Public health needs evolutionary thinking

Grazyna Jasienska[a,1]

Breastfeeding is the best way to feed an infant. Not only does it supply the proper nutrition, but it also supports the development of the immune system, provides healthy microbiome, reduces risk of diseases, and brings down overall mortality (1). There are also benefits resulting from the ability of breastfeeding to suppress maternal ovarian function and to delay the next pregnancy. Birth spacing is an important predictor of infant mortality, maternal health, and, in an evolutionary perspective, maternal reproductive success.

Todd and Lerch (2) document a significant decline in the ability of breastfeeding to cause suppression of the ovarian function and thus to reduce the chance of the next pregnancy. In breastfeeding mothers from 84 low- and middle-income countries, the duration of lactational amenorrhea (i.e., the length of time without menstrual cycles after having given birth) strongly decreased between 1975 and 2009. For example, lactational amenorrhea in Bangladesh decreased from 15.2 to 7.7 mo during the span of about 40 y. In some countries, thanks to substantial public health efforts in recent years, women extended their breastfeeding, but despite this, the timing of cycle resumption did not change! Even though it sounds like a mystery, it is not, from an evolutionary vantage point.

Energy as a Crucial Determinant of Reproductive Function in Women

In Ethiopian villages, women's daily walking routine, due to installation of water pumps, shrank from about 3 h to 15 min. However, in response to this innovation, the risk of conceiving in a given month rose more than threefold (3). In the rural Gambia, increases in energy intake by nutritional supplementation provided to women during pregnancy and lactation were related to changes in the levels of prolactin and sex hormones, and shortened the time until next pregnancy (4). In Guatemala, women who, prenatally and during first 3 y of life, received supplement with higher energy and protein, had shorter time from menarche to first birth and an earlier age at first birth than women with poorer supplementation (5).

These are just some examples that show the crucial role of energy in regulating reproduction in women. This is why women participating in professional sports or women with anorexia nervosa often experience a total lack of menstrual cycles. However, ovarian function is also sensitive to even relatively mild energy deprivation, as shown in studies from the area of human reproductive ecology (6). Recreational sports, or occupational physical work, that increase energy expenditure cause changes in reproductive physiology, leading to reduced levels of sex hormones (estradiol and progesterone). A reduction in body weight has a similar effect. Importantly, even a relatively small decline in the levels of sex hormones reduces a chance of conception (7).

Todd and Lerch (2) investigate the hypothesis that energetic factors are responsible for the observed weakening of the ability of lactation to cause amenorrhea. While in their study of about 2.7 million births, information on energetic status of mothers (i.e., body weight, dietary intake, or physical work) was not available, they used proxies for energy intake and expenditure. Such variables as the Human Development Index, urbanization, access to electricity, and access to water and education predicted well how strong the relationship was between the duration of lactation and the resumption of cycles. Indeed, better living standards, indicative of better energetic status of mothers, were related to shorter duration of amenorrhea.

Energetic Status Weakens Contraceptive Effect of Breastfeeding

The idea that maternal energetic status is a crucial determinant of cycle resumption in breastfeeding women is not new. This concept, proposed by Valeggia and Ellison (8), is based on the principle of energy allocation and termed "metabolic load." A breastfeeding woman allocates energy from dietary intake to her own metabolic needs, physical activity, and milk production, thus metabolizing for two. A new pregnancy, while lactating, would lead to metabolizing

[a]Department of Environmental Health, Faculty of Health Sciences, Jagiellonian University Medical College, 31-066 Krakow, Poland

Author contributions: G.J. wrote the paper.

The author declares no competing interest.

See companion article, "Socioeconomic development predicts a weaker contraceptive effect of breastfeeding," 10.1073/pnas.2025348118.

[1]Email: jasienska@post.harvard.edu.

Published July 30, 2021.

for three—quite a risky strategy if the mother is not well nourished. One prediction of this model is that an exclusive (nonsupplemented) and frequent breastfeeding would cause a longer duration of amenorrhea than supplemented and/or less frequent breastfeeding, simply because more milk is produced in the former scenario, and thus more energy must be allocated to milk production. However, the weakening of the relation between lactation and amenorrhea, as described by Todd and Lerch (2), was not likely to result from changes in lactation practices, because only data on exclusive breastfeeding were included in their analyses.

