Original Article

Maternal Mortality in Burkina Faso: A Method from Population Census 2006

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Abstract

Background: Estimating maternal mortality level is constantly challenging researchers and planners both in rich and poor countries. In developing countries, particularly in Burkina Faso where the registration system is not working properly, censuses and surveys are the main providers of maternal mortality estimates. However, censuses provide more reliable data about maternal mortality especially at sub-national level. Strength of this situation, the census 2006 of Burkina Faso collected information about maternal mortality. Unfortunately, the census also under reported the phenomenon. In this regard, a methodology was developed to provide adjusted estimates of the phenomenon.

Methods: This paper aims to assess the census 2006 estimates of maternal mortality through a critical review of the questionnaire, data quality, adjustment technique and outputs. Incoherencies, duplicated cases and missing data were the key aspects of the data quality assessment. The assumptions and outputs of the method were examined and comparison made with existent estimates.

Results: Findings highlighted weaknesses regarding the assumptions of the method and showed that the levels of the phenomenon were still under-estimated. In this research, propositions have been made concerning data cleaning, situations of adjustment coefficients less than 1 and the problem of weak assumptions. Findings led to a MMRatio of 331 [293-402] maternal deaths per 100 000 live births.

Conclusion: The level of maternal mortality as published in the census 2006 report (MMRatio of 307) is acceptable because falling in the range 293-402. However, the questionnaire, data and method used needed improvements.

Keywords: Maternal deaths, Delivery, Pregnancy, Age of death, Burkina Faso

Introduction

Estimate of maternal mortality level is one of the important challenges surrounding the issue. Measurement of maternal mortality is a constant challenge for researchers and planners both in rich and poor countries (1, 2). The lack of data and the poor quality of existent information in many countries motivated United Nation agencies and many researchers to focus on estimating the level of maternal mortality worldwide (3-5). However, the different estimates provide sometimes conflicting or incomparable outputs. These estimates generally concern the national level but not sub-country level where the need of maternal mortality statistics is growing particularly in developing countries.

In Burkina Faso where the registration system is not working properly, almost not existent, censuses and surveys are the main providers of maternal mortality estimates (6, 7). However, surveys face the problem of representative sample size to capture maternal mortality in country and regional level. Even the sisterhood method viewed

as the solution is still providing sometimes very few number of maternal deaths especially at sub-national level. Therefore, data provided by surveys are still in need of serious adjustments for both sampling errors (huge confidence intervals) and under declaration.

Because of the lack of acceptable registration system, many authors state that censuses provide the most reliable data about maternal mortality in developing countries (1, 5). Indeed, censuses data are free from sampling errors and the issue of sample representativeness. Unfortunately, censuses data are also tainted of errors which need urgent adjustment such as under declaration of maternal deaths.

In Burkina Faso, only the census 2006 provided households' information susceptible to estimate maternal mortality level for all current administrative regions of the country (8, 9). During this census, a method has been developed to adjust observed information. This research is initiated to examine the method used to estimate the phenomenon during the census 2006, highlight the weaknesses and strengths as well as proposing improvements in capturing, estimating and assessing the phenomenon for future censuses. The purpose of this paper is to contribute to a decrease of maternal mortality trend in Burkina Faso by bringing necessary statistical information at regional level for a better orientation of population programs and projects.

Study Design

The issue of maternal mortality, particularly the need of estimating the level and trends rose as an important concern with the Millennium Goal for development established in 1990. For many authors (6), the solution is not to wait forever the perfect data to provide maternal mortality statistics needed. Existent data should be used to estimate and understand the phenomenon in order to help policy makers to take actions and improve the monitoring system of projects and programs (10, 11). The census 2006 estimated the level of maternal mortality at national and regional level. But, what do we keep as strengths of the methods used for these estimates? What can we improve?

At international scale, many approaches of maternal mortality estimate have been developed since 1990. How to get profit of the scientific advance in maternal mortality estimates?

This study does not have the ambition to find solutions to all challenges surrounding maternal mortality estimates in Burkina Faso. But, it tries to improve the estimates by reducing the bias in the all process from the methodology of data collection, questionnaire to the estimate method of census data.

Materials and Methods

Capturing maternal mortality with censuses data is quite new in Africa and mostly presented as a particularity of African 2000 censuses (1). The study investigates the probable impacts of the choices made in maternal mortality data quality treatment and estimate technique.

