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A model for the distribution of daily number of births in obstetric clinics based on a descriptive retrospective study

Christiane M B Gam,[1] Julien Tanniou,[2] Niels Keiding,[2] Ellen L Løkkegaard[1]

ABSTRACT

Objective: To test whether the relatively unpredictable nature of labour onset can be described by the Poisson distribution.

Design: A descriptive retrospective study.

Setting: From the Danish Birth Registry, we identified births from all seven obstetric clinics in the capital region of Denmark (n=211 290) between 2000 and the end of 2009. On each date, the number of births at each department was registered. Births are categorised based on whether an elective caesarean section or induction of labour has been performed, and among the remaining 'non-elective births', acute caesareans were registered.

Methods: After the exclusion of elective caesarean sections and births after induction of labour, only 'non-elective' births (n=171 009) were included for the main statistical analysis. Simple descriptive plots and one-way analysis of variance were used to analyse the distribution of 'non-elective' births for each day of the week.

Main outcome measures: The daily number of 'non-elective' births.

Results: The number of 'non-elective' births varies considerably over the days of the week and over the year for each obstetric clinic regardless of clinic size. However, for each fixed day of the week, the variation over the year is well described by a Poisson distribution, allowing simple prediction of the variability. For births at each fixed day of the week, the Poisson distribution is indistinguishable from a normal distribution.

Conclusions: The number of 'non-elective' births for each day of the week is well described by a Poisson distribution. Consequently, the Poisson model is suitable for estimating the variation in the daily number of 'non-elective' births and could be used for planning of staffing in obstetric clinics. The model can be used in smaller as well as larger clinics.

ARTICLE SUMMARY

Article focus
- Does the Poisson distribution correspond precisely to actual random variation in the number of 'non-elective' births for each fixed day of the week?

Key messages
- For each day of the week, the variation of 'non-elective' births over the year is well described by a Poisson distribution.
- The Poisson distribution makes it easy to estimate the variation in the daily number of births and can be used for planning of staffing in obstetric clinics. Standard tables of the normal distribution may be used as exemplified.
- The model is adequate for use in smaller as well as larger clinics and can be used in the management of staffing in obstetric clinics.

Strengths and limitations of this study
- The main strength is the large data set of non-selected births. The main limitation is that births are registered only by date, not by the time of birth.

[1]Department of Gynaecology and Obstetrics, Hillerød Hospital, Hillerød, Denmark
[2]Department of Biostatistics, University of Copenhagen, Copenhagen, Denmark

Correspondence to
Dr Christiane Marie Bourgin Gam;
christiane.gam@sund.ku.dk

INTRODUCTION

There is a structural reorganisation of hospitals going on in Denmark implying larger but fewer hospitals. This applies also to the departments of gynaecology and obstetrics as smaller departments are being merged, resulting in fewer larger departments.[1-3] The main motivation for these changes has been that larger departments would enhance the capacity and quality of patient treatment and additionally reduce the costs for staff at shifts. In Denmark, the overall year-to-year variation in the number of births in each department is centrally determined as each department of gynaecology and obstetrics on an administrative level is intended to have a given number of births from a specified geographical region, and therefore the staffing required in each obstetric clinic in each department is determined from this figure. The largest part of staffing consists of a daily number of midwives working 8 h shifts

during the day, evening and night, as well as a varying number of midwives on 24 h duty on call from home. Their actual working hours vary considerably. The number of doctors on shift is fixed for each obstetric clinic and depends on the size of the obstetric clinic, as does the number of doctors on call from home.

An interesting organisational feature in obstetrics is the inherent random variation in onset of spontaneous labour which makes it difficult to precisely plan the necessary number of staff at the obstetric clinics. The planning of staffing in the departments is, to our knowledge, not based on published methods. Statistics on the number of births on each day for each department every year is available online from Statistics Denmark.[4] These numbers indicate considerable day-to-day variation and week-to-week variation. The observation of a weekly cycle is in accordance with reports from other countries such as England, Wales, Australia, the USA, Israel and Norway,[5–13] and interestingly, it has also been shown that the variation depends on whether the Sabbath occurs on a Friday,[14] a Saturday[5] or a Sunday.[6–13] However, these former studies included all births regardless of whether or not there had been an elective obstetric intervention, which raises the question whether the variation between the days of the week disappears when births resulting from an elective obstetric intervention as elective caesarean or induction of labour are excluded from the data set. There is a long tradition of describing the variation in the daily demand for hospital beds by the Poisson distribution,[15–17] sometimes based on queuing theory and with varying efforts at empirical verification. In her well-known textbook, Kirkwood[18] used an apparently hypothetical example of staffing planning in the face of merging two obstetrical departments to illustrate the Poisson distribution.

In this study, we examined from a broad Danish experience how well the Poisson distribution corresponds to actual random variation in the number of 'non-elective' births for each fixed day of the week. Since the variation in the 'non-elective' births is most obviously random, we exclude in the main analysis 'elective' births (resulting from induction of labour and elective caesarean sections). However, as a sensitivity analysis, we report results on the variation of all births and of acute caesarean sections.

MATERIAL AND METHODS
Data
The number of births for each date in the period from 1 January 2000 until 31 December 2009 at all seven obstetric clinics in the capital region of Denmark was extracted from the Danish Birth Registry. The obstetric clinics were Rigshospitalet, Frederiksberg, Glostrup, Gentofte, Herlev, Hvidovre and Hillerød, which cover over 99% of all births in the region, as a dwindling number of births takes place at home in Denmark. The data included information on the type of birth: elective caesarean sections, births after elective induction of labour, acute caesarean sections and births after spontaneous onset of labour. The labelling of the type of birth has been performed by using information from the National Birth registry on operation codes for elective caesarean sections (KMCA10B and D) and obstetric codes for induction of labour (KMAC00 amniotomy prior to birth, KMAC96A mechanical catheter induction, BKHD2 unspecific medical induction, BKHD20 induction with prostaglandin and BKHD21 induction with oxytocin). The coding of birth information is based on information from midwives and is generally considered very valid.

Statistical methods
The main concept of these analyses builds on the empirical fact that even for 'non-elective' births there is a non-ignorable variation across the 7 days of the week; however, for each fixed day of the week, the variation across the 52 (53) weeks in a given year may be interpreted as random. We exploit the well-known fact that Poisson distributions are well approximated by normal distributions with the same mean and variance, clearly distinguishable by the Poisson distribution property that the mean equals the variance. In this way, the key issue—whether the Poisson distribution is an adequate description—is captured by a one-way analysis of variance comparing the 7 days of the week for each of the 10 years and each of the seven clinics. The results are illustrated by descriptive graphs and worked examples of possible use in staffing planning. Additional sensitivity analyses are performed including all births and acute caesareans.

Details of ethics approval
The data used are available online in an anonymous form.

RESULTS
There were 211 290 births distributed on seven departments in the capital region of Denmark from 1 January 2000 until 31 December 2009. In order to exclude potential elective births, births were subdivided into induced or spontaneous labour and elective and acute caesareans (table 1). Births where the mode of delivery was an elective caesarean (n=16 325 (7.73%)) and births initiated by induction of labour (n=23 956 (11.34%)) were excluded from the data set for main analyses, thus leaving a total of 171 009 (80.94%) spontaneous births and acute caesareans, to be denoted 'non-elective' below.

As mentioned in the introduction, the main problem in obstetrics management is the variation over days of the week. This variation is, to a large degree, a result of decisions by the obstetricians on how to distribute elective caesareans and electively induced labour over the days of the week.[6 12] Preliminary descriptive analyses of

Table 1 Type of births in each obstetric clinic in the Capital Region of Denmark during 2000–2009, with the number and percentages of spontaneous births, acute caesarean sections after spontaneous onset of labour, births after induction of labour and elective caesarean sections

