THE EFFECTS OF CHANGING MORTALITY ON NATALITY
SOME ESTIMATES FROM A SIMULATION MODEL

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Recent spectacular declines in mortality rates of developing countries have been associated with relatively high and stable natality rates.[1] Indeed, some instances of increasing natality have been observed.[2] Further investigation and clarification of the possible contributions of declining mortality to changes in natality is therefore of interest. This paper reports an effort to study some relations between mortality and natality by means of an analytic simulation model on an electronic computer.[3]

Clearly, lowered mortality may increase births by increasing not only the proportion of babies that survive to marry, but also the number of years women spend in the married state.[4] This, however, is not the only consequence of decreased mortality for natality. Declines in general mortality also involve appreciable declines in infant mortality. Evidence now available indicates that, in societies where the postpartum non-susceptible period is prolonged due to the widespread practice of lactation, intervals between births are longer when the preceding child survives.[5] Consequently, improved survival of infants may be expected to reduce the number of births.

Improvements in mortality, then, may have at least two opposite effects on natality: an inflationary effect of increased marital duration and a deflationary effect of lowered infant mortality. Furthermore, the interaction between these factors may obscure their respective effects on natality.

To study some of the relations between mortality and natality and to estimate quantitatively the effects of specified changes in mortality under controlled conditions, a series of experiments was conducted using a Monte Carlo simulation model ("REPSIM") on an electronic computer.[6] This report will include a brief description of the model and its principal assumptions, and will present the results obtained under varying survival patterns and lengths of the post-partum non-susceptible period.

METHODS

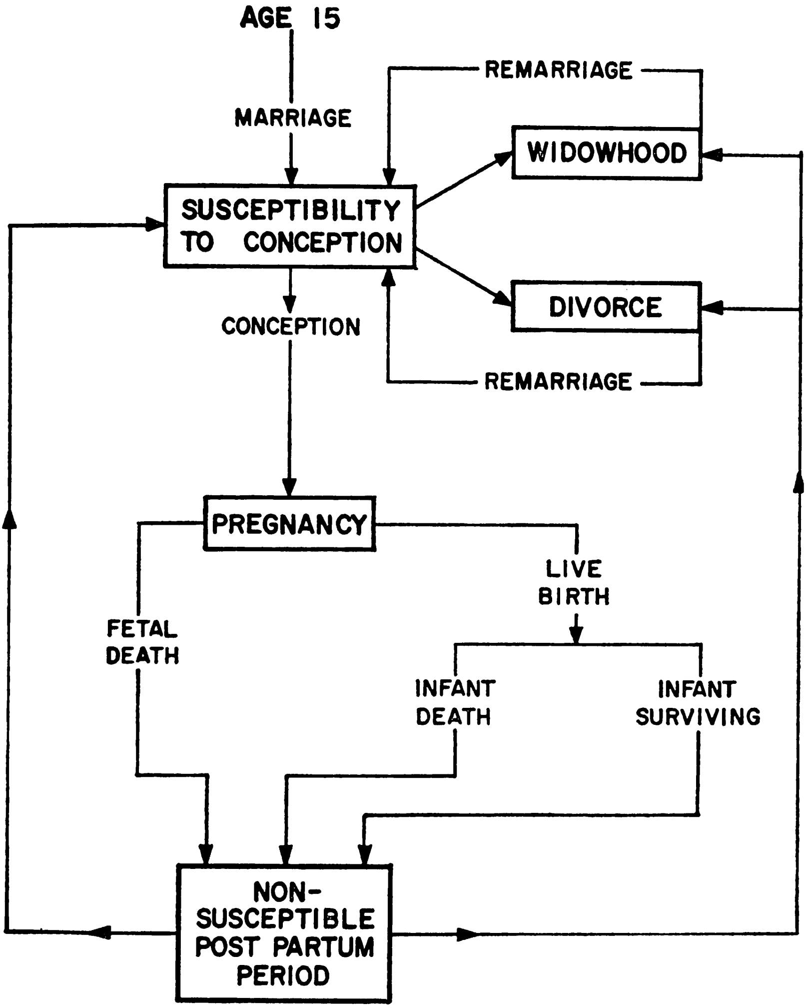
The Model

"REPSIM" generates the reproductive history of a birth cohort of hypothetical women. In the results to be presented, each hypothetical cohort consists of 1,000 women ranging from age 15 to age 50. The reproductive history of each woman in turn is developed sequentially. The model includes two kinds of states into which a woman may pass: 1. temporary states such as marriage, widowhood, pregnancy, etc., which are shown in Figure 1, and 2. permanent changes of status, such as death and sterility, that are superimposed on the temporary states shown in Figure 1. The probabilities of passing into specific states may vary with age, parity and other features of a woman's history.