The Questionnaire

Maternal deaths were captured during the census 2006 in terms of pregnancy related deaths. That means the number of females' deaths occurring during the pregnancy, delivery or 42 days post-partum period. The questionnaire of the census 2006 does not have specific arrangements or instructions which could improve data collection related to maternal mortality. In the section of the questionnaire related to mortality, deaths occurring during the last 12 months are listed per household. Hence, the gender, date of death and age at death was recorded (7-9). When the death was a female aged between 10 and 54 years old, the following additional four questions were asked to identify the period of death:

Did the death occur during pregnancy?
Did the death occur during delivery?
Did the death occur after the termination of the pregnancy or the delivery?
If yes, mention the number of days after the termination of the pregnancy or the delivery.

Data quality

During the census 2006, the total number of maternal deaths in the country was obtained by a sys-

tematic addition of maternal deaths during pregnancy, delivery and after delivery (7, 12). But, the systematic summation induced duplicated cases. That is why the census estimate of maternal mortality is based on 1485 observed maternal deaths aged 10-54 while in this study, the observe number of maternal deaths is 1286. The method used to solve this problem consisted in considering deaths registered in more than one period only in this first period.

The analysis of the census data quality concerned also the variable "*age at death*". We registered 22 missing age of maternal deaths (12 during pregnancy, 3 during delivery and 7 after delivery). In this paper, it is proposed to proportionally distribute these missing cases. In addition, 9 cases of maternal deaths were declared for ages out of the established range of 10-54 years old. Decision have been made to ignore maternal deaths for women aged less than 10 years because all of the 9 cases were recorded at the age '0' year old. Concerning the maternal deaths reported at age 55 years old, the age was changed to 54 years to stay in the range define in the questionnaire.

Furthermore, some respondents (3 %) did not mention anything about the period of death. During the census 2006, these non-responses have been ignored. This study suggests to treat these missing information using existent imputation techniques such that Hot deck, cold deck, etc (13). Such technique should sort out this problem as did during the census 2001 of South Africa (8, 14, 15). The assessment of the quality of some variables intervening in the calculation of maternal mortality indicators is also important. We propose for further censuses to proportionally distribute the missing information related to ages of females' alive and the ages of females' deaths. Performing these actions permitted to gain around 30 cases of maternal deaths. The proportional distribution of missing information follows the formula:

$$n_r^{adj} = n_r + mis \times \frac{n_r}{(T - mis)}$$

Where T is the total number of observation, *mis* is the missing observations related to ages, n_r is the reported number of observations at age r and n_r^{adj} is the adjusted number of observations at age r.

To obtain better picture of maternal mortality levels, this paper started by assessing the number of live births before going any further in the calculation of maternal mortality ratio. Because of the important under-reported number of live births, an indirect technique of adjustment is undertaken to improve collected information (9, 16). Hence, the P/F Ratio method (10) method is applied in this study using the software PASEX. The application of the P/F ratio method adjusted the number of live births from 612840 to 642560 for mothers aged 15-49 years. That means an increase of 29 720 live births whether 4.8% of the observe information. However, the software PASEX does not permit the P/F method for ages out of the range 15-49 years. That is maybe why the census 2006 did not take into account the adjusted number of lives births during the estimate process of the census 2006.

Census 2006 estimate of maternal mortality indicators

The main indicators used to estimate the level of maternal mortality are the following:

Maternal mortality Ratio (*MMRatio*)

$$MMRatio = 100000 \times \frac{Md}{Lb}$$

Where Lb is the last 12 months number of live births from mothers aged 15-49 years old and Md is the number of maternal deaths at age 15-49 years old (11, 12, 17).

Maternal mortality Rate (MMRate)

$$MMRate = 100000 \times \frac{Md}{Fa}$$

Where Fa is the number of adult females aged 15-49 years old at the time of the census (11, 12, 18).

Proportion maternal deaths among females at reproductive age (PMDF)

$$PMDF = 100000 \times \frac{Md}{Fd}$$

Where Fd is the number of females deaths aged 15-49 years old

The direct measure of these indicators using the census 2006 data did not provide satisfactory results (7). That is why an indirect method has been developed to adjust observed information.