Obstetric clinics	Births per clinic	Non-elective births (81%)				Elective births (19%)			
		Spontaneous births	Per cent	Acute caesarean	Per cent	Induced births	Per cent	Elective caesarean	Per cent
Rigshospitalet	35.657	19.144	54	5.740	16	6.345	18	4.428	12
Hvidovre	53.300	39.335	74	7.264	14	2.375	4	4.326	8
Frederiksberg	17.751	13.784	78	1.794	10	1.266	7	907	5
Gentofte	21.988	14.216	65	2.863	13	3.349	15	1.560	7
Glostrup	22.737	15.972	70	2.883	13	2.808	12	1.074	5
Herlev	23.967	17.352	72	2.800	12	2.680	11	1.135	5
Hillerød	35.890	23.209	65	4.653	13	5.133	14	2.895	8
All seven clinics	211.290	143.012	68	27.997	13	23.956	11	16.325	8

the data clearly indicated that such policies varied considerably over the 10 years for each department and that the patterns were rather different between departments; however, overall, a mid-weekly peak in births remained even when 'elective' births were excluded (please see the online supplementary file, figures III–IX). The staffing required for these 'elective' births is a consequence of management decisions, and our focus here is on how to capture the primarily random variation in the 'non-elective' births. Owing to the strong heterogeneity in the day-to-day pattern for several of the involved departments over the 10 years under study, we performed a set of 70 one-way analyses of variance comparing the number of 'non-elective' births at each day of the week for each fixed combination of department (n=7) and year (n=10). The residual variances from these 70 analyses were compared to the annual mean number of births for each department. Additional sensitivity analyses were performed including all births and acute caesareans. As seen in figure 1, the residual variances are very close to the means, indicating a Poisson distribution of the variation in the number of 'non-elective' births for each day of the week around the yearly average for that day. We also see that the closeness of residual variance to the mean improves when we only look at the 'non-elective' births, while for the acute caesareans only there is a clear trend that the variance is larger than the mean, so-called overdispersion, which violates the assumption of Poisson distribution. In view of these findings, we focus on the 'non-elective' births in the following.

To illustrate our findings, three selected combinations of department and year, a small, medium and large clinic, were chosen. For each day of the week, a histogram shows the observed distribution of the 52 (53) numbers of births per day for that year with fitted normal distribution (red) and a fitted Poisson distribution was produced (green; figure 2). It is seen that there is a nice fit throughout of the Poisson distributions, and also that they are very close to the normal distributions with the same variance. This means that calculations of

the likely variation in the number of 'non-elective' births can be based on the normal distribution with variance given by the average number of 'non-elective' births per day over the year.

For example, if at a particular department in a particular year the mean number of 'non-elective' births is 9, the residual variance is estimated to be 9 and SD as the square root of 9, that is, 3. Assume that the mean number of 'non-elective' births on Tuesdays for that department for that year is 10.5. In 95% of Tuesdays, the actual number of 'non-elective' births in that department will be in the interval between 10.5−3×1.96=4.6 and 10.5+3×1.96=17.4, while in 80% of Tuesdays there will be between 10.5−3×1.28=6.7 and 10.5+3×1.28=14.3 non-elective births. This model is suitable for estimating the daily number of births and planning of staffing in obstetric clinics, and the model is adequate to be used in smaller as well as larger clinics.

DISCUSSION

The management of staffing in obstetric clinics is a difficult task, due to the relatively unpredictable nature of labour onset. Nowadays, many births are 'elective' births in the sense that elective caesarean sections or medically induced labour more or less governs the time of the week where the birth happens. It has been assumed that the day-to-day variation on the numbers of births fits a Poisson distribution,[13][18] but suitable data on live births, including the mode of delivery, from a larger population have not been studied previously, thus limiting the means of studying day-to-day variation.[7][13] Furthermore, the impact of elective obstetric intervention on the distribution has not been considered in any of the previous studies addressing birth variation.[5–14][19]