The second prediction from the metabolic load model helps understand these recent findings (2), suggesting that, the cost of lactation being equal, women in better nutritional status can afford to become pregnant sooner, compared to poorly nourished women. This prediction was supported by the study on the Argentinian indigenous Toba women (8). Toba, originally hunter-gatherers, but settled at the time of the study, breastfed their infants for 2 to 3 y, with exclusive breastfeeding lasting for at least first 6 mo. Despite the long and intense breastfeeding, the lactational amenorrhea lasted only for about 10 mo. These women were well nourished and also had relatively low levels of physical activity. While the absolute level of their body mass index (BMI) was not a good predictor of the resumption of menstrual cycles, changes in the BMI, indicative of entering the period of positive energy balance, correlated with a start of cycles. In addition, initially high energy allocation to milk production declined in months immediately before resumption of menstruation, as indicated by a strong rise in insulin production. Thus, insulin may provide one of the physiological signals for the organism that energy is again available for new reproduction.

Additional suggestion that maternal energetic status is an important predictor of fertility comes from the studies that show that higher parity is associated with a longer duration of lactational amenorrhea (2). Reproduction is costly, and each pregnancy and lactation take a toll on the maternal organism. Even though there are mechanisms allowing the organism to recuperate between consecutive reproductive events, intense reproduction (i.e., early start, high parity, short interbirth intervals, long breastfeeding) has an accumulating, negative impact on women's health (9). Women with high parity have an increased risk of diseases and reduced life span, in comparison to mothers with fewer children. Todd and Lerch (2) hypothesized that the relation between parity and duration of amenorrhea may indeed result from maternal depletion, which suggests that women with higher parity need longer periods to recuperate from reproductive events due to accumulated costs of reproduction. While this is a plausible explanation, it should be treated with caution. Parity is confounded with age and the functioning of ovarian function declines with age. Thus, a longer lactational amenorrhea may result simply from aging of ovarian function rather than from maternal depletion. In addition, age dependence may be an attribute of an evolved reproductive maternal strategy. Women who already have reproduced, may slow down their future reproduction in order to invest more in the children that they already have. Such strategy would manifest itself in longer interbirth intervals.

Demography and Public Health Need the Evolutionary Perspective

The paper by Todd and Lerch (2) provides important guidelines for demography and public health. The main take-home message is that human fertility cannot be fully understood without an evolutionary perspective (10). The evolved reproductive strategy of any organism, including humans, is to maximize fitness. Since energy is crucial for successful reproduction, maternal physiology must be sensitive to energetic factors—energy intake, energy expenditure, and energy balance. The organism should have evolved mechanisms that carefully assess its own energetic status and make decisions, based on energetic cues, whether to begin the next reproduction. It is also possible that these decisions are made not only in response to the current conditions, but are based on integrated, intergenerational signals of the quality of life, as experienced across many years (11).

In adult women, a suppression of ovarian function due to energetic stress caused by high energy expenditure was less pronounced in women who were born with larger size than in those smaller at birth (12). It can be hypothesized that a similar phenomenon will be expected in the case of a physiological response to lactation. Better prenatal conditions provide a rather reliable signal to the organism that energy will also be easily accessible during the postnatal life. In response to such prenatal signals, lactation is likely to have a milder suppressive effect on the ovarian function.

The paper by Todd and Lerch provides important guidelines for demography and public health. The main take-home message is that human fertility cannot be fully understood without an evolutionary perspective.

The functioning of ovarian physiology in adult women also depends on the quality of life during their childhood development (13). Thus, perhaps, it can be expected that improvements of living standards will have impact on the relationship between breastfeeding and lactational amenorrhea not only in women who experience improved conditions during adulthood, but also during prenatal and childhood phases of their lives. In general, the better energetic condition the less pronounced suppression of reproductive function is expected.

