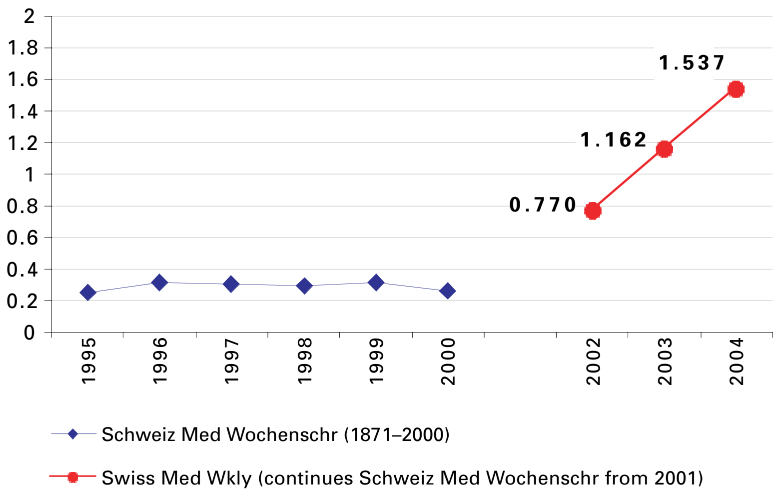

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