The adjustment technique developed during the census 2006 is based on the constraint that the adjusted number of maternal deaths should always be less than the adjusted number of total adult females' deaths. This method also assumed equality between the proportion of undeclared adult female deaths and those of maternal deaths. The method consisted to first adjust the number of adult female's deaths (Fd) using the life table produce by the software Mortpack (LIFTB component). By making the product of the adult female mortality ratio of the life table *(FMRatio)* and total number of females alive (Fa), we obtain the adjusted female death ($\hat{F}d$).

$$\hat{F}d = FMRatio \times Fa$$

The second step consisted to compute the adjustment coefficients of maternal mortality which is only the undeclared rate of adult females' deaths aged 15-49 years. This coefficient responds to the formula:

$$c = \frac{\hat{F}d}{Fd}$$

This coefficient is calculated for every age group ($r; r+5$) of each region (j). Multiply this coefficient by the observed number of maternal deaths (Md) led to the adjusted number of maternal mortality ($\hat{M}d$) per age group and region.

$$\hat{M}d = c \times Md$$

Using the adjusted number of maternal deaths ($\hat{M}d$), we can calculate the adjusted maternal mortality ratio others related indicators.

The adjustment of the census 2006 presents numbers of shortcomings. The adjustment coefficients were applied to redress maternal deaths separately for each age group, region and at national level. Such procedure introduced some errors or noises. To avoid that, we propose to proportionally distribute the noises. Noises are the differences between the adjusted total number of maternal deaths at country level and summation of the adjusted number of maternal deaths for all age groups and regions (19, 20).

Another weakness of this method could be the main assumption. This method assumes that the adjustment coefficient of adult females' deaths is the same as the adjustment coefficient of maternal deaths. Under this hypothesis, the proportion of maternal deaths among females deaths (PMDF) remains identical before (observe) and after adjustments.

$$c = \frac{\hat{F}d}{Fd} = \frac{\hat{M}d}{Md} \Rightarrow PMDF = \frac{Md}{Fd} = \frac{\hat{M}d}{\hat{F}d}$$

This assumption also implicitly suggests that for every age group of each region, the under reported rate of adult females deaths is the same as the proportion of under reported maternal deaths. In opposition, we firmly believe that the proportion of reported maternal deaths among the reported females' deaths should normally be different to (more probably smaller than) the proportion of undeclared maternal deaths (U_{Md}) among the undeclared females' death (U_{Fd}). The demonstration is made below:

If $\frac{Md}{Fd} = c_1$ and $\frac{U_{Md}}{U_{Fd}} = c_2$ with $c_1 \neq c_2$ $\Rightarrow \frac{Md}{Fd} \neq \frac{\hat{M}d}{\hat{F}d}$

The above statement about this weakness of the method is also discussable because not absolute. Therefore, we continue the assessment of the method through an exam of the outputs.

Results

Need of indirect estimate method

The section about the data quality showed an under-reported number of live births as well as maternal deaths. Therefore, we can suppose that the under-reported number of live births can maybe compensate the under-declared maternal deaths. That is why it is also important to calculate MMRatio without any adjustment in the data and examine the crude value before any further step. In table 1 below we put one near to other, the observe maternal mortality ratio when no change is made in the data collected (MMRatio 1), the observe maternal mortality when the number of maternal deaths is cleaned from missing data and duplicated cases (MMRatio 2) and finally when the number of maternal deaths is cleaned from missing data and duplicated cases and the number of live births is also adjusted (MMRatio 3).

The table 1 clearly shows the importance of cleaning the data. Indeed, MMRatio decrease from

234.6 to 203.1 when the data is cleaned from missing data and duplicated cases. If solving the problem of missing cases contributed to increase the indicator, the elimination of duplicated cases led to a huge decrease of MMRatio. An important decrease from 234.6 to 196.9 maternal deaths to 100 000 live births appeared when we clean the data about maternal deaths and number of live births. The difference is very important: more than 30 points difference. It is definitely clear that,

there is no compensation between the decrease of the numerator and the reduction of the denominator of MMRatio. That also shows how crucial were the cleaning process needed during the census 2006. In other hand, a MMRatio of 196.9 is largely under a realistic level for Burkina Faso when compared to previous or existent estimates. It is clear that the data as collected need a real and deep adjustment.