In demography, including as a variable the information about maternal energetic status would likely lead to better predictions of fertility models and population projections. According to the models by Todd and Lerch (2), an improvement in the standards of living in some regions may lead to a 24% increase in the total fertility rate, even with a long duration of breastfeeding.

Despite many public health efforts aimed at promoting the practice of breastfeeding, in low- and middle-income countries 63% of children younger than 6 mo are not exclusively breastfed. More effective programs and more funding are clearly necessary. However, among the many benefits of breastfeeding, public health still takes for granted its contraceptive effect (1). The analysis by Todd and Lerch (2) inevitably leads one to question this assumption and strongly suggests that family planning and contraception are crucial for breastfeeding women, even those who breastfeed exclusively. Nursing women should be made aware that breastfeeding may not have the same effect as it had on their mothers and grandmothers. In the past, without access to contraception, breastfeeding was one of the main practices to regulate human fertility, but those times are most likely over. Women should still be taught about all benefits of breastfeeding for the health of their children and of their own, but postponing of

the next pregnancy should no longer be considered one of these benefits.

The famous adage by Theodosius Dobzhansky (14) has been repeated so many times with a reason. We cannot really understand the functioning of any organism until we apply the evolutionary approach. One could paraphrase it again, stating that "nothing in demography and public health makes sense except in the light of evolution."

Acknowledgments

This work was supported by National Science Centre Poland Grants UMO-2017/25/B/NZ7/01509 and NN404 273440.

1 C. G. Victora *et al.*; Lancet Breastfeeding Series Group, Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *Lancet* **387**, 475–490 (2016).
2 N. Todd, M. Lerch, Socioeconomic development predicts a weaker contraceptive effect of breastfeeding. *Proc. Natl. Acad. Sci. U.S.A.*, 10.1073/pnas.2025348118 (2021).
3 M. A. Gibson, R. Mace, An energy-saving development initiative increases birth rate and childhood malnutrition in rural Ethiopia. *PLoS Med.* **3**, e87 (2006).
4 P. G. Lunn, S. Austin, A. M. Prentice, R. G. Whitehead, The effect of improved nutrition on plasma prolactin concentrations and postpartum infertility in lactating Gambian women. *Am. J. Clin. Nutr.* **39**, 227–235 (1984).
5 U. Ramakrishnan, H. Barnhart, D. G. Schroeder, A. D. Stein, R. Martorell, Early childhood nutrition, education and fertility milestones in Guatemala. *J. Nutr.* **129**, 2196–2202 (1999).
6 P. T. Ellison, *On Fertile Ground* (Harvard University Press, Cambridge, MA, 2003).
7 S. F. Lipson, P. T. Ellison, Comparison of salivary steroid profiles in naturally occurring conception and non-conception cycles. *Hum. Reprod.* **11**, 2090–2096 (1996).
8 C. Valeggia, P. T. Ellison, Interactions between metabolic and reproductive functions in the resumption of postpartum fecundity. *Am. J. Hum. Biol.* **21**, 559–566 (2009).
9 G. Jasienska, *The Fragile Wisdom. An Evolutionary View on Women's Biology and Health* (Harvard University Press, Cambridge, MA, 2013).
10 G. Jasienska, R. G. Bribiescas, A. S. Furberg, S. Helle, A. Núñez-de la Mora, Human reproduction and health: An evolutionary perspective. *Lancet* **390**, 510–520 (2017).
11 C. W. Kuzawa, Fetal origins of developmental plasticity: Are fetal cues reliable predictors of future nutritional environments? *Am. J. Hum. Biol.* **17**, 5–21 (2005).
12 G. Jasienska, I. Thune, P. T. Ellison, Fatness at birth predicts adult susceptibility to ovarian suppression: An empirical test of the Predictive Adaptive Response hypothesis. *Proc. Natl. Acad. Sci. U.S.A.* **103**, 12759–12762 (2006).
13 A. Núñez-de la Mora *et al.*, Developmental effects on salivary progesterone levels in migrant Bangladeshi women. *Am. J. Hum. Biol.* **15**, 277 (2003).
14 T. Dobzhansky, Nothing in biology makes sense except in the light of evolution. *Am. Biol. Teach.* **35**, 125–129 (1973).