Inputs

Each simulated cohort is characterized by a series of constants and probabilities called "inputs." Most of the inputs used here are based on other applications of the model that attempted to simulate natality levels characteristic of the female population of India. In the cohorts reported here, identical inputs were used for the age-specific probabilities of marriage, sterility, remarriage and fecundability (see Figure 2); for the probability of fetal death (25 per cent); and for the duration of pregnancy.[7] The age difference between husbands

FIGURE I. TEMPORARY STATES THROUGH WHICH A WOMAN MAY PASS IN THE MODEL. FOR RESULTS GIVEN HERE, THE PROBABILITY OF DIVORCE WAS ASSUMED TO BE EQUAL TO ZERO.



and wives was set at seven years and it was assumed that no divorce took place.

A very long non-susceptible period following live births, with a mean length of 20.9 months and a standard deviation of 11.7 months, was postulated for the initial cohorts, labeled A-F in later tables. After the results for Cohorts A-F are presented, experiments in which a much shorter period was postulated will be described.

Apart from postpartum non-susceptibility, only the inputs relating to the probabilities for the occurrence of widowhood, infant death and deaths among cohort members were varied. Five levels of mortality, derived from the United Nations Model Life Tables,[8] were established ranging from an extremely low level of survival ($e_0^0 = 31$ years), to a relatively high level ($e_0^0 = 72$ years). As an additional comparison, the purely hypothetical case of "immortality" was postulated, with 100 per cent surviving through the ages involved. Since the inputs were otherwise identical, differences observed in the reproductive behavior of these cohorts must be attributed either to the postulated changes in mortality levels or to random variation.[9]

Expected Values

Expected years of reproductive life, survival patterns, and selected aspects of marital experience were calculated from the life tables and first marriage distributions used in these simulations, and are shown in Table 1. As might be expected, the successive improvements in mortality have a diminishing effect on the expected number of years spent in reproductive life and on the per cent of women surviving to each successive age.[10] The change from the poorest survival pattern ($e_0^0 = 31$ years) to the best ($e_0^0 = 72$ years) is nonetheless impressive.

Furthermore, since over 95 per cent of women in each cohort survive to age 20, by which time more than four-fifths of the marriages have occurred, it is not surprising that the numbers marrying do not change markedly in Table 1. In contrast, the effects on subsequent marital history are of considerable magnitude. Thus, the number of marriages expected to end in widowhood declines from 382 to 109, proceeding from lowest to highest survival patterns, while in the corresponding cohorts, the number of women expected to be alive and still married at age 50 increases from 245 to 780.

More detailed analyses of the effects of postulated improvements in mortality on marital history will be presented in the next section, since these analyses will call on some of the results of the simulation efforts.

FIGURE 2. MONTHLY PROBABILITY OF CONCEPTION (FECUNDABILITY) BY AGE.

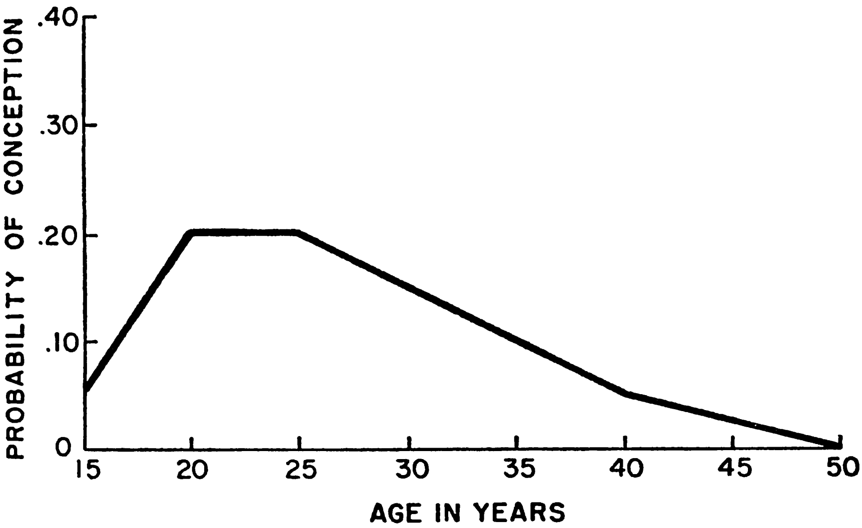


TABLE I. EXPECTED VALUES FROM INPUT DISTRIBUTIONS

	Model Life Table					*No*
	31	*25*	*20*	*13*	*1*	*Mortality*
Life expectancy						
Years of life from birth (e_0°)	31	41	51	61	72	∞
Years of life between ages 15–50	26.9	29.8	31.7	33.2	34.3	35.0
Infant mortality rate	240	180	130	80	20	0
Percent surviving from age 15 to age:						
20	95	97	98	99	100	100
30	82	88	92	96	99	100
40	68	78	86	93	97	100
50	54	68	79	88	94	100
Expected number of						
First marriages	916	924	930	934	938	940
First marriages ending in widowhood	382	306	237	171	109	0
Wives aged 50 (FM)*	245	385	529	662	780	940

* Wives surviving to age 50, first marriage intact.

RESULTS

Marital Patterns

Table 2 presents, in the first section, the expected number of years spent in the first marriage, according to the postulated marriage rates and male and female mortality rates. In addition, the effect of widowhood may be estimated, in part, from the results shown for the expected duration of first marriage in the absence of widowhood.

The effect of widowhood is, however, mitigated to some extent by remarriage of widows. The second part of Table 2 presents estimates, derived from the simulated cohorts, of the frequency of remarriage (line 3) and the number of years contributed to married life by these subsequent marriages of widows (line 4). The estimates in lines 1 and 4 of Table 2 are then combined in line 5 to estimate the expected married life per woman in the successive cohorts.

Although the probability distribution for remarriage is identical for all cohorts, interesting differences appear in the estimates presented. In addition to the decline in the number of widows already noted, improved survival is associated with lower proportions of

TABLE 2. EFFECT OF MORTALITY ON MARRIED LIFE

	Model Life Table					*No*
	31	*25*	*20*	*13*	*1*	*Mortality*
Expected values calculated from input distributions						
(1) Number of years in first marriage	18.1	21.7	24.5	26.9	29.0	30.7
(2) Number of married years in the absence of widowhood	23.5	25.8	27.6	29.0	30.1	30.7
Expected values estimated from simulated cohorts						
(3) Percent of widows remarrying	27	26	24	22	16	—
(4) Number of years added to married life by remarriage	0.9	0.8	0.7	0.4	0.2	0
(5) Number of married years (5) = (1) + (4)	19.0	22.5	25.2	27.3	29.2	30.7
Estimated loss in married life						
(6) Total years lost (6) = 30.7 − (5)	11.7	8.2	5.5	3.4	1.5	—
(7) Loss due to widowhood (7) = (2) − (5)	4.5	3.3	2.4	1.7	0.9	—
(8) Loss due to death of woman (8) = 30.7 − (2)	7.2	4.9	3.1	1.7	0.6	—
(9) Percent of loss due to widowhood	38	40	44	50	60	—

widows remarrying and with decreasing numbers of years added to married life by remarriage. These phenomena result from the fact that the exposure to the risk of remarriage declines with the number of marriages ending in widowhood and with increasing age at widowhood.

The last part of Table 2 presents estimates, based on the foregoing results, of the loss in married life due respectively to the mortality of the women themselves and to that of their husbands. A cohort in which all women and husbands survive and 94 per cent of women marry at an average age of 17.3 years, would experience an average of 30.7 years of marriage per woman before the age of 50 years, i.e., $0.94(50 - 17.3) = 30.7$. In Table 2, estimates of the total expected loss in married life per woman, as shown in line 6, were obtained by subtracting the value in line 5 from 30.7 years. The number of years lost because of widowhood, as shown in line 7, was estimated as the difference between lines 2 and 5, i.e., the expected number of married years in the absence of widowhood minus the estimated total. The loss caused by female deaths (line 8) may then be obtained either as line 6 minus line 7 or as 30.7 minus line 2.

The cohort with the highest mortality is expected to lose 4.5 years of married life per woman because of widowhood and 7.2 years because of death of women. These estimates are in contrast to those for the cohort with the lowest mortality studied ($e_0^0 = 72$ years). Here the loss in married life due to widowhood is slightly less than one year and the loss due to the death of a woman is only about one-half of a year. As mortality improves, the relative role of widowhood in the reproductive years increases.

Survival and marital patterns observed in the simulated cohorts naturally deviate to some degree from the expected values in Tables 1 and 2. Some of these results are summarized in the Appendix.

Natality Patterns

Long postpartum non-susceptible periods. Table 3 presents the mean and standard deviation of the number of live births per woman for cohorts A to F. For the total cohort and for ever-married women, natality increases substantially as survival improves, an increase of

TABLE 3. MEAN AND STANDARD DEVIATION OF NUMBER OF LIVE BIRTHS FOR SIMULATED COHORTS WITH VARYING LEVELS OF MORTALITY

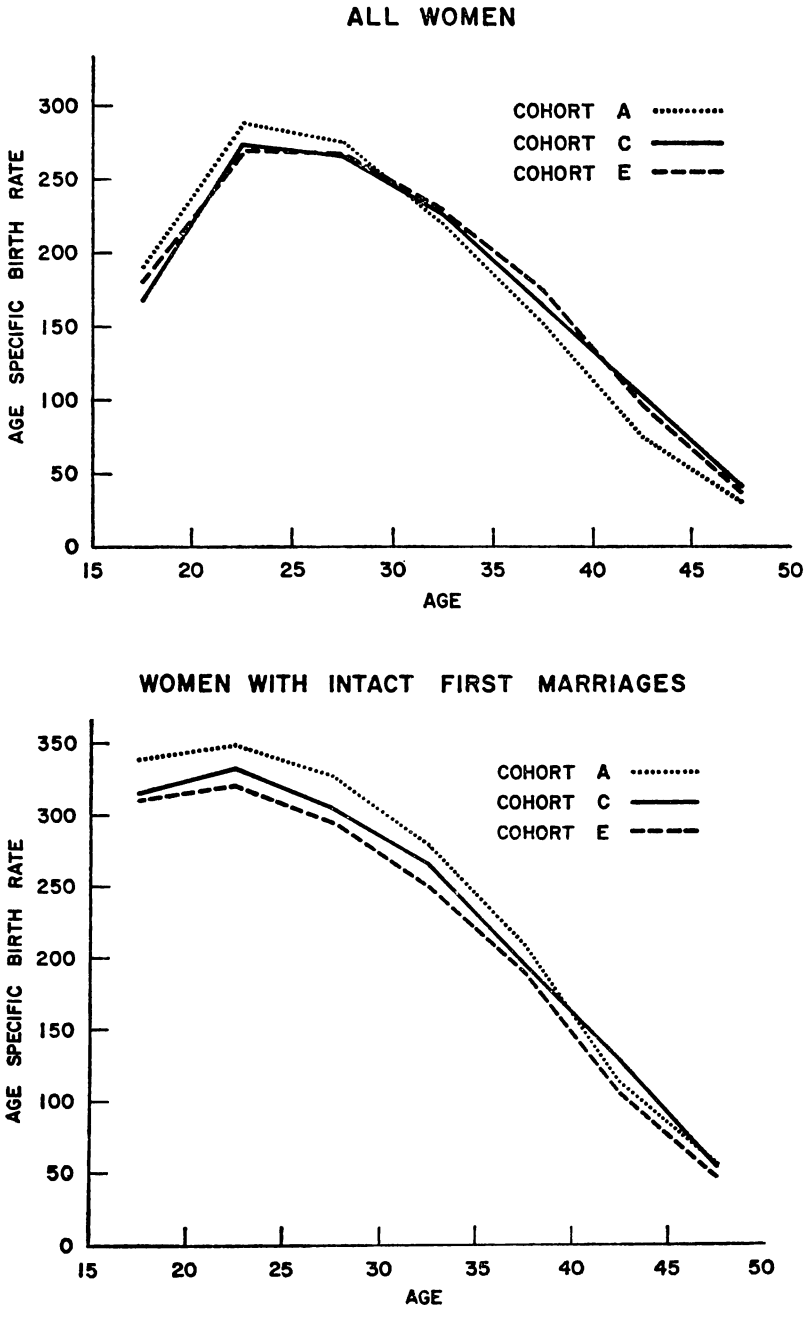
	Cohorts					
	A	*B*	*C*	*D*	*E*	*F*
e_0^o	31	41	51	61	72	∞
Infant mortality rate	247	178	129	81	20	0
Total cohort						
All women	5.2 ±3.3	5.6 ±3.2	5.8 ±3.3	6.2 ±3.1	6.3 ±3.0	6.4 ±2.8
Ever-married women	5.7 ±3.1	6.1 ±2.9	6.3 ±2.9	6.6 ±2.7	6.8 ±2.5	6.8 ±2.3
Women surviving to age 50						
All women	6.3 ±3.2	6.4 ±3.1	6.3 ±3.1	6.5 ±3.0	6.3 ±3.0	6.4 ±2.8
Ever-married women	6.7 ±2.8	6.8 ±2.7	6.8 ±2.7	6.9 ±2.6	6.8 ±2.3	6.8 ±2.3
First marriage intact	7.8 ±2.6	7.3 ±2.7	7.3 ±2.6	7.2 ±2.5	6.9 ±2.4	6.8 ±2.3

slightly more than one birth per woman being observed in Cohort F over Cohort A. In contrast to these increases, the standard deviation of the number of live births per woman decreases with improved survival, undoubtedly because of the associated decreased variance in marital experience. As a result, the coefficient of variation of the number of live births to all women decreases from 63 per cent in Cohort A to 44 per cent in Cohort F.

For women who survive to age 50, whether ever-married or not, the mean number of live births shows little or no change with improved survival, although a decrease in the standard deviation occurs similar to that observed in the earlier part of Table 3. The irregularities seen in the results for the mean number of children born to all women who survive to age 50 are undoubtedly due in part to the effects of sampling variation in the marital experience of these simulated cohorts. (*cf.* Appendix Tables 1 and 2 with expected values presented above.)

The lack of change in the mean despite the decreased incidence of widowhood among these women is explained by the counteracting effect shown in the last row of Table 3. For women surviving to age 50 with first marriages intact, henceforth referred to as *wives aged 50 (FM)*, the trend is reversed. When, as here, widowhood and death are eliminated, and only changes in levels of infant mortality and in the timing of infant deaths[11] operate, the predicated improvements in infant mortality produce a decreasing number of births per

FIGURE 3. AGE-SPECIFIC BIRTH RATES FOR TOTAL COHORTS AND WOMEN SURVIVING TO EACH AGE WITH FIRST MARRIAGE INTACT.



wife aged 50 (FM). Hence, the results noted for the total cohorts reflect not only the increase in married life but also the decrease in the total natality of wives aged 50 (FM).

Figure 3 shows age-specific birth rates of all women and of wives with intact first marriages at each age for Cohorts A, C and E. At later ages, these rates for all women (top panel) tend to increase with improved survival, a reflection of the reduction in widowhood.[12] For wives with intact first marriages, however, natality rates are lower at practically all ages as survival improves (bottom panel). This result is consistent with the findings for wives aged 50 (FM) in Table 3.

The effects of improved infant survival are shown further in the intervals between successive births. A birth interval is made up of: 1. the period of postpartum non-susceptibility following a birth; 2. the time from the end of this period until a conception leading to a live birth, including time added by pregnancy wastage; and 3. the months of pregnancy leading to the next live birth. In the current application, the input distributions for time added by pregnancy wastage, the time to conception and the length of pregnancy were not varied. Although the inputs for the distribution of the length of the postpartum non-susceptible period were also identical for all cohorts, this period is reduced in the case of an infant death. In the computer program, if a child dies before the time selected at random for the duration of the postpartum non-susceptible period, the non-susceptible state terminates one month after the infant's death. Consequently, as infant mortality decreases, the need for this modification arises less frequently, thus birth intervals tend to be prolonged.

Table 4 presents estimated means of the first eight birth intervals for the six cohorts.[13] As mortality decreases, intervals after the first[14] tend to lengthen for each birth order. The slightly longer birth intervals in cohorts with higher survival consequently reduce the number of births a woman may have during her childbearing period, and produce the previously observed inverse relationship of survivorship to natality among wives aged 50 (FM). Nevertheless, the natality of total cohorts is increased, since increasing marital duration more than offsets the effects of longer birth intervals.

The birth interval data in Table 4 have other interesting features.

TABLE 4. LIFE TABLE ESTIMATES OF THE MEAN LENGTH OF BIRTH INTERVALS (IN MONTHS) FOR COHORTS WITH VARYING LEVELS OF MORTALITY*

	Cohorts					
	A	*B*	*C*	*D*	*E*	*F*
Interval to Live Birth Order	(e_0° *31*)	(e_0° *41*)	(e_0° *51*)	(e_0° *61*)	(e_0° *72*)	(e_0° ∞)
1	20.4	21.4	21.0	20.7	21.6	20.6
2	33.8	35.5	35.8	35.5	36.9	37.0
3	34.1	34.9	34.5	35.0	36.8	37.1
4	34.9	35.3	35.9	37.2	38.4	38.0
5	34.9	35.7	37.0	38.5	39.9	39.9
6	36.9	37.8	41.4	39.7	40.0	41.2
7	39.6	40.4	42.2	43.0	46.7	44.6
8	41.7	45.5	44.4	45.9	46.3	50.7

* Measures of variability (standard deviations and coefficients of variations) tend to increase not only by order of birth interval, but also with improved survival.

Within each cohort birth intervals lengthen with increasing birth order, since fecundability is assumed to decrease with age (Figure 2). Second, the effects of improved mortality tend to increase with birth order. For example, the second interval for Cohort F is approximately three months longer than for Cohort A; for the eighth interval, the difference is nine months. Consequently, cohorts with relatively high infant mortality have more opportunity for childbirth in their younger, more fecund years. This is also reflected in the fact that the number of births per 1,000 years of married life decreases with improved life expectancy. For cohorts A to F, these numbers are 271, 249, 238, 230, 219 and 212 respectively.

These data, then, result from a fairly complex relationship between fecundability, the postpartum non-susceptible period and the length of birth intervals. If a woman experiences a number of relatively long postpartum non-susceptible periods, and thus longer birth intervals, she has a lower probability of an *n*th conception because she is older and therefore less fecund than a woman who has shorter birth intervals, as well as having less time left before her reproductive period ends. This effect is also illustrated by cumulative parity distributions. For example, among the wives aged 50 (FM) of Cohort E, 37 per cent have fewer than seven live births, in contrast to 24 per cent in Cohort A.

In summary, the higher natality produced by the longer survival of spouses is partly offset by the effect of improved infant survival in these cohorts. The foregoing, however, is limited not only by the assumptions of the model but by the various parameters postulated, particularly the long period of postpartum non-susceptibility.

Short postpartum non-susceptible periods. To study the effects of changing mortality on natality under another condition, Cohorts A′ to F′ were simulated at the same six mortality levels, but with a postpartum non-susceptible period of 6.5 ± 2.5 months. In every other respect, the inputs for these runs were identical with those for the corresponding Cohorts A to F. In Table 5, natality indices are presented for Cohorts A′ to F′, analogous to those in Table 3. Most striking are the extremely high levels of natality that result from the appreciably shorter postpartum non-susceptible period.

The impact of changing mortality on Cohorts A′ to F′ is greater than that previously observed in Table 3. Thus, in Table 5, a maximum improvement in survival (Cohorts A′ to F′) produces an increase of approximately 2.7 births per woman, about 38 per cent, in contrast to the previously observed increase for Cohorts A to F of 1.2 births; approximately 23 per cent (Table 3). All women and ever-married women surviving to age 50 have more than one additional birth on the average. The relative variation in these data is similar to that in Table 3.

Another contrast between the data in Tables 3 and 5 appears for wives aged 50 (FM). Rather than the decrease in live births to these women, associated with improved infant survival shown in Table 3, virtually no differences in natality appear among the women in the various cohorts in Table 5. Moreover, in this case, age-specific birth rates (all women) are consistently higher with improved mortality, and birth intervals are not lengthened (data not shown).

Thus, with the short period of non-susceptibility, and the other assumptions made regarding the level of infant mortality and time at death of infants, the inhibiting effects of changing infant mortality cannot be discerned. The relationship between mortality and natality observed in Table 5 is thus in essence a result only of increasing length of married life due to improved survival of spouses.

TABLE 5. MEAN AND STANDARD DEVIATION OF THE NUMBER OF LIVE BIRTHS FOR SIMULATED COHORTS WITH VARYING LEVELS OF MORTALITY AND SHORT POSTPARTUM NON-SUSCEPTIBLE PERIOD

	Cohorts					
	A'	*B'*	*C'*	*D'*	*E'*	*F'*
e_0°	31	41	51	61	72	∞
Infant mortality rate	241	180	132	76	20	0
Total cohort						
All women	7.1 ± 4.5	7.8 ± 4.5	8.6 ± 4.6	9.0 ± 4.4	9.7 ± 4.2	9.8 ± 4.2
Ever-married women	7.8 ± 4.2	8.5 ± 4.0	9.2 ± 4.0	9.6 ± 3.8	10.3 ± 3.5	10.4 ± 3.5
Women surviving to age 50						
All women	8.7 ± 5.1	8.6 ± 4.4	9.1 ± 4.4	9.2 ± 4.3	9.8 ± 4.1	9.8 ± 4.2
Ever-married women	9.1 ± 3.5	9.2 ± 3.9	9.8 ± 3.8	9.9 ± 3.7	10.4 ± 3.4	10.4 ± 3.5
First marriage intact	10.2 ± 3.7	10.1 ± 3.7	10.3 ± 3.7	10.3 ± 3.5	10.6 ± 3.4	10.4 ± 3.5

TABLE 6. SELECTED INDICES OF REPRODUCTION FOR THE COHORTS

			*Intrinsic Rates per 1000***		
Cohort	*TFR**	*NRR*†	*Birth Rate*	*Death Rate*	*Rate of Increase*
A(e_0° 31)	6.2	1.5	46.0	31.7	14.3
B(e_0° 41)	6.3	2.0	45.2	21.7	23.5
C(e_0° 51)	6.2	2.3	43.8	14.9	28.9
D(e_0° 61)	6.4	2.6	44.4	9.2	35.2
E(e_0° 72)	6.3	3.0	42.9	4.0	38.9
F(e_0° ∞)	6.4	3.1	42.0	0	42.0
A'(e_0° 31)	8.5	2.0	59.6	32.9	26.7
B'(e_0° 41)	8.8	2.7	58.9	22.3	36.6
C'(e_0° 51)	9.2	3.3	58.9	15.1	43.8
D'(e_0° 61)	9.3	3.9	57.8	9.0	48.8
E'(e_0° 72)	9.8	4.6	58.4	3.1	55.3
F'(e_0° ∞)	9.8	4.8	56.5	0	56.5

* TFR $= \sum_{15}^{50}$ age-specific birth rates.

† Net reproduction rate $= \frac{\text{Total No. of Births } ({}_{15}P_0)}{1{,}000} \times .487$ where ${}_{15}P_0 = (1 - {}_5q_0)\ (1 - {}_5q_5)\ (1 - {}_5q_{10})$.

** These intrinsic rates resulted from calculating stable populations. Stable populations were computed by assuming the mortality rates employed in each simulated cohort and the age-specific birth rates generated for each cohort.

Implications for Population Growth

Table 6 presents the results in terms of several familiar indices of population growth for the simulated cohorts. The first two columns present cohort total fertility rates and cohort net reproduction rates. While the values for both these rates are high, improved survivorship is strikingly reflected in the cohort net reproduction rate.

The interacting tendencies noted earlier produce practically constant values for the total fertility rates in Cohorts A to F. With the shorter non-susceptible periods, however, the impact of a reduced incidence of widowhood is revealed in the tendency for the total fertility rate to increase.[15]

In contrast with the other measures of natality, intrinsic birth rates tend to *decrease* with improved survivorship in both parts of the table, since with higher survival, stable populations have higher proportions of children surviving and hence decreasing proportions of women aged 15 to 50. In these examples, therefore, the intrinsic birth rates fail to reflect the previously observed natality trends. On the other hand, when these birth rates are related to the striking drop in the intrinsic death rates, a large rise is seen in the intrinsic rate of increase. Thus, in the first set of cohorts, this rate rises from a level of 1.4 per cent per year in Cohort A to 3.9 per cent in Cohort E. In the second set, the corresponding rates are 2.7 per cent in Cohort A′ and 5.5 per cent in Cohort E′.

DISCUSSION

The preceding analysis of relationships between mortality and natality is, of course, confined by the particular assumptions made for these simulations. For example, other marital patterns would produce quite different results. The assumption that marriage patterns do not change with changing mortality is unrealistic in a number of ways. For any particular marital pattern, the assumption is made in the model that husbands of the postulated age are always available. The lack of realism in this assumption is underscored by the fact that increased survival of young men and women is likely to affect the "marriage market" and may increase the age at marriage of women, reduce the proportions marrying and change the age differential between spouses.[16] Moreover, with high mortality, widowers are added to the supply of available husbands.[17] In a number of ways, therefore, improved survival may decrease the proportion of women who marry.

More generally, this paper did not explore the many complex effects of changing population numbers and age composition on the social milieu and on natality.[18] In addition, these experiments have not dealt with the transitional aspects of mortality changes.

Despite these limitations and others inherent in the model, the results have implications of interest. They indicate that, in the presence of a long period of postpartum non-susceptibility, decreased infant mortality may considerably lengthen birth intervals and depress the natality of intact marriages. Accordingly, improvements in infant survivorship may, to some extent, reduce the number of births. This, coupled with the plausible hypothesis that family limitation is likely to be more acceptable if infant survivorship improves,[19] adds additional weight to the desirability of policies aimed at reducing infant mortality.

On the other hand, improvements in mortality may be associated with significant social and economic changes. The prolonged postpartum non-susceptible periods observed in some populations may be related to poor nutrition.[20] Thus, improvements in nutritional levels could lead to shorter postpartum non-susceptible periods and therefore higher natality. Other concomitants of social and economic change may also affect the length of the non-susceptible period, notably a possible decline in the practice of lactation.

The findings in this investigation support earlier indications that the length of the postpartum non-susceptible period may be a particularly important determinant of natality levels and differentials.[21] The paucity of data pertaining to this period represents a gap in information relevant to the dynamics of natality. Greater attention should be given in field studies to this basically biological factor as it operates in a variety of populations, if the effects of other biological and social factors are to be assessed accurately.

The method employed here succeeds in doing for a hypothetical cohort what the net reproduction rate was intended to do for period data. In other words, such indices as the mean number of live births per woman for the total cohort and the cohort net reproduction rate reflect mortality patterns as well as natality patterns. Since these indices reflect the total experience of the cohort, they differ from cohort natality rates calculated from registration data[22] in this respect.

Analysis indicates the value of examining a wide variety of indices of natality, and particularly the importance of studying the experience of all women of a cohort for an insight into the complexities of natality trends. It suggests that similar insights could be gained from such data for real populations.

Data obtained from surveys omit the reproductive performance of women who have not survived or have migrated prior to the date of the survey. This inevitable deficiency of surveys is compounded when they are restricted to women with intact marriages only. As this investigation demonstrates, data pertaining only to surviving women or women in surviving marriages would lead to erroneous conclusions regarding the relationship of mortality to natality. Thus, despite the inherent difficulties, attempting to collect cohort data on a longitudinal basis is desirable. These considerations hold even in the absence of possible differential natality of those dying or migrating.

SUMMARY

A computer model, "REPSIM," which simulates the reproductive history of a hypothetical cohort of women, was applied to study the effects of improved survival on natality and to derive quantitative estimates of these effects. In the reported experiments, varying mortality levels for the women, their infants and their husbands were postulated, the particular schedules being derived from United Nations Model Life Tables. The simplifications introduced into these experiments included the elimination of divorce and of any voluntary limitation of births, as well as assumptions that marriage probabilities

did not change with different survival patterns and that all husbands were exactly seven years older than their wives. Therefore, these experiments eliminated any effects that changing survival rates have on these aspects of marriage.

For those aspects of the problem that were considered, the model provided a method of observing more directly the results produced by varying selected conditions while holding others constant. Information that cannot be secured from real populations could thus be made available for analysis.

In the particular situations investigated, the principal findings were:

1. Improved survival increases the number of children born per woman in a cohort and per ever-married woman (while it decreases the variation), and increases the net reproduction rate.

2. Insofar as it reduces widowhood, improved survival tends to increase births to surviving ever-married women and hence may produce an increase in age-specific birth rates, the total fertility rate and the gross reproduction rate.

3. In the presence of prolonged periods of postpartum non-susceptibility, these increases may be counteracted in part by prolonged intervals between births. In contrast to the overall results, therefore, women with intact marriages may have fewer rather than more births.

4. The intrinsic birth rate tends to decrease with improved survival; the decrease, however, is much smaller than that in the intrinsic death rate. The intrinsic rate of increase therefore rises with improved survival.

APPENDIX TABLE I. OBSERVED VALUES FOR COHORTS WITH LONG POSTPARTUM PERIOD

	Cohorts					
	A ($\overset{\circ}{e}_o$ *31*)	*B* ($\overset{\circ}{e}_o$ 41)	*C* ($\overset{\circ}{e}_o$ *51*)	*D* ($\overset{\circ}{e}_o$ *61*)	*E* ($\overset{\circ}{e}_o$ *72*)	*F* ($\overset{\circ}{e}_o$ ∞)
Years of life between ages 15 and 50	27.6	29.9	32.0	33.0	34.5	35.0
Infant mortality rate	247	178	129	81	20	0
Percent surviving from age 15 to age:						
20	95	97	98	98	100	100
30	83	88	94	95	99	100
40	70	78	88	92	98	100
50	56	69	79	87	95	100
Number of:						
First marriages	917	918	918	926	928	940
First marriages ending in widowhood	399	286	238	164	112	0
Wives aged 50 (FM)	246	422	532	666	773	940
Percent of widows remarrying	26	24	23	23	13	—
Number of years in first marriage	18.7	22.3	24.4	26.7	29.0	30.8
Number of married years	19.8	23.0	25.0	27.2	29.2	30.8

APPENDIX TABLE 2. OBSERVED VALUES FOR COHORTS WITH SHORT POSTPARTUM PERIOD

	Cohorts					
	A' ($\overset{\circ}{e}_o$ *31*)	*B'* ($\overset{\circ}{e}_o$ *41*)	*C'* ($\overset{\circ}{e}_o$ *51*)	*D'* ($\overset{\circ}{e}_o$ *61*)	*E'* ($\overset{\circ}{e}_o$ *72*)	*F'* ($\overset{\circ}{e}_o$ ∞)
Years of life between ages 15 and 50	27.0	29.5	31.8	33.5	33.3	35.0
Infant mortality rate	241	180	132	76	20	0
Percent surviving from age 15 to age:						
20	94	96	98	99	100	100
30	81	87	93	97	99	100
40	67	77	87	94	98	100
50	52	68	80	89	95	100
Number of:						
First marriages	914	918	929	934	944	939
First marriages ending in widowhood	388	320	232	183	128	0
Wives aged 50 (FM)	245	377	539	667	779	939
Percent of widows remarrying	27	28	25	21	19	—
Number of years in first marriage	18.8	21.6	24.6	27.0	29.3	30.6
Number of married years	19.7	22.5	25.3	27.4	29.4	30.6

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[7] The mean ± the standard deviation of the relevant probability distributions were: age at first marriage, 17.3 ± 2.8 years; age at permanent sterility, 41.0 ± 7.6 years; duration of pregnancy for a live birth, 9.1 ± 0.6 months, for a fetal death, 2.5 ± 1.6 months; and postpartum non-susceptible state for a fetal death, 1.7 ± 0.5 months. For further details *see* Ridley, Jeanne C. and Sheps, Mindel C., An Analytic Simulation Model of Reproduction with Demographic and Biological Components, *loc. cit.;* and Sheps, Mindel C., Ridley, Jeanne C. and Lingner, Joan W., Effects of Selected Factors on Natality: Quantitative Estimation Through Simulation (in press).

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[14] Since the interval from marriage to the first birth contains no postpartum component, the effects of infant survival do not influence its length and thus this interval is constant for all cohorts.

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