Interestingly, we find that even with the exclusion of births resulting from an obstetric intervention such as an elective caesarean or induction of labour, the remaining data still show significant weekly variation with a mid-weekly peak. As such, this variation might be ascribed not only to measurable obstetric interventions but also
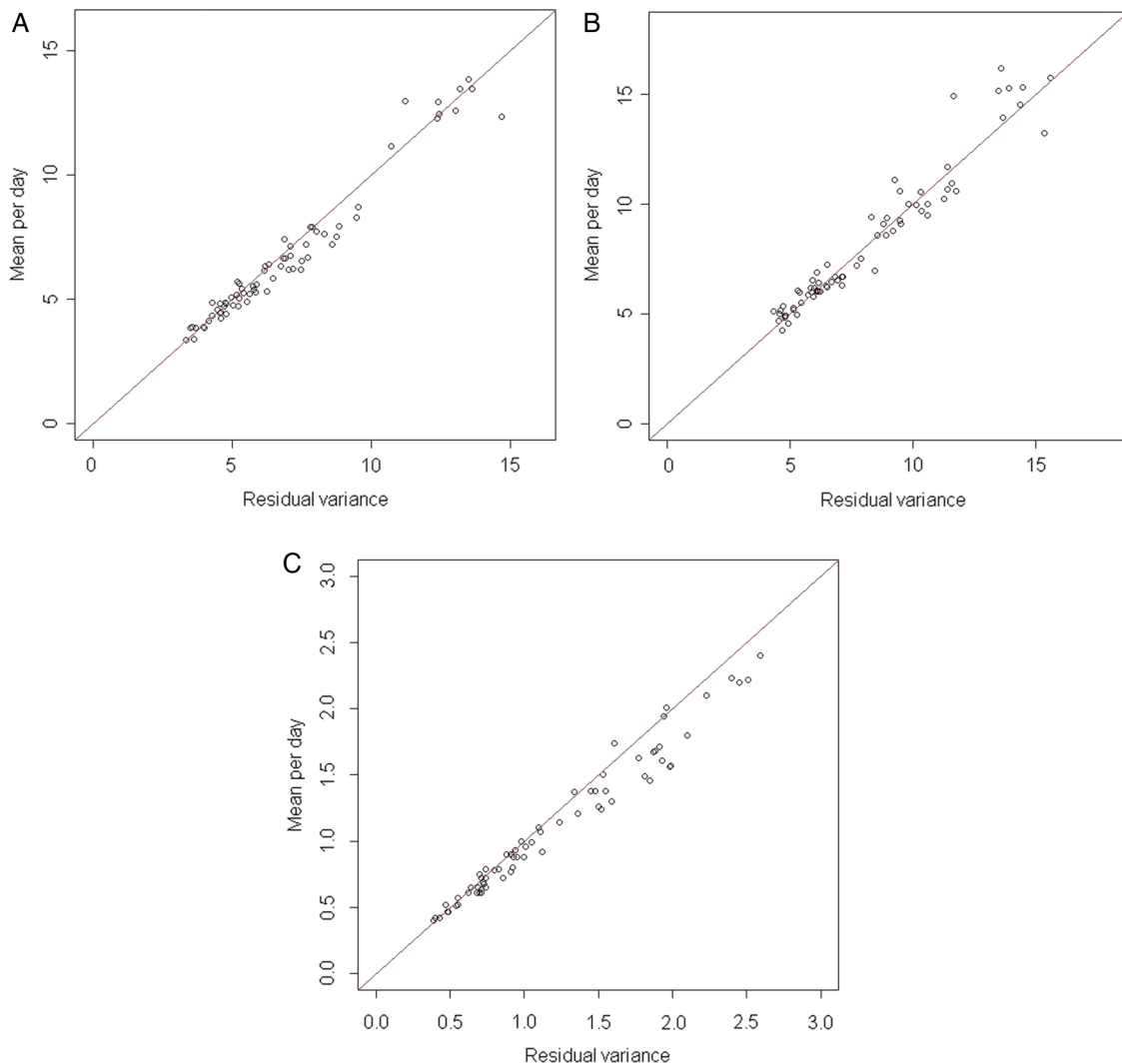
Figure 1 Residual variance compared with the mean number of births per day for (A) 'non-elective' births, (B) all births and (C) acute caesarean sections.

less tangible practices; for instance, the time of admittance of a woman in early stages of labour might depend on staff numbers, which vary during the week. Also, traditional non-medical methods of starting labour (hot baths, sexual intercourse, etc) might be less likely to be tried by mothers at the weekends.[7]

However, regardless of any obstetric practices or mothers' practice, we found that the distribution of the remaining 'non-elective' births for each day of the week, each year and each department is still well approximated by a Poisson distribution, where the mean equals the variance. For the relevant parameter values, this Poisson distribution is indistinguishable from a normal distribution, where we may then estimate the variance from the mean. This means that calculations of the likely variation in the number of 'non-elective' births can be based on the normal distribution with variance given by the average number of 'non-elective' births per day over the year.

This provides us with a useful tool for planning of the staffing necessary to handle all births on a given

weekday in an obstetric clinic. Elective caesarean sections are usually planned to be performed on specific weekdays with staff dedicated to this task. Births after induction of labour will also in most cases be planned. Combining the known number of elective births with the calculation of a 95% or 80% CI of 'non-elective' births on a given weekday gives a good possibility to avoid overstaffing or understaffing and utilise the available human resources to their best. For larger clinics where the mean number of 'non-elective' births for a given weekday may vary by more than 1–2 births, the relocation of staffing to 'peak' weekdays has the most to offer, but even smaller clinics can benefit from more concrete calculation, for example on how weekend staffing should be.

The fact that the distribution of 'non-elective' births is indistinguishable from a normal distribution provides a simple, but elegant, tool for planning of staffing in obstetric clinics and, used wisely, may prove a positive adjustment for work efficiency, cost and environment.
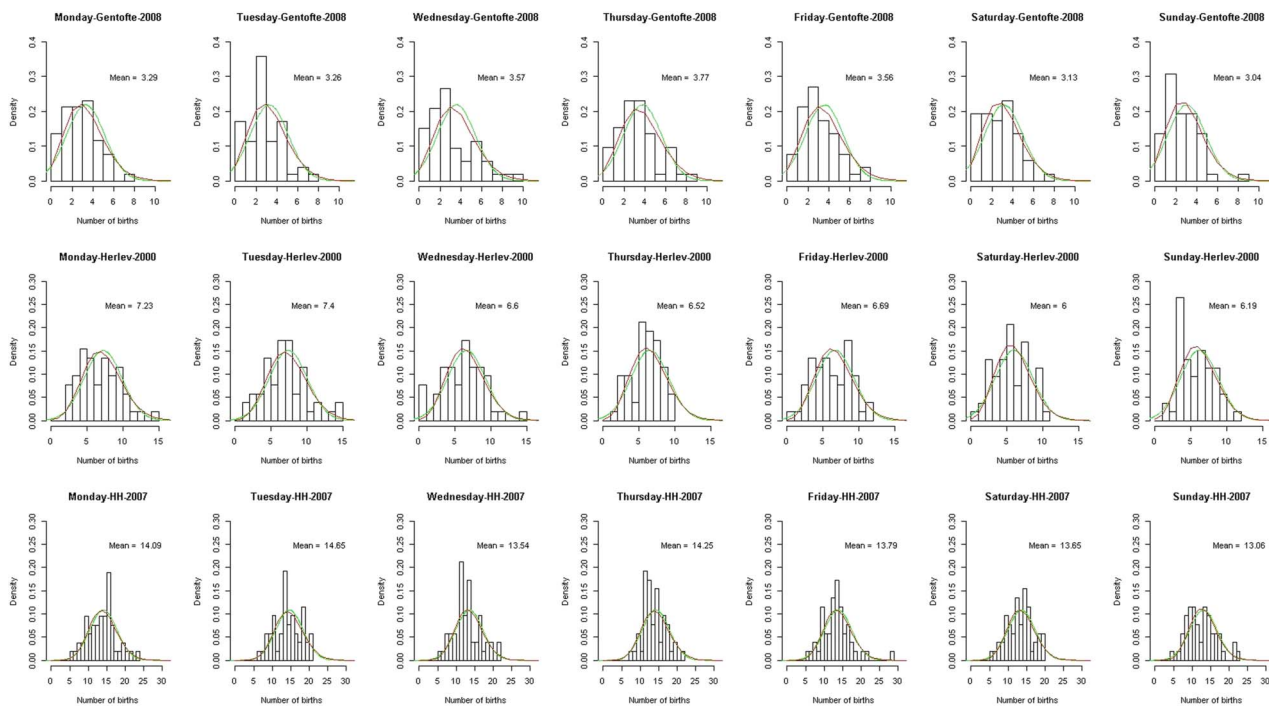
Figure 2 Exemplification of small (Gentofte), medium (Herlev) and large (Hvidovre Hospital, HH) obstetric clinics with the number of births at the x axis and density at the y axis with curves indicating the Poisson distribution (red) and the normal distribution (green).

CONCLUSIONS

We may estimate the variance from the mean, as the Poisson distribution for these parameters is indistinguishable from a normal distribution. This model is suitable for estimating the variation in the daily number of 'non-elective' births and could be used for planning of staffing in obstetric clinics.

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