Table 1: Observed maternal mortality ratios for crude and clean data

Age groups (yr)	MMRatio 1	MMRatio 2	MMRatio 3
15-19	326.1	283.4	235.4
20-24	206.3	178.8	171.3
25-29	210.1	179.4	177.7
30-34	193.5	171.2	172.4
35-39	265.2	231.6	237.0
40-44	356.0	305.2	327.9
45-49	231.3	185.0	216.7
Total	234.6	203.1	196.9

Source: Burkina Faso population census 2006; MMRatio: Maternal mortality ratio

Assessment of the output of the census adjustment technique

During the census 2006, the adjustment technique was applied to observed information without any distribution of the missing data or adjusted fertility information. In this section, the adjusted estimate of maternal mortality level using the census 2006 technique in unclean data is assessed as well as the outputs which would have been obtained if the data was cleaned. The Fig. 1 shows the adjusted level of maternal mortality in Burkina Faso as obtained by the census 2006 in confrontation with existent estimates from different years and sources.

The figure 1 highlights important gaps between levels of maternal mortality provided by different sources of estimates. Indeed, the comparison with other estimates showed an important under-estimated level of the census 2006. The trend of the decrease in maternal mortality ratio from the DHS 1991 and 1998 would have led to a MMRatio of 388 in 2006 if it is remaining. But, the census 2006 provided the very low level compare to this expec-

tation. Whatever the age interval considered, since the maternal mortality ratio in Burkina Faso is far below the expected value, we are able to doubt the level of maternal mortality as estimates during the census. However, the figure 1 lets appear that maternal mortality estimates provided by the census is currently the lowest level of maternal mortality. Globally, this assessment did not bring out strong evidence that the census estimate of maternal mortality is totally wrong, but increase the presumption of an underestimation of the phenomenon.

The internal assessment of the adjusted information focuses on the geographical and age distribution of maternal mortality ratio. The distribution of maternal mortality by ages as showed revealed that the quality of the data is quite acceptable because maternal mortality ratio should be increasing from young to old ages in order to have a graph in form of "J". Findings shows that the distribution of the adjusted MMRatio is closer to the expected decrease from 15-19 to 20-24 or 25-29 years old and thereafter the increase until 40-45

years old. However, maternal mortality ratio at old ages, particularly the last age group 45-49 years presented a problem because lower than MMRatio at 40-45 years old. However, there is another way to assess the quality of maternal mortality data by ages. The shapes of maternal mortality rate and fertility rate by ages are quite similar. That means that the age structure of maternal mortality is

lightly acceptable but still in need of adjustment. The internal assessment revealed once more a need of improvements in the data quality related to the age structure. This problem could take source from the lower declaration of maternal deaths at some age groups (generally the old ages) than others.
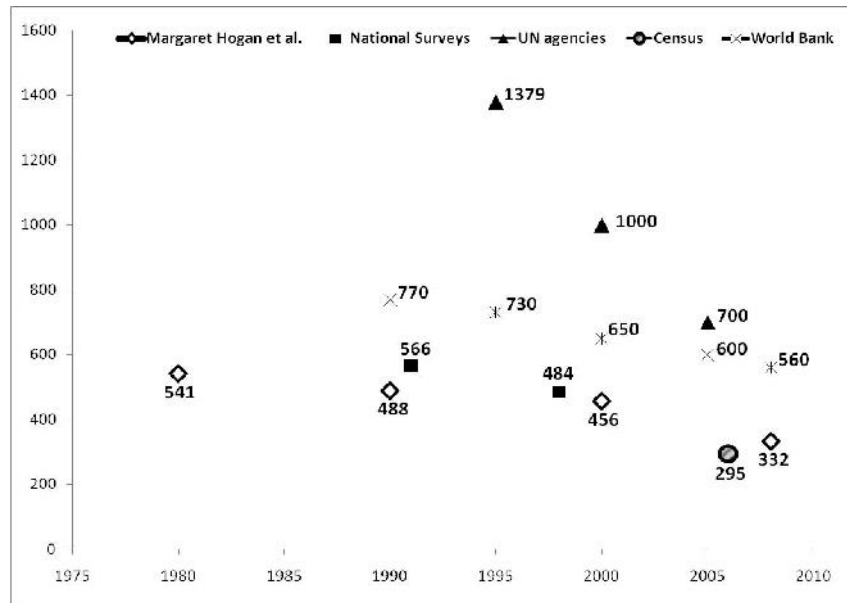
Source: *Burkina Faso Population Census 2006*

Fig. 1: Comparison of adjusted maternal mortality ratio provided by the census 2006 and others sources of estimates

Since the need of information at regional level is very important, the regional structure of maternal mortality ratio should also be assessed. The Fig. 2 clearly shows a change in the regional structure of maternal mortality due to the adjustment of the number of maternal mortality. These changes pose a real question of the regional structure of the phenomenon. However, the regional structure of adjusted MMRatio is more realistic than the unadjusted. In addition, two important remarks come out and highlight very pertinent facts.

The first point is that the new structure of maternal mortality distribution per region is more acceptable because closer to previous knowledge and concordant with other development indicators (poverty, availability of health services, etc) distribution per regions.
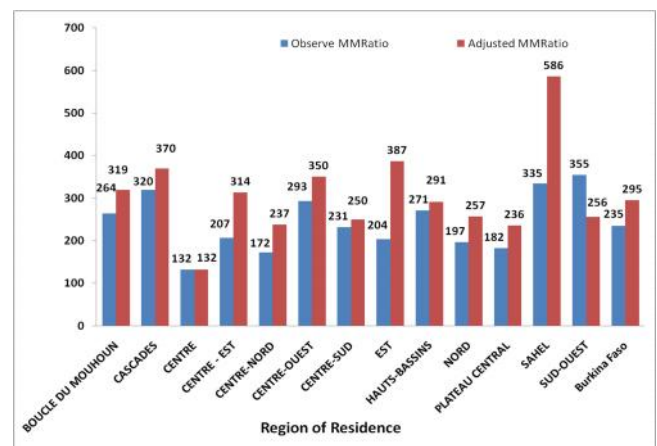
Source: *Burkina Faso Population Census 2006*

Fig. 2: Compared distributions of observe and adjusted maternal mortality ratio per age

If the first point comforts the census technique of estimate, the second point in opposite highlight problems in the adjustment. Indeed, it concerns the diminution of reported maternal deaths due to the adjustment. This situation is hard to explain practically because it really means that the observe number of maternal deaths in the region "Sud-Ouest" were over-declared and the adjustment reduce it to the right value. This point makes us suspecting the technique used to estimate the phenomenon since no clear and acceptable explanation able to justify such situation has been found. The internal assessment of maternal mortality data quality confirmed our suspicion about an under-estimation of the census adjusted maternal mortality particularly for some age groups and some regions of the country. But, the external assessment is an important step to highlight the adequacy of maternal mortality level in the global picture of countries in the world and particularly in Africa. Comparison of maternal mortality level with those of others countries in Africa (Table 2) reinforces the need of improving the census methodology of estimating maternal mortality. Problems of quality in the adjusted maternal mortality level as published by the census 2006 could derived from the missing information or others incoherencies related to any important variable which can impact the phenomenon measurement.

That is why we also assessed the estimates of maternal mortality level after application of the adjustment method on cleaned data.

The application of the census 2006 adjustment technique on the clean information led to an adjusted MMRatio of 241.6 maternal deaths per 100 000 live births of mothers aged 15-49 years old. That means a decrease of 54 points of MMRatio compare to the estimate from the unclean data. However, this adjusted level of maternal mortality ratio is still far below the expected level around 388 maternal deaths per 100 000 live births. In addition, the clean data provided lower MMRatio compared to the adjusted MMRatio during the census 2006 (295.3 maternal deaths per 100 000 live births). Confronted to observe MMRatio of 196.9 for clean data, the application of the adjustment method developed during the census 2006 in Burkina Faso tends to increase the level of the phenomenon. The doubt about the quality of this estimate is also reinforced by the distribution of MMRatio per age groups and region. Indeed, the age distribution of maternal mortality ratio still shows the same problem at old ages as before. However, the comparison of maternal mortality age structure and fertility age structure highlighted more acceptable structure. Indeed, MMRatio and ASFR distributions per age were slightly close to each other.

Table 2: Comparison of adjusted maternal mortality ratio 2005 and 20010 in Burkina Faso with those of selected countries

Countries	2010 MMR with 95% CI Lower and Upper level		2005 MMR with 95% CI Lower and Upper level	
Burkina Faso	332	(208- 522)	700	(390-1000)
Cote D'Ivoire	944	(566-1500)	810	(310-1600)
Ghana	409	(248-633)	560	(200-1300)
Mali	670	(422-1017)	970	(620-1300)
Niger	601	(373-927)	1800	(840-2900)
Senegal	401	(252-627)	980	(590-1400)
Togo	629	(508-787)	510	(290-750)
South Africa	237	(146-372)	400	(270-530)
Morocco	124	(70-200)	240	(140-350)

Source: Hogan, M.C. et al. (2010) and WHO (2007)

The next step of the assessment consisted to compare the level of maternal mortality obtained with

some others existent estimates. Most importantly, the use of the census 2006 method on the clean

data decreases the observe MMRatio from 107.3 to 104.4 and from 311.9 to 218.6 for the region of "Centre" and "Sud-Ouest" respectively. These reductions of maternal mortality level imputed by the adjustment confirmed the doubt about the adjustment technique proposed during the census 2006. That is why we concluded that the uncertainty around the quality of the adjusted level from the clean data is influenced by the weaknesses of the adjustment technique itself. It is therefore very important to improve the original technique as used during the census 2006.

Checking alternative of the census 2006 technique

The data collected from the census 2006 was in real need of cleaning as showed above but the technique used to estimate the phenomenon also requires improvement. This study explored paths of improvement of estimates in order to provide better outputs. Unfortunately, few are existent indirect methods of maternal mortality adjustment. In fact, the sisterhood method and regression model are not applicable in the case of the census 2006 data. There is a real lack of methods for census data in term of indirect estimate of maternal mortality level. However some methods such as the Brass Growth Balance Method can be used. Unfortunately, the application of this method in Burkina Faso census 2006 data lead to a huge diminution of the observe maternal mortality ratio. The adjustment using the Growth Balance Method on its both variances for stable and non-stable population was not adapted because led to erroneous and unreliable level of maternal mortality (MMRatio less than 10 maternal deaths per 100 000 live births). That is why this method is not presented here and the outputs not displayed in details. The explanation of the failure of this method could be the crucial changes in demographic growth particularly migration due to the army conflict in Cote d'Ivoire started in 2002. However, the strength of this technique to adjust maternal mortality level is not contested.

The research for improvement in maternal mortality estimate finally focused on the method developed during Burkina Faso census 2006. The method used to estimate maternal mortality during the census 2006 of Burkina Faso is very comprehensive and scientifically consistent even suffering from some insufficiencies. That is why we tried in this section to improve the method using the approaches explained below.

Approach 1: Improve the situation where adjustment coefficient is less than 1

In this approach, we applied the adjustment method of the census 2006 to the data. The only difference is that we decided in this approach to keep the observe number of maternal deaths for each ages group where the adjustment coefficient reduces the reported number of maternal deaths (Adjustment coefficient less than 1) This way of improving maternal mortality estimate technique led us to an increase of MMRatio from the observe value of 196.9 to 244 maternal deaths per 100 000 live births. This approach also increase the MMRatio of about 3 points compare to the adjusted MMRatio using the clean data. However, there is no significant change between the new distributions of maternal mortality Ratio per age groups. In general, this method seems to provide better outputs at regional scales. At least this approach solves the problem of a decrease of reported number of maternal mortality for some age groups and regions. Nevertheless, this is not enough because serious problems remain about the age distribution of MMRatio and the national level of 244.1 maternal deaths per 100 000 live births which is still far below the general trend of the phenomenon in the country. Collected data shows a total absence of maternal deaths (zero case of maternal death) for the age group 45-49 years old of some regions such as "Cascades", "Centre" and "Plateau Central". In such situation, the census 2006 adjustment technique did not make any change in the collected information because it consisted to a multiplication of observe number by a coefficient. That is why improvement was undertaken in the approach 2 to also take into account such situation.

Approach 2: Improve the situation of non maternal deaths at some age groups

This approach 2 method consisted to attribute to those cases, the number of maternal deaths of the previous age group (40-44 years old). This approach considered the aspects of the previous improvement (approach 1). This second improvement led to MMRatio of 247 maternal deaths per 100 000 live births. The age distribution presented in the figure 5 showed a nice "J" shape proves of a good age distribution of maternal mortality. Despite these improvements on the census 2006 adjustment technique, adjusted level of 247 maternal deaths per 100 000 live births obtained is also far below a reasonable expectation. However, there is a strong doubt about the assumptions of the technique used in 2006. Research for improving census technique in such a way that the assumption becomes more convincible led us to the approach 3.

Approach 3: Alternative to the main assumption under the census 2006 method

The method of the approach 3 is a continuation of the previous. Indeed, based on the adjusted number of female deaths ($\hat{F}d$) and the observe number of female deaths (Fd), we deduce the undeclared number of female deaths (U_{Fd}) as follow:

$$U_{Fd} = \hat{F}d - Fd$$

It is certain that the undeclared number of maternal deaths is a proportion (p) of undeclared female deaths. The problem is to find the percentage (p) of undeclared female adult deaths which are due to maternal causes. The approach 2 of improving the census 2006 technique showed that the proportions of undeclared maternal deaths among the undeclared adult female deaths are 23.2%, 24.5 % and 50.2 % for the age groups 20-24, 25-29 and 30-34 years old respectively. Based on these results, we firmly believe that the national proportion (p) of undeclared maternal deaths among the undeclared female deaths is between 23.2 % and 50.2 % and more probably the average of 32.6 % because we believe that the best declarations of maternal deaths concern women aged between 20 to 34 years old. We can also use previous knowledge to approximate this proportion (p). The DHS 1998 of Burkina Faso found that 22%

of females' deaths between 15 and 49 years old were due to maternal causes (8). We are also convince that the proportion (p) of undeclared maternal deaths is greater that the proportion (22%) of declared maternal deaths that is why the consideration of the proportion is $p=32.6\%$ [23.2%, 50.2%].

This approach served to obtain a reasonably interval of maternal mortality ratio according to the reasonable range of percentage of undeclared maternal death $p=$ [23.2%; 50%]. The formulas below show how to obtain the adjusted number of maternal deaths once the proportion p is found.

$$\hat{M}d = Md + U_{Md}$$

$$\Rightarrow \hat{M}d_3 = Md + p \times U_{Fd} \text{ Where } U_{Md} = p \times U_{Fd}$$

In this approach, we have been able to establish at national level a realistic value of maternal mortality ratio within a convincible confidence interval. However, we still got another step to reach.

The ratio between the adjusted number of maternal deaths at national level obtained in this approach 3 ($\hat{M}d_3$) and that obtained in the previous approach 2 ($\hat{M}d_2$) corresponds to a coefficient of correction (k). By multiplying the coefficient of correction with the adjustment coefficient (c), we obtain a corrected adjustment coefficient ($\hat{c}$) which is used to obtained the adjusted number of maternal deaths per ages and by summation per regions and for the all country.

$$\hat{M}d = \hat{c} \times Md$$

Where $\hat{c} = k \times c$, $k = \dfrac{\hat{M}d_3}{\hat{M}d_2}$ and $c = \dfrac{\hat{F}d}{Fd}$

This additional improvement of the census estimate method led to a "J" shape of the age distribution of maternal mortality ratio and a maternal mortality ratio of 331 maternal deaths per 100 000 live births with a confidence intervals of 293 and 402 maternal deaths per 100 000 live births.

The adjusted maternal mortality ratio of 247.3 (approach 2) as obtained before is out of the confidence interval [292.6, 401.7]. However, the adjusted maternal mortality level as published in the census 2006 report is within the interval of acceptable estimate.

The regions with the lower maternal mortality ratios are "Centre", "Plateau-Central" and "Nord" with respective values of "170.4", "257.7" and "265.5". In opposition, the regions of "Cascades", "Sud-Ouest" and "Sahel" have the higher ratio of maternal mortality with "397.8", "418.0" and "554.3" respectively. To finish, it is clear that whatever the importance of the improvement made in the census 2006 technique, there is still a lot to improve and particularly the way of obtaining the proportion "p" needs also improvement.

Discussion

Existent estimates of maternal mortality level in Burkina Faso come from different sources. The estimate provided by the census is currently the lowest level of maternal mortality compared to international estimates. This situation is an indication of a probable under-estimated level of the phenomenon. Nevertheless, this level is closer to the estimates provided by (9) than those of the United Nation agencies.

At national level, MMRatio were 566 per 100 000 live births in 1991 and 484 in 1998 (8, 20). It results a decrease of MMRatio of around 82 points in 7 years. Based on these calculations, we were expecting an MMRatio of 388 in 2006 (8 years after 1998) if the same trend was maintained. The census 2006 estimates MMRatio of 307 for women aged 10-54 and 295.3 for women aged 15-49 (7). Thus simple calculation raises doubt about the estimate of the census 2006 and support the idea of under-estimated level.

A comparison of the census 2006 estimates of maternal mortality with the level of the phenomenon in other African countries highlighted the necessity of improving the adjustment method used during this census. MMRatio in South Africa for example was 400 and 237 maternal deaths per 100 000 live births in 2008 (9) and 2010 respectively while Burkina Faso census 2006 provided levels of 307 and 295.3 maternal deaths per 100 000 live births for women aged 10-54 and 15-49 respectively. This result shows an obvious under-estimated level because all existent estimates

lead to a higher level of the phenomenon in Burkina Faso than in South Africa. For example, (9, 10) provided MMRatio estimates of 700 and 332 in Burkina Faso in 2007 and 2010 respectively. These are also reasons contributing to justify the need of improving the adjustment technique use during the census 2006.

The method developed by Brass in 1975 (Brass Growth Balance Method) to measure the coverage of adult deaths can be update and use as indirect method of estimate adult female deaths from maternal causes (1, 2). The use of the Brass Growth Balance Method did not reach to satisfactory results in the context of this paper. The application of Brass Growth Balance Method on Zimbabwe census data 1992 led also to unacceptable results (17). Therefore, during the census of Zimbabwe, they only used the observed number of maternal mortality with proportional distribution of missing information rather than using the Brass Growth Balance Method.

However, proposition made in improving the method developed during the census 2006 led to interesting results. In fact, the distribution of MMRatio per age is now in form of "J" as proven in previous studies. Also, the result is close to international and other existent estimates of maternal mortality in the country.

Conclusion and Policy Implications

This study confirmed that Burkina Faso census 2006 data as collected were under-estimating the number of maternal deaths and presenting some irregularities particularly regarding the age and regional structure. The observed maternal mortality ratio was 235 maternal deaths per 100 000 live births. But, after cleaning data from missing information, duplicated cases, other imperfections and also adjustment of the number of live births, we obtain an observe MMRatio of 197 maternal deaths per 100 000 live births. This level of maternal mortality based on clean data was still inappropriate. That is why indirect method of estimate was developed during the census 2006 of Burkina Faso.

The application of the census 2006 adjustment technique on the clean information led to an ad-

justed MMRatio of 241.6 maternal deaths per 100 000 live births of mothers aged 15-49 years old. Findings also showed that the method of estimates developed during the 2006 census followed a clear and scientific methodology. However, this technique was also criticized for shortcomings based on its main assumption, not rigid and obviously contestable. The main weakness of the adjustment technique concerned the cases of some age groups and the regions of "Centre" and "Sud-Ouest" where adjusted number of maternal deaths is lower than observe number of maternal deaths. Analysis of existent methods of adjustment such as the Brass Growth Balance Method did not help us to redress the census 2006 of Burkina Faso.

This research proposed improvement of the census 2006 adjustment technique by first sorting out the case of adjustment coefficient less than 1, after the case of non maternal deaths for 45-49 years old and finally the problem of the technique assumption. The first step of the improvement led to a change of MMRatio from 241.6 to the adjusted number of 244 maternal deaths per 100 000 live births. The second phase increased the level to 247.3 maternal deaths per 100 000 live births. The last improvement led to a level of 331 maternal deaths per 100 000 live births with a confidence intervals of 293 and 402.

In future questionnaires of censuses, we suggest to insert a question about an existent of a death certificate in the household. This information will help to adjust both census and health facilities information related to mortality by region. This study proposes to add a question about the relationship between the deaths and the head of the household". This information should help to understand if most of the maternal deaths appeared in the family or family in law or elsewhere and this can facilitate explanatory analysis and help to avoid double count.

Questions related the occurrence of the death during pregnancy could have the modalities "*Yes*", "*No*" and "*Not sure*" or "*don't know*" or clear directives should be given to census agent about this situation. We firmly believe that an important part of under-reported cases came from this aspect. The problem of lower maternal mortality for the

age group 45-49 years old needs further analysis. The suggestion of this study is to replace the information by the closer young age groups since we know that the curve of maternal mortality rate per age should be in form of "*J*".

The analyses of maternal mortality could be undertaken for the age group 10-54 and 15-49 separately. Because the phenomenon is very sensitive to small numbers, every missing case related to maternal deaths should also be treated by proportional distribution or more sophisticate statistics techniques such as Hot-deck, cold deck, etc. More attention should be given to the analysis of the phenomenon at regional level. For the future, we recommend considering maternal mortality questions related in the post-enumeration survey to be able to adjust the phenomenon from under-declaration.

Ethical Considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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