SOME RELATIONSHIPS BETWEEN SHORT RANGE AND LONG RANGE RISKS OF UNWANTED PREGNANCY

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Introduction

Today in the United States it is common for a woman to be married near her twentieth year, to have her 2, 3, or 4 desired children by thirty, but not to lose her capacity for pregnancy until age 40 or somewhat later. If her first marriage endures until the menopause, then usually she and her husband face a "risk period" of 10 years or longer during which they must prevent any additional pregnancies. This problem of family limitation is all the harder because ease of conception typically does not decline significantly until near the end of the risk period.

Some couples solve their problem of fertility control by shortening or even eliminating, the risk period by means of sterilization. According to evidence collected in a recent survey, only a minority in the United States use this drastic solution while the majority rely, or try to rely, entirely on contraception.[2]

It has been shown in another article that very efficient contraception is required for a half-chance, much less a good chance, of full protection during a risk period as long as 10 years.[3] Such efficiency is not always attained. While some couples are able to adjust themselves to one or two unintended pregnancies, presumably very few couples are prepared to accommodate themselves to three or more excess pregnancies. Three excess pregnancies may appear as very ineffective family

[1] Office of Population Research, Princeton University. The writer is indebted to W. D. Borrie and P. C. Sagi for their valuable criticisms.

[2] Freedman, Ronald; Whelpton, Pascal K.; and Campbell, Arthur A.: Family Planning, Sterility, and Population Growth. New York, McGraw-Hill, 1959, pp. 26–31, 64–68.

[3] Potter, R. G.: Some Problems in Predicting a Couple's Contraceptive Future. *Eugenics Quarterly*, December, 1959, 6, pp. 254–256.

limitation. Yet it can be shown that when risk periods are as long as ten years, it requires surprisingly efficient contraception even to be reasonably assured of not experiencing three unsought pregnancies.

Accordingly, interest attaches to the levels of contraceptive efficiency needed in order to provide a high assurance, say a .95 chance, of not exceeding one excess pregnancy or, at the least, not exceeding two excess pregnancies. More specifically, how low must the monthly risk of pregnancy be kept in order to have, during risk periods of stated length, a specified likelihood of not exceeding x pregnancies? Deriving answers to this question is complicated by the fact that conception is followed by several months of pregnancy, amenorrhea, and anovulatory cycles. During this "immunity period" reimpregnation is impossible and the remainder of the risk period is shortened correspondingly.

V. M. Dandekar has published a "modified binomial distribution" which takes account of these immunity periods.[4] It is the objective of this paper to show the relevance of Dandekar's model and then to apply it to the problem outlined.

Length of Risk Period

Typically risk periods are longest when no recourse is made to sterilization and the marriage remains intact until the couple are past childbearing. In such cases, the risk period starts when the couple recover their capacity for conception after the last desired birth; it ends when the couple become sterile, an event usually synonymous with the wife's loss of capacity to become pregnant.

According to 1950 census figures, in the United States the median age of brides at first marriage is 20 years.[5] Two, three, and four children are the most popular family sizes.[6] These

[4] Dandekar, V. M.: Certain Modified Forms of Binomial and Poisson Distributions. *Sankhya,* July, 1955, pp. 237, 238.

[5] Glick, Paul C.: American Families. New York, John Wiley and Sons, 1957, p. 54.

[6] Freedman, *et al, op. cit.,* pp. 220–226. The roughly equal popularity of 2, 3 or 4

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facts, together with what is known about child-spacing,[7] suggest that a majority of once-married wives reach desired family size, if ever, during ages 25 to 30. The inference that a majority of wives reach their preferred family size by thirty is more suspect for remarriages. Nor does it necessarily apply to those first marriages in which an accidental pregnancy occurs after the last intended child, since the number of children wanted may then be adjusted to accommodate the newcomer.

The end of the risk period is best measured in terms of the age distribution of wives at last confinement in societies practicing little family limitation for marriages enduring until the end of the reproductive period. Tietze furnishes such an age distribution for 204 Hutterite women, but the ages are grouped into five-year classes.[8] Hyrenius offers a more detailed age distribution for 581 Swedish women.[9] Agreement between the two distributions is good and Hyrenius' distribution is chosen chiefly because of its greater detail and larger sample size.

Several sets of data indicate that in societies practicing little family limitation consecutive birth intervals average approximately the same length until the penultimate interval, which is barely longer, and the last birth interval, which is moderately longer.[10] This evidence suggests that fecundability—i.e., ease

children is also found in a recent study of two-child families in metropolitan areas over 2,000,000: Westoff, Charles F.; Potter, Robert G., Jr.; Sagi, Philip C.; and Mishler, Elliot G.; FAMILY GROWTH IN METROPOLITAN AMERICA, to be published by Princeton University Press.

[7] Child-spacing data based on the Census Bureau's Current Population Survey for April 1954 yields approximate median intervals of 2.0, 2.7, 2.7, and 2.3 years between marriage and first birth, first and second birth, second and third birth, and third and fourth birth respectively. *See* Child Spacing as Measured from Data Enumerated. *In* the Current Population Survey: United States, April 1950 to April 1954. *Vital Statistics-Special Reports,* October, 1958, 47, No. 3, p. 92.

[8] Tietze, C.: Reproductive Span and Rate of Reproduction among Hutterite Women. *Fertility and Sterility,* January–February, 1957, 8, p. 91.

[9] Hyrenius, H.: Fertility and Reproduction in a Swedish Population Group without Family Limitation. *Population Studies,* November, 1958, 12, pp. 121, 122.

[10] Direct evidence comes from Henry, Louis: ANCIENNES FAMILLES GENEVOISES. Presses Universitaires de France, 1956, pp. 122–124, and Tietze, *op. cit.,* pp. 92, 95. In these two studies, the last intervals average 12 and 6 months longer than prior intervals, respectively. Additional evidence of the essentially constant length of successive birth intervals, classified by parity, is in Hyrenius, H.: *op. cit.,* p. 128, and Henry, L.: Intervals Entre Naissances. *Population,* October–December, 1954, pp.

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Wife's Age at Start of Risk Period	Percentages of Risk Period As Long As:		
	10 Years	15 Years	20 Years
25	85	56	7
30	57	7	—
35	8	—	—

Table 1. Percentages of risk periods as long as 10, 15, and 20 years, by age of wife at start of risk period, assuming that marriage endures until end of reproductive period.

of conception in the absence of anti-conception measures—remains essentially uniform until quite close to the last birth. Accordingly, the assumption that fecundability remains constant throughout the risk period is not too unrealistic, especially when one is dealing with long risk periods, say 10 years or longer.

In Table 1, the percentages of risk periods longer than 10, 15, and 20 years are given for women attaining desired family size and recovering fecundability at specified ages. It is assumed that marriages endure until age at last birth, distributed as in Hyrenius' distribution. It is seen with this restriction over half the wives reaching desired family size between ages 25 to 30 theoretically experience risk periods longer than 10 years and an appreciable minority experience risk periods as long as 15 years. For this reason, the analysis below will focus on risk periods of 10 and 15 years duration. Risk periods of 20 years do not assume numerical significance except for women having all the children they want by their early twenties.

The Model

A model is needed which can convert monthly likelihoods of accidental pregnancy into probabilities of not exceeding 0,

759–761, and Tuan, Chi-Hsein: Reproductive Histories of Chinese Women in Rural Taiwan. *Population Studies,* July, 1958, 12, p. 49. The only experience representing an apparent exception to the generalization that consecutive intervals do not lengthen appreciably with parity comes from Henry, L.: Intervals Between Confinements in the Absence of Birth Control, *Eugenics Quarterly,* December 1958, 5, pp. 202–203. But this analysis is restricted to the first four "normal" birth intervals of only 46 couples and Henry, admitting the inconsistency of these results with previous results, seeks an explanation in terms of progressively longer time lapses between birth and next onset of ovulation as parity increases.

1, 2, . . . excess pregnancies during risk periods of specified length. The model must allow for the periods of immunity following conception when reimpregnation is impossible.

Three simplifying assumptions are made:

(i) Any conception is followed by a constant immunity period of (m-1) months during which reimpregnation is impossible.

(ii) The monthly likelihood of pregnancy despite contraception remains constant at p throughout the risk period of n months, except during immunity periods when it is zero.

(iii) All events—i.e., conceptions, ends of immunity periods, start and finish of risk period—occur in the middle of the month.

From (i)–(iii), it follows that conception may occur any month of the risk period provided that a conception has not occurred during one of the preceding $(m-1)$ months.

These assumptions correspond to those made by Dandekar in deriving his modified binomial distribution. Adopting his notation, let $P(r,n)$ be the probability of r excess pregnancies in a risk period of n months and $F(r,n)$ be the probability of not exceeding r pregnancies during the same risk period. As indicated already, $(m-1)$ measures the length of the immunity period and p designates the monthly likelihood of accidental pregnancy outside of immunity periods, with $q = 1 - p$. Dandekar has shown, among other things, that

$$F(0,n) = q^{n},$$
$$F(1,n) = q^{n-m}\,[1 + (n\text{-}m)\,p] \text{ and}$$
$$F(2,n) = q^{n-2m}\left[1 + (n\text{-}2m)\,p + \frac{(n\text{-}2m)(n\text{-}2m+1)}{2}\,p^2\right],$$

provided that $(n\text{-}2m) \geq 0$. Furthermore,

$$P(0,n) = F(0,n),$$
$$P(1,n) = F(1,n) - F(0,n) \text{ and}$$
$$P(2,n) = F(2,n) - F(1,n).$$

Finally use will also be made of the relationship

$$P(3 \text{ or more}, n) = 1 - F(2,n).$$

It follows from the formulas that the longer the immunity period of (m − 1) months, the greater the monthly likelihood of accidental pregnancy, or p, can be and still obtain the same chance F(x,n) of not exceeding x pregnancies, provided of course that the risk period of n months is kept constant. For purposes of this paper, it is desirable to overestimate, rather than underestimate, the immunity period lest exaggeratedly low monthly risks of pregnancy be calculated as necessary to achieve stated degrees of long range protection. A value of 18 is assigned (m − 1), providing for 9 months of pregnancy and 9 months of postpartum amenorrhea and anovulatory cycles. Almost certainly in the United States as a whole the average immunity period falls short of 18 months.[11] Fortunately the formulas are rather insensitive to the value assigned (m − 1) as long as (m − 1)/n and p are both small.

[11] It is fairly generally agreed that: (1) after childbirth there ensues a period of amenorrhea, usually followed by one or more anovulatory menstrual cycles; and (2) the length of this period of temporary sterility varies greatly among women and, for a given woman, tends to be longer the longer she nurses her infant. Documentation comes from several investigations. In 1940, R. K. Stix reported mean durations of amenorrhea of 4.5, 4.9, and 6.1 months in three large samples averaging 6.0, 7.8, and 9.8 months of lactation in "Factors Underlying Individual and Group Differences in Uncontrolled Fertility," *Milbank Memorial Fund Quarterly*, July, 1940, xxviii, p. 256. Peckham recorded averages of 5.1 and 5.6 months of amenorrhea for an unspecified division of 2,885 patients into groups averaging 7.8 and 8.9 months of lactation respectively. These data are cited in Guttmacher, A. F.: Fertility of Man, *Fertility and Sterility*, May–June, 1952, III, pp. 284–285. To the writer's knowledge, there exists no large scale survey of amenorrhea among nonlactators, though fragmentary evidence, based on medical practices, suggests that its duration averages well under 4.5 months. A. Sharman's review of the literature and his own data indicate that nonlactators may average in the neighborhood of two anovulatory cycles once menstruation is resumed, while lactators average more, "Ovulation After Pregnancy," *Fertility and Sterility*, Sept.–Oct. 1951, II, pp. 371–393. In his model of fecundity, A. F. Guttmacher posits an average of 2 months of amenorrhea and 2 months of anovulatory cycles for nonlactators as opposed to 6 and 3 months for lactators, though he does not state what lengths of lactation he is assuming (*op. cit.*, pp. 284–286). From the above results, one infers that if a population of mothers are lactating an average of less than 6 months, then amenorrhea will average under 4.5 months, to which must be added an expectation of perhaps 3 or 4 anovulatory cycles, so that total postpartum sterility averages under 9 months.

A national sample of British mothers in 1946 were found to nurse their infants on the average of 4.2 months, Douglas, J. W. B.: The Extent of Breast Feeding in Great Britain in 1946 With Special Reference to the Health and Survival of Children. *Journal of Obstetrics and Gynecology of the British Empire*, 1950, 57, pp. 339–340. No comparable study exists for the United States in recent years, but there is little reason to believe that residents of this country nurse much longer on the average than British women. On this premise, the average length of postpartum sterility in this country is established as well under 9 months.

Protection During Risk Period	Length of Risk Period	
	Ten Years	Fifteen Years
No Pregnancies	.0004	.0003
One Pregnancy or Less	.0035	.0022
Two Pregnancies or Less	.0098	.0057

Table 2. Monthly risks of accidental pregnancy yielding .95 assurances of specified levels of protection during risk periods of 10 and 15 years, assuming immunity periods of 18 months.

Results

What are the monthly risks of accidental pregnancy which must be maintained in order to have a .95 chance of not exceeding 0, 1, or 2 pregnancies during risk periods of 10 or 15 years? The results, predicated on Dandekar's model and an immunity period of 18 months, are given in Table 2. Even to be 95 per cent sure of not exceeding two pregnancies in a risk period of 10 years requires that couples keep the monthly risk of contraceptive failure below .01. Thus efficient contraception is required not merely for complete protection but for a reasonable certainty of staying under three excess pregnancies.[12] The requirements are much more stringent for risk periods lasting 15 years.

In a recent survey, representing a specialized probability sample of urban two-child families, the pregnancy rate during contraception was found to average over .025 when the experience of each couple was weighted equally so as to obtain a simple mean of individual accident rates.[13] A similar result was obtained from the Indianapolis Study.[14] Short marriage

[12] If a value of 12 is substituted for (m-1), in place of 18, the requisite monthly risks of contraceptive failures decrease very slightly. For example, for risk periods of 10 years, values of .0004, .0033, and .0084 are obtained, in contrast to values of .0004, .0035, and .0098 appearing in Table 2.

[13] Potter, R. G.: Contraceptive Practice and Birth Intervals among Two-Child White Couples in Metropolitan America. *In* Thirty Years of Research in Human Fertility: Retrospect and Prospect. New York, Milbank Memorial Fund, 1959, p. 76.

[14] Potter, R. G.: Length of the Observation Period as a Factor Affecting the Contraceptive Failure Rate. The Milbank Memorial Fund *Quarterly*, April, 1960, xxxviii, No. 2, pp. 148–149.

Length of Risk Period	Number of Excess Pregnancies			
	0	1	2	3 or More
10 Years	.05	.23	.38	.34
15 Years	.01	.07	.21	.71

Table 3. Probabilities of excess fertility during risk periods of 10 or 15 years, when the monthly chance of accidental pregnancy is .025, assuming that each conception is followed by an immunity period of 18 months.

durations have such a large weight in these findings that it is not certain whether the accident rate declines or not after attainment of desired family size. Nevertheless it is of interest to consider the long range consequences of a monthly pregnancy rate as high as .025.

Just how poor is the protection secured from contraception when it allows a .025 monthly chance of pregnancy is shown in Table 3. With risk periods of 10 years, few couples gain complete protection; a majority experience one or two pregnancies; and one-third may anticipate three pregnancies or more.[15] When the risk period is 15 years, a majority have to expect three or more pregnancies.

Discussion

Upon first reflection, one might suppose that very efficient contraception would be needed for complete protection during a long risk period, but that mediocre contraception, say holding the monthly likelihood of pregnancy down to 2 or 3 per cent, would seldom exact a penalty greater than one or two unsought pregnancies. Yet the previous section has shown that such mediocre contraception generates a very real risk of exceeding three pregnancies in a risk period of 10 years.

A corollary of this result is that even occasional omissions of contraception during a long risk period may lead to as many

[15] Here because p is as large as .025, substitution of 12 instead of 18 for (m-1) does moderately affect the probabilities of excess pregnancy. For example, with (m-1) set equal to 12, the top row of Table 3 would show .05, .20, .32, and .43 as the probabilities respectively of 0, 1, 2, and 3 or more pregnancies in a 10-year risk period.

as three excess pregnancies. As simplifying assumptions, assume that times of chance-taking are distributed randomly over the menstrual cycle; that contraception is foolproof when used; and that in the absence of contraception during an entire menstrual cycle, chances of pregnancy are .33.[16] Under these artificial conditions, a .075 rate of chance-taking suffices to yield a .025 monthly risk of accidental pregnancy. In other words, it does not take frequent chance-taking, but an omission rate less than one in ten, to yield an appreciable chance of exceeding three excess pregnancies in a risk period of 10 years or longer. Of course, the danger is less if the couple recognize the middle of the month as the most fertile time and regulate their chance-taking accordingly; but by the same token, the danger is all the greater if the couple are guided by incorrect information about the menstrual cycle.

[16] The figure of .33 comes close to the estimate of .34 used by Tietze, C.: Differential Fecundity and Effectiveness of Contraception. *The Eugenics Review,* January, 1959, 50, No. 4, p